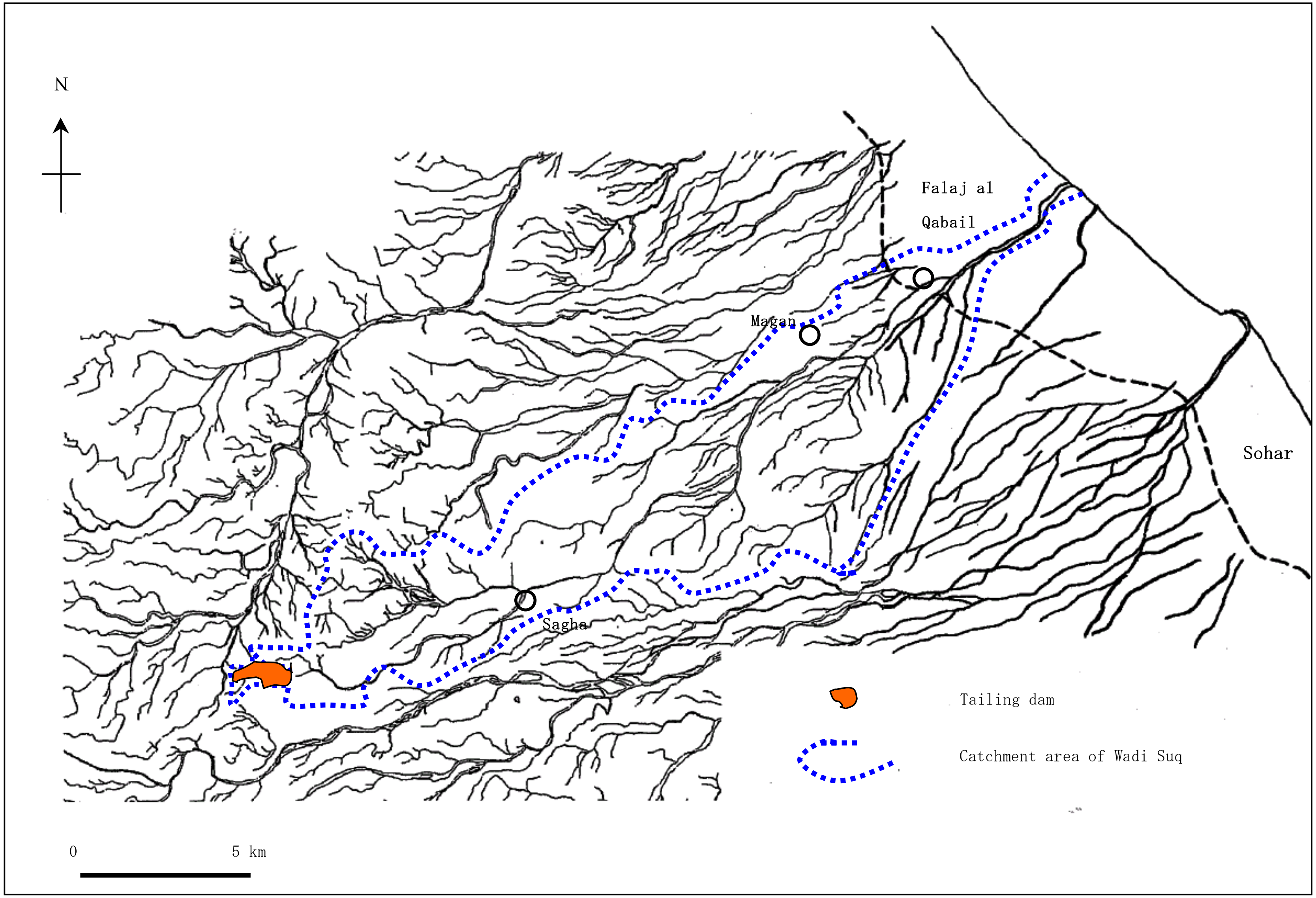

Figure 2.4 Catchments area of Wadi Suq

the mouth and has a width of 100 to 200 m. In the coastal plain, the small streams disappear into sand dunes in the vicinity of the Falaj al Qabail village or highway. The main stream of Wadi Suq erodes alluvial terrace plains and dunes with depths of 1.5 m to 4.5 m.

2.2 Geology

2.2.1 General Geology

On the geology of the Study area, the basement rocks consist mainly of the Samail Nappe, which is composed of the Ophiolite and Batinah Olistostrome of the Pre-Tertiary period (Figure 2.5). Tertiary Deposits are found locally in the eastern part of the area, while terrace deposits and alluvial deposits of the Quaternary period are widely distributed in the eastern part of the area. The Samail Nappe in this area consists of Gabbroic Rocks, Sheeted-dyke Complex, Effusive Rocks, and Supra-Ophiolite Sediments, which are middle and upper horizon of the Ophiolite. The Effusive Rocks consist of pillow and massive lavas of basaltic to andesitic (partially rhyolitic) rocks. The Batinah Olistostrome belongs to the Supra-Ophiolite Sediments. Cupriferous iron sulfide deposits of the Cyprus type occur in the effusive rocks.

The Gabbroic Rocks and Sheeted-dyke Complex are found in the northwestern part of the area, forming steep and rugged topography belonging to the moderate and low-relief mountains. Characteristics of these rocks are relatively fresh and hard in spite of development of slight fractures. The basaltic to andesitic (partly rhyolitic) pillow and massive lavas are found to the north, west and middle parts of the area. Because these rocks have developed fractures and are strongly influenced by green alteration, they belong to relatively soft rock, being easily eroded. Permeability of these rocks seems to be relatively higher in places where fissures are well developed.

The Batinah Olistostrome mainly consists of olistoliths of the Hawasinah group and Ophiolite. This rock is composed of chert, siliceous shale, shale, calcareous shale, limestone, etc. Chert and siliceous shale are very hard, but the rock is relatively brittle because of well-developed fissures. The shale is strongly weathered and relatively soft, so that it is easily eroded. The calcareous shale and limestone are relatively well fractured, but still hard. This is especially true of reef coral limestone, locally called as "Exotics", that forms isolated hills on small and large scale.

The Tertiary Deposits mainly consist of mudstone, calcareous mudstone and limestone, forming terraces or small hills that are almost covered by middle and low terrace deposits. The mudstone and calcareous mudstone are brown to gray in color and are softened and weakened by weathering. The limestone, which is mostly grayish white, occurs as massive and well fissured. These types of rock are thought to be less permeable.

The Quaternary Deposits consist of terrace deposits in diluvium, wadi sediments and screes. The terrace

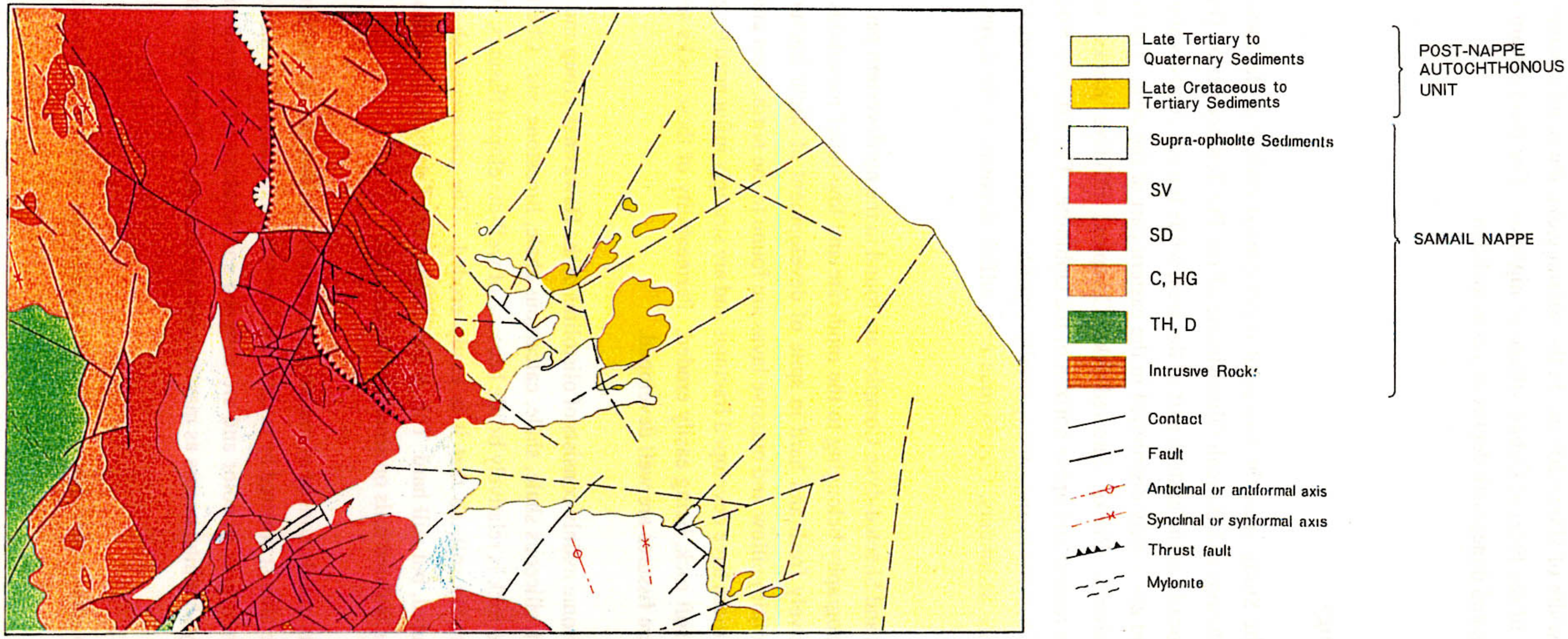

Figure 2.5 Geologic Map of the Study Area

deposits consist of mainly high, middle and low terrace deposits and contain sand and gravel including cobbles. The matrix of the Terrace deposits generally consists of fine sand to coarse gravel and is almost consolidated by calcrete, which occurs by the precipitation of calcium carbonate. The permeability is estimated to be high because of the presence of well developed and relatively loose fissures.

Alluvial terrace deposits and wadi sediments are widely found along each wadi. Alluvial terrace deposits mainly consist of sand and gravel containing gravel of cobble to boulder sizes. The matrix of the deposits consists of fine sand to pebbles, and is mostly consolidated by calcrete, which is formed by the precipitation of calcium carbonate. Generally, calcreted beds in the upper part of the alluvial deposits are thought to be higher permeability because of relatively loose and well-developed fissures in the beds. Calcreted beds in the lower part of the deposits are mostly compacted and hard, so that the permeability of these beds seems to be low.

2.2.2 Geological Structure

The geological structure of the Study area is shown in Figure 2.6. Generally, the dominant directions of faults in the Ophiolite and Batinah Olistostrome are northeast to southwest and northwest to southwest. A narrow graven structure from 1 km to 1.5 km wide runs along Wadi al Jizi in an east-northeast to west-southwest direction.

The dominant direction of faults along Wadi Suq is northwest to southeast. Faults with northwest to southeast directions are especially well developed in the upper wadi stream. These faults cross in the tailing dam. No significant faults occur in the middle reaches of the stream from the 2 km point to 14 km.,

In the lower reaches of the stream from the 14 km point, many faults with northwest to southeast directions are distributed, especially in the lower-most reaches.

2.3 Hydrogeology

2.3.1 Water System

Normally dry riverbeds flowing out from the Study area consist of Wadi Bani Umar al Gharbi, Wadi Suq, and Wadi al Jizi from north to south, respectively. All wadis flow from the west to northeast and east-northeast.

The water system in the Study area is shown in Figure 2.7. A summary of each wadi is shown in Table 2.1.

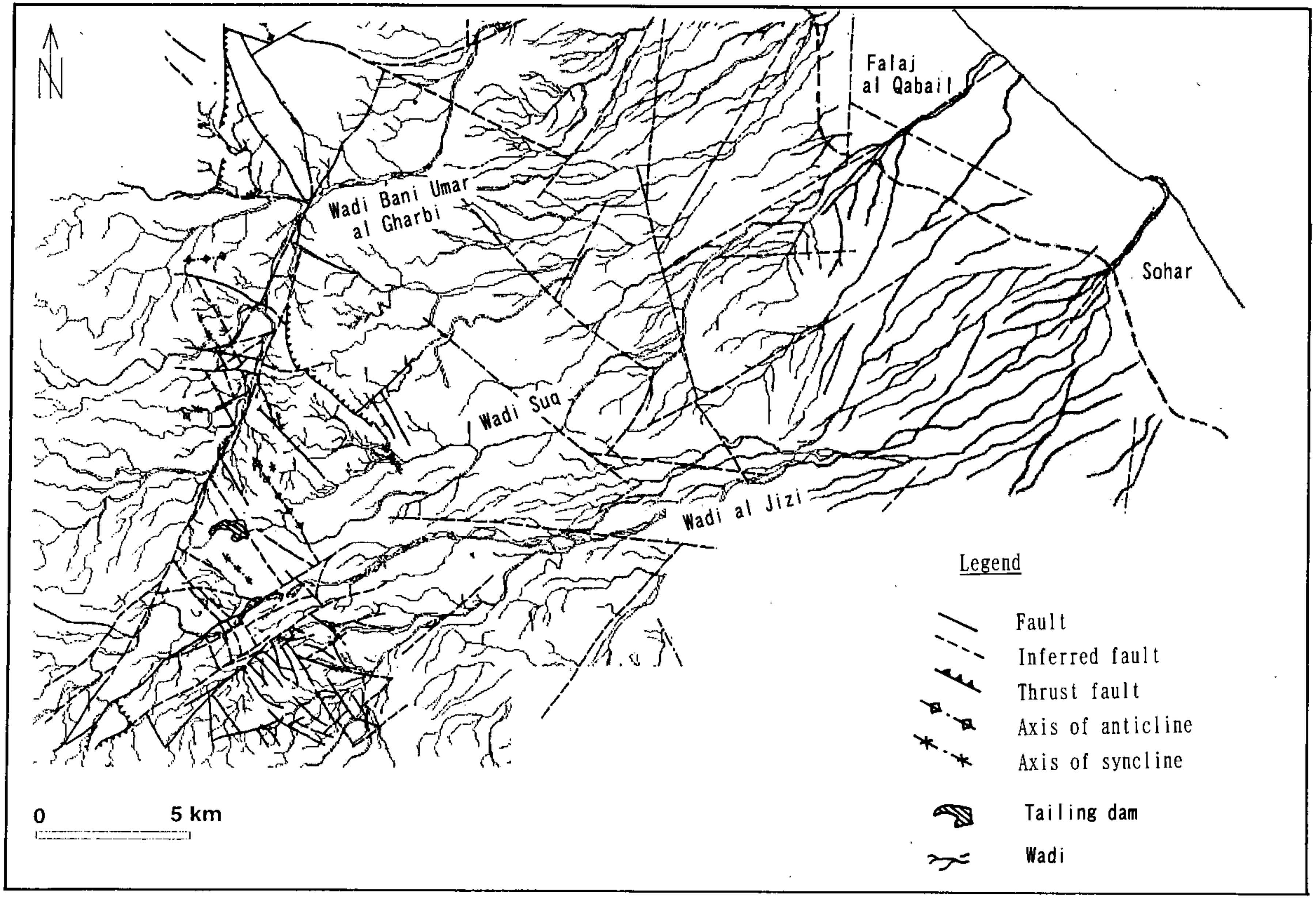

Figure 2.6 Geologic Structural Map of the Study Area

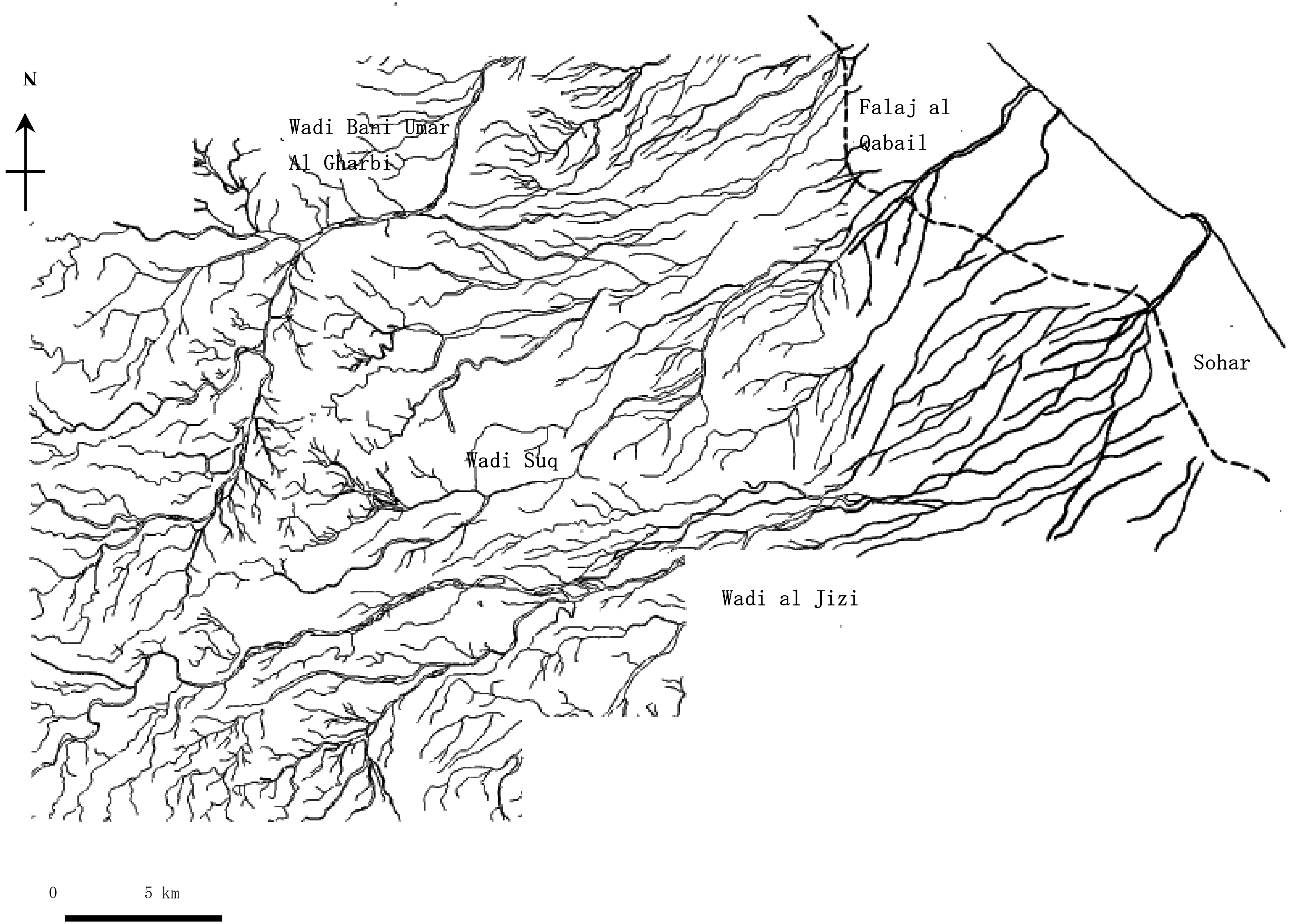

Figure 2.7 River System in the Study Area

Table 2.1 Summary of Hydrological Features of Wadis in the Study Area

River name	Length (km)	Catchment area (km^2)	Altitude above sea level Elevation (m)	River gradient
Wadi Suq	34	115	275	0.008
Wadi al Jizi	75	1,100	1,567	0.021
Wadi Bani Umar al Gharbi	65	450	1,452	0.022

(1) Wadi Suq

The topographical classification and hydrological features on Wadi Suq are shown in Figure 2.8 (1), (2) and Table 2.2, respectively.

Wadi Suq is 34 km in length with an average gradient of 0.008 (1:125). The maximum elevation of the wadi is 275 m. The altitude at Falaj al Qabail is 30 m in elevation. The total catchment area is 71 km^2 with the mountainous zone of the wadi occupying 29 km^2. The tailing dam located at the uppermost part of Wadi Suq, as shown in Figure 2.9. The radiant in the upper part of the wadi is relatively steep (0.02), but the lower part of the wadi from the tailing dam shows an almost constant gradient of 0.008.

Wdi Suq is topographically divided into seven subareas, including Subarea 1 to 7 as shown in Table 2.2 and Figure 2.8.

The upstream area consists of hilly land, consisting of basaltic rocks. The flow pattern of the wadi consists of a dendritic system, so that the channel density is relatively high in this area. In constrast, the Batinah Olistostrome is predominant in the middle section of the wadi. Hence, the topography is characterized by terraces, so that the channel density is much lower than in the upper section. In the downstream section, the wadi forms a wide floodplain with numerous streams showing a dendritic pattern typical of the whole district. However, eolian sands cover the lowest part of the wadi and most of the small streams disappear in this lowest section with only the main stream remaining visible in this district.

No surface water is found in Wadi Suq in the upper part of the wadi; but then only after heavy rains. Floods create new natural channels with depths from 2.5 m to 3.2 m in the lowest part of the wadi. Sediments in the riverbed consist of alluvial terrace deposits and wadi sediments. The alluvial terrace deposits and the lower part of the wadi sediments are consolidated by calcrete. The permeability of calcreted beds is thought to be relatively poor. However, calcreted beds in the upper part of the deposits are generally loose and exhibit some remaining porosity in the calcrete. However, the top layer of the alluvial sediments is extremely loose, but its depth ranges in thickness from only 0.1 m to 2 m. Calcreted beds are exposed in some places by local erosion. Water wells along Wadi Suq are distributed around Sagha, Misyal A'sadar, and Falaj al Qabail villages.

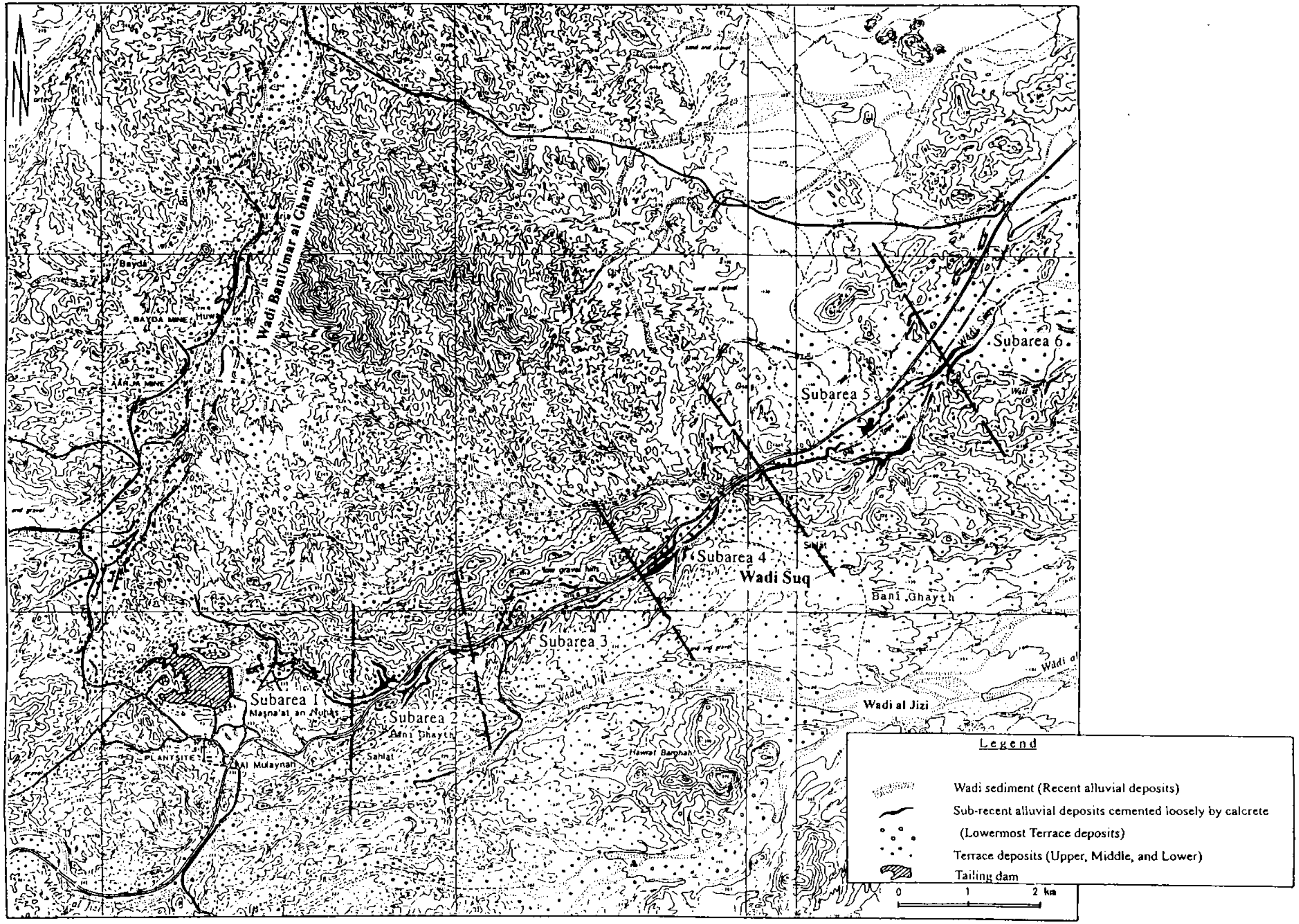

Figure 2.8 Topographical and Geological Features along Wadi Suq (1)

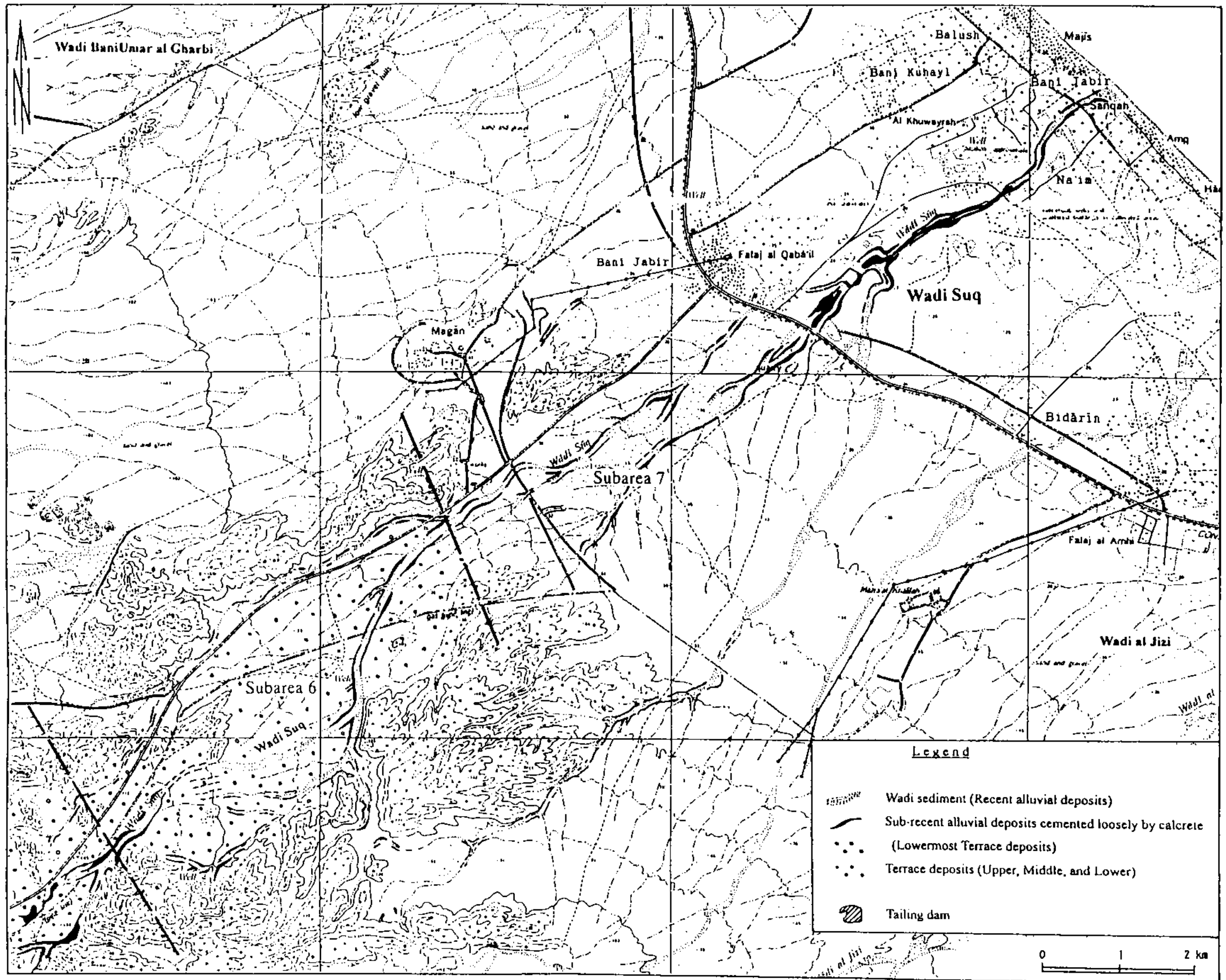

Figure 2.8 Topographical and Geological Features along Wadi Suq (2)

Table 2.2 Hydrological Features on the Wadi Suq

(1) Situation of Wadi Suq

1. Total river length (m)	34 km		
2. River length (m) and elevation (m)	Location	Length (km)	Elevation (m)
Upper part of Wadi Suq Middle part of Wadi Suq Lower part of Wadi Suq	From top to KM14 (Sagha) From KM14 (Sagha) to Magan (D-7 point) From Magan (D-7 point) to river mouth	12.2 11.3 11.0	312 to 152 152 to 60 60 to 0
3. Total catchments area (km^2)	90.66 km^2 (including main water course area and Tributary-1) 111.81 km^2 (including main water course area, Tributary-1 and -2) 158.16 km^2 (including main water course area, Tributary-1, -2 and -3)		
4. Highest elevation (m)	312 m		
5. Total river gradient (°)	0.5° (1/110)		
6. River gradient (°) Upper part of Wadi Suq Middle part of Wadi Suq Lower part of Wadi Suq	From top to KM14 (Sagha) From KM14 (Sagha) to Magan (D-7 point) From Magan (D-7 point) to river mouth	0.7° (1/77) 0.5° (1/122) 0.3° (1/183)	
7. Topographical features Upper part of Wadi Suq Middle part of Wadi Suq Lower part of Wadi Suq	Low relieved mountainous land Hilly land and terrace plane Alluvial plane		
8. Vegetation in the catchments area	Classification : Sub-arid area Vegetation : Very rare		
9. Surface water	No surface water		

(2) On the Subarea along Wadi Suq

1. Tributaries of Wadi Suq	Name	Length (m)	Catchments area (km^2)	
	Tributary-1 Tributary-2 Triburart-3	7.5 14.5 20.9	15.68 21.15 46.35	
2. Sub-areas in main water course of the wadi	Subareas	Location	Length (km)	Area of alluvial plane (km^2)
	Subarea-1	End of Tailing dam to D-5 point	1.5	0.71
	Subarea-2	D-5 point to 6.2 km point	1.5	0.52
	Subarea-3	6.2 km point to D-6 point	2.5	0.89
	Subarea-4	D-6 point to KM14 (Sagha)	3.45	1.02
	Subarea-5	KM14 (Sagha) to D-13 point	4.0	4.87
	Subarea-6	D-13 point to D-7 point	7.35	13.29
	Subarea-7	D-7 point to D-16 point	8.9	18.72
	Total		29.2 km	40.02 km^2

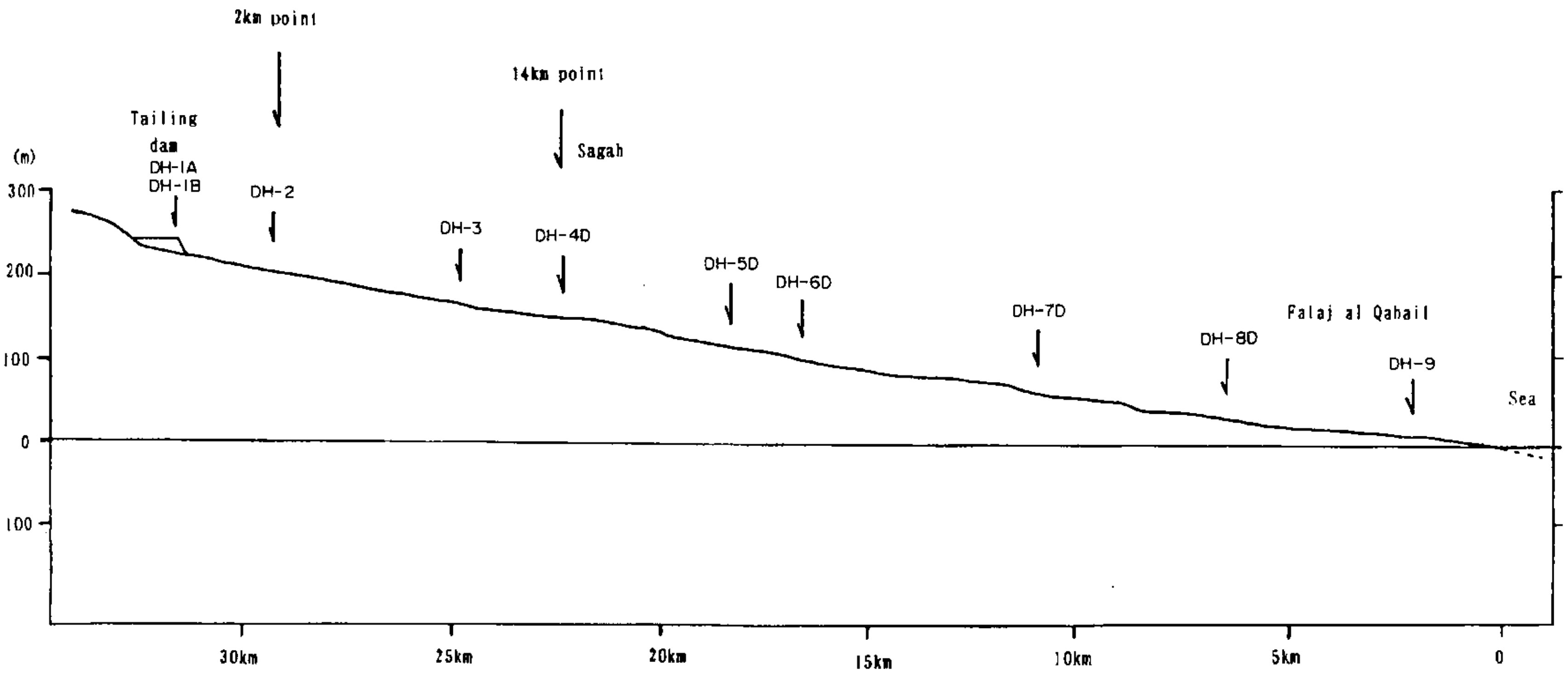

Figure 2.9 River Section of the Wadi Suq

Most of the wells in Wadi Suq are hand dug, ranging in depth from 6 m to 15 m. The diameter of the wells is typically between 1 m and 1.5 m. The walls of the wells generally consist of gravel materials but the surface completions are usually made of concrete. Water is typically pumped from the wells by electric or gasoline powered pumps. Well water is mostly used for irrigation and livestock. Potable water is currently obtained by delivery trucks from OMCO since the mine pollution has affected the quality of the water. Water quality of the Falaj at Amhi in the downstream area is shown in Table 2.4.

Table 2.4 Water Quality of Surface Water and Falaj

River	Location	Flow rate (m^3/min)	Water quality				Remarks
			pH	ORP	EC*	Water temperature	
Wadi Suq	Falaj al Qabail	3	8.29	110	0.106	32.9°C	Falaj
Wadi al Jizi	Suhaylah	1	8.11	77	0.135	30.1	Surface water
Wadi al Jizi	Falaj al amhi	3	8.13	104	0.065	31.7	Falaj

* EC: Electric Conductivity (S/m)

(2) Wadi al Jizi

Wadi al Jizi has total length of 90 km, with a catchment area of 71 km^2. The altitude at the highest point is 1,567 m and average gradient is 0.021 (1:48). The Study area includes from middle to lower part of the wadi, i.e. from Suhaylah village to Sohar city. The Lasail and Lasail West mines are located along Wadi Lasail, which is one of the tributaries in middle reach of Wadi al Jizi.

The middle section of the Study area is characterized by mountainous to hilly land, with dry dendritic river systems. The district between the middle and lower part of the wadi consists of a terrace district where the Batinah Olistostrome predominates and the river system exhibits a dendritic pattern with relatively high channel density. An extremely wide floodplain is formed in the lower part of the wadi and numerous streams are developed in the floodplain, again showing a dendritic pattern. However, the lowest part of the wadi is covered by eolian sand deposit and most of the streams disappear except for the main stream.

The alluvial terrace deposits and wadi sediments fill the wadi. And the matrix of the sediments is generally consolidated by calcrete,so its permeability seems to be relatively poor. Wadi sediments, which range in thickness from 1 to several meters, are composed of sand and gravel with pebbles and are extremely loose.

Surface water in the wadi is very rare, especially in recent years when it has been quite difficult to find a surface stream because there has been no rainfall. In the western part of the Suhaylah village, the surface water can be seen on a small scale. The water quality is presented in Table 2.2. Water wells are distributed in villages along the main stream and tributaries of the wadi. Most of the wells are hand dug and water is typically pumped from the wells using electric or gasoline powered pumps. A falaj is constructed around the main stream. Water quality of the Falaj at Amhi in the downstream area is shown in Table 2.4.

(3) Wadi Bani Umar al Gharbi

Wadi Bani Umar al Gharbi is 90 km in length with a catchment area of 71 km^2. The altitude at the highest point is 1,452m and the average gradient is 0.022 (1:45). The middle to downstream reaches of the wadi, i.e. a range from Bayda village to its downstream is included in the Study area. The Aarja and Bayda mines are located along one of the tributaries in the middle stream area.

The middle stream of the Study area consists of hilly land consisting of basaltic rocks and Batinah Olistostrome with a dendritic stream pattern containing a relatively high channel density. The downstream area consists of a terrace district and the wadi forms a wide floodplain with numerous streams forming a dendritic pattern.

Riverbed sediments consist of alluvial terrace deposits and wadi sediments. The matrix of the alluvial terrace deposits is solidified by calcrete. Its permeability seems to be relatively poor. However, calcrete in the upper part of the alluvial terrace deposits is relatively porous. Also, the top layer of the wadi sediments consists of sand and gravel and is extremely loose, so its permeability seems to be very high.

No surface water is usually found in Wadi Bani Umar al Gharbi stream, except in the upper part and then only after rare heavy rains.

Water wells are distributed in villages along the main stream. Most of the wells are hand dug ranging in depth from 6 to 10 m. The diameters of the wells range from 1 to 1.5 m. The wall of the wells is almost always covered by pebbles, and the surface completions are usually made from concrete. Water is typically pumped from the wells by electric or gasoline powered pumps. Well water is mostly used for irrigation and livestock. Potable water is currently obtained by delivery trucks from OMCO since the mine pollution has affected the quality of the water.

2.3.2 Water Wells

The distribution of wells in the Study area is shown in Figure 2.10 and the details of the construction are shown in Table 2.3. Water wells are distributed in riverbeds or on alluvial terrace plains along Wadi Suq, Wadi al Jizi and Wadi Falaj al Qabail. The wells are mostly hand dug with diameters ranging from 1 m to 1.5 m. The walls of the wells are almost always covered by gravel, and the surface completions are usually made from concrete. Water is typically pumped from the wells by electric or gasoline powered pumps. Well water is mostly used for irrigation and livestock.

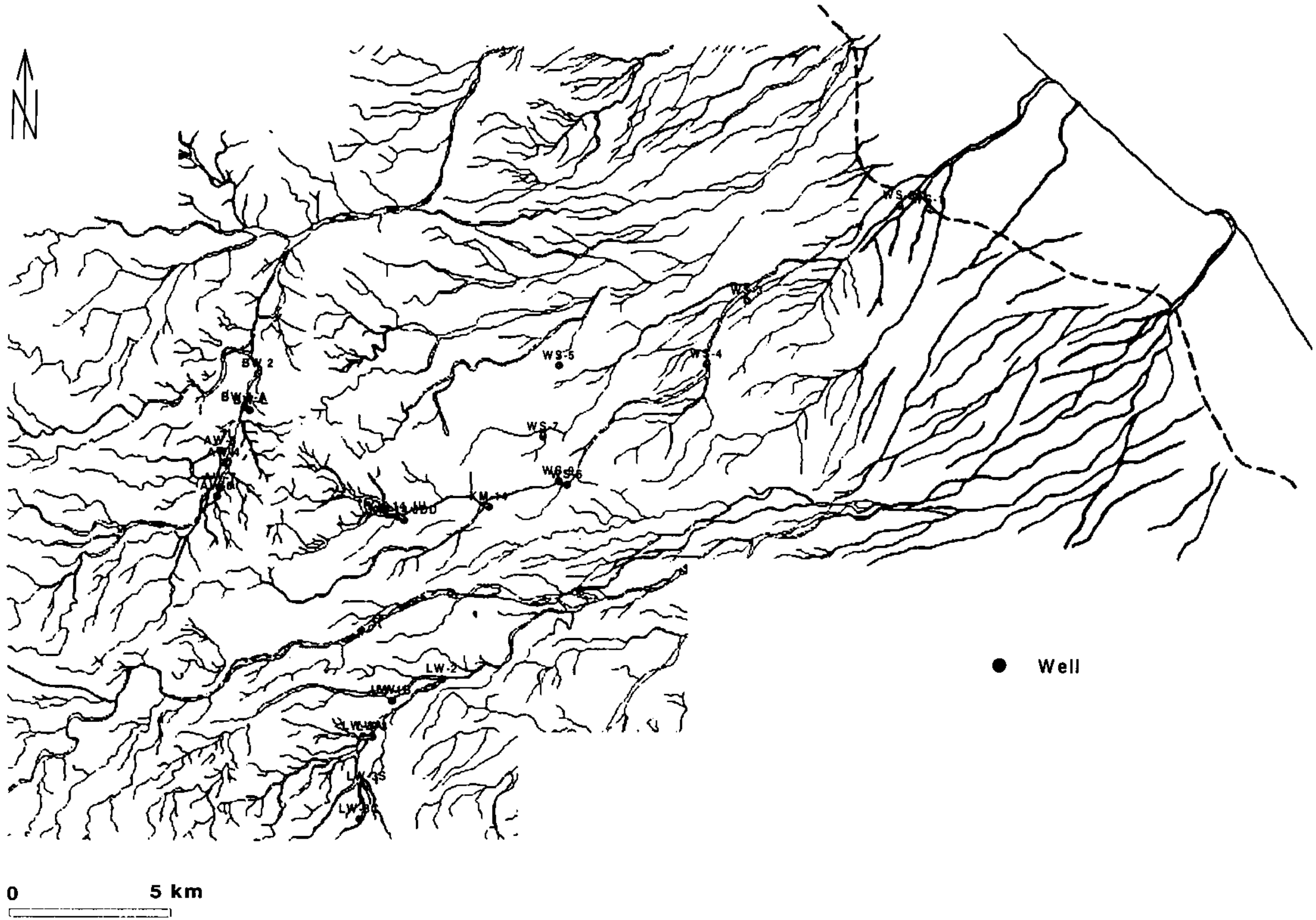

Figure 2.10 Existing Water wells in the Study Area

Table 2.3 Water Wells in the Study Area

Well Name	Type of Well	Area And Location	Depth from TOC to Water	Coodinates	
				Northing	Easting
			m	m	m
KM-14	Open dug well	Wadi Suq	3.80	2691600	449025
KM-14JDD	Open dug well	Wadi Suq	NA	2691200	446500
KM-14JU	Open dug well	Wadi Suq	NA	2691317	446303
WS-1	Open dug well	Wadi Suq	NA	2700390	462065
WS-2	Open dug well	Wadi Suq	NA	2700513	461142
WS-3	Open dug well	Wadi Suq	NA	2697708	456648
WS-4	Open dug well	Wadi Suq	NA	2695835	455448
WS-5	Open dug well	Wadi Suq	6.98	2695787	451081
WS-6	Open dug well	Wadi Suq	12.40	2692253	451336
WS-7	Open dug well	Wadi Suq	12.42	2693681	450618
WS-8	Open dug well	Wadi Suq	NA	2692363	451091
WS-9	Open dug well	Wadi Suq	-	2692900	441150
AW-4	Open dug well	Aarja Area	5.43	2693250	441050
AW-5	Open dug well	Aarja Area	6.08	2692150	441050
AW-7	Open dug well	Aarja Area	10.07	2691900	440950
AW-8	Open dug well	Aarja Area	8.68	2694550	441750
BW1-A	Open dug well	Bayda Area	5.44	2695550	442150
BW-2	Open dug well	Bayda Area	5.95	2694450	441900
BW-1	Open dug well	Bayda Area	5.11	2685904	446163
LW-1	Open dug well	Wadi al Owainah	13.48	2685900	446150
LW-1B	Open dug well	Wadi al Owainah	11.25	2686534	447637
LW-2	Open dug well	Wadi al Owainah	6.11	2684838	445576
LW-3	Open dug well	Wadi al Owainah	5.97	2684850	445300
LW-3A	Open dug well	Wadi al Owainah	7.54	2683363	445419
LW-3S	Open dug well	Wadi al Owainah	12.50	2682400	445200
LW-3C	Open dug well	Wadi al Owainah	7.91	2682400	445200

2.3.3 Falaj System

Falaj systems are found in the Study area as shown in Table 2.4 and Figure 2.8. Two falaj systems are still using and supplying water to farms. Water quality of the falaj and suface water is shown in Table 2.4.