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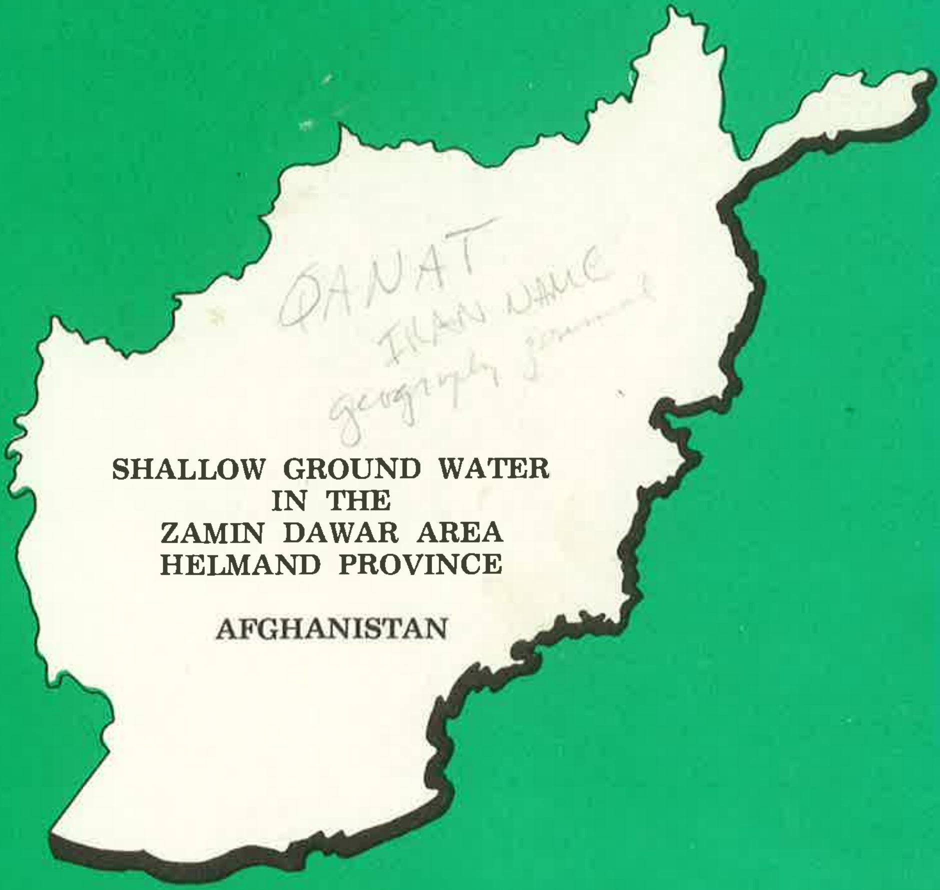

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SHALLOW GROUND WATER IN THE ZAMIN DAWAR AREA HELMAND PROVINCE

AFGHANISTAN

Prepared by
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Shallow Ground Water in the Zamin Dawar Area,
Helmand Province,
Afghanistan

by

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Abstract

The Zamin Dawar area lies between Kajakai Reservoir and Musa Qala Rud (river) in south-central Afghanistan, about 90 km (kilometers) northeast of Lashkar Gah. The area comprises two main stream drainage areas: that of Gulmesh Mandeh (ephemeral stream) to the east which includes mostly plains with low hills on the east and north slopes and a high limestone scarp on the west slope; and Baghni Rud to the west which drains a mountainous area to the north and spreads onto a large alluvial fan with distributaries leading both to Helmand Rud to the southeast and Musa Qala Rud to the west. Most of the cultivated lands in the Zamin Dawar area lie in the southern part of the Gulmesh plains and in the Baghni alluvial fan, as well as a ribbon of cultivation on the flood plain of Baghni Rud in the mountains. The southern end of the Zamin Dawar area with high terraces and sharply incised ephemeral stream valleys is uninhabited.

Karezes provide the chief source of water in the plains. Some 80 were examined and inventoried during the course of the present investigation. Several springs and one large-yield well also contribute to the water supply on the plains. In Baghni valley, developed springs provide the main source of water supply.

During the present investigation, conducted in 1971, it was found that the karezes yield a total of about 20,000 ac-ft (acre-feet) (25 million cu m /cubic meters/) of water per year.

The springs on the plains yield about 3,000 ac-ft (4 million cu m) per year, and the wells yield about 300 ac-ft (375,000 cu m) per year. The inventoried springs in Baghni valley yield about 6,500 ac-ft (8 million cu m) per year, and probably supply about 70 percent of the total water used in the valley. Therefore, the total amount of water used in the Zamin Dawar area in 1971 was about 32,000 ac-ft (40 million cu m). This amount of water was used to irrigate about 10,000 jiribs (approximately 5,000 acres or 2,000 hectares) of cultivated land and served a population of about 40,000 people.

Twenty years ago the water supply was more than double the 1971 flow from karezes and springs, and the population of the area was probably 60,000 to 70,000 people. During the past 10 years and particularly during the last 3 years, the water table has been declining as a direct result of a dry-weather cycle which has affected much of Afghanistan. Concurrently, the population of the area has declined.

Rainfall, based on data from the Kajakai Camp weather station, has declined from a 27-year annual average of about 200 mm (millimeters) to about 160 mm per year, which is the annual average for the last 5 years and equivalent to a reduction of approximately 70,000 ac-ft (88 million cu m) of precipitation per year over the entire area. To compensate for the declining water levels many karezes have been deepened or lengthened at great financial cost to the people.

This report evaluates present ground-water conditions in the area and suggests ways and means by which more water can be obtained for local requirements.

Introduction

Location and Brief History of Area

The Zamin Dawar area is located 90 km (kilometers) northeast of Lashkar Gah, in south-central Afghanistan. The area is named after the ruins of the fort of Dawar, which is situated in about the middle of the cultivated area on the plains between Helmand Rud (river) and Musa Qala Rud. Dawar was the ruler and chief land owner of the area during the Ghaznavid period, about 1,000 years ago. Many ruins, from small individual forts to the larger, 14-hectare (35-acre) compound of Zamin Dawar, are still recognizable today.

The development of ground water by the construction of karezes elsewhere, notably in Iran, probably predates the Ghaznavid period by as much as 1,500 years. However, whether karezes existed in this area 2,500 years ago is not known. Many old karezes, abandoned long ago, exist as rows of low doughnut-shaped mounds. The ages of these are not known.

Karezes, as well as the developed springs in the area, have probably been in use at least since the Ghaznavid period. Weather cycles, though, have been the determining factor in the use of karezes. During wet cycles the water table may have been high enough so that water was supplied by surface streams and springs. During dry cycles, the people may have needed to dig down to the water table to keep springs flowing. Extensive spring development resulted in full-scale karezes. Many of the people of the area, when interviewed, stated that the karezes are 300 to 400 years old. This could mean that 300 years is the remote past to the people, or it could mean that about 300 years ago a wet cycle ended and karezes were redeveloped. It might also reflect expansion of agriculture, which could result from political stability rather than climatic change. Whatever the implications, it is probable that most of the karezes presently used in the Zamin Dawar area are at least 300 years old.

Extent of Area

The area covered by the present study comprises the drainage basins of Gulmesh Mandeh (wash or ephemeral stream) and Baghni Rud (river). The eastern limit of the study area is the divide along the eastern edge of Gulmesh Mandeh drainage basin (fig. 1). To the north, the boundary is the northern divide of Gulmesh Mandeh and Baghni Rud. The western limit follows the divide of Baghni Rud drainage basin to the upper part of the Baghni alluvial fan, then arbitrarily crosses the distributaries of Baghni Rud which flow to Musa Qala Rud and follows the divide on the terrace hills between Helmand and Musa Qala Ruds to the confluence of these rivers. The southeastern limit is Helmand Rud.

The Zamin Dawar area is about 100 km long from north to south and about 30 km wide from east to west. The total area is about 2,140 sq km (square kilometers), but the area of intensive study was about 500 sq km, including most of the cultivated lands.

Purpose and Scope of Study

The water supply of the Zamin Dawar area has been decreasing for the past several years. In the spring of 1971, HAVA (Helmand-Arghandab Valley Authority) through the auspices of the U.S. Agency for International Development (USAID) requested that members of a USGS (U.S. Geological Survey) hydrogeologic team, then temporarily assigned to Afghanistan, advise on and help conduct an investigation on the possibilities of obtaining additional ground-water supplies for irrigation in the Zamin Dawar, Musa Qala, and Naw Zad areas in the northern part of Helmand Province. USGS and HAVA personnel completed preliminary reconnaissance studies of the three areas in June 1971.

A more intensive field investigation of the Zamin Dawar area began under the guidance of the writer in July 1971 and is still continuing. The present report describes and evaluates the findings of the first phase this investigation through December 1971. This report, moreover, relates only to the occurrence and use of the shallow ground water in the Zamin Dawar area and presents brief recommendations. As originally proposed the chief purpose of the investigation of the area was to determine the feasibility of increasing the supply of ground water that could be used for irrigation. In order to accomplish this objective, however, a thorough study of all the water resources of the area must be made, including evaluation of data on surface water and precipitation. No surface-water data and little precipitation information were found to be available for the area at the beginning of the study. Also, information is needed on the lithology and water-bearing properties of deep aquifers. These data are expected to be collected in the course of continuing field investigation. A second, but equally important, purpose of the first phase of the investigation was to train HAVA personnel on the methods of data collection and analysis in order that they may carry on the continuing study of the Zamin Dawar area and conduct similar investigations in other areas.

A report by Jones (1971) includes recommendations for future ground-water studies and continued data collection in the Zamin Dawar area and elsewhere in the upper Helmand Valley. Another report by Sammel (1971) evaluates the ground-water resources of the Arghandab River Valley near Kandahar.

Personnel and Acknowledgments

An initial preliminary reconnaissance of the Zamin Dawar area was conducted by J. R. Jones, Chief of Party, E. A. Sammel, and N. E. McClymonds, all of the USGS team, accompanied by Mehrabuddin Formali, Mohammad Asif, Mohammad Sarwar Samadi, and Barat Mohammad Baluch of the Project Development Planning Division of HAVA. More detailed investigations in the area were continued by Barat and McClymonds with the help of other individuals from HAVA and from the USGS team.

A survey crew, headed by Nasir Ahmad Talib, determined the elevations of the measuring points at the first (mother) wells of the karezes and also of the water surfaces at karez and spring outlets. A power-auger crew, headed by Mohammad Sarwar Samadi, attempted to bore holes to determine the lithology of the shallow alluvial deposits. The HAVA chemical laboratory, headed by Mohammad Asif, analysed water samples to determine the chemical constituents.

The writer wishes to acknowledge the help and support of the U. S. Bureau of Reclamation team in Lashkar Gah and the logistical support of the Helmand-Arghandab Valley Region of USAID/Afghanistan. He also acknowledges his appreciation for the helpful guidance and criticisms of J. R. Jones and E. A. Sammel. The U.S. Agency for International Development (USAID) arranged the assignment of and provided financing for the USGS team.

Numbering System for Karezes, Springs, and Wells

During the inventory of the karezes, springs, and wells in the Zamin Dawar area, water sources were numbered consecutively as inventoried. The karezes were numbered 1, 2, 3, ... without prefixes. The springs and wells were numbered with the prefixes S- and W-, respectively. These numbers are shown on accompanying maps (figs. 1 and 2). In addition, the inventory schedules show the latitude and longitude coordinates from which a permanent office number is derived. The grid number for a karez is taken as the point where the karez tunnel ends and the outlet canal begins. Springs and wells are located by the latitude and longitude of the main outlet.

Locations on the map can be determined with an accuracy of about 5 seconds at latitude and 5 seconds of longitude (150 m and 130 m, respectively), but in order to make the permanent office number reasonably concise, the number designating each hydrologic data point includes only the digits for degrees and minutes. Thus a well location is characterized by two four-digit numbers for latitude and longitude, which specify the southwest corner of a 1-minute by 1-minute quadrangle in which the karez, spring, or well is found. Within the 1-minute quadrangles, water sources are further distinguished by the addition of a serial number based on the order in which they were inventoried. Karezes, springs, and wells are not differentiated in this system. Figure 3 shows examples of the numbering system.

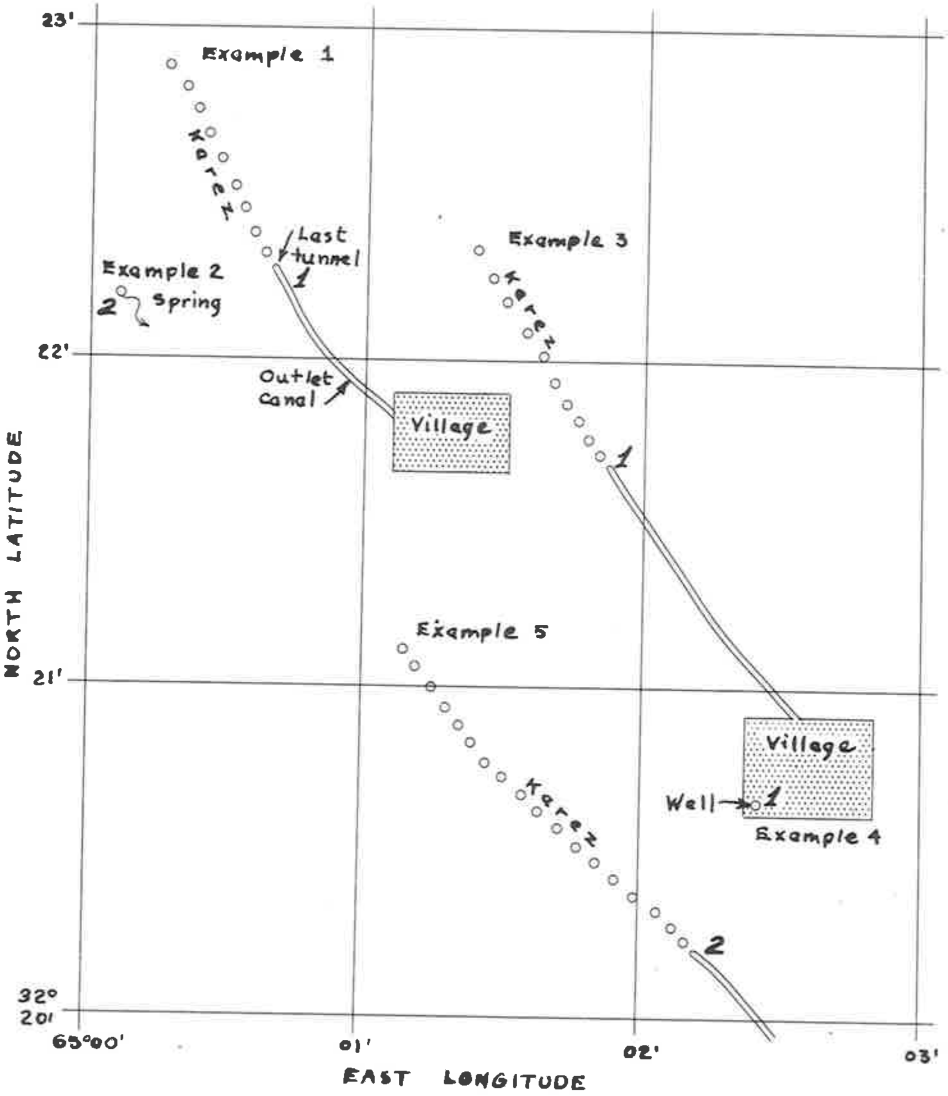

Figure 3--Examples of geographic coordinates numbering system to be used as the permanent office number for karezes, springs and wells.

Example 1-Karez in upper left corner would have a permanent office number of: 3222-6500-1; that is, it is within the minute grid quadrangle bounded by 32°22' and 32°23' north latitude and 65°00' and 65°01' east longitude, and it is the first water source inventoried in the quadrangle.

Example 2-Spring to upper left would have a number of: 3222-6500-2.

Example 3-Karez in middle of sketch would be: 3221-6501-1.

Example 4-Well in lower right would be: 3220-6502-1.

Example 5-Karez in lower right would be: 3220-6502-2.

Physical Setting

Geography and Geology

The Zamin Dawar area includes a diverse array of mountains, plains, and stream valleys.

Mountains--About one-half of the Zamin Dawar area, as defined in this report, is mountainous. The Baghni drainage basin consists of mountainous terrain except for a narrow ribbon, 0.5 to 2 km wide, of alluvial valley land along the Baghni Rud and Onay Rud (fig. 1). The drainage basin of Baghni Rud is about 900 sq km down to Roshanabad. The highest point in the area is a peak at the north end of Baghni Ghar, which is unnamed on available maps. It is 3,140 m (meters) (10,300 feet) in elevation. The higher ridges near the northern end of the Baghni valley rise to elevations of about 2,800 m and those near the southern end of the valley reach about 2,400 m. The mountains adjacent to the Gulmesh plains are considerably lower, although the scarp of Sherei Ghar (figs. 5, 7 and 10) which rises abruptly about 900 m above the plain on the west side, has an elevation of about 2,000 m. The hills along the east edge of the study area have elevations of about 1,300 m and rise 200 to 300 m above the plains.

At this stage of investigation little is known of the geology of the Zamin Dawar area. The geologic description below is based on very general field reconnaissance with some observations made from a distance. The Geologic Map of Afghanistan (Afghan Geol. Survey Dept., 1969) shows only very large features. The mountains consist almost entirely of limestone of Permo-Triassic age. The geologic structure and stratigraphic sequence of the limestones have not been studied in detail, but faulting is probably more important than folding in determining the structure of the area. The general dip of the limestone strata is westerly at angles of less than 30 degrees. Many of the limestone beds are dense and massive. Karst features were not observed, although evidence of some solution by ground water was noted on discrete blocks of limestone at Sharhkonah and Diyak springs. Fractures, probably associated with faulting, exist at most of the spring sites, and probably control the occurrence and movement of ground water in the limestone beds.

Two large faults, shown on the Geological Map of Afghanistan, are readily identifiable in the field. One fault is on the western edge of the Gulmesh plains. It apparently is upthrown on the west side, causing the high limestone scarp of Sherei Ghar (figs. 5, 7 and 10). The other fault is on the eastern edge of the Musa Qala valley and apparently has been upthrown on the east side, causing another high scarp. Between the faults, the mountainous area of the Baghni Rud drainage appears to lie on a horst some 25 km wide. Smaller faults exist throughout these mountains, some trending north-northeast, parallel to the two large faults and the general trend of the other mountain ranges in south-central Afghanistan, and some east-west.

Igneous dikes, at most a few meters thick, intrude the limestone beds at scattered places; however, no potentially valuable mineralization was noted in association with these dikes. Influence of the dikes on occurrence and movement of water is not known, but is assumed to be minor compared with influence of fractures or bedding and jointing of the limestones.

Plains--Broad alluvial plains exist in most of the central and southern parts of the Zamin Dawar area. They include the Gulmesh plains in the eastern part, the Baghni alluvial fan in the west-central part, and the high terrace uplands (fig. 9) in the southwestern part of the area. The Gulmesh plains and the Baghni alluvial fan can be further divided into higher uncultivated and lower cultivated parts. The Gulmesh Mandeh drainage basin, an area of about 630 sq km, includes about 80 percent plains and about 20 percent mountains around the edges of the plains to the east, north, and west. The Gulmesh plains in the north near Sherei (fig. 1), are about 8 km wide with evidence of some formerly cultivated fields and are crossed by many tributaries and distributaries of Gulmesh Mandeh (fig. 7). The southern Gulmesh plains broaden to about 18 km include a large area of presently cultivated fields (fig. 2).

The Baghni alluvial fan covers an area of 470 sq km and is crossed by distributary streams from Baghni Rud which flow southwest to Musa Qala Rud and south and southeast to Helmand Rud (fig. 1). The distributaries flowing to Musa Qala Rud are cut by an arbitrary line chosen for the western limit of the Zamin Dawar area. The area to the west of this line will be included later as part of a study of the Musa Qala area. Only the southern part of the Baghni alluvial fan has been cultivated in recent years, but there is evidence of former cultivation across much of the upper part of the fan (fig. 2).

Rolling terrace uplands (fig. 9) to the south of Baghni alluvial fan comprise an area of about 140 sq km. This area consists of old stream terraces presently being dissected by numerous small ephemeral streams which drain to Helmand Rud. The area is apparently uninhabited.

The alluvial materials of the plains of the Zamin Dawar area consist of thick layers (about 5 to 20 m thick) of silty clay to clayey silt (loam) and thin layers (about 0.5 to 2 m thick) of gravel or conglomerate. Some plastic clay layers and a few gypsum deposits exist locally. The relative thickness of the silty clay and the conglomerate is known only in the upper 30 to 40 m of the alluvial sediments -- the maximum depth of upper karez wells. Most of the karezes and wells obtain water from cracks or small holes in the silty clay material. The gravel layers are mostly packed with sand, silt, and clay, or are cemented into tight conglomerates by calcium carbonate deposits. They, therefore, usually have as little or less permeability than the silty clay layers.

Bedrock underlies the alluvial deposits of the plains at unknown depth. The depth to bedrock could be 100 to more than 300 m below the land surface. The characteristics of the alluvium from 30 m depth to bedrock are also not known. The writer suspects that layers of more permeable sands and gravels exist at depth, particularly near the base of the alluvium, but at present there are no data to support this supposition. The need for deep test holes (from 100 to 300 m deep) is emphasized by this lack of data.

Stream Valleys--The major streams of the Zamin Dawar area are Baghni Rud and Gulmesh Mandeh. Gulmesh Mandeh obtains water from the direct runoff of precipitation within its drainage basin. Distributaries in the upper part of the basin rejoin the main stem above its confluence with Helmand Rud. Several tributaries also join Gulmesh Mandeh in the lower part of the basin from the west and east.

Baghni Rud, with a drainage area of 900 sq km above Roshanabad, is the source of surface water and recharge for the ground-water system in Baghni valley and on the Baghni alluvial fan. The upper part of the drainage basin is in high mountainous terrain which has considerably greater precipitation than in the valley and fan areas. Probably a large amount of ground water and the bulk of the surface water flows southwest toward the Musa Qala drainage. The remainder flows underground toward the southeast and in the eastern distributaries of Baghni Rud to supply the Zamin Dawar area.

All the streams in the area have gravel channels. The streams, at least in the lower parts of the Gulmesh plains and the Baghni alluvial fan, are eroding the underlying silty clay of the older alluvium (fig. 6). In the upper part of the plains and the fan the streams appear to be depositing sediments (fig. 7). All streams, at least in recent years, flow only after rains during the winter and spring months and are dry the rest of the year. At the present stage of investigation in the Zamin Dawar area, it is impossible to estimate the amount of water lost from the area by surface-water outflow, but the amount is believed to be considerable.

Figure 4.--Line of Shafts (Wells) of Walang Karez (76). Zamin Dawar Ruins in Middleground Right. Helmand Rud Flows along Base of Limestone Hills in Background. Looking Southwest.

Figure 5.--Village of Machikel on Low Terrace above Gulmesh Plains. Limestone Ridge of Sherei Ghar in Left Background. Looking Northwest.

Figure 6.--Ephemeral Stream Bed with Thin Veneer of Gravel on Older Clayey Alluvium. Near Eastern Edge of Lower Gulmesh Plains. Shafts (Wells) of Qala-i-Gul Karez (44) Follow Left Bank of Stream. Looking Southwest.

Figure 7.--Ephemeral Stream, One of Several Distributaries of Gulmesh Mandeh in Foreground. East-Facing Scarp of Sherei Ghar with Cultivated Area near Diyak Village and Spring (S-2) at Base of Scarp between Talus Fans. Sherai Ghar Rises 900 m above Stream. Looking West.

Figure 8.--Main Outlet of Khohna Spring (S-3) which is Circular Pond to Right. Outlet Canal of Torghui Karez (20) Left Center. Village of Torghui in Middleground. Valley of Helmand Rud at Base of Limestone Ridge in Background. Looking Southeast.

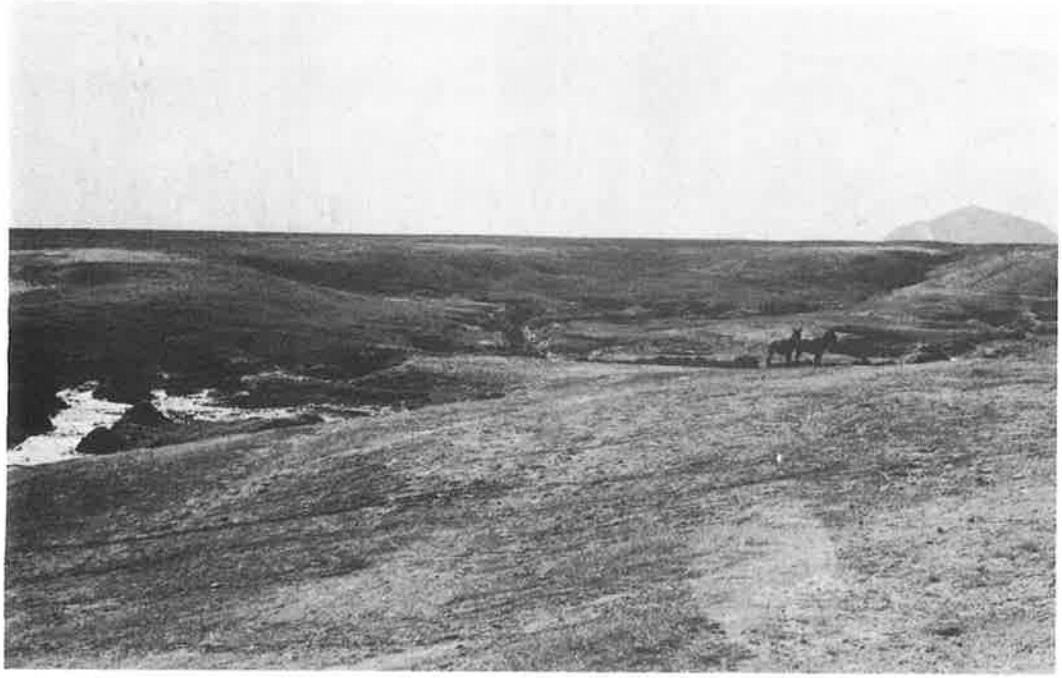

Figure 9.--Multiple Outlets of Sharhkonah Springs (S-4) Immediately South of De Khwaja Khaleq Ghar. Water Issues from Alluvial Gravels and Clay, but Parent Source is Underlying Fractured Limestone. Surface of Terrace Uplands and Baghni Alluvial Fan on Horizon. Musa Qala Mountain in Right Background. Looking West.

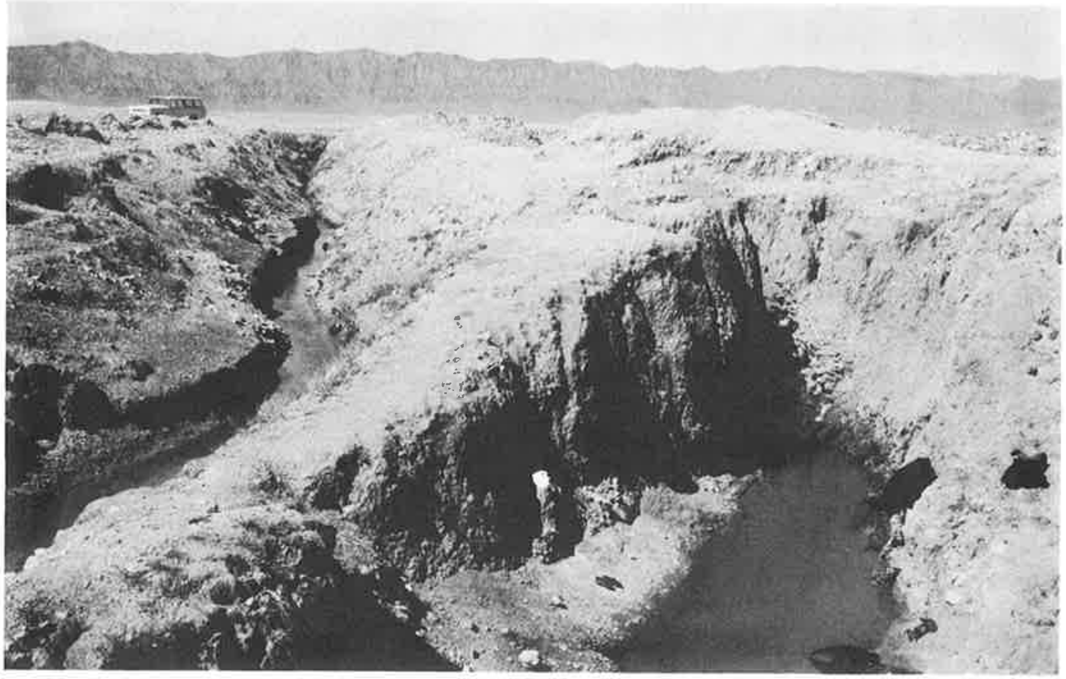

Figure 10.--Outlet Tunnel and Canal of Necha Karez (1) on Right and Outlet Canal of Kishmishkhan Karez (2) on Left in Northeastern Part of Lower Gulmesh Plains. Water Level in Necha Canal is about 1 meter Lower than that in Kishmishkhan Canal. Sherei Ghar Ridge in Background. Looking West-Northwest.

Figure 11.--Apparatus for Lifting Spoil from Digging and Cleaning Karezes. Men Working on Markhor Karez (45) on East Side of Lower Gulmesh Plains. Sherei Ghar in Background. Looking Southeast.

Figure 12.--Line of Shafts with Spoil Piles of Markhor Karez (45). Workmen Cleaning Karez and Irrigated Area near Markhor Village in Middle Distance. Sherei Ghar on the Right, De Kwaji Khaleq Ghar in Center, and Musa Qala Mountain on the Left. Looking West.

Figure 13.--Old Tunnel of Qala-i-Gul Karez (44) which has been cut through by Ephemeral Stream Channel at Lower Left. Still Older Transected Tunnel lies Mid-way up Stream Cut at Middle Right. Looking North.

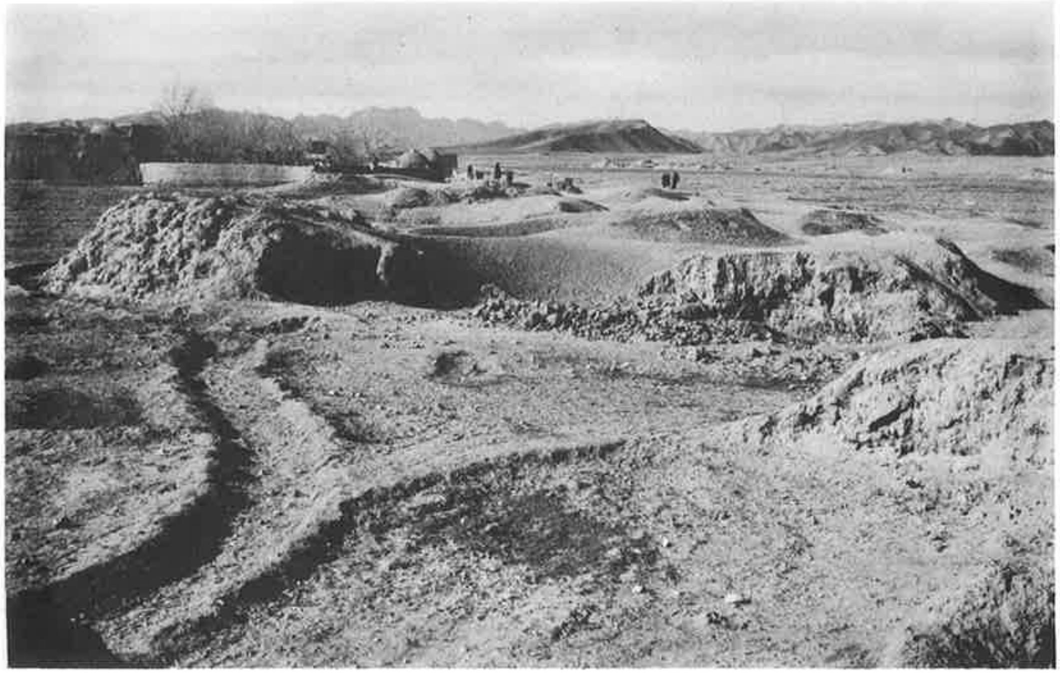

Figure 14.--Spoil Piles of Shafts of Walang Karez (76) in Foreground and Sharh Karez (36) Middleground to Right. Village of Suchi in Middle Left in Swale between Lower Gulmesh Plains and Baghni Alluvial Fan. Looking North.

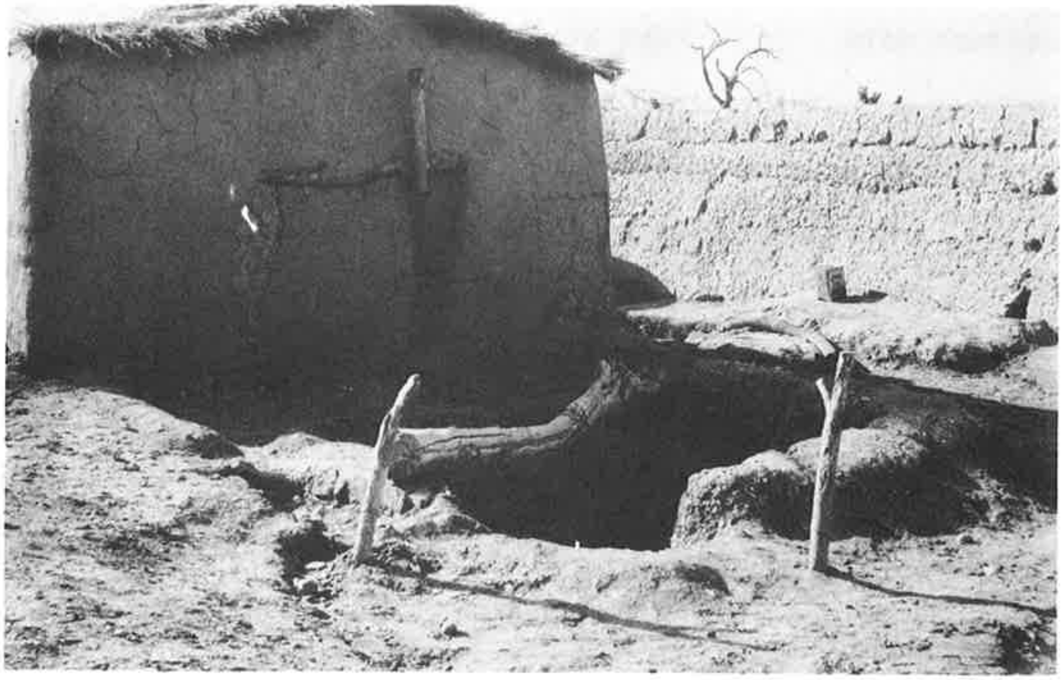

Figure 15.--Main Shaft (no. 5 Hole) of Deh Baba Well (W-2). Mud and Wattle Building to Left Houses Water Mill. Looking Northwest.

Climate

The Zamin Dawar area is located in the extensive arid region of southern Afghanistan and southwest Asia. Climatological data are available from the Morrison-Knudsen Afghanistan, Inc. camp at Kajakai, below the Kajakai Reservoir, for the period 1956-59. Longer-term data are available at the Manzel Bagh station in Kandahar and at the staff house station in Lashkar Gah. All three stations have precipitation, temperature, and evaporation data. No wind velocity nor relative humidity data were collected at Kajakai Camp.

<u>Precipitation</u>--The 4 years of records collected at Kajakai Camp (Brigham, 1964) are given in table 1, below. This period, 1956-59, however, was particularly wet and does not represent the long-term annual average precipitation for the Zamin Dawar area. Therefore, a series of calculations were made in an attempt to determine the approximate long-term average and the annual average for the last 5 years of below-average precipitation for which no records are available at Kajakai Camp.

Table 1.--Monthly precipitation, in millimeters, at Kajakai Camp, during period of record

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1956	40e	23	237	16	0	0	18	0	0	0e	0	17	351
1957	140	20	83	32	14	0	0	0	0	0	60	63	412
1958	60	0	8	0	0	0	0	0	0	0	0	15	83
1959	40	68	24	17	15	0	0	0	0	0	29	16	209
Average	70	28	88	16	7	0	5	0	0	0	22	28	264

(Note: e = estimated)

Table 2.--Average monthly precipitation, in millimeters, at Manzel Bagh station, Kandahar (1956-59)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
56	28	36	20	2	0	10	0	0	0	22	40	214

Table 3.--Average monthly precipitation, in millimeters, at Manzel Bagh station, Kandahar (1940-59, 1964-70)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
54	37	29	13	5	0	3	0	0	0	5	23	169

Table 4.--Average monthly precipitation, in millimeters, at Manzel Bagh station, Kandahar (1966-70)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
32	39	18	17	1	0	0	0	0	1	3	25	136

Table 5.--Average monthly precipitation, in millimeters, at staff house station, Lashkar Gah (1956-59)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
40	10	27	16	1	0	8	0	0	2	12	25	141

Table 6.--Average monthly precipitation, in millimeters, at staff house station, Lashkar Gah (1966-70)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
27	20	18	3	0	0	0	0	0	1	3	18	90

By comparing the 1956-59 precipitation records at Kajakai Camp (table 1) with the other two stations for the same period (tables 2 and 5), it is found that Kajakai Camp had about 120 percent of the precipitation of that at Kandahar and nearly 190 percent of that at Lashkar Gah. Using the Kajakai to Kandahar ratio, table 7 was devised from table 3 to indicate the long-term average for Kajakai Camp. Table 8 was devised to indicate the 1966-70 dry period average at Kajakai using comparisons with tables 4 and 6. These figures are approximate.

Table 7.--Calculated average monthly precipitation, in millimeters, at Kajakai Camp (about 27-year average)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
65	44	35	16	6	0	3	0	0	0	6	28	203

Table 8.--Calculated average monthly precipitation, in millimeters, at Kajakai Camp (1966-70)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
38	47	22	20	1	0	0	0	0	1	4	30	163

The precipitation records and calculations for Kajakai Camp are probably fair representations of the precipitation on the plains of the Zamin Dawar area. However, much more rain would fall on the mountainous part in the upper Baghni valley drainage area. There are, to date, no stations recording precipitation in the mountains north of the Zamin Dawar area.

Temperature--Records are available for the average daily maximum and average daily minimum temperatures as well as the monthly maximum and minimum temperatures at Kajakai Camp, for the period from February 1956 through September 1960. Table 9 shows the mean monthly temperatures calculated from the average daily maximum and minimum records for the period 1956-59. These temperatures are generally 0.5 to 1 degrees C (Centigrade) lower in the summer and 0.5 degrees C higher in the winter than the average temperatures for the same period at Kandahar station.

Table 9.--Mean monthly temperatures, in degrees Centigrade, at Kajakai Camp (1956-59)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
7.6	9.2	14.6	19.7	24.8	28.9	31.0	28.9	23.8	18.5	11.9	8.4	19.0°C
[46	49	58	67	77	84	88	84	75	65	53	47	66 °F]

The position of Kajakai Camp, at the west end of a gorge of the Helmand Rud, and the proximity of the river probably affects the air temperatures. On the plains to the west and northwest the winter temperatures are probably lower and the summer temperatures are probably higher. Also, if Kandahar station is representative of the region, the 1956-59 temperatures were generally warmer than the long-term average.

Evaporation--Pan evaporation records were also kept at Kajakai Camp for the 1956-59 period. Again, the position of this station is probably not very representative of evaporation on the plains of the Zamin Dawar area. The temperature, wind velocity, and relative humidity at Kajakai are probably significantly different than in the open plains, but may be similar to the lower parts of the mountainous area in Baghni valley and in the upper part of the Gulmesh Rud drainage basin. Nevertheless, as the records at Kajakai Camp are the only ones available, they are shown in table 10.

Table 10.--Average monthly pan evaporation, in millimeters, at Kajakai Camp (1956-59)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
60	81	106	190	270	352	380	371	290	214	130	70	2,514

For the same period in Kandahar the average annual evaporation was 1,683 mm, as compared with a 9-year (1951-59) average of 1,723 mm. Lashkar Gah station recorded 2,827 mm of average annual evaporation for the period 1956-59.

Cultural Setting

Population

To the knowledge of the writer, no census has been taken of the Zamin Dawar area. During the inventory of the water sources, one of the questions asked was: how many people does the water source support? Some of the answers were obvious exaggerations, but some answers seemed to be underestimates. A best estimate of the population of the area is approximately 40,000 people, but the number could be more than 50,000. Almost the entire population is engaged in agriculture.

Many people have left the area in the past 10 years. From information gathered during the water-source inventory, it is estimated that 10 years ago there may have been one and a half to two times as many people in the Zamin Dawar area as live there today. The declining flow of the springs and karezes is the chief reason for the exodus. The declining flow is directly related to a deficiency in recharge to the groundwater system which is, in turn, related to the dry cycle of the past 5 to 10 years.

Agriculture

Wheat, corn (maize), alfalfa, and garden vegetables were the main crops observed in cultivation during the investigation of the area. An inventory of the acreages of each crop was not, however, the concern of this study, so only casual observations were made. The soil is loam (silty clay to clayey silt) which, although probably lacking in certain nutrients and chemicals, seems to be fairly fertile. A thorough study of the agricultural potential and classification of soils will need to be made as part of the overall development of the area.

Shallow Ground-Water Resources

Present Water Development

Reconnaissance examination of water-use practices in the Zamin Dawar area leads to the conclusion that the people have developed the obvious water resources of the area or to nearly their fullest extent. All the springs in the area are developed; the water is directed through canals to the villages and fields. Karezes exist throughout the lower plains. The water from the karezes is directed to irrigated fields by a network of canals, and it appears that very little water is being wasted. The higher plains are barren and uncultivated, possibly because the material there is too loose to dig karezes in safely.

In the Baghni valley during 1971 all springs are developed and in use. It was reported that 5 to 10 years ago the springs had flows exceeding the amount that could be used, and that Baghni Rud flowed throughout the year. Ten years ago the stream flowed past Roshanabad and disappeared in the alluvial gravels on the upper part of the Baghni alluvial fan. This year (1971) Roshanabad is deserted and Baghni Rud is dry, except during the winter and early spring months, as far north as Giman, 37 km north of and upstream from Roshanabad.

It would be possible to deepen many of the karezes and in this manner increase the discharge. The cost, however, would be prohibitive for most villages. One village, Deh Baba, has dug a well which provides a large supply of water, and other villages are planning to do the same.

Sources of Water

Springs

Springs are the original water source in the Zamin Dawar area. Before development of karezes, spring outlets were improved and the water was directed by juis (canals) to the fields. It is believed by the writer that karez development originated because of decrease in discharge from used springs caused by water-level decline at some time in the remote past. The people improved the flows of the springs by deepening outlet channels, as was being done in 1971 at several localities, and finally by digging tunnels to the water source resulting in a full-scale karez.

The springs presently existing in the Zamin Dawar area can be divided into three types: (1) water-table springs, (2) springs issuing from fractured limestone, and (3) deep-fault springs. The water-table springs are the most common and exist in the Baghni valley and on the lower plains areas. The springs issuing from fractured limestone are also fairly common and many yield large volumes of water. The deep-fault springs are not common in the Zamin Dawar area. Until more is learned of the geologic structure of the area, such springs are recognized only by the warmer temperature of the water.

<u>Water-table Springs</u>--Examples of water-table springs in the Zamin Dawar area are Deh Yak (S-12), Sangwana (S-11), Sharghambar (S-7), and Khenjak Mazar (S-6) in the Baghni Valley; Nanokhel (S-9)

and Kanzi (S-10) on the lower plains of Gulmash Rud; and Kokochel (S-14), Lwar Bajaghar (S-15), and Azan spring (not inventoried) on the lower plains of the Baghni alluvial fan (fig. 2). Several other smaller springs in Baghni valley and on the lower plains have not been inventoried as yet. Pertinent data on the water-table springs are listed in table 11.

In Baghni valley the spring flow emerges from river gravels which underlie the alluvial valley of Baghni Rud. It is probable that some of the water feeding these springs comes from sources along the sides of the valley -- particularly the case of Khenjak Mazar spring -- but most of the springs are fed by water flowing through the alluvial fill down the main valley. Fractured limestone, buried by the alluvial deposits, could also be the source of some spring water, but unless there is a surface indication along the edges of the valley most of these springs are grouped with the water-table springs.

On the lower plains the springs usually rise where channels of ephemeral streams have cut down through the alluvium to the water table. The water usually emerges from partings in silty clay -- the same material that forms an aquifer in karezes. Lwar Bajaghar spring is an exception; here the water issues from a gravel layer at the edge of an ephemeral stream, but this gravel layer is probably fed by water from silty clay deposits higher on the plains.

Table 11.--Data on Water-Table Springs, 1971

Field No.	Name	Discharge (in cfs) 1971	Discharge (in cfs) 20 yrs. ago[2]	Discharge (in lps) 1971	Discharge (in lps) 20 yrs. ago[2]	Specific Conductance (in micro-mhos per cm at 25°C)	Water Temperature (°F)	Water Temperature (°C)	Land Irrigated (in jiribs) 1971	Land Irrigated (in jiribs) Total owned by village	Population of Village(s)
S-6	Khenjak Mazar	1e[1]	20	30e	560	460	67	19.5	10	225	600
S-7	Sharghambar	1.5e	15	40e	420	440	66	19	50	50	250
S-9	Nanokhel	0.45	0.7	13	20	690	71	21.5	100	200	400
S-10	Kanzi	0.25	0.3	7	8	760	72	22	-	125	160
S-11	Sangwana	0.3	4	8	110	450	63	17	80	120	500
S-12	Deh Yak	0.2	4	6	110	460	62	16.5	80	120	120
S-14	Kokochel	0.1e	1	3e	30	680	62	16.5	0	-	300
S-15	Lwar Bajaghar	1.3	5	36	140	660	66	19	100	200	1,500

[1] e, estimated

[2] Reported

The average discharge of the inventoried water-table springs is 0.6 cfs (cubic-feet per second) [16 lps (liters per second)]; the range is from 0.1 to 1.5 cfs (3 to 42 lps). The larger flows are mostly in the Baghni valley. Nearly all of the springs could be developed to increase flow by deepening outlets and outlet canals. In some cases this would drop the canal below a convenient level for the village. Deepening the outlet and canal would have only a small effect on the areal water table. Local lowering of the water table in the plains merely intercepts water that is passing under the area and leaving it to the south. In Baghni valley, taking more water higher in the valley could affect springs downstream, but it is believed that this effect would be small.

Local cultivators report that almost all the springs had maximum discharge 20 to 25 years ago. 1/ At that time the discharge from the four springs in Baghni valley (S-6, S-7, S-11, and S-12) was considerably more than that in 1971, and, it is

---

1/ Footnote: The reported flow is in puls; one pul is the amount of water used to irrigate one jirib (approximately 0.5 acre or 0.2 hectare) of land in 24 hours. Conversion from puls to cfs is inexact because puls are estimates of the villagers which do not take into account the amount of water lost by bank seepage and channel loss, nor the permeability of the field being irrigated. The calculated average is 1.9 puls = 1 cfs (30 lps); the range is from 1 to 3.5 puls = 1 cfs, but most values range from 1.5 to 2 puls = 1 cfs.

reported, many more springs existed. Two of the springs (S-6 and S-7) are now discharging about 1 cfs (30 lps) or more; 20 years ago they reportedly had discharges of about 15 cfs (420 lps) or more. The other two springs (S-11 and S-12) had discharges of about 0.25 cfs (7 lps) this year and about 4 cfs (110 lps) 20 years ago. All of the discharges 20 years ago exceeded the amount of water used by the villages, so the unused discharge plus a large flow from Deh Wana spring (reported to be the head waters of Baghni Rud) fed Baghni Rud. It was reported that Baghni Rud had perennial flow downstream to Roshanabad as recently as 10 years ago and to a point about 15 km north of Roshanabad 5 years ago.

On the plains the decline of discharge from springs was also noticeable during late 1971, but not as drastic as in Baghni valley. The two springs (S-9 and S-10) in lower Gulmesh Rud have less discharge than 5 years ago, but had remained about the same from 5 to 20 years ago. The discharge of Nanokhel spring (S-9) is directly associated with the depth of the ephemeral stream in which it rises. This stream has been eroding a deeper gully each year for at least the last 80 years, and apparently erosion has matched water-table declines in the past 20 years for the reported discharge was about 0.75 cfs (20 lps) from 20 to 5 years ago. The discharge this year (1971) was about 0.5 cfs (15 lps). On the lower Baghni alluvial fan the two inventoried springs (S-14 and S-15) had discharges of about 0.1 and 1.3 cfs (3 and 35 lps), respectively, in 1971. Twenty years ago the discharges were reported to have been 1 and 5 cfs (30 and 140 lps), respectively.

Fractured-limestone Springs--Springs issuing from fractured limestone include Shar Chashma (S-1) near Mazar village, Diyak (S-2) (fig. 7), Sharhkonah (S-4) (fig. 9), Oughol (S-5), Shah Ibrahim (S-13), and Deh Wana (not inventoried) (fig. 2). Pertinent data on these springs are listed on table 12. The water from some springs grouped with the water-table springs may ultimately come from fractures in the underlying limestone beds. The outlets of the fractured-limestone springs are at the water-table or piezometric surface, but because of the extent and depth of the fractures, these springs are more dependable than water-table springs.

Shar Chashma spring is located on the Gulmesh plains north of the cultivated fields. It is grouped with the fractured-limestone springs because its water levels are above the general water table in nearby karezes, although there is no evidence of fractured limestone in the immediate vicinity of the outlet.

Diyak spring is one of several springs with outlets under the high scarp along the west side of Gulmesh plains. These are probably associated with a north-northeast trending fault of large vertical displacement. Diyak spring issues from the talus (fig. 7) slope under the limestone cliff, and, although no limestone bedrock crops out at the site of the spring, it is presumed that the water comes from limestone because of the position high on the slope.

Table 12.--Data on Fractured-Limestone Springs, 1971

Field No.	Spring Name	Discharge (in cfs)		Discharge (in lps)		Specific Conductance (in micro-mhos per cm at 25°C)	Water Temperature		Land irrigated (in jiribs)		Population of village(s)
		1971	20 yrs. ago2/	1971	20 yrs. ago2/		(°F)	(°C)	1971	Total owned by village	
S-1	Shar Chashma	0	1	0	30	-	-	-	0	-	abandoned
S-2	Diyak	0.1e1/	1	3	30	345	68	20	25	500	80
S-4	Sharhkonah	2e	5	55e	140	460	71	21.5	300e	-	2,000e
S-5	Oughol	1e	3	30e	85	610	70	21	50e	300e	300
S-13	Shah Ibrahim	4.0	10	115	280	440	62	16.5	500	500	3,000

1/ e, estimate

2/ Reported

Sharhkonah spring (fig. 9) is a large-discharge spring issuing from many outlets at the south end of De Khwajz Khaleq Ghar, an isolated limestone mountain (fig. 12) between the Gulmesh plains and the Baghni alluvial fan. Some of the outlets are large cracks in the limestone beds, but most are in recent gravels covered by silty clay beds, through which water probably seeps up from fractured limestone (fig. 9).

Oughol spring is located in a ravine which joins a large valley west of Sherei Ghar; the spring is 9 km northeast of Oughol village. The water issues from talus and tumble-block debris high up in the ravine, but probably originates from fractures in the underlying limestone beds. This water is slightly higher in mineral content than that of other springs in the area. Evidence of the higher mineral concentration is seen in deposits of travertine, as much as 10 m thick, down the ravine. The spring has been developed by a series of three karezes which obtain water from alluvial deposits downstream from the main outlet and which supplement the discharge of the natural main outlet.

Shah Ibrahim spring is located high in the Baghni valley, 37 km north of Roshanabad. The water comes from stream gravels along the west side of the valley, but because of the amount of flow, the history of discharge, and the fact that there is no flow in Baghni Rud at a lower elevation about 400 m to the northeast, the spring is classed in the fractured limestone group. Shah Ibrahim spring and Deh Wana spring, about 2 km farther upvalley, were the sources of flow in Baghni Rud 5 years ago. Since then, Deh Wana spring has gone dry. Shah Ibrahim spring serves four villages and about 3,000 people. The only development at the spring site is diversion canals leading to the villages.

Discharges from the fractured-limestone springs range from 0 to 4 cfs (0 to 110 lps). The two largest springs in the Zamin Dawar area, Sharhkonah and Shah Ibrahim, have discharges of about 2 and 4 cfs (55 and 110 lps), respectively. With some exceptions, the fractured-limestone springs have maintained a fairly consistent discharge from that of 2 to 20 years ago, while most other water sources had generally declined in flow and water level. The exceptions are Shar Chashma spring near Mazar village in which the water table has declined about 5 m in the last 20 years, and Diyak spring from which the discharge has declined to about 10 percent of its flow 5 years ago. Several other springs have declined in discharge during the last two years, but had maintained fairly steady flows up to 1969.

Deep-fault Springs--Only two deep-fault springs were recognized during the initial inventory in the Zamin Dawar area. Because of their relatively warmer water temperatures, both are believed to rise from depth through fractured limestone. Pertinent data on the deep-fault springs are given in table 13.

Khohna spring (S-3), located on the west side of the Gulmesh plains about 3 km east of Sharhkonah spring and 0.5 km west of Torghui village (fig. 8), has no surface indication of fractured limestone for it lies well away from the nearest limestone outcrops, but the elevation of the water level at its outlets is about 20 m above the general water table of this area. The temperature of the water was 82° F (28° C) in July 1971, while nearby karezes had water temperatures of from 65° to 70° F (18° to 21° C). The discharge in July 1971 was about 0.04 cfs (1 lps). Local people say that this has been the discharge of the spring for as long as they can remember. Ruins of an old fort exist between the outlets, suggesting that the flow may have been greater at some time in the past. It is possible that with development, for example, a large pit dug at the site of the main outlet, this spring could be used as a well and produce more water by pumping.

The other spring here classed as a deep-fault spring is called Khwaja Garmab (S-8) and is located in Baghni valley about 15 km north of Roshanabad (fig. 2). This spring rises at an offset in the Baghni valley, and the offset occurs along a probable east-west fault with the southern block displaced about 1 km to the west. The temperature of the spring water was 72° F (22° C) in August 1971, as compared with prevailing temperatures of about 66° F (19° C) in water from the water-table springs in Baghni valley. This temperature difference indicates that the water of Khwaja Garmab spring is coming from depth through the fractured limestone in the fault zone. The local cultivators reported that the temperature is the same all winter and that the discharge, estimated to be about 0.7 cfs (20 lps) in August 1971, has been the same each summer as long as can be remembered. The winter discharge, however, is reported to be about 4 cfs (110 lps), and the winter-summer fluctuation is constant each year.

Other evidence of water from deep-fault zones is the higher temperature of the water from some karezes, particularly the Markhor (45) (figs. 11 and 12) and Necha (1) (fig. 10) karezes which have the first (mother) wells along the low hills at the eastern side of the Gulmesh plains. All or a substantial part of the flow of these karezes may rise from deep-fault zones.

Table 13.--Data on Deep-Fault Springs, 1971

Field No.	Spring Name	Discharge (in cfs) 1971	Discharge (in cfs) 20 yrs. ago2/	Discharge (in lps) 1971	Discharge (in lps) 20 yrs ago2/	Specific Conductance (in micro-mhos per cm at 25°C)	Water Temperature (°F)	Water Temperature (°C)	Land Irrigated (in jiribs) 1971	Land Irrigated (in jiribs) Total owned by Village	Population of Village(s)
S-3	Khohna	0.04	0.04	1	1	445	82	28	0	-	-
S-8	Khwaja Garmab	0.7e1/	0.7	20e	20	440	72	22	100	100	800

1/ e, estimate

2/ Reported

Karezes

Karezes are the principal sources for domestic and irrigation water supply in the Zamin Dawar area. A karez is an infiltration tunnel which taps ground water in its upper reach and slopes down to an outlet at a gradient somewhat less than that of either the land surface or the water table. Thus, the upper reach of the karez tunnel acts as a drain or collecting gallery and the lower reach acts as a conduit (fig. 16). Karezes are normally constructed (fig. 11) by sinking, usually with bucket and windlass, aligned vertical shafts (essentially dug wells) and then interconnecting these underground by lateral drifts to form a tunnel. Most of the tunnels are usually unlined, but caving sections may be shored or supported by baked clay rings.

Although many karezes follow down the general slope of the land surface, it is not necessary for them to do so. Some pass under ridges, others pass under ephemeral streams, and at several places in the Zamin Dawar area some karez tunnels pass over or under those of other karezes. The gradients in the tunnels within the Zamin Dawar area range from 0.5 to 3.5 m per km. The land-surface gradient is generally from 7 to 10 m per km in the plains and somewhat steeper on terraces near the mountains. The water-table gradients range from about 6 to 10 m per km.

Depending on the permeability of the aquifer at the upper end of a karez, the first (mother) well is usually dug from 2 to 5 m below the water table, and the tunnel lies below the water

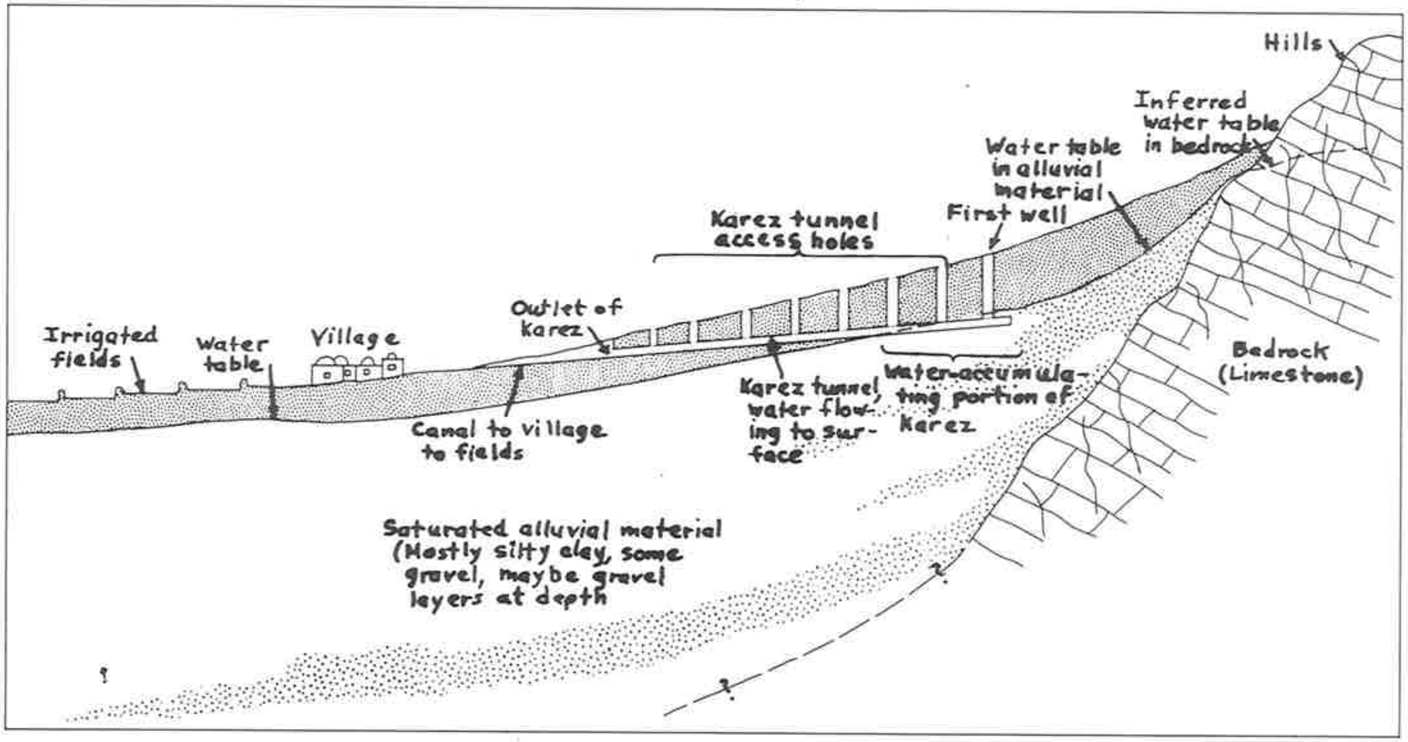

Figure 16.--Generalized cross-section of a karez, and its method of operation.

table for a lateral distance of 100 to 300 m. Thus, the karez can be considered as essentially a horizontal well with as much as 300 m of aquifer penetration. The aquifer is usually silty clay to clayey silt with thin partings or small openings through which the ground water seeps into the karez tunnel. The permeability of this material is difficult to determine because it depends on the size and number of partings or openings rather than on the particle size of the sediments. However, the discharge from the karez depends more on the length of tunnel penetration in the aquifer than on the permeability of the materials. In 1971 discharges from individual karezes ranged from about 56 down to 0.3 lps in the Zamin Dawar area.

Karez Inventory--Eighty karezes had been inventoried through December 1971 in the Zamin Dawar area. (The inventory is still in progress). Because inventory of karezes is new to southern Afghanistan, a form was devised to facilitate the field work (fig. 17). This form was modified several times early in the study as unanticipated data were discovered. The form shown in figure 17 may be further modified as other data pertinent to the inventory are found.

A karez numbering system (field and office) has already been described earlier in this report. The name of the karez is also the name of the village it serves. The owner named on the karez schedule form is usually the largest landowner of the village, or the village "malek" (leader). Most karezes are actually owned by all the men of the village, and each has a share of the flow

AFGHANISTAN HYDROLOGIC SURVEY
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KAREZ SCHEDULE

Date:________________. Karez (village) name:________________.
Observer:________________. Project karez no.:________________.
Source of Info.:________________. Office no. (grid):________________.

---

1. Location:________________________________

________________. 1:50,000 Map Quad.:________________. (see sketch map)

2. Owner:________________. Address:________________.

Digger:________________. Address:________________.

3. Description: Length km; No. of holes____; Condition________________;

Geol. and Geog. setting________________________________;

Repairs________________; Difficulties________________.

4. Date finished:________ month / year; Date started:________ month / year;

5. Description of ___well: Dimensions________________; Depth________m below MP;

Materials________________________________.

Entry of water________________________________.

6. Measuring point (MP) of ___well:________________, which is________m above below lsd;

Marked by ________________; Elev. of MP________m above msl;

Surveyor's general land surface________________________________.

7. Water Level (WL) in ___well:________m below MP, at ________hour, on ________________ day month year

8. Description of outlet:________________________________;

Canal materials:________________________________;

Surveyor's general land surface________________________________.

9. Discharge:________ gpm cfs, lps meas. rept., esti. at______hour, on ________________ day month year; Discharge history

____.

10. Quality of Water (QW): Water sample collected yes no, at___hour, on ________________ day/month/year;

Water temp.______ °F °C; Additional data________________________________.

11. Use of Water: Dom. (no. of people________); Stock (no. and kind________________);

Irrig. (no. of jiribs hectare________________); Other________________.

12. Remarks:________________________________

____

____

____.

13. (on back of schedule sheet) Location sketch: (to include the allignment, general land slope, terraine description, direction and distance to bedrock hills, unusual features, and details of measuring places and surveyor's marks at first well and outlet.)

Figure 17.--Sample Form of Schedule for Inventory of Karezes in Zamin Dawar Area.

proportional to the amount of land he owns. The original diggers have not been determined as practically all operating karezes were dug 300 or more years ago. The karez diggers (fig. 11) now working on repair and cleaning of the karezes are usually members of families that have been employed in this work for generations. There are no karez digging companies as such.

The karez length was determined from maps or aerial photographs and is the distance from the first shaft (well) to the tunnel outlet. Except where they could be counted on the aerial photographs, the number of vertical shafts (wells) was not determined. This feature was included on the karez schedule to determine the spacing of the shafts which is usually related to the type of material in which the karez is dug -- the closer the spacing the looser the material.

The general description includes the terrain surrounding the first well and along the line of the karez. The terrain description is important to help in determining the type of material in which the karez is dug and possibly in determining the source of the water entering the karez. Repairs include the frequency which the karez is cleaned and the dates of deepening the tunnel, as well as difficulties encountered by the karez diggers while cleaning.

The date finished and started has been found to be difficult, if not impossible, to obtain, because the karezes are older than the memories of the oldest villagers. Apparently, the karezes existed before the times of their grandfathers. Most of the people reported that existing karezes were 300 to 400 years old.

The description of the first well -- dimensions, depth, and materials -- usually describes the type of aquifer through which the water is seeping into the tunnel. In several instances the first well has been filled in by caving, so the second, third, fourth, or other well farther down the line, is described. In a few other cases, the first well is purposely covered to protect the tunnel channel from debris. Until facilities are devised to allow the observer to climb into the first well, the entry of water is determined by hearsay from the karez owner or diggers.

The water level in the first well is measured, but is more an indication of how effectively the tunnel delivers water to the outlet than an indication of the actual position of the water table in the area. The actual water table could be as much as 2 to 5 m above the measured water level in the first well. A periodic check, however, on the water levels of several wells along the line could help the karez owners determine the trouble spots in the tunnel.

Description of the outlet and canal, including depth of canal and materials, helps to determine the possible water loss to bank storage or infiltration. Also to be noted here is the point of discharge measurement and the water-sampling site, so that future investigators can use the same point in order to maintain consistency.

The discharge at nearly all karezes was measured by the float method; that is, a timed measurement of a float over a 10-foot length of canal to obtain the velocity of the flow, and an average cross-sectional area. To compensate for side and bottom drag effects, a factor of 0.6 was applied to the velocity on slow-moving flows and a factor of 0.7 was applied when the flow was 1 foot per second or faster in a channel that is straight and even. Discharge measurements by weir and by current meter were also made in a few instances but were found to be too time consuming for reconnaissance work.

A history of the discharge was included on the karez schedule to determine the effects of the recent dry-weather cycle and to find out which karezes were most and least affected. Most karezes in water-table aquifers have had marked declines of discharge in recent years. Deepening the karez tunnels improves the yields and has been carried out in many karezes throughout the study area. Some karezes have had fairly regular discharges through the dry weather cycle; these presumably are fed by fractured limestone aquifers in or near the first (mother) wells.

The quality of the water was usually measured in the field with a specific conductance meter and the temperature was recorded. At selected karezes a water sample was taken for more detailed analysis at the HAVA chemical laboratory. The temperatures measured were assumed to be close to the ambient temperatures of the ground water. In some cases, however, the temperature measurement was made several hundred meters down from the last tunnel and, where the water flowed slowly, the water had probably warmed or cooled in the intervening distance.

The use of the water in the Zamin Dawar area is dominantly for irrigation, but usually the flow in outlet canals passes through a village and is used enroute for domestic purposes before being delivered to the fields. Stock, including sheep, goats, donkeys, and a few cattle, horses, and camels also drink from such canals. Many villages have water mills, but only a few of these have been in use in recent years, because of declines in discharge. The number of jiribs irrigated with the water is in direct proportion to the amount of discharge from the karez. Also, in this section of the karez schedule, a place is provided to note how many jiribs the village controls and how many jiribs were cultivated in the current year, in order to determine how badly the village was affected by the drought.

The remarks section on the karez schedule (fig. 17) is for any unusual facts about the karez which are not covered elsewhere on the schedule. The location sketch is included to enable other observers to visit the karez and use the same measuring points for future monitoring.

Hypothetical Typical Karez--Pertinent data on all of the karezes inventoried through December 1971 are listed on table 14. Averages from these data are used to describe a hypothetical typical karez in the Zamin Dawar area.

Table 14.--Data on Karezes of the Zamin Dawar area, 1971

Field no.	Name	Length (in km)	Average gradient (in m per km)	Approximate Discharge (in cfs)		Approximate Discharge (in lps)		Specific Conductance (in micromhos per cm at 25°C)	Temperature 1/		Land irrigated (in jiribs)	Population of village(s)
				1971	20 yrs. ago(±)	1971	20 yrs. ago(±)		(°F)	(°C)		
1	Necha	3.9	2.1	2.0	2	56	55	500	74	23.5	600	400
2	Kishmishkhan	3.8	1.1	0.7	0.7	20	20	510	66	19	130	500
3	Abdar 2/	3.0	0.5 ±	0								0
4	Khenjakak	2.7	0.45	1.1	0.1	31	4	465	*76	*24.5	50	400
5	Sultan Rabat 3/	3.3	0.5 ±	dry								0
6	Rabat	3.5	2 ±	0.2	1.5	6	40	440	*56	*13.5	75	300
7	Gondumrez Sufla	4.0	1.9	0.5	0.7	14	20	840	63	17	130	300
8	Gondumrez Ulya	3.6	3.1	0.25	0.2	7	7	475	62	16.5	290	1,000
9	Ghawond	2.8	0.7	0.8	2	23	55	450	*71	*21.5	130	350
10	Chacha 4/	2.0	1 ±	dry								0
11	"Old" Rabat 5/	2.2	-	0								0
12	Necha Ulya 6/	1.3	1 ±	dry								0
13	Naw	1.5	0.95	1.0	0.2	28	7	460	*75	*24	60	800
14	Necha Sufla	2.0	-	0.6	1	17	28	450	*77	*25	150	500
15	Baghak	2.0	0.2	0.1	0.1	3	4	450	77	25	25	700
16	Yarbaba	2.3	1.2	0.01	1	0.3	28	400	*46	*8	0	50
17	Ghachi Zar	3.1	3 ±	1.5	1.5	42	40	460	75	24	650	200
18	Tutak 7/	1.1	-	dry								0
19	Mazdurak	2.8	1.7	0.5	5	14	140	430	71	21.5	75	500
20	Thorghui	2.1	0.65	0.35	2	10	55	450	65	18.5	150	300

Table 14.--Continued

Field no.	Name	Length (in km)	Average gradient (in m per km)	Approximate Discharge (in cfs)		Approximate Discharge (in lps)		Specific Conductance (in michromhos per cm at 25°C)	Temperature 1/		Land irrigated (in jiribs)	Population of village(s)
				1971	20 yrs. ago(±)	1971	20 yrs. ago(±)		(°F)	(°C)		
21	Safeid	2.0	2.1	0.1	0.2	3	5	430	66	19	50	100
22	Ahingaran 8/	2.3	0.2 ±	0								0
23	Subzikar	4.2	3.1	0.3	1	8	28	600	65	18.5	70	100
24	Hajikhel	3.5	0.95	0.05	0.5	1.5	14	460	63	17	80	100
25	Thaghawai	3.5	2.4	0.1	0.2	3	7	630	65	18.5	35	60
26	Nowaiy	2.8	0.45	0.01	0.2	0.3	5	580	*78	*25.5	gardens only	10
27	Abdul Malek	2.1	1.0	0.25	2	7	55	550	*50	* 10	30	320
28	Deh Baba	2.5	0.5	1.4	3	39	85	490	71	21.5	100	500
29	Kundagha	2.0	1.3	0.3	0.2	8	7	475	69	20.5	50	60
30	Gholam Hosein	2.2	0.45	0.2	0.5	6	14	460	69	20.5	30	45
31	Gargak	2.2	0.25	0.45	.3	13	85	480	69	20.5	50	320
32	Zobayr	5.3	1.0	0.1	1.5	3	40	425	60	15.5	gardens only	160
33	Landei	2.3	1.1	0.15	0.7	4	20	430	68	20	25	100
34	Surkh	2.7	0.6	0.5	2	14	55	440	69	20.5	25	600
35	Suchi 9/	2.5	-	0								-
36	Sharh	3.0	1.8	0.55	1	16	28	450	69	20.5	30	200
37	Albelagh	2.3	3.8	1.1	4	31	110	490	68	20	600	3,000

Table 14.--Continued

Field no.	Name	Length (in km)	Average grad-ient (in m per km)	Approximate Discharge (in cfs)		Approximate Discharge (in lps)		Specific Conductance (in michromhos per cm at 25°C)	Temperature 1/		Land irrig-ated (in jiribs)	Popul-ation of vill-age(s)
				1971	20 yrs. ago(±)	1971	20 yrs. ago(±)		(°F)	(°C)		
38	Dawran	2.7	0.6	0.4	1.5	11	40	470	68	20	50	400
39	Khwaja Paksar	3.2	1.4	0.85	3	24	85	440	69	20.5	125	700
40	Haji Bora	3.5	0.5	0.85	2	24	55	440	68	20	175	200
41	Khwaja Aziz	1.8	1.3	0.3	0.7	8	20	820	65	18.5	150	300
42	Sapeda	1.9	1.2	0.2	0.7	6	20	700	68	20	50	300
43	Shabazkhel	1.4	2.8	0.2	0.5	6	14	750	68	20	75	220
44	Qala-i-Gul	0.8	0.25	0.1	0.5	3	14	760	62	16.5	50	60
45	Markhor	1.5	1.2	0.45	0.5	13	14	470	80	26.5	45	240
46	Kalizai-Akhundkhel	1.9	0.9	0.2	1	6	28	825	64	18	270	140
47	Kuti	2.8	1.7	0.3	0.7	8	20	690	62	16.5	50	500
48	Karezdai	2.8	1.4	0.3	0.2	8	7	710	63	17	90	300
49	Mirzi	2.0	1.7	0.1	0.2	3	7	480	*58	*14.5	35	250
50	Khake Jahannum 10/	2.6	2 ±								75	25
51	Jarya	2.6	9.5	0.15	0.5	4	14	460	64	18	60	150
52	Bawr	3.4	2.5	0.25	1	7	28	610	66	19	100	100
53	Naw Sharqi	3.0	1 ±	0.2	3	6	85	520	66	19	125	100

Table 14.--Continued

Field no.	Name	Length (in km)	Average gradient (in m per km)	Approximate Discharge (in cfs)		Approximate Discharge (in lps)		Specific Conductance (in michromhos per cm at 25°C)	Temperature 1/		Land irrigated (in jiribs)	Population of village(s)
				1971	20 yrs. ago(±)	1971	20 yrs. ago(±)		(°F)	(°C)		
54	Jula	3.4	0.35	0.3	0.3	8	10	500	64	18	100	100
55	Labe Joy	1.7	0.6	0.15	1	4	28	485	65	18.5	20	100
56	Naw Gharbi	3.1	1.8	0.6	1	17	28	440	62	16.5	40	500
57	Syaghul	2.9	1.1	0.15	0.2	4	7	620	*68	*20	50	50
58	Thurkak	2.2	3.8	0.3	0.5	8	14	800	66	19	125	50
59	Kalu 11/	2.6	-	dry	0.1	-	3					0
60	Qasem Lur	2.7	2.8	0.2	0.5	6	14	460	60	15.5	120	100
61	Chaharbagh	1.6	-	0.8	2	23	55	455	65	18.5	200	300
62	Biabanak	2.7	1.0	0.4	0.5	11	14	625	62	16.5	50	100
63	Bagharkhel	1.7	0.55	0.35	0.5±	10	14	730	66	19	60	150
64	Kakakhel-Kajoi	1.4	1.8	0.35	0.5	10	14	610	64	18	200	200
65	Khola Abad	2.0	2.9	0.25	0.5	7	14	640	*70	*21	125	200
66	Khoja Gharib	0.8	2.±	0.5	2	14	55	440	67	19.5	50	300
67	Mughrei	1.8	0.2 ±	0.2	0.7	6	20	500	60	15.5	15	80
68	Agha Ahmad	2.7	2 ±	0.15	0.2	4	7	600	62	16.5	30	300
69	Moyen Abad 12/	1.4	-	dry	1.2	dry	14					-
70	Atal	1.4	2 ±	0.01	0.5	0.3	14	415	*50	*10	7	60

Table 14.--Continued

Field no.	Name	Length (in km)	Average gradient (in m per km)	Approximated Discharge (in cfs)		Approximate Discharge (in lps)		Specific Conductance (in micromhos per cm at 25°C)	Temperature 1/		Land irrigated (in jiribs)	Population of village(s)
				1971	20 yrs. ago(+)	1971	20 yrs. ago(+)		(°F)	(°C)		
71	Hokumatkhan	4.2	2 ±	0.7	0.7	20	20	480	62	16.5	300	200
72	Khochai	1.6	1 ±	0.15	0.5	4	14	680	*56	*13.5	gardens only	150
73	Benoush	2.3	2 ±	0.3	3	8	85	600	64	18	100	500
74	Behsham	1.6	0.2 ±	1.5	1.5	42	40	460	64	18	200	400
75	Sher Ahmad	1.3	0.2 ±	0.2	0.3	6	10	750	62	16.5	5	100
76	Walang	3.2	0.2 ±	0.45	-	13	-	480	62	16.5	75	400
77	Shpokhta	2.1	2 ±	0.2	1.5	6	40	650	*56	*13.5	35	150
78	Sayedan-i-Janubi	2.6	0.2 ±	0.05	1	1.5	28	435	*55	*13	12	100
79	Khandeq	0.7	0.5 ±	0.6	0.1	17	3	460	*58	*14.5	75	100
80	Shekhzwi	1.2	0.5 ±	0.02	0.5	1/2	14	440	*52	*11	4	150

1/ Where asterisk appears with temperature, indications are that water probably has been warmed or cooled in outlet canal above point of measurement.

2/ Karez tunnel caved and never repaired, although upper wells have water.

3/ Karez went dry and village abandoned in June 1971.

4/ Karez went dry 25 years ago.

5/ Karez tunnel caved near outlet and never repaired, although wells have water.

6/ Karez went dry many years ago.

7/ Karez went dry 35 years ago.

8/ Karez went dry 26 years ago. New line of upper wells have water.

9/ Karez reportedly has water but tunnel caved.

10/ Karez collapsed in 1971. Flow reportedly 0.25 cfs or 7 lps in 1971; and 0.5 cfs or 14 lps, 20 years ago.

11/ Karez went dry 8 years ago.

12/ Karez went dry 12 years ago.

The first (mother) well of a typical karez is dug on the plains at higher elevation and upgradient from the cultivated fields. The well is 23 m deep with a rectangular shaft about 0.65 m by 1 m. The water table is about 20 m below the land surface, but the water level in the first well stands at only 0.3 m above the bottom of the tunnel, because of the drawdown resulting from drainage of water from the aquifer to the tunnel. In a typical karez, the first 10 to 15 wells reach the water table, so in effect, the connecting tunnel between these wells forms a horizontal well (collecting gallery) about 200 m long. The total length of a typical karez is about 2.4 km, and the tunnel gradient is about 1.3 m/km.

The discharge from a typical karez is about 0.4 cfs (11 lps) and it supports a village of about 300 people. Such a village controls about 440 jiribs (220 acres or about 90 hectares) and irrigated about 120 jiribs in 1971. Five years ago a typical karez had a discharge of 0.7 cfs (20 lps); 10 years ago, 0.9 cfs (25 lps); and 20 years ago, 1.1 cfs (31 lps). It was reported from many sources that the best flow from karezes occurred 20 to 25 years ago.

A typical karez is cleaned once every 2 to 3 years. The cleaning process involves removing the sediment from the bottom of the tunnel. Very few karezes in the Zamin Dawar have troubles with collapsing tunnels, although occasional collapses have been reported. The average cost of cleaning the karez is about 20 Afs (Afghanis) per m, thus a karez 2.4 km long can be cleaned for about 50,000 Afs (about US $600). Normally, the cleaning process takes more than a year to complete, so that the cost is spread out over several months. To deepen a karez, while cleaning, the rate is from 40 to 100 Afs per m, probably depending on how much the tunnel is deepened. Generally, the karez digger charges 60 to 70 Afs per cubic meter of material removed. To extend the karez beyond the first well the cost would be about 400 Afs per m, which would include the cost of the vertical shafts as well as the tunnel.

An attempt was made to determine a relationship between karez length and discharge, karez tunnel gradient and discharge, and other variables. The calculated ratios, however, showed no consistent relationship. Apparently, the determining factors are the condition of the karez, the permeability of the aquifer at the uppermost wells, and the length of the karez tunnel under the water table. One definite relationship was found: above-average karez discharges support more prosperous villages.

Exceptional Karezes--The most productive karezes in the Zamin Dawar area are: Necha (1) (fig. 10), Kishmishkhan (2) (fig. 10), Kenjakak (4), Ghawond (9), Naw (13), Ghachi Zar (17), and Chaharbagh (61) karezes on the Gulmesh plains; and Deh Baba (28), Albelagh (37), Khwaja Paksar (39), Haji Bora (40), and Hokumatkhan (71) karezes on the lower Baghni alluvial fan. (The numbers are the field inventory numbers for reference to table 14 and figure 2.) All these karezes are first generation, that is, the upper end of the karez begins on the terrace uplands above the cultivated areas. Other karezes, however, along the periphery of the cultivated plains, adjacent to these better karezes, have moderate to low discharges and some are dry.

It is suspected that Necha and Ghachi Zar karezes tap fractured limestone beds, because it is reported that both have had little change of discharge through the dry cycle, and both have above-normal water temperatures indicating deep-fault sources. Other karezes with warmer water are: Naw (13), Necha Sufla (14), and Baghak (15) originating near the limestone outcrop north of Ghachi Zar village, which may be in line with the major fault on the western edge of Gulmesh plains. Also, the flow of Markhor karez (45) (figs. 11 and 12), which originates at the base of the limestone outcrop on the eastern edge of Gulmesh plains 9 km south of the first well of Necha karez, is probably also associated with faulting.

The most productive karezes had discharges ranging from 0.7 to 2 cfs (20 to 55 lps) in 1971. Karezes Ghawond (9), Thorghui (20) (fig. 8), Abdul Malek (27), Deh Baba (28), Surkh (34), Albelagh (37), Khwaja Paksar (39), Haji Bora (40), Naw Sharqi (53), Chaharbagh (61), Khoja Gharib (66), and Bendush (73) are reported to have had discharges ranging from 2 to 4 cfs (55 to 110 lps) some 20 to 25 years ago. Most other karezes throughout the area had from 2 to 20 times more discharge 20 years ago than in 1971.

Wells

Only six wells were inventoried in the Zamin Dawar area (fig. 3). Also it is not possible from present (1971) knowledge to estimate the total number of wells in the area. Apparently only a few villages use wells, because most domestic water is obtained from karez outlet canals. Four of the wells inventoried are simple dug wells from 11 to 14 m deep and are used only for domestic purposes. Each of these wells is dug down until about 1 m of water is standing in the hole. Almost all these wells were deepened during the summer of 1971 to maintain the 1 m depth of water as the water table declined. None of these four wells would yield much more than 1 gpm (gallon per minute) (0.07 lps) over a period of a few hours.

Deh Baba Well--Deh Baba well (W-2) (fig. 15) at Deh Baba village is a large pit connected by a tunnel (partly an old karez) with 4 other dug wells. The main well is a 2.5 by 3.5 m rectangle at the bottom and is 16.4 m deep. The tunnel connecting the 5 wells is about 1 m high and 0.5 m wide; the total length is 130 m. Water is pumped from the large pit by a 4-inch centrifugal pump driven by a diesel engine. The discharge is about 0.9 cfs (400 gpm) (26 lps) for 10 hours a day, at the end of which time the water level is near the bottom of the well. The water level must then be allowed to recover for about 14 hours before pumping can be resumed.

A pumping test was conducted on the well in mid-November, 1971, in an attempt to calculate the permeability (hydraulic conductivity) of the aquifer contributing the well. The odd shape of the well (fig. 18), however, and the nature of the aquifer (tight silty clay with cracks and small holes through which the water seeps) make interpretation of the pumping test data by established techniques very tentative. The graph on figure 19 shows plots of the water level drawdown and time of pumping. From this graph it can be seen that the configuration of the wells and tunnel effects the shape of the drawdown curve.

On figure 20, those same data are plotted on a semi-log graph and a formula, modified from the Cooper and Jacob equations (Cooper and Jacobs, 1946), is applied to determine the transmissivity of the aquifer (how much water the aquifer yields per unit volume for unit time). The calculated transmissivity value, 7,000 gpd/ft (gallons per day per foot) (25 m^2 per day) is probably high. The drawdown measurements near the end of the test indicate that the tunnel was being dewatered, but was not completely dewatered at the end of the pumping period (fig. 19). Therefore, the transmissivity value is probably something less than 7,000 gpd/ft. (25 m^2/d).

In order to calculate the hydraulic conductivity of the aquifer the transmissivity may be divided by the thickness of the water-bearing strata. Because of the nature of the sediments making up the aquifer, even with the help of a detailed lithologic log (which is not available) it would be difficult

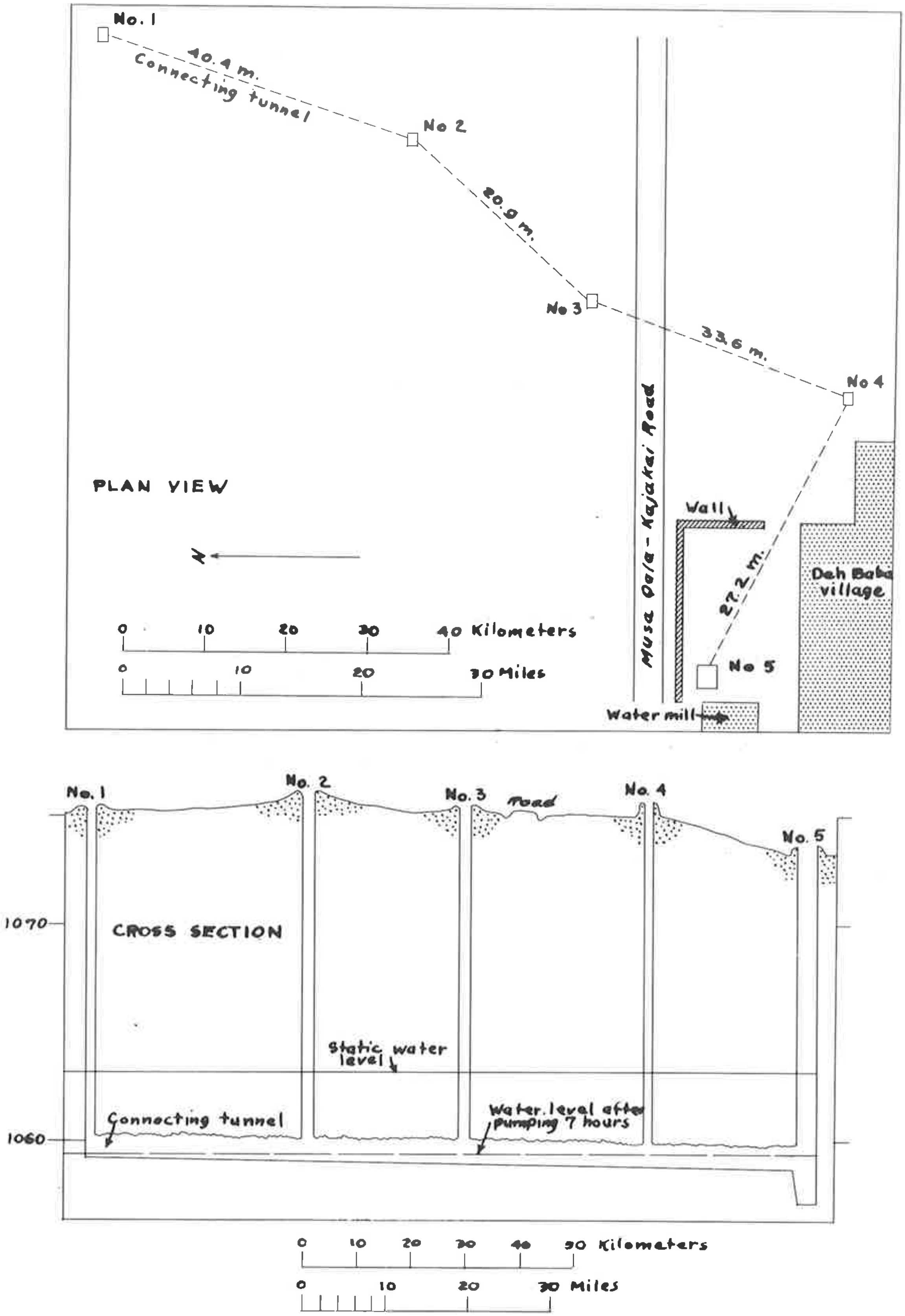

Figure 18.--Plan view and cross section of Deh Baba Well(W-2), Zamin Dawar area.

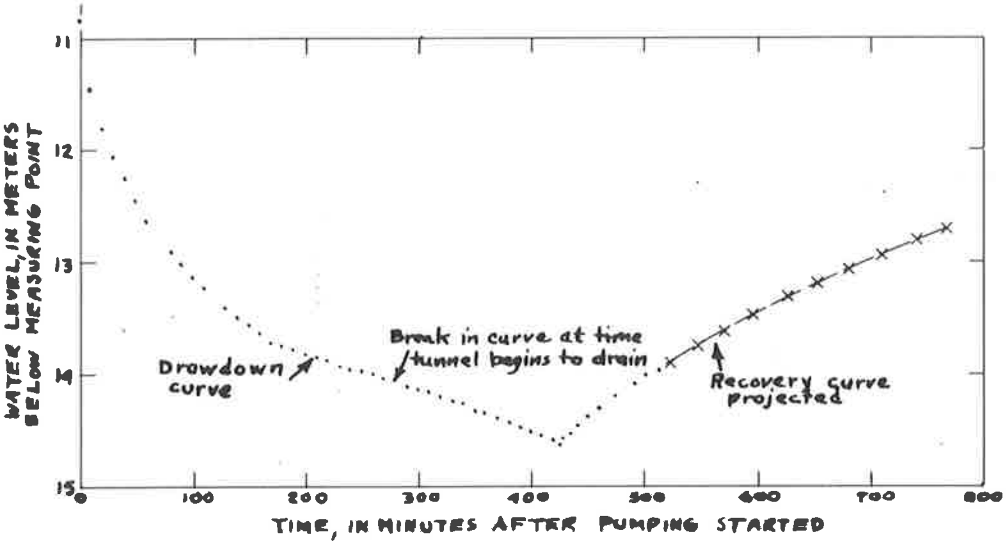

Figure 19--Drawdown and recovery curves, from measurments taken during Deh Baba Well(W-2) pumping test conducted 16 November 1971.

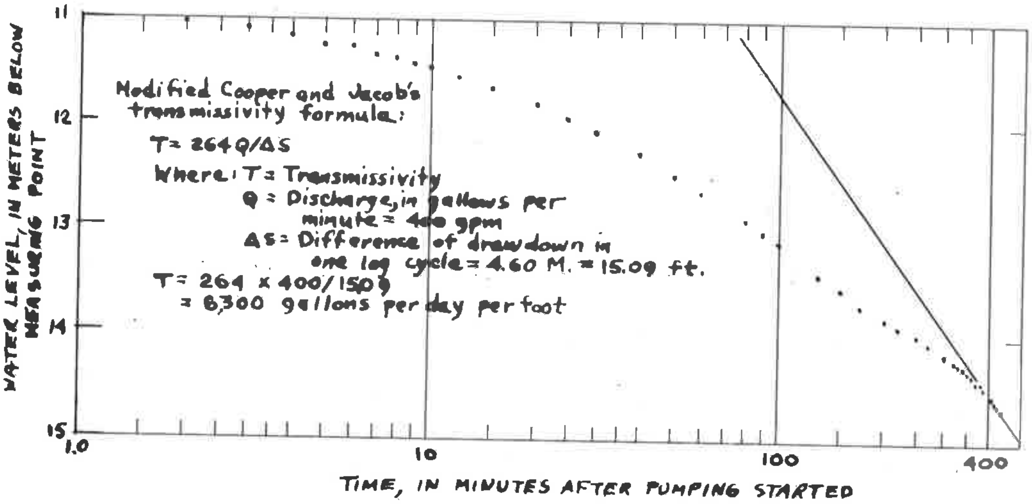

Figure 20.--Drawdown measurments plotted on semi-logarithmic graph and calculations to determine approximate transmissivity of aquifer at Deh Baba Well(W-2)

to determine the thickness of the strata contributing water to the well. Assuming that the aquifer is 16 feet (5m) thick (approximately the amount of drawdown during the pumping test), the hydraulic conductivity would be about 400 gpd/sq ft (gallons per day per square foot) (16 m per day). The actual hydraulic conductivity would probably be something less than this value, because the calculated value of transmissivity is probably too large and because the thickness of strata contributing water is probably greater than 16 feet.

A grossly approximate calculation of the hydraulic conductivity can be made by using alternative assumptions. The amount of water pumped from the well (400 gpm for 427 minutes) was about 170,000 gallons. The amount of water in storage in the well was about 120 cu m or 32,000 gallons. Thus about 140,000 gallons was yielded by the aquifer. By dividing that value by the area of the walls of the wells and tunnel contributing to the well, which is about 300 sq m or 3,200 sq ft, the calculated hydraulic conductivity is about 150 gpd/sq ft (6 m per day). This is one-third the value determined from the pumping test. The only conclusion that can be reached using the available data is that the actual hydraulic conductivity is between the two calculated values, and is probably closer to the smaller value.

Deh Baba well, with its 130 m of tunnel, exemplifies the low permeability of the aquifers in the Zamin Dawar area. It is concluded that only karez-cum-well type construction would produce the needed quantity of water to make large pumps economically feasible, at least in the shallow aquifers.

The sixth well (W-6) in the Zamin Dawar area is in Mazar village near Shar Chasma spring (S-1) north of Necha village (fig. 3). This well is presently (November 1971) being dug and the people have great expectations that it will yield a large amount of water. In the opinion of the writer, the well would yield more water if it were constructed like Deh Baba well, with the tunnel leading from Shar Chashma spring at a level 3 to 5 meters under the present water level of the spring.

Hydrology

Hydrologic Cycle--The hydrologic cycle is the process through which water is transformed from water vapor in clouds, to precipitation, to streamflow or recharge to the ground-water system, to evaporation from water bodies (streams, ponds, lakes, oceans) and transpiration from plants, and back to water vapor in the air. Figure 21 shows a schematic diagram of the hydrologic cycle in the Zamin Dawar area.

Normally, in a ground-water study, an attempt is made to quantify all of the parameters of the hydrologic cycle: the volume of rainfall; the part of rain that flows as floods through the area; the part that is evapotranspired: the part that seeps into the ground and recharges the ground-water system; the volume of water that is used for irrigation, domestic supplies and stock; and the volume of water that passes out of the area as ground-water underflow. As it happens, sufficient information to determine these quantities is not presently at hand, and even some of the information available, such as rainfall data, is not accurate. Even so, an attempt is made to calculate quantities for some of the parameters and estimates are made for the magnitudes of others.

Precipitation--From the short span of data for precipitation at Kajakai Camp, and from comparison with Kandahar and Lashkar Gah stations, it was estimated that the average annual precipitation at Kajakai is about 200 mm and that the average annual

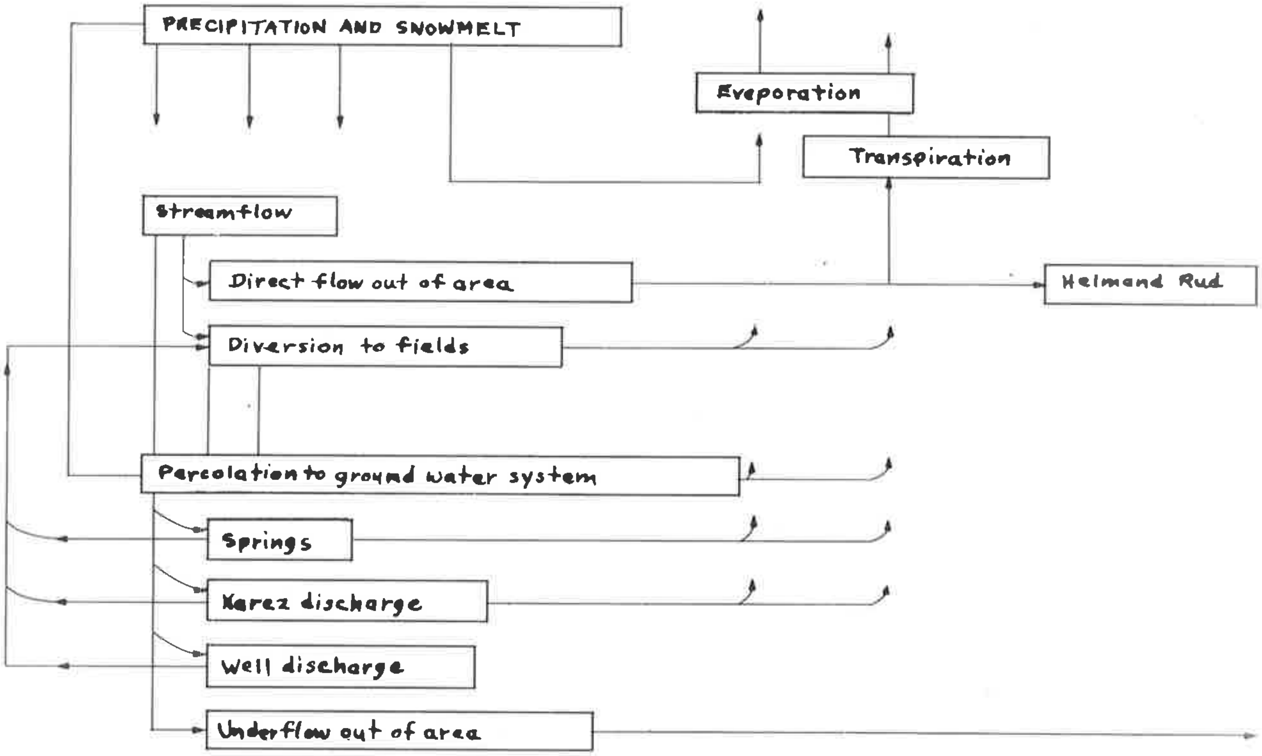

Figure 21.--Hydrologic cycle in the Zamin Dawar area

precipitation for 5 dry years (1966-1970) was about 160 mm per year. Using the latter (drought period) value and assuming that the figure is valid for the whole of the Zamin Dawar area, approximately 280,000 acre-feet (ac-ft) (340 million cu m) of precipitation falls annually within the boundaries of the Zamin Dawar area. It is probable that more precipitation falls in the mountainous sectors, but for purposes of these calculations this fact will be ignored. Thus, the figure used is conservatively low.

Streamflow--No records on flow of any stream in the Zamin Dawar area now exist, and very little information was collected on the flooding of the streams. It is apparent from investigation of the area and the small amount of hearsay data that the streams flow only after rains in the winter and spring months. It is assumed for purposes of this report that 60 percent, or about 170,000 ac-ft (200 million cu m) of the precipitation annually passes out of the area as flood flow and sheet wash.

Evapotranspiration--No records are available on transpiration, but this is considered to be negligible, except in irrigated areas which constitute a relatively small part of the whole Zamin Dawar area. The records of evaporation at Kajakai Camp weather station show that abut 2,500 mm of evaporation occurs annually. During the rainy months, however, from December through April, a total of about 510 mm of evaporation occurs; but the highest evaporation occurs during the hot summer months when no rain falls.

Also, water from precipitation is not available for a long enough period of time for much to be evaporated, except on the plains areas. On the plains, although the rainwater may percolate into the ground, it will probably be held near the surface and evaporated later. In the mountainous terrain probably a much smaller amount of the precipitation is evaporated. It is estimated that 20 percent of the precipitation, or about 55,000 ac-ft (70 million cu m), is evaporated in the Zamin Dawar area annually.

Ground-water Recharge--Assuming that the above figures are reasonably accurate, there remains 20 percent or 55,000 ac-ft (70 million cu m) of the annual rainfall reaching the ground-water reservoir. Most of this water is recharged in the mountainous terrain, either directly into the more pervious limestones or into the gravels of the stream channels through which the water moves slowly to the plains to recharge the shallow ground-water system.

Recharge also occurs directly in the plains, not so much from precipitation as from irrigated fields. Some of the water discharging from the shallow ground-water system through karezes, springs or wells above the village in part returns to the aquifer under the fields and is available for reuse downslope after some loss from transpiration and evaporation.

Ground-water Use--From the 80 inventoried karezes about 27 cfs (760 lps) flows. Assuming an additional cfs (85 lps) comes from uninventoried karezes and approximately 10 cfs (280 lps) issues from springs on the plains and the Deh Baba well, a total of about 40 cfs (1,130 lps), or 30,000 ac-ft (37 million cu m) per year is used for irrigation, domestic supplies, and stock. As explained earlier, some portion of this water is reused through the karezes and springs serving villages in the lower reaches of Gulmesh plains and in the lower part of Baghni alluvial fan.

Ground Water Outflow--An unknown volume of water passes under the Zamin Dawar area and moves onward to the south. From the above figures, based largely on assumptions or estimates which could be 50 percent, or possible 100 percent or more off, approximately 55,000 ac-ft enter the ground-water system by direct recharge and 30,000 ac-ft is used and reused in the study area. Therefore, about 25,000 ac-ft (30 million cu m) of the water may pass out of the area in the ground-water system.

The amount of ground water passing through the area depends on the gradient of the water table and the permeability and thickness of the alluvial aquifer. No information is now (1971) available, however, on the lithology or thickness of alluvium below a depth of 30 to 40 m. If the study area is like many desert basins, the alluvial fill could be as much as 500 m thick in the southern end of the Zamin Dawar area. The alluvium could contain many layers of permeable gravel capable of storing and transmitting large quantities of water. Part of the water-table lowering in the Zamin Dawar area is caused by water flowing from the drought-affected northern recharge area to other areas to the south through the aquifer system.

The estimates presented above are based on drought-year averages. During periods of more normal rainfall, the volume of streamflow, evapotranspiration, and recharge would increase. Also, the figures on karez and spring discharge would increase because an increase in recharge would raise the water table and allow the karezes access to larger supplies of water.

Water-table Map--A contour map of the water table is included in this report as a general reference (fig. 1). The map is based mainly on the water-level measurements made near the first (mother) wells of the karezes. It must be recalled, however, that these water levels may be depressed 3 to 5 m below the actual position of the water table. For this reason the water-table contours on the map were drawn about 4 m above the measured water levels.

The map shows that the water table generally follows land-surface contours but is about 15 m below the land surface in the lower part of the plains and 25 to 30 m below the land surface higher on the plains. Anomalies, such as points of spring discharge are not shown on the map, because not enough is known of the geologic control of the springs.

The map can be useful for determining general depths of karezes and how deep new karezes or wells need to be.

Quality of Water

Many of the karezes, springs, and wells in the Zamin Dawar area were checked by means of an electrical conductivity meter to determine the specific conductance of the water. The specific conductance is a factor by which the total dissolved solids in the water can be estimated. Generally, specific conductance in micromhos per cm at 25° C multiplied by 0.7 equals the approximate concentration of dissolved solids in milligrams per liter. A few rough chemical analysis have been made of the water from some karezes and springs. C. L. Fly (1959) reported only cations and specific conductance. Comparison of the specific conductances of the water obtained by Fly with those obtained during the course of the present investigation generally indicates that the quality of the ground water has changed very little since 1959.

The karezes, springs, and wells have been divided into three groups; first, second, and third generation. First generation are those beginning above all cultivated areas, usually along the mountain borders or on the upper reaches of the Gulmesh plains and above the presently cultivated fields or in the terrace upland areas on the Baghni alluvial fan. The second generation are those that begin in the upper part of the cultivated areas, and the third generation begin well into the cultivated areas. Using this breakdown for the inventoried water sources for which specific conductance was measured, there are 33 karezes, 2 springs, and 3 wells in the first generation group; 18 karezes in the second generation group; and 10 karezes, 4 springs, and 2 wells in the third generation group. The specific conductance is plotted on figure 3 at the upper end of the karezes and at the spring and well sites to show the areal distribution.

The average specific conductance of water of the first generation group is 460 micromhos per cm (about 320 mg/l /milligrams per liter/ total dissolved solids); of the second generation group, 590 micromhos per cm (about 415 mg/l); and of the third generation group, 700 micromhos per cm (about 490 mg/l) (excluding the two wells, each of which has a specific conductance of about 1,300 micromhos per cm /about 900 mg/l/). These results show conclusively that the water is recycled through irrigation use and that it picks up dissolved salts from the irrigated areas. Even so, the water at the lower ends of the cultivated areas is still acceptable for further irrigation use. The two wells which have the unusually high specific conductance are located at Markhor and Qali-i-Gul villages on the lower part of Gulmesh plains along the eastern edge of the Zamin Dawar area where gypsum has been noted in the alluvial sediments.

Future Development of Ground Water

Continued Reliance on Karezes

Karezes are the most efficient means of obtaining ground water without greatly disrupting the position of the water table. However, as has been proved during the drought of the last 4 or 5 years, a declining water table will lessen the discharge from karezes unless the karez tunnels are deepened, which is very expensive. New karezes would be prohibitively expensive to dig as compared to the construction cost of wells like that at Deh Baba village. This well is essentially the upper end of a karez without the long aqueduct tunnel reaching to the land surface.

Before the introduction of engine-driven pumps, karezes were the only reliable means of bringing ground water to the surface. Diesel engines are now (1971) changing this situation, and when electric power is supplied to the Zamin Dawar area an even cheaper power source will be available.

Existing karezes will probably remain the main source of irrigation water in the Zamin Dawar area for many years. If the water table rises again, as is anticipated when the present drought breaks, the existing karezes will begin to discharge as much water as they did 10 or 20 years ago and the need for pumping water will diminish -- until the next drought cycle. However, with increasing technological competence in Afghanistan and the large amount of irrigable land on the plains above the present area where karezes are concentrated, it is probable that wells will be dug or drilled. Pumping wells in the higher areas would cause inevitably a decline of water levels in the lower plains. Karezes, therefore, will eventually become obsolete, monuments to the ingenuity of man but victims of technological change.

Deep Wells

At the present time, nothing is known of the lithology of the alluvial sediments below depths of 30 to 40 m. It is presumed that layers of water-bearing gravel exist at depth, as they do in most alluvial basins, but the permeability of these inferred aquifers, their thicknesses, and their depths cannot be predicted. Existing knowledge indicates that the silty clay materials in the upper part of the alluvial sediments will yield water at almost any place in the Zamin Dawar area. The permeability is so low in these materials, however, that an extremely large diameter well or a tunnel cut to below the water table and from 100 to 300 m long is needed to extract enough water for irrigation. A relatively small-diameter deep well, such as would be provided by a cable-tool drilling rig, would yield very little water from the silty clay material. Unconsolidated permeable gravel or sand layers, or fractured bedrock zones are required to produce water from deep wells.

Test Wells--Deep test holes, from 100 to 300 m deep, preferably reaching bedrock, should be drilled at selected sites in the Zamin Dawar area in order to determine the lithologic characteristics of the alluvial materials, to discover if deeper aquifers exist which could yield irrigation water supplies, and to determine the quality of the water from deeper sources. It is entirely possible, though from present knowledge not very probable, that deeper aquifers may have artesian flow. The amount of flow would depend on the hydraulic head of the aquifer and its permeability.

Three sites for exploratory test holes are here recommended: (1) near the lower Gulmesh Mandeh, south of Khola Abad village; (2) near the west edge of the study area, southwest of Albelagh village; (3) in the central part of the upper Baghni alluvial fan, north of the abandoned village of Joy Daraz. (Locations shown on figure 2). For a more complete investigation of the deep strata in the Zamin Dawar area, another 3 to 5 deep test holes would be required.

Development--Assuming the discovery of deep aquifers in the Zamin Dawar area which would yield sufficient quantities of water for irrigation, it is presumed, at least in the early years of development, that most of the wells will be situated on the plains above the presently cultivated areas. This land is suitable for irrigation and has been farmed in the past when water was available from the streams. Many thousands of jiribs, particularly in the upper part of the Baghni alluvial fan, show evidence of past cultivation. The probable reason that karezes were not dug to continue the farming of this area is that the material is sandier and generally looser than the tight silty clay of the lower parts of the plains, and therefore would not hold the karez tunnels open. Also it would be dangerous for ~~the~~ karez diggers because of the likelihood of cave-ins. Deep wells, with slotted casings or screens at the bottom, could take advantage of the looser, sandy materials.

During early stages of development, deep-well sites will need to be carefully selected in order not to interfere with the discharges from springs and karezes. Such interference, eventually, is inevitable, but hopefully by then wells will have taken the place of karezes as the chief source of irrigation water. Because of the nature of karezes, which dewater only the uppermost part of the aquifer, the discharge of water never exceeds the recharge to the aquifer. Extensive pumping from wells, on the other hand, may allow discharge to exceed recharge unless artificial means of increasing recharge are developed. At first, deep wells would obtain water from aquifers which have not been tapped before; eventually, water recharging the deep aquifers will be subtracted from the water that is recharging the shallow aquifer.

Records--From the time of drilling the first three test wells, which are to be purely exploratory holes to determine if deep aquifers exist and how much water they will yield, and on through the development of wells throughout the area, it will be of utmost importance to keep detailed records on each well. These records should include complete and detailed lithologic logs, pumping-test data on each aquifer encountered, chemical analyses of the water from each aquifer, complete and detailed diagrams of well construction and pump and motor specifications, a finished-well pumping test, and after the well is in production complete data on pumpage and use of the water. The production data should include a log for each well showing daily pumpage and maintenance. Periodic measurements of the discharge and the static and pumping water levels, and checks on the quality of water should also be made. All of this information should be collected, analysed, and filed by one division of HAVA. The information on the individual wells is important in determining the causes of well failure if such occurs, and interpretation of the collected data will help in estimating the limits of groundwater development in the Zamin Dawar area. The development should proceed in carefully monitored stages so that overdevelopment does not occur. It is possible literally to mine water from aquifer systems to the point where it may become uneconomic to lift the water to the surface.

Flood Check-Dams

If the estimate, made in this report, of the amount of water lost via streams after rainstorms is reasonably accurate, a prime source of additional water in the Zamin Dawar area is flood runoff. With a few flood check-dams in the upper part of the major streams, or a large number of small structures to check flood runoff on many of the minor streams, a large volume of water could be retained and released slowly, thus allowing time for infiltration and recharge to the ground-water system. Alternatively, such flood flows could be diverted by surface canals to cultivated areas. Flood irrigation could nearly double the present area of cultivation. Before construction of the dams, however, a full-scale feasibility study should be made of the actual flood flow, the agricultural potential of the land, and probable siltation rate behind dams or diversions. One important drawback to this scheme is the possibility of over-development, as has occurred in the Kandahar area. The development should be restricted to the area that can be supplied during dry years -- the present drought cycle offers the opportunity to define this limitation. An important advantage of this scheme is that it would not adversely affect the water supply from the existing karezes and springs.

Need for Additional Data

This report and the field investigations made in 1971 are only initial phases of the study of the Zamin Dawar area. The study is to continue in order to obtain information for at least a full annual weather cycle with observations on the water levels of selected wells and on the discharges of selected karezes and springs to determine fluctuations. It will probably be sufficient to make monthly measurements at most places, but, through the winter and spring months when the rains come, weekly measurements should be made on some of the observation wells, karezes, and springs.

Rainfall and Streamflow--Only 4 years of records are available from the rain gage set up at Kajakai Camp by Morrison-Knudsen of Afghanistan, Inc. in 1956. This station was re-established in December 1971 by HAVA, but many years of records must be accumulated before trends and relationships between rainfall and ground-water levels can be established.

In addition to the rain gage at Kajakai Camp, precipitation data will be needed at scattered places throughout the Zamin Dawar area. Seven stations are recommended, of which three are absolutely necessary. The stations can have the simplest kind of rain gages installed, and selected villagers can operate them and keep the records. One of the three stations, and the most important, should be high in the Baghni valley, as much as 40 km north of Roshanabad near Giman village. The second station should be at or near Necha in the northeast part of the lower Gulmesh plains, and the third station should be at or near Deh Baba in the northern part of the cultivated area of the Baghni alluvial fan. If practicable, four other stations should be placed at or near the following villages: (4) Sherei village, at the head of Gulmesh Mandeh valley; (5) Khenjak Mazar, near the lower end of Baghni valley; (6) Ghachi Zar, in the western part of the lower Gulmesh plains; and (7) Azan at the lower end of the Baghni alluvial fan. (See figure 1.)

Streamflow records at present are non-existent. In any case actual streamflow measurements would be difficult to make in this environment with present personnel. First, someone would have to be on hand when the streams are in flood after a rainstorm, then he would have to be able to cross the streams at flood stage, well nigh an impossibility. Alternatively, the best means of obtaining a rough measure of actual flood flow after rains would be to have the villagers mark the highest as well as several other stages of the flood and the duration (the number of hours the streams flows at various stages). Using this information field surveys can be made shortly after flood events, and estimates of flood flows can be calculated indirectly. Data of this kind would have to be collected on at least the two main streams, the distributary of Baghni Rud which passes Landei, Albelagh, and Azan villages; and Gulmesh Mandeh which passes Rabat, Chaharabagh, and Khola Abad villages.

Many of the smaller streams should also be observed and flow records kept in order to obtain a more complete picture of what happens after rainstorms, and to get an estimate of what proportion of the rainfall runoff passes through the Zamin Dawar area. To obtain this kind of information would require the cooperation of the people living in the area or at least local observers.

Monitoring Network--A network of selected karezes and springs has been set up in the Zamin Dawar area in which the discharges and specific conductance of the water are measured once each month. The selection was based on areal distribution and the volume of discharge; nearly all of the high-yield karezes in the area are included. The karezes are: Necha (1), Gondumrez Sufla (7), Ghawond (9), Ghachi Zar (17), Subzikar (23), Deh Baba (28), Albelagh (37), Haji Bora (40), Kalizai-Akhundkhel (46), Turkak (58), and Sher Ahmad (75). The springs are: Sharhkonah (S-4), Nanokhel (S-9), and Lwar Bajaghar (S-15). They are identified on figure 2 by circles around the numbers at their outlets.

Monitoring the discharges and quality of water of these karezes and springs is expected to continue into the summer of 1972 in order to determine seasonal fluctuations through the winter and spring rainy period. After this time, when the preliminary study of the Zamin Dawar area should be completed, three or four of the karezes and two or three springs should continue to be monitored once every 3 months in order to check longer-term weather cycles. It is anticipated that these karezes and springs can be included in a nationwide monitoring network which should eventually be set up by the hydrology branch of the central government.

Water levels in four wells are planned to be measured once a week by their owners in the villages. The wells are: Bagi (W-1), in Gondumrez Ulya; Deh Baba (W-2); Qala-i-Gul Mosque (W-4); and Haji Gul Mohammed (W-6) in Mazar (fig. 2). It is hoped that other wells can be identified for inclusion in the monitoring network in order to broaden areal coverage. The existing wells are not the best for water-level observation, because they are pumped or used almost continuously, so true static water levels are seldom attained. However, by measuring the water level early in the morning before many buckets of water have been removed general trends of water-level fluctuations can be observed.

A more advantageous method of observing water-level fluctuations would be to use a 2-inch well pipe placed away from other wells and the upper end of karezes. Because such a well would be unused, small fluctuations of the water level, such as occur after rains or flooding in a stream, could be easily observed.

Summary and Conclusions

The Area--The Zamin Dawar area, located 90 km northeast of Lashkar Gah in south-central Afghanistan, was chosen for a ground-water study by HAVA and USAID with the help of advisors from a USGS team. The total area is about 2,140 sq km, including the drainage basin of Gulmesh Mandeh to the east (630 sq km), the drainage basin of Baghni Rud to the west (900 sq km), the Baghni alluvial fan (470 sq km) and the terrace uplands to the south (140 sq km). The presently cultivated area includes about 80 sq km on the lower Gulmesh plains and about 55 sq km on the lower part of the Baghni alluvial fan, plus about 30 sq km in the Baghni valley.

Ground-Water Resources--The main sources of irrigation water in the area are karezes, although springs are important in the Baghni valley, in the lower part of the Gulmesh plains, and in the Baghni alluvial fan. Domestic and stock water comes from the same sources. Wells are scarce and, except for one irrigation well at Deh Baba village, have small yields.

Springs occur at several points in the valley of Baghni Rud, in the high mountains and on the plains. Some, such as Sharhkonah spring northeast of Deh Baba village, are controlled by fractures in limestones, but most are controlled by the level of the water table. The latter type spring occurs mainly in the Baghni valley, in the lower part of the Gulmesh plains, and on the Baghni alluvial fan. Of 15 inventoried springs throughout the area, 11 have significant discharges. The total discharge from springs on the plains (excluding the 6 inventoried springs in the Baghni valley) is about 5 cfs (140 lps) or about 3,800 ac-ft (4.7 million cu m) per year. Sharhkonah spring alone has a discharge of about 2 cfs (55 lps).

Of 80 karezes inventoried throughout the area, 54 are in the Gulmesh plains and 26 are on the lower part of the Baghni alluvial fan. These karezes represent about 90 percent of the total number of presently used karezes and all of the karezes with large discharge. The total discharge from 66 karezes (14 of the inventoried karezes are dry or have very little discharge) is about 27 cfs (760 lps) or an average of 0.4 cfs (11 lps) per karez. A few of the better karezes have discharges of from 1 to 2 cfs (28 to 55 lps). It is estimated that the other karezes in the area, yet to be inventoried, have a combined discharge of about 3 cfs (85 lps). The total discharge would be about 22,000 acre-feet (27 million cu m) per year from all karezes.

Most wells in the Zamin Dawar area are shallow, low-yield, domestic wells. One irrigation well at Deh Baba village, equipped with a centrifugal pump, yields 0.9 cfs (26 lps) for about 10 hours a day.

It is calculated that during the 5 years of below-average rainfall, from 1966 through 1970, an average amount of about 160 mm of precipitation has fallen on the Zamin Dawar area. This is a total of 280,000 ac-ft (340 million cu m) spread over the whole area. Assuming that about 60 percent (170,000 ac-ft or 200 million cu m) is lost from the area by flood runoff, and 20 percent (55,000 ac-ft or 70 million cu m) is lost by evapotranspiration, then about 20 percent (55,000 ac-ft or 70 million cu m) is recharged to the ground-water system.

Calculations based on discharges of karezes, springs, and wells, including some assumptions and estimates, indicate that about 30,000 ac-ft (37 million cu m) of water is used each year. This calculation includes the water recycled to the lower plains area. The fact that water applied in the upper fields infiltrates into the soil, returns to the ground-water system and then is reused in the lower cultivated areas, is fairly well established by downgradient increases measured in mineral content of the ground water.

Because the water table slopes toward the south, a certain portion of the ground water must move out of the area as outflow. Without information on the permeability and thickness of the aquifers under the Zamin Dawar area, however, the amount of ground-water outflow cannot be accurately calculated.

Conclusions--The present study should be continued by collecting data on water-level and discharge fluctuation at least until June 1972. Deep test holes to be drilled by cable-tool rig, will permit determination of the lithology of the alluvial sediments down to 300 m, will identify any existing deep aquifers and provide information on the quality of the deep water.

The potential availability of ground water in the Zamin Dawar area is difficult to estimate at present. Too many parameters of the hydrologic system are as yet unknown, or known imperfectly. It is probable that more water can be obtained from ground-water sources but increased development, such as by deep production wells, will need to be accompanied by careful monitoring of the system. Ultimately, decisions will be required on whether to continue to rely on karezes or to draw water through wells--mutually exclusive courses of action.

Recommendations--

1. Establish at least 3 rain gages in the Zamin Dawar area, one in the Baghni valley, the second near Necha village on the Gulmesh plains, and the third near Deh Baba village on the Baghni alluvial fan.

2. Begin estimates of flood runoff by noting high-water marks of flood flows in streams and recording duration of floods.

3. Drill deep test holes and conduct pumping tests to determine the permeability and the water quality of the deep aquifers in the Zamin Dawar area.

4. Continue to monitor selected wells to get long-term water-level and discharge records.

5. Investigate the feasibility of constructing flood flow check structures to retain some flood runoff either for diversion to irrigated fields or for ground-water recharge.

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Orthographic List of Geographic Names

Names in this report come from Afghanistan sources and are not necessarily authoritative. The country and familar name is used in the report.

A glossary of the country names with their equivalent in the Board on Geographic Names(BGN) system follows this introduction. The glossary may aid in cross-reference to U.S. Geological Survey reports using the BGN system.

The glossary is arranged in two columns, 1,Report Name; 2,Board on Geographic Names(BGN). BGN names are approved standard names where possible to verify. Where none is given, this is not verified(nv).

Report and BGN names may have as part of the name, or following, a description that is generic, description of feature, preferred, other. Where none is shown this is a populated area, village, town, other.

A difference in description between the Report Name and the BGN name may be from scientific versus geographic usage in each field of science.

Report Name	Board on Geographic Names(BGN)
Albelagh	Kārīz-e Albelāgh
Azan	Āzān
Abdul Malek	Kārīz-e ʿAbd ol Malek
Abdar	Avdar Baba cemetary
Atal	Aṭal
Ahingaran	Āhangarān
Akhandkh	Not verified(nv)
Asso khwi-i-Gul	nv
Agha Ahmad	Āqā Aḥmad
Bendush	Bēnavsh
Behsham	Bī Shām
Baghni valley	nv
Baghni alluvial fan	Dasht-e Jūy Derāz plain
Baghni Rud stm	Daryā-ye Baghnī stm
Baghni Gar range	Selseleh-ye Kūh-e Baghnī Mtn range
Baghak	Bāghak
Bagi	nv
Bedhak	nv
Biabanak	Bībānak
Bagharkhel	Bagārkheyl
Bawr	Bavr
Chacha	Chahchah ruins
Chaharbagh	Chahār Bāgh
Chamdia	nv
Daruzi	Dārūzī
Deh Wana	nv
Deh Yak	Deh Yak
Diyak	Dehak
Dughol	Qaryeh-ye Owghowl
De Khwaja Khaleq Ghar mtn	De K͟hvajeh K͟haleq Ghar mtn
Deh Baba	Kārīz Deh Bābā
Dawdan	Kariz-e Davran
Den Mushhar	Deh Mushak
Denbaba	nv

Ghachi Zar	Ghach Zār
Ghaysaraka	Gheysarakeh
Giman	Gīmān
Ghawond	Ghāvand
Gulmesh Mandeh stm	Gholmīsh Māndeh stm
Gulmesh Plains	De Shīray Dasht plain
Gondumrez Sufla	Gandom Rīz-e Sofá
Gondumrez Ulya	Gandom Rīz-e ʿOlyā
Gholam Husein	Kārīz-e Gholām Ḥoseyn
Gargak	Kārīz-e Gorgak

Haji Bora	Ḥājī Bowreh
Helmand Rud stm	Daryā-ye Helmand stm
Hokumatkhan	Kārīz-e Ḥokūmat
Haji Gul Mohammed	nv
Helmand Province	Velāyat-E Helmand
Hajikhel	Ḥājī Kheyl

Jula	Jūlā
Jarya	Jaryeh
Joy Daraz	Jūy Derāz

Khwaja Garmab	Khvājeh Garm Āb
Khohna	nv
Kuti	Kūṭi-ye ʿOlyā
	Kūṭi-ye Sofia
Kanzi	Kānzī
Kajakai Reservoir	Band-e Kajakaī reservoir
Kajakai Camp	nv
Kokochel	Kowkah Chēl
Kohe Musa Qala **mtn**	Kūh-e Mūsá Qalʿeh mtn
Khenjak Mazar	Khenjak Mazār
Kabul	Kābul
Kishmishkhan	Keshmesh Khān
Kenjakak	Khenjakak
Khwaja Paksar	Khvājeh Pāksār
Khola Abad	Khvolehābād
Kalizai-Akhundkhel	Kalīzeh-Ākhond Kheyl
Kundagha	Kārīz-e Kondāgheh
Khadeq	Kārīz-e Khandaq
Karezdei	Kārīzdī
Kakakhel	nv
Kajoi	Kajī

Kalu	Kalū
Khwaja Aziz	Khvājeh ʿAzīz
Kalizai	Kalīzeh
Khake Jahannum	Khāk-e Jahannam
Kocak	Kūchak
Khochai	Khvochāʾ ī
Kanzi	Kānzī
Kandahar	Qandahār
Khoja Gharib	Kārīz-e Gharīb
Lewanian	Līvanīān
Lwar Bajaghar	Lwaṟ Bājaghar
Lashkar Gah	Lashgar Gah
Landei	nv
Labe Joy	Lab-e Jūy
Lange	Kārīz-e Landay
Markor	Mār Khvor-e Soflá
	Mār Khvor-e ʿOlyā-ye Jonūbī
	Mār Khvor-e ʿOlyā
Musa Qala Rud stm	Mūsā QalʿEh Rūd stm
Mazar	Mazār Ghar mtn
Moyenabad	Kārīz-e Moʿīnābād
Manzuc	nv
Mughrei	Kārīz-e Moghrī
Mazdurak	Mazdūrak
Muzi	Mīrzī
Manzel Bagh station	nv
Necha	Neycheḩ
Nanokhel	Māchī Kheyl
Necha Ulya	Neycheh-ye ʿOlyā
Naw	Kārīz-e Now
Necha Sufla	Neycheh-ye Soflá
Nowai	Navay Kārīz
Naw Gharbi	nv
Nerkhor	Mār Khvor-e ʿOlyā
Naw Zad area	Now_Zād pop
Naw Sharqi	Kārīz-e Now-ye Sharqī
	Kārīz-e Now-ye Gharbī
Onay	Ownay
Oughol	nv

Porghui	nv	
Qala-i Gul Mosque	Qalʿeh-ye Gol	
Qasem Lur	nv	
Roshanabad	Rowshanābad	
Rabat	Robāṭ	
Shekhzei	Shaghzay Kārīz	
Safeid	Kārīz-e Safīd	
Syaghul	Sīāh Ghūl	
Sapeda	Sapīdeh	
Shpokhta	Shapowkhteh Kalay	
Sawan Qala	nv	
Shabazkhel	Shābāz Kheyl	
Surkh	Kārīz-e Sorkh	
Subzikar	Sabzīkār	
Sher Ahmad	Shīr Aḥmad	
Sultan Rabat	Solṭān Robāṭ	
Sarchashma	Kārīz-e Sar Chashmeh	
Sayedan Shamali	Kārīz-e Sahīdan-e Shomālī	
Suchi	nv	
Sharh	Kārīz-e Shahr	
Sayedan-i Janubi	Kārīz-e Sahīdān-e Jonūbī	
Sangwana	Sangvāneh	
Sharghambar	nv	
Sherei	Shīray	
Shar Chashma	nv	
Sharhkonah	nv	
Sherai Ghar	Shīray Ghar	
Shah Ibrahim	Shāh Ebrāhīm	shrine
Torghui	Torghī	
Turkak	Torkak	
Taghawai	Taghāvī	
Taleak	Tūtak	
Walang	Kārīz-e Valang	

Yaraba	Yār Bāba
Zamin Dawar ruins	nv
Zobayr	Zobeyr
Zamin Dawar area	nv