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ASSESSMENT OF ROCKFALL HAZARD IN THE NORTHWESTERN PLUNGING AREA OF HAMRIN ANTICLINE FOLD / NORTHERN IRAQ

Saman Sardar Mohammed
Applied Geology Department, College of Science, Tikrit University, Tikrit, Iraq
samangeo2018@gmail.com

Mohammed Rashed Abood
Applied Geology Department, College of Science, Tikrit University, Tikrit, Iraq
mrabood@tu.edu.iq

Abstract

The geology of the study area is dominated by limestone rocks with strength (moderately weak to moderately strong) and containing joints that yield easily. Consequently, rockfalls along roadcuts are a major geological hazard. In this study, we performed a rockfall hazard-risk assessment on the three sections of the road expected to have the highest possibility of rockfall. We employed the evaluation criteria of "RHRS" developed by the Federal Highway Administration (FHA). An analysis of roadcuts at 3 ranges concerning geographic and geological conditions resulted in the identification of one class of rockfall hazard (low). slopes were assessed as low class.

Keywords: Fatha Formation, Hamrin anticline, Rockfall, RHRS system, Hazard Assessment

Introduction:

Studying and categorizing the risks resulting from landslides is very important for areas where landslides occur frequently, especially for mountainous areas where roads and railways are built, which leads to cutting in the rock layers that make up the slope, causing instability in the rocky layers, which may lead to damage and human and material losses. In addition to the damage to facilities such as bridges, dams, railways, and others. And those landslides are defined as the movement of the land mass, which is represented by (rocks, debris, and other ground materials) down the slope, and that slope collapse can be defined as a movement of the land masses under the influence of the weight of its weight down the slope, and the

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collapse of the slope occurs because it is The stress that occurs in the rock mass is greater than its ability to resist, and therefore it can be considered that the rocky slopes are the basis for all earthly phenomena[1], as any form of the floor is surrounded from all directions by a group of slopes resulting from human activities such as (quarries, mines, agriculture, external roads, dams, and others), in addition to that, the rocky slopes represent the geomorphological features in nature, and the stability of the slope is defined as the resistance shown by the inclined surface exposed to collapse to slipping and falling [2]. The study of collapses and the risks resulting from them is very important in areas that are prone to collapses frequently, and the study area included two stations located near the railways, and a study of the stations located on the road between (Baije and Kirkuk) and the road (Al-Alam and Al-Fatah) located in the study area, where in the study area the risks of collapses were classified using the (RHRS) Rockfall Hazard Rating System, to evaluate the risks, collapses, according to [3], by applying the system to the data obtained in the study area is for risk assessment, according to [3].

Location of the study area:

The study area in northern Iraq is about 50 km from the northeast of the city of Sallahaddin governorate. The area is located between latitudes (35° 02' 48") , (35° 03' 20") and longitudes (43° 33' 36") , (43° 34' 12"), (Fig. 1).

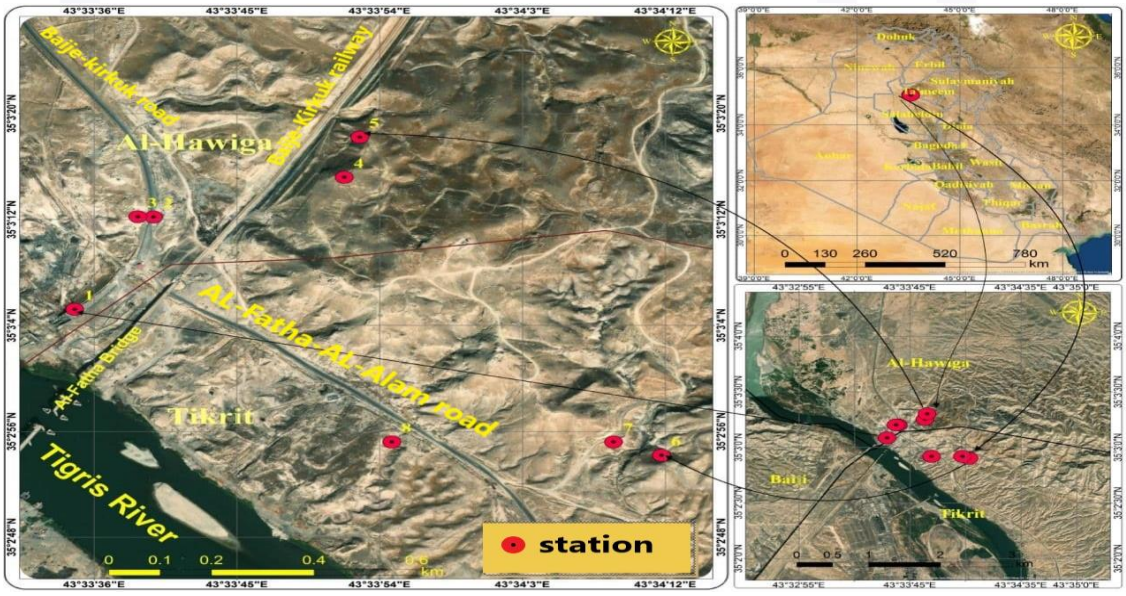

Figure (1) is an image showing stations locations in the study area

Geological setting

Tectonically, the region is located within the low fold zone, the Hamrin fold resulted from the collision of the Arabian plate with the Iranian plate [4], The Hamrin series is a natural belt and is long and wide.

Stratigraphically the geological formation exposed in the study area from the middle Miocene era is represented by the fatha formation, It was named in Iraq the Fatha Formation by use of an ideal section, which is located in the Al-Fatha area (Sallahaddin Governorate). The fatha formation consists of complete lagoon sedimentary cycles of successions of Marl, Limestone, Marly Limestone, and Gypsum[5] .

Geomorphology features in the study area were found, parallel, and semi-parallel drainage systems in the limestone rock, Hills, and cross valleys, Additionally, there is the phenomenon of rock falls.

Field and Laboratory Investigations:

The current study was conducted in two phases:

The first stage is the field survey, which includes taking the required information at each of the stations from the station's coordinates, position, layers, slopes, dividers, slope height, the distance of the slope from the street, and other information related to the evaluation of (RHRS) for the stations within the formation of the hatch, which was selected depending on the field information and the nature of the study.

The second stage: the library's work included drawing a geological map of the study area and dividing it into ranges (A, B, and C), and evaluating each area according to the field information obtained.

Rockfall Hazard Rating System (RHRS):

This system was developed by [6] to assess the risks that result from avalanches, and it is considered one of the most widely used systems to assess the risks resulting from avalanches and landslides that cause damage to the facilities located near them, such as dams, highways and bridges, especially in Mountain areas and other engineering facilities. This system is adopted when setting up any engineering facility project that priority should be given to maintenance and treatment works, and when it was applied in different regions of the world, it

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proved the effectiveness of its use. To evaluate according to this system, points must be calculated from the nine main categories, which represent the characteristics of the basic system on which this system depends. Several stages are required to assess and assess risks according to this system, which are:

1- Conduct a comprehensive survey of the collapses occurring in the stations of the study area.

2- Conduct a preliminary assessment of the collapses occurring in the stations of the study area.

3- Suggest the work of treatments and preliminary designs for slopes that are dangerous and determine the approximate cost of them.

4- Working on developing annual updates and reviews for the study of slopes.

Table (1) basic classes of RHRS according to [6]

Category		Rating criteria by score			
		Points 3	Points 9	Points 27	Points 81
Slope height		7.5 m	15 m	22.5 m	> 30 m
Ditch effectiveness		Good catchment	Moderate catchment	Limited catchment	No catchment
Average vehicle risk (% of time)		25%	50%	75%	100%
Decision sight distance (% of design value)		Adequate (100%)	Moderate (80%)	Limited (60%)	Very limited (40%)
Roadway width (including paved shoulders)		13.20 m	10.80 m	8.40 m	6 m
characteristics Case 1	Structural condition	Discontinuous joints, favorable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints, adverse orientation
	Friction	Rough, irregular	Undulating	Planar	Clay infilling or slickensided
Geologic Case 2	Structural condition	Few differential erosion features	Occasional erosion features	Many erosion features	Major erosion features
	Difference in erosion rates	Small	Moderate	Large	Extreme
Block size Volume of rockfall per event		0.3cm 2.3 m^3	0.6 cm 4.6 m^3	0.9 cm 6.9 m^3	1.20 cm 9.2 m^3
Climate and presence of water on slope		Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation or short freezing periods or intermittent water on slope	High precipitation or long freezing periods or continual water on slope and long freezing periods	High precipitation and long freezing periods or continual
Rockfall history		Few falls	Occasional falls	Many falls	Constan falls

1-Slope Height

It is one of the basic and important criteria, as it shows the height of the slope vertically, and it is measured with a tape measure, and its relative value is calculated according to the following four criteria:

1- Its value shall be (3) points for a height of up to (7.5m).

2- Its value is (9) points for a height that reaches (15m).

3- Its value shall be (27) points for a height that reaches (22.5m).

4- Its value is (81) points for a height of up to (30m) and more.

2- Ditch Effectiveness

It is the unpaved part of the road, on which the falling blocks fall from the slopes, and its effectiveness is measured by the extent of its ability to prevent the blocks from reaching the paved road, and its relative value is calculated based on the following four criteria:

1- Its value shall be (3) points if the rocky blocks falling from the cliffs are located within the pavement and do not reach the paved road, and it is called a good reservation.

2- Its value is (9) points if part of the rocky blocks falling from the slopes reach the tiled road and rest on it, and it is called the intermediate reservation.

3- Its value is (27) points if the rocky blocks falling from the slopes reach the paved road and rest on it, and it is called the limited reservation.

4- Its value is (81) points if the blocks of rock falling from the slopes fall directly on the paved road and rest on it, and there is no sidewalk where the road is adjacent to the slope, and the presence of the sidewalk is important for resting on the collapsed rocks on the road, and it is called empty Reservation.

3- Average Vehicle Risk (AVR)

It can be defined as the average percentage of the time required for the car to travel the distance exposed to the occurrence of collapses, as it depends on the daily rate of passing cars on the road and the length of the slope face. To calculate it, the following equation is applied:

$$AVR=\left(\frac{Slope\ face\ length * hours\ pedestrian\ cars\ number}{Road\ on\ set(Vehicle\ speed)}\right) X100\% \ldots\ldots\ldots\ldots(1)$$

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By knowing the rate of breakdown risk to which the car is exposed, the relative value that corresponds to it is as follows:

1- Its value shall be (3) points if a car is at risk of collapsing at a rate of (25%) of the time it takes for the car to cover the collapsible distance from the road.

2- Its value is (9) points if a car is at risk of collapsing at a rate of (50%) of the time that the car requires to cover the collapsible distance from the road.

3- Its value shall be (27) points if a car is at risk of collapsing at a rate of (75%) of the time that the car requires to cover the collapsible distance from the road.

4- Its value is (81) points if a car is at risk of collapsing for a percentage of (100%) of the time that the car requires to cover the collapsible distance from the road.

4- Percent of Vision Distance

It is a percentage of the distance that is clear in front of the driver and he sees the straight road, for the driver to estimate the distance of the road and make his decision within that distance, and it is free of obstacles that prevent or reduce the visibility of the road to the driver and that expose him to the risk of collapses Such as trees and an unstable road (turns), and the relative value is calculated as follows:

1- Its value shall be (3) points if the visibility of the road is suitable (100%) of the road in danger of collapse.

2- Its value shall be (9) points if the visibility of the road is moderate (80%) of the road at risk of collapse.

3- Its value shall be (27) points if the visibility of the road is limited (60%) of the road is at risk of collapse.

4- Its value shall be (81) points if the visibility of the road is very limited (40%) of the road is exposed to the danger of collapse.

5- Paved Roadway Width

It is the width of the paved part of the road, it is paved, and it represents the vertical distance towards the direction of the road, it is measured with a tape measure, and the relative value is calculated as follows:

1- Its value shall be (3) points if the width of the paved road reaches (13 m) or more.

2- Its value is (9) points if the width of the paved road reaches (11-13 m).

3- Its value is (27) points if the width of the paved road reaches (8.5-11 m).
4- Its value is (81) points if the width of the paved road is less than (8.5 m).

6- Geologic Characteristics

It is considered one of the important characteristics to estimate the risk of collapse. It is divided into two cases, and one of them is taken for evaluation according to the nature of the area and the study as follows:

First: If the structural geological conditions are the main cause of the collapses in the region, and they are divided into two parts:

A-Structural Condition

The relative values are calculated depending on the conditions and nature of the interruption surfaces, as follows:

1- Its value is (3) points if the interruptions and their trends are not conducive to the collapse.
2- Its value is (9) points if the interruptions and their directions are random and not regular.
3- Its value is (27) points if the interruptions and their trends are conducive to the collapse.
4- Its value is (81) points if the outages and their directions are completely helpful to the collapse.

B - The nature of the surfaces of the fractures and rock friction

Depending on the nature of the surface roughness of the discontinuities, its relative value is calculated as follows:

1- Its value is (3) points, if the surfaces of the interruptions are rough, it increases the cohesion.
2- Its value is (9) points if the surfaces of the discontinuities are undulating.
3- Its value is (27) points if the surfaces of the cuts are flat (Planer) facilitating the occurrence of slips.
4- Its value is (81) points if the surfaces of the interruptions are open and filled with mud deposits.

Second: If the geological conditions of differential erosion and weathering are the prevailing and the main cause for the occurrence of landslides, it is divided into two parts:

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A- The relative value is calculated depending on the extent of the change in the stony, as well as on the extent of its exposure to differential weathering and erosion, as follows:

1- Its value shall be (3) points if it differs a little from rocky.

2- Its value shall be (9) points if it is a heterogeneous osprey.

3- Its value shall be (27) points if it is distinct from stony.

4- Its value is (81) points if it is a sharp stony heterogeneity.

B-Depending on the intensity of differential erosion, its value is calculated as follows:

1- Its value shall be (3) points if the intensity of the differential erosion is small.

2- Its value is (9) points if the intensity of the differential erosion is average.

3- Its value is (27) points if the intensity of differential erosion is high.

4- Its value is (81) points if the intensity of the differential erosion is very sharp.

7- Block Size Rockfall

It represents the volume of rocks that have collapsed and are likely to collapse, and its value is calculated as follows:

1- Its value is (3) points if the size of the collapsed rock blocks is within $(2.3m^3 ، 0.3cm^3)$.

2- Its value is (9) points if the size of the collapsed rock blocks is within $(4.6m^3 ، 0.6cm^3)$.

3- Its value is (27) points if the size of the collapsed rock blocks is within $(6.9m^3 ، 0.9cm^3)$.

4- Its value is (81) points if the size of the collapsed rock blocks is within $(9.2m^3 ، 1.20cm^3)$.

8- Climate and Presence of water on Slope

It is a property that measures the extent to which slopes are exposed to rain and snow, as well as to the processes of freezing and melting water, and its relative value is calculated as follows:

1- Its value is (3) points if the slope is slightly exposed to falling rain and is not exposed to freezing and thawing processes.

2- Its value is (9) points if the slope is moderately exposed to falling rain and freezing and thawing processes.

3- Its value is (27) points if the slope is heavily exposed to the processes of freezing, thawing, and falling rain.
4- Its value is (81) points if the slope is very heavily exposed to the processes of freezing and thawing, the rainfall is high, and also moisture is present throughout the year.

9-Previous Breakdowns Rockfall History

It is a measure of the historical record of the occurrence of collapses in the region, and its relative value is calculated as follows:
1- Its value is (3) points if the slopes are exposed to collapses slightly.
2- Its value is (9) points if the slopes are subject to collapses in an oscillating manner.
3- Its value is (27) points if the slopes are exposed to collapses a lot.
4- Its value is (81) points if the slopes are continuously exposed to collapse.

Evaluation of Failure Hazards on the Study Area:

Many collapses occurred on the slopes of the study area, and estimating the risks resulting from the avalanches on the road passing in the region, as well as the railway line, is of great importance to avoid the occurrence of risks on the road by developing an appropriate treatment for the unstable slopes that cause danger on the road, and to evaluate the area According to the (RHRS) system, by dividing the study area into three areas and evaluating the risk for each area according to [3], Table (2), as through the field data of the stations, the study area that It is obtained and applied to the above categories for each of the nine characteristics of the system (RHRS) and after collecting points for each range through which the risk levels are evaluated.

Table (2) Evaluation of Failure Hazards according to [3]

risk score Collapse	Total points	Nature of risk
Level 4	<199	Low risk: slopes do not require a detailed study
Level 3	200-399	Moderate risk: Slopes need weekly monitoring, and require warning signs
Level 2	400-599	High Risk: Slopes need daily monitoring and require warning signs, speed limits for passing vehicles, potential avalanche treatments, and recommendations for slope studies
Level 1	≥600	Very high risk: immediate intervention was required to address potential avalanches, prevent vehicles from passing, and conduct a detailed study of slopes

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Where the areas were divided and evaluated according to the (RHRS) system for the three areas, depending on the nature of the study area, which is shown in Figure (1), and the areas are as follows:

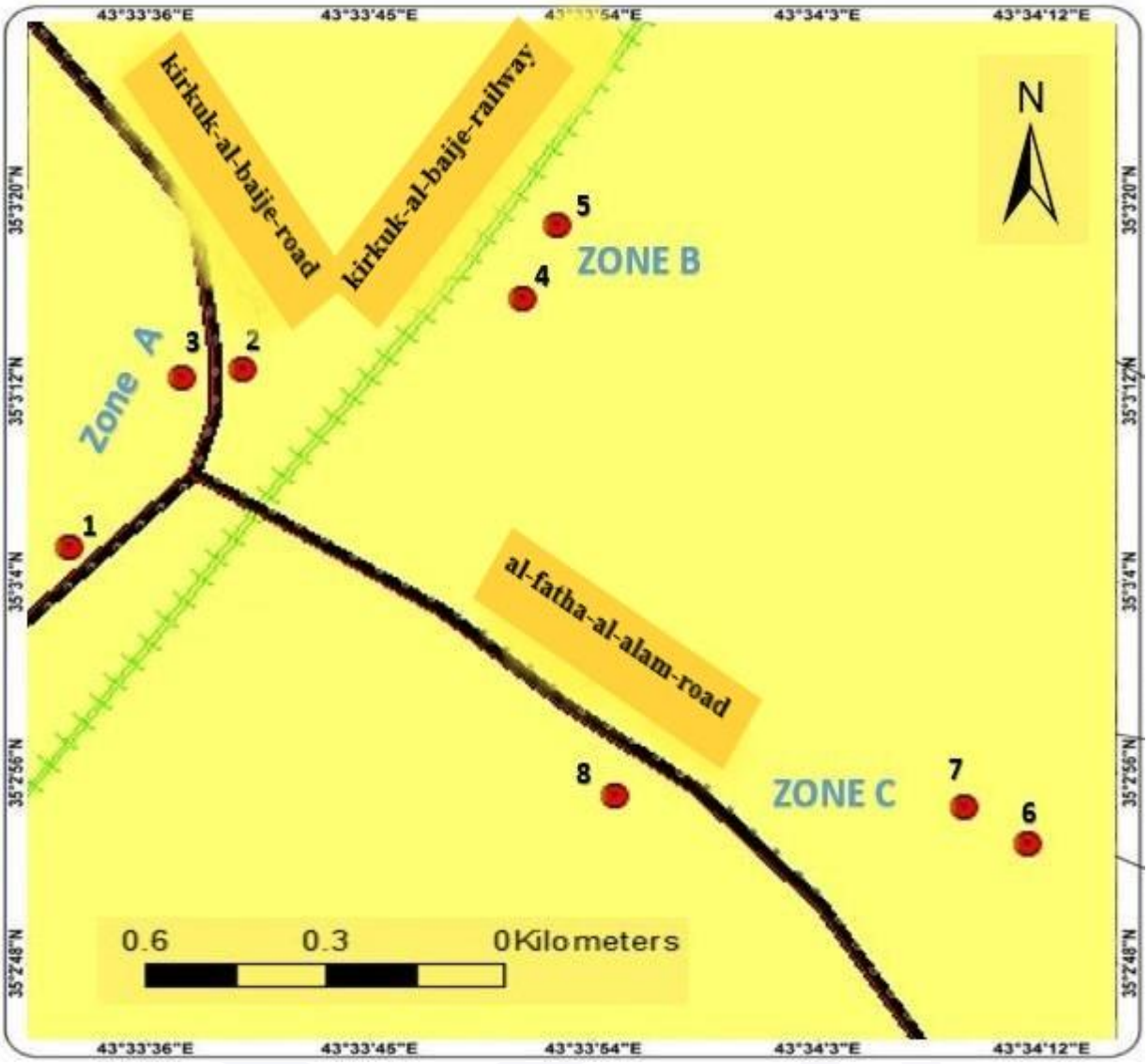

Figure (2) is a geological map of the study area, showing the main areas

1-Zone (A)

The range is located in the northwestern part of the Plunging Hamrin Anticline fold within the fatha, and it consists of (3) stations, which are stations (1,2,3), and its length is about (75) m. The results of the field data according to the (RHRS) system Table (1), are as follows:

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Table (3) Results for range (A) Assessment according to (RHRS)

points	isotropic		
3	Slope Height		
27	Ditch Effectiveness		
3	Average Vehicle Risk		
9	Percent of Vision Distance		
81	Paved Roadway Width		
27	A-Structural Condition	type 1	Geologic Characteristics
27	B - The nature of the surfaces of the fractures and rock friction		
----	A-state lithic heterochromatic	type 2	
----	B-intensity differential erosion		
3	Block Size Rockfall		
3	Climate and Presence of water on Slope		
9	Previous Breakdowns Rockfall History		
192	total points		

From the results of the above table, it is noted that it falls within the fourth level of risk, which are slopes of low risk and does not need a detailed study.

2- Zone (B)

The range is located in the northwest part of the Plunging Hamrin Anticline fold within the fatha formation, and includes two stations (4,5), and a length of about (165) m. The results of the field data according to the (RHRS) system Table (1), are as follows:

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Table (4) Results of Scope Assessment (B) according to (RHRS)

points	isotropic		
9	Slope Height		
27	Ditch Effectiveness		
3	Average Vehicle Risk		
3	Percent of Vision Distance		
81	Paved Roadway Width		
27	A-Structural Condition	type 1	Geologic Characteristics
27	B - The nature of the surfaces of the fractures and rock friction		
----	A-state lithic heterochromatic	type 2	
----	B-intensity differential erosion		
9	Block Size Rockfall		
3	Climate and Presence of water on Slope		
9	Previous Breakdowns Rockfall History		
198	total points		

From the results of the above table, it is noted that the (B) range is located in the fourth level, whose slopes are of little risk, and do not need a detailed study of its slopes.

3-Zone (C)

The range is located in the northwestern part of the Plunging Hamrin Anticline fold, within the fatha formation, and it consists of (3) stations, which are (6,7,8), and its length is about (155) m. The results of the field data according to the (RHRS) system Table (1), are as follows:

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Table (5) results for the evaluation of the scope of (C) according to the (RHRS) system.

points	isotropic		
9	Slope Height		
9	Ditch Effectiveness		
3	Average Vehicle Risk		
81	Percent of Vision Distance		
27	Paved Roadway Width		
27	A-Structural Condition	type 1	Geologic Characteristics
9	B - The nature of the surfaces of the fractures and rock friction		
----	A-state lithic heterochromatic	type 2	
----	B-intensity differential erosion		
9	Block Size Rockfall		
3	Climate and Presence of water on Slope		
9	Previous Breakdowns Rockfall History		
180	total points		

From the results of the above table, it is noted that the (C) range is located in the fourth level, whose slopes are of little risk, and do not need a detailed study of its slopes.

Discussion:

It was found through the results of the field study and an assessment of the study area that the average risk of vehicles exposed to a road has few points, which results from the few passing cars, as well as the climate and the appearance of water on the slope, which was studied in the field, with few points due to the few rainfalls in the study area, which directly led to few points Evaluation of the range (A,B, and C). In addition to other factors that are relatively few in general in the areas, which led to the study area being unaffected by rockfall significantly and not at risk of rockfall significantly.

Conclusions:

1. It was found by using the risk classification system (RHRS) that the ranges (A, B, and C) of the study area are within the fourth (4) level of risk, which is classified as low risk and does not need a detailed study.

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Recommendations:

1. Carrying out more study in the nearby areas to know the stability of slope station near in railway
2. Conducting a recent seismic and tectonic study of the study area and knowing the tectonic activity of the area and its seismic record must be recorded, which is important in the stability of the rocky slopes.

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