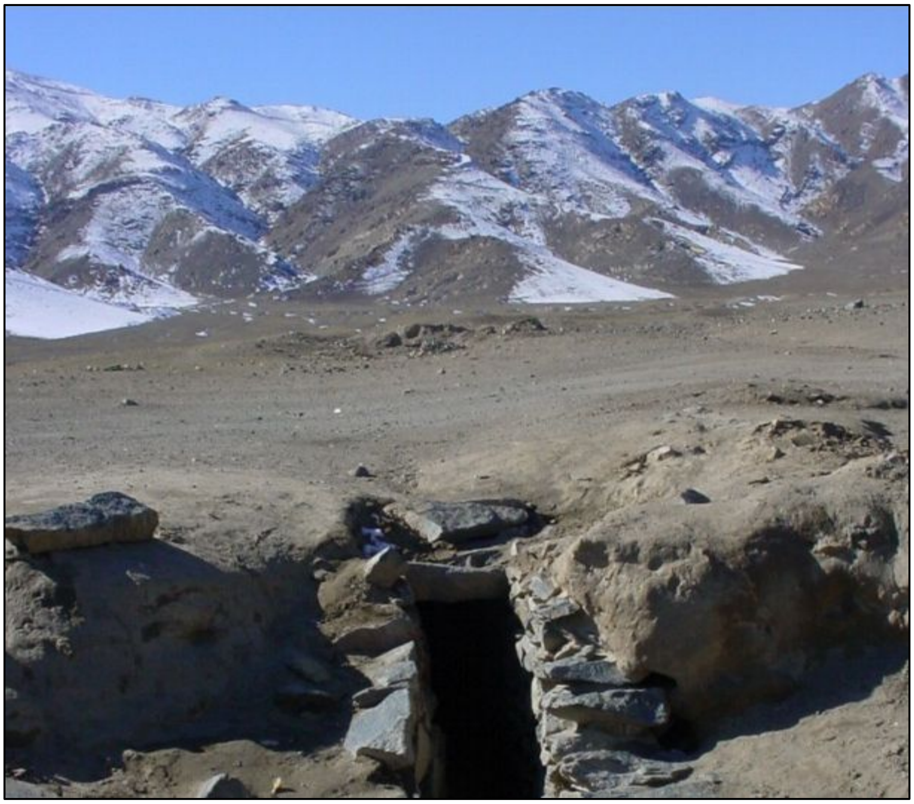
AFGHANISTAN

AN OVERVIEW OF GROUNDWATER RESOURCES AND CHALLENGES



Vincent W. Uhl
Uhl, Baron, Rana Associates, Inc.
Washington Crossing, PA, USA

Assisted By:

Eng. M Qasem Tahiri
Basic Afghanistan Services
Kabul, Afghanistan

2003

AN OVERVIEW OF GROUNDWATER RESOURCES AND CHALLENGES

CONTENTS

AFGHANISTAN

AN OVERVIEW OF GROUNDWATER RESOURCES AND CHALLENGES

CONTENTS (CONTINUED)

AFGHANISTAN

AN OVERVIEW OF GROUNDWATER RESOURCES AND CHALLENGES

CONTENTS (CONTINUED)

TABLE

FIGURES

APPENDIX

Cover Photo: The outlet of a Karez in Logar Province.

AFGHANISTAN

AN OVERVIEW OF GROUNDWATER RESOURCES AND CHALLENGES

EXECUTIVE SUMMARY

In Afghanistan, groundwater has traditionally been developed and utilized for irrigation purposes through the use of karezes, springs and shallow hand dug open wells. In more recent years, deep drilled wells have become a more common means of extraction for irrigation usage particularly in the Tarnak, Ghazni, Kabul and Logar river valleys.

Groundwater is an under-utilized resource in certain parts of the country and, more than likely, over-utilized in others. There is clearly a need to develop sustainability estimates for the principal aquifer systems in the country to allow for a wise and judicious development of this resource. This effort, in concert with a water resource management approach, will be necessary to prevent over allocation and serious depletion of the groundwater resources in certain river basins.

The principal objectives of this study, which was carried out in 2003, were to:

1. Provide a general overview of country-wide groundwater conditions from a review of available documents, data, reports and meetings with government officials and NGOs working in the area and from field visits.

2. Develop preliminary water balances for the major river basins on the basis of readily available data of groundwater usage (principally from FAO data and reports) and assumptions in regard to groundwater recharge to the unconsolidated and bedrock aquifer systems in the five major river basins.

3. Provide a preliminary assessment of river basins and sub basins where additional groundwater could be developed for irrigation purposes and where overdevelopment might be a concern and management practices need to be instituted.

4. Develop recommendations for basin studies and the technical elements of these studies.

The water balances that were developed from this study are preliminary and will be refined as more detailed basin wide studies are conducted in the country. Most of the available hydrogeologic data and information is for the unconsolidated and semi-consolidated Quaternary and Neocene aquifer systems. The bedrock aquifer systems in

the country are largely unexplored and some of these units may well represent valuable sources of irrigation and potable supply in the future.

The principal identified aquifer systems include:

- Quaternary deposits in the major river valleys particularly in the Kabul River Basin, the river systems in the Helmand River Basin to the east (Ghazni, Tarnak, Arghistan and Arghandab), the Hari Rud River and certain river systems within the Northern Flowing Rivers and Amu Darya Basins.

- The semi-consolidated Neocene Age deposits in the Kabul River and other river basins.

- Carbonate rock aquifer systems on the northern flank of the Hindu Kush Mountain Range and along portions of the Helmand River in Oruzgan Province.

- Carbonate rock systems at other locations.

Groundwater Resources: Availability and Use

Kabul River Basin

While the estimates of groundwater recharge (FAO and Uhl/BAS study) indicate that groundwater recharge is in excess of irrigation withdrawals for the entire Kabul basin, the Uhl/BAS recharge estimate for the unconsolidated aquifer systems in the river valleys (380Mm^3/yr.) is less than the estimated groundwater withdrawal (450Mm^3/yr.) for irrigation purposes. This is a river basin which requires an evaluation of the potential for additional groundwater withdrawals in each of the sub basins.

For the southeastern tributaries of the Indus River Basin, the estimate of groundwater recharge for the unconsolidated aquifer systems (140Mm^3/yr.) is about double the estimated groundwater withdrawal estimate (80Mm^3/yr.) indicating the potential for modest additional withdrawals.

Eastern Helmand Basin:

The estimated annual groundwater recharge (1,170Mm^3/yr.) is somewhat greater than the estimated usage (750Mm^3/yr.) However, as most of the irrigation usage is derived from unconsolidated aquifer systems, the estimated usage may well exceed the estimated annual recharge (530Mm^3/yr.) for the unconsolidated aquifer systems. The groundwater systems in the Eastern Helmand Basin require hydrogeological investigations and monitoring to assess sustainability at current and projected future rates of withdrawal.

Western Helmand Basin:

The estimated annual recharge (1,310Mm^3/yr.) for the upper part of the Western Helmand River Basin is considerably larger than the estimated groundwater use for irrigation (750Mm^3/yr.). Overall, the middle and upper Helmand River Basin likely has the potential for additional groundwater development on the basis of groundwater use and this recharge analysis. This is another basin where a detailed hydrogeologic assessment of groundwater use and sustainability should be given priority.

Western Rivers Basin:

The recharge estimate (500Mm^3/yr.) for the basin at large is somewhat higher than the estimated irrigation groundwater use (300Mm^3/yr.). However, the estimated recharge for the unconsolidated aquifer units (340Mm^3/yr.), where much of the irrigation withdrawal takes place, is comparable to irrigation usage. Overall, this basin appears to have a limited potential for natural groundwater recharge primarily because of low annual average precipitation and high evapotranspiration rates.

Hari Rud:

The recharge estimate (640Mm^3/yr.) for this basin, when compared to the 160 Mm^3/yr. estimated irrigation usage, indicates the potential for additional groundwater development in this basin for irrigation purposes.

Northern Flowing Rivers:

The estimated annual groundwater use for irrigation (210Mm^3/yr.) is considerably lower than the groundwater recharge estimate (2,140Mm^3/yr.) indicating the potential for developing significant additional groundwater for irrigation purposes in The Northern Basin.

Amu Darya Basin:

The estimated annual groundwater use for irrigation (100Mm^3/yr.) is minimal in comparison to the groundwater recharge estimate (2,970Mm^3/yr.) indicating a significant surplus of groundwater reserves in this river basin and the potential for future development of groundwater resources for irrigation in the Amu Darya Basin.

1.0 RIVER BASINS OF AFGHANISTAN

1.1 Topography and Climate

Afghanistan is characterized by extensive desert plains, high mountain ranges and scattered fertile valleys along the major rivers. The Hindu Kush, the westernmost extension of the Himalaya-Pamir Mountain Range, cuts the country in half from northeast to southwest (**Figure 1**).

Afghanistan has a dry continental climate and ninety percent of the country's annual precipitation occurs during the winter months between December and April, mostly falling as snow. In the summer months, Afghanistan receives mostly warm dry air from the north and northeast with very little precipitation. The amount of precipitation directly correlates with altitude. It varies from less than 100mm/yr. at altitudes below 1000m in the southern, northern and western parts of the country, to over 1000mm/yr. at altitudes above 4000m in the northeast.

Most of the rivers in the country, and all of the perennial ones, originate from the mountains of the Hindu Kush range in the center of the country and flow towards Afghanistan's international borders. Most river systems have maximum flow in the spring and early summer months from snowmelt, and lower flows in the fall and winter months.

The Hindu Kush Mountains decrease in altitude from the northeast towards the southwest, and the rivers originating from the higher northeast part of the range demonstrate more sustainable flows as compared to the rivers originating from the central and lower parts of this mountain range.

1.2 Principal River Systems

The five major river systems include:

1. The Kabul River and the southeast tributaries of the Indus (drain 15% of the country).
2. The Helmand River and its tributaries (30%).
3. The Western Flowing Rivers including the Hari Rud, Farah Rud, Khash Rud and other westward flowing rivers (20%).
4. The Northwestern Rivers including the Murghab, Shirin Tagab, Sare Pul and Balkh Rivers (20%).
5. The Amu Darya River and its left bank tributaries which include the Kunduz, Kokcha, and Wakhan Rivers (15%).

The Registan and Dasht-i-Margo deserts in the South, which comprise about 5% of the country, receive very limited precipitation that mostly evaporates. The only perennial rivers are those originating from the Hindu Kush, which include: the Kabul River and its tributaries the Konar, Laghman, Logar, and Panjsher Rivers, the Helmand and the Arghandab, the Hari Rud, the Kunduz and the Kokcha, and the Amu Darya.

1.2.1 The Kabul River and Eastward Flowing Rivers

The Kabul River originates in the central part of the Hindu Kush, about 100 km west of Kabul, and has a drainage area of 54,000 km^2 in Afghanistan. It flows eastward through Kabul and Jalalabad and after entering Pakistan, joins the Indus River east of Peshawar. Its main tributaries include the Logar, Panjsher (with its own major tributary the Ghorband), Laghman-Alingar, and Konar Rivers. Most of these rivers are perennial with peak flows during the spring months as their drainage area encompasses the snow-covered central and northeastern parts of the Hindu Kush. The Kabul River is the only river in Afghanistan that is tributary to a river system (the Indus River) that reaches an ocean (the Indian Ocean).

Other minor Indus tributaries drain southeast areas of Afghanistan. The main tributaries from north to south include the Khurram, Urgun, Gomal, and Shamal Rivers with a combined drainage area of 18,600 km^2. All of these rivers flow eastwards into Pakistan and eventually join the Indus River. They have intermittent flow supplied by meager winter precipitation and limited snowmelt in the early spring. The Kabul River and the other tributaries of the Indus drain 10% of Afghanistan.

1.2.2 The Helmand River Basin

The 1,300 km long Helmand River rises out of the central Hindu Kush Mountains and very near to the headwaters of the Kabul River. The Helmand River flows southwesterly and then westwards to its terminus in the Seistan Depression along the border with Iran. The flow of the Helmand is mostly supplied by the upper catchment areas that receive snowfall in the winter months.

The most significant tributary of the Helmand River is the Arghandab with its tributaries, the Arghastan, Dori and Tarnak Rivers. The Arghandab and its tributaries originate in the southern foothills of the Hindu Kush and in the Balochistan Mountains that form the border with Pakistan.

Further east, the Ghazni River, with its tributary the Jilga (or Sarde) is considered part of this river basin. The Ghazni River flows southwards and parallel to the Tarnak and Arghandab Rivers and empties into the Ab-i-Istada depression, a closed basin.

The Helmand, Arghandab and Ghazni Rivers drain about 30% of Afghanistan's area or about 190,000 km^2. Along the southern border of Afghanistan, the Registan and Dasht-i-Margo deserts receive very limited precipitation most of which evaporates.

1.2.3 <u>The Hari Rud and Western Flowing Rivers</u>

The Hari Rud River, which has a drainage area of 39,000 km^2, flows due west from its source 250 km west of Kabul through the city of Herat and into Iran. At the Iranian border, the river turns northwards and eventually empties into the Tejen Oasis in Turkmenistan. Because of the narrow and elongated configuration of this river basin, the Hari Rud does not have significant tributaries.

The Adraskan or Harut Rud, the Farah Rud, and the Khask Rud are included in this river basin, although these river systems drain to the Seistan Depression like the Helmand River. These rivers, along with the Hari Rud, drain the southwestern part of Afghanistan (20% of Afghanistan's area or about 120,000 km^2). Due to the low precipitation in this part of the country, these river systems flow intermittently.

1.2.4 <u>Northern Flowing Rivers</u>

The Northern Flowing Rivers originate on the northern slopes of the Hindu Kush and flow northwards towards the Amu Darya River. Most of these rivers die out in the Turkistan Plains before reaching the Amu Darya. From west to east, the main rivers include the Murghab, the Shirin Tagab, the Sarepul, the Balkh and the Khulm Rivers. These river basins cover about 20% of Afghanistan, or about 115,000 km^2.

1.2.5 <u>The Amu Darya and Its Tributaries</u>

The Amu Darya River (also called the Oxus) originates in the Afghanistan part of the Pamir (the Badakhshan corridor) as the Ab-i-Wakhan. Formerly called the Ab-i-Panja, it forms over 1,100 km of Afghanistan's northern border with the countries of Tajikistan and Turkmenistan.

There are two main tributaries draining Afghanistan: the Kunduz River (and its tributary the Khanabad), and the Kokcha River. Both of these rivers originate from the northeastern part of the Hindu Kush, are perennial, and have substantial flows in the spring months from snowmelt. These two river basins and the upper drainage area of the Amu Darya cover about 15% of Afghanistan, or about 91,000 km^2.

1.3 Delineation of River Systems

In this report, the delineations chosen by the Government of Afghanistan in the 1970s to monitor water resources have been maintained [per the hydrological and hydrogeological yearbooks published at that time]. The rivers are organized into five major drainage systems and 16 major rivers:

I. Rivers of Indus Basin
  - I-1 Kabul River basin
  - I-2 Khurram (also Gomal and Shamal) River basin

II. Rivers of Helmand Basin
  - II-3 Ghazni River basin
  - II-4 Helmand River basin
    - II-4a Helmand
    - II-4b Arghandab

III. Western Flowing Rivers
  - III-5 Khash River basin
  - III-6 Farah River basin
  - III-7 Adraskan River basin
  - III-8 Harirud River basin

IV. Northern Flowing Rivers
  - IV- 9 Murghab River basin
  - IV-10 Shirin Tagab River basin
  - IV-11 Saripul River basin
  - IV-12 Balkh River basin
  - IV-13 Khulm River basin

V. Rivers of Amu Darya Basin
  - V-14 Kunduz River basin
  - V-15 Kokcha River basin
  - V-16 Wakhan River basin (upper Amu Darya)

1.4 Precipitation Distribution

The Food & Agricultural Organization (FAO, 1996) indicated that, in an average year, precipitation from snow melt is in the range of 150,000 million m^3 and from rainfall about 30,000 million m^3. Total precipitation for the country is in the range of 180,000 million m^3/year. In the past, there were 140 stations for river gauging and /or rainfall measurements. **Figure 2** is an average annual precipitation map for Afghanistan.

2.0 OVERVIEW OF GROUNDWATER SYSTEMS

2.1 Introduction

Over the past five decades, there have been several groundwater studies carried out by various international agencies and Afghanistan governmental agencies:

- The Amu Darya River basin has been investigated by the Russians (mostly exploring for oil and gas).
- Various United States (US) firms and the United States Geological Survey (USGS), under the auspices of USAID programs, were involved with groundwater and surface water assessments and development projects in the Central Helmand River Basin in the 1950s through the 1970s. The southeast part of the Helmand River Basin has been studied by the United Nations Development Program (UNDP) in the Ghazni and Moqur areas.
- Sogreah, a French engineering firm, studied the Farah River Basin in 1975, while the Hari Rud River Basin was studied by the British firm Engineering and Resources Consultants (ERCON) in the 1970's.
- The Kabul River Basin has been investigated by Russian, US, German, Canadian and other countries.
- In addition, United Nation agencies such as the Food and Agricultural Organization (FAO), UNDP, and the United Nations International Children's Emergency Fund (UNICEF) have contributed greatly in the area of groundwater assessment and development, mostly through their water supply programs.

For the most part, these studies have been conducted prior to the late 1970s, and since then there has been very little work done in the groundwater resources assessment area. During this 20+ year vacuum, there reportedly has been increased drilling of deep wells (deeper than hand dug wells) for water supply and irrigation purposes. This development has been viewed by some NGOs, hydrogeologists, and governmental groups as alarming due to the potential to abstract groundwater at rates in excess of sustainable natural recharge and to impact shallow sources of groundwater supply such as shallow wells, springs and karezes (**Figure 3**). Hard data are lacking to assess the exact or even approximate numbers of drilled wells per river basin and their net total abstraction.

Groundwater in some areas of Afghanistan represents an unexplored and underutilized resource that will likely, in years to come, provide a major input for water supply and irrigation uses. The wise development and management of this resource will enable its sustainable use.

This section provides:

1. A brief summary of selected previous studies,
2. A general overview of the principal aquifer systems and of potential aquifer systems for which information is not available.

3. A discussion of water-level declines in the current 4+-year drought for selected river basins.
4. A general discussion of groundwater recharge mechanisms and a summary of previous studies that provide estimates of groundwater recharge.

Figure 4 is a geologic map of the country (Geokart, 1984); **Figure 5** is a geomorphology map (Geokart, 1984), and **Figure 6** is a composite satellite image map showing the extent of snow cover in the winter of 2002.

2.2 Review of Previous Studies

Several regional groundwater studies have been undertaken over the past several decades but no national scale hydrogeologic assessment has been conducted. One comprehensive hydrogeological investigation was the study conducted by Malyarov/Chmyriov in 1976.

2.2.1 Malyarov/Chmyriov, 1975/76

These authors divided Afghanistan into three hydrogeological zones:

i. The Northern Afghanistan artesian region.
ii. The Central Afghanistan "hydrogeologically folded" region.
iii. The Southern Afghanistan artesian region.

These three hydrogeological zones were further subdivided into:

i. Artesian Basins
ii. Basins with Fracture-Karst Water
iii. Intermontane Basins
iv. Hydrogeological Massifs – which correspond to areas underlain by relatively low yielding crystalline and igneous rocks

2.2.2 Afghanistan Agricultural Strategy (FAO, 1996)

The 1996 FAO Report provides an overview of water resources and irrigation conditions in the country. This report notes that: "Groundwater is usually abundant in quaternary aquifers along all major river valleys where infiltration of surface water is high". The report further indicates that if an estimate of 10% of precipitation is adopted for recharge to the groundwater systems, the annual groundwater recharge would be on the order of 18,000 million m^3/yr. for the country.

The report estimates that approximately 300,000 hectares (ha) are irrigated utilizing groundwater sources (springs, karezes, and shallow open wells). Using 10,000 m^3/hectare as a basis, FAO estimates the total annual irrigation water use at 3,000 million m^3/yr.

FAO is conducting (2003) an inventory of all karezes, wells and springs in the country using local Non Governmental Organizations (NGOs).

2.2.3 Norwegian Church Aid - Guidelines for Sustainable Use of Groundwater in Afghanistan, 2002

The Norwegian Church Aid – Afghanistan Program (NCAAP) prepared a technical report, partly in response to the increased installation of private and NGO-funded deep irrigation wells in certain river basins. The installation of these wells, and the deepening of hand dug open wells, has been accelerated by the 4+ year drought and resultant decreasing water levels in some river basins.

The main focus of the report was to offer guidelines to prevent over-abstraction of the lowland Quaternary and Neocene sedimentary aquifer systems.

The report outlines groundwater recharge mechanisms and provides anecdotal evidence of groundwater level declines during the recent drought (see Section 2.4). The author also provides some thoughts about rates of natural recharge to the lowland Quaternary and Neocene aquifer systems.

2.2.4 UNDP, 1986

The UNDP in their document "Ground Water in Continental Asia; Natural Resources/Water Series No. 15" outline similar hydrogeological regions as Malyarov/Chmyriov in 1976. These include:

1. The Northern Plain (the Amu Darya Basin and the Northern Basin).
2. The Great Southern Plain (Seistan Basin) in the south and southwest which includes the Helmand and Western Flowing Rivers Basins.
3. The Central Highland Region (the Hindu Kush Mountain Range and its offshoots) which includes the Kabul Basin.

2.2.5 DACAAR – Danish Committee for Aid to Afghan Refugees

DACAAR is an NGO that has been involved in the installation and maintenance of drinking water wells for more than a decade. They have installed over 26,000 water points in 22 provinces. Each water point is visited yearly and DACAAR has developed a data base since 2000. They have 3 drilling rigs and 10 crews that install concrete ring wells which are a very common feature in the country for drinking water wells in the unconsolidated Quaternary alluvial and semi-consolidated Neocene aquifer units.

2.2.6 <u>UNICEF – Various Studies</u>

UNICEF conducted several hydrogeologic studies in various provinces in the 1970s which were principally focused on assessing the potential for developing rural groundwater supplies for villages, schools and health institutions. Some of the provinces that were visited and evaluated included: Ghor, Badakhshan, Nimroz, Parwan, Logar, Bamyan, Kabul, Ghazni, Nangharar, and Paktya.

2.2.7 <u>World Bank Report, 2003 – Northern Basins Focus</u>

A recent World Bank report (2003) estimates surface and groundwater resources in the Northern Flowing Rivers and the Amu Darya River Basins. The report references various governmental studies from 1956 until 1990. For groundwater, the report notes that in 1990, the total yield (renewable or sustainable) for the whole country was estimated at about 9,500Mm^3/yr as compared to an earlier 1978 estimate of 6,500Mm^3/yr and groundwater use in this timeframe was estimated at 2,200Mm^3/yr.

The report notes that "The estimates suggest that groundwater could be used for irrigation and water supply in several regions of Afghanistan…".

2.2.8 <u>Government of Afghanistan 1975 Hydrogeological Yearbook; Water and Soil Survey Department</u>

This yearbook, published in June 1978, provides an overview of geology for the country at large and summarizes groundwater exploration and development projects and geophysical investigations for various regions in Afghanistan. Hydrogeological investigations carried out by international agencies are also summarized in brief.

2.3 Overview of Principal Aquifer Systems

Unconsolidated Aquifer Systems are comprised of Quaternary and Neocene Age sediments which are found along major river systems and in intermontane basins. These sediments comprise the most prolific aquifers in Afghanistan. Most of the irrigation from groundwater sources (springs, karezes, open wells and drilled wells) is derived from these aquifer systems. **Figure 4**, a geologic map of Afghanistan with River Basin overlays, shows the locations of the Quaternary and Neocene sediments.

These aquifer systems are comprised of alternating layers of pebbles/gravels, sands, silts and clays. The sediments range from unconsolidated to partially consolidated (semi-indurated). Adjacent to the mountains, the sediments are typically coarse grained and deposited, in many places, as alluvial fans.

Along the major river systems, alluvial deposits are present which can be several tens of metres thick and coarse grained. A description of some of these aquifer systems by river basin is provided below.

These aquifer systems have also been described as "Intermontane River Basins" as well as structural river basins and are of hydrogeological importance for the country. They are either of tectonic (trough) or erosional (valley) origin and are in-filled with alluvial, proluvial, colluvial and locally glacial deposits.

Some of the important basins underlain by Quaternary and Neocene sediment aquifer systems include the Hari Rud valley, the Tarnak Trough (structural and along the Moqor Fault system), the Ghazni River valley, the Loghar Basin (tributary to the Kabul River from the south), the Khost-Yaqubi Basin, the Jalalabad Basin (part of the Kabul River system), and the Parwan Basin (north of Kabul) with the Panjsher River being the principal river system in this basin.

In addition, there are several intermontane basins in the Hindu Kush Mountain Range, particularly in Ghor and Bamyan Provinces, that have not been explored in any detail but should have excellent potential for groundwater development for irrigation purposes.

The **Hari Rud** aquifer was investigated in the early 1970s by ERCON between the locales of Marwa and Ghuryan. The investigation involved reconnaissance boreholes, 13 exploration boreholes, and 4 major pumping tests. UNICEF, in the 1970s, installed over 27 water supply wells in this valley. Available information needs to be updated to obtain a better picture of groundwater development efforts during the present 4+-year drought.

The **Tarnak River Valley** is an old tectonic trough stretching northeast to southwest and is filled with Quaternary and Neocene deposits. There are multi-layered aquifers in this river valley and detailed geophysical and hydrogeological investigations were carried out in the 1970s under a UNDP programme in the Upper Tarnak River Valley. Two aquifers were studied: the Shinkay and the Sengasi Moqur. To give an idea of the substantial amount of groundwater that is held in storage in these river valley aquifer systems, the Shinkay Aquifer is 140 km^2 in area and there is over 1,400Mm^3 of water stored in the first 50m of saturation in this aquifer system.

Other Quaternary and Neocene sediment aquifer systems along river valleys include the Ghazni, Qarabagh, Gardez, Khost-Yakubi Basin (northeast part of Paktya Province), Jalalabad basin, Parwan basin, and four aquifer systems in the Kabul City Area (Upper Kabul River, Paghman River Aquifer, Lower Kabul River Aquifer, and the Loghar River Aquifer).

Carbonate rock systems occur within the Hindu Kush and at its northern and southern flanks. The carbonate massif to the north (Northern Flowing Rivers Basin and the western part of the Amu Darya Basin) is comprised of limestone and dolomite locally interbedded with sandstone and conglomerate. There are occurrences of sink holes, caves and caverns. Significant springs issue from the carbonate massif on the northern flank of the Hindu Kush Mountain range and some of these springs form the headwaters of the rivers in north central and northwest Afghanistan.

The principal carbonate rock aquifer systems include the Upper Cretaceous Age limestones that lie to the north of the Hindu Kush Mountain range (**Figure 4)** and the older Permian and Jurassic Age carbonate rock aquifer systems in the Helmand River basin.

Consolidated bedrock aquifer systems - There is very little documentation on the groundwater development potential of the bedrock aquifer systems in Afghanistan. The yield potential of the crystalline rocks (granites, schist, gneiss, etc) is expected to be significantly lower than the unconsolidated aquifer systems in the country. The sedimentary and igneous rock units, which underlie large parts of the country may have development potential, but as yet have not been explored in any detail.

The 1986 UNDP report and the work of Malyarov/Chmyriov, 1975-6 divided the country into the following hydrogeologic regions:

The Great Southern Plain (Seistan Basin) in the south and southwest which includes the Helmand and Western Flowing Rivers Basins.

The Great Southern Plain is subdivided hydrogeologically into the:

- Registan Desert
- Dasht-i-Margo Desert, and
- The Piedmont area

The Central Highland Region (the Hindu Kush Mountain Range and its offshoots) which includes the Kabul Basin.

The Central Highlands is divided into the:

- Carbonate massif
- Non-carbonate complex, and
- Intermontane river basins

The Northern Plain (the Amu Darya Basin and the Northern Rivers Basin).

The Northern Plain is divided into:

- River valleys, and
- Aeolian-proluvial complex.

Great Southern Plain

Registan Desert: This vast sand desert, comprised primarily of aeolian sand, is primarily an unsettled area with very little groundwater exploration work conducted. Given the sparse rainfall and high evapotranspiration rates, groundwater in this desert region is expected to be primarily brackish and saline. The extreme eastern area is characterized by igneous rocks and some Paleocene sandstones, silts, and conglomerates along the Pishin Lora River valley. The far eastern Lora Valley, in contrast to the desert, reportedly contains limited quantities of fresh groundwater.

The Dasht-i-Margo Desert to the west of the Registan Desert and south of the Piedmont region is largely unexplored. The groundwater development potential is probably good along the Helmand River Valley and possibly in the limestone formations in the very south of the country along the border with Pakistan (Chaghay Area).

Piedmont Area: The principal aquifers in the Piedmont include:

- River Valleys with Quaternary alluvial and Neocene deposits.
- Carbonate aquifers in the southeast Arghistan River valley.
- Carbonate aquifers in the Helmand River valley in Oruzgan Province.

Central Highlands

In the Central highlands, three hydrogeological units or regimes are identified:

- The Carbonate Massif,
- The consolidated crystalline, igneous and sedimentary rocks of low productivity, and
- The Intermontane River Basins.

The carbonate massif to the north of the Hindu Kush mountain range outcrops over a very large area and provides base flow, in the form of springs, to many rivers that originate within this massif in the Northern Flowing Rivers Basin. These limestone units range in age from Upper Permian (mostly south of the Hindu Kush mountains and in the Helmand Basin); Upper Jurassic-Cretaceous and Upper Cretaceous-Paleocene (Northern Basin) and Miocene.

Many large springs reportedly issue from the Upper Cretaceous-Paleocene limestones in the Northern Flowing Rivers Basin. The Upper Permian limestones and dolomites are found along the southeast marginal parts of the highland region from southern Oruzgan Province to Kapisa Province in the northeast.

The Northern Plain and Amu Darya Basin

Northern Basin: According to the UNDP 1985 study, the northern basin of the Amu Darya from the Balkh River west has fresh groundwater in areas closer to the recharge/mountain areas. Some excerpts:

- The Balkh River Valley is filled with fluvial deposits saturated with fresh groundwater. Two aquifers are of significant productivity: Sholgara in the south and Mazor-Balkh as the river exits from the mountainous area.

- The water supply system of Mazar-i-Sharif is based on deep wells drilled in the aquifer along the Balkh River. The water is of good quality only in the part of the aquifer that is fed by infiltration of the Balkh River water.

- The Saripul River valley is filled with alluvial-proluvial deposits (sand gravel, cobbles and boulders) saturated with fresh water from Saripul to Sheberghan. The Sheberghan water supply originates from deep wells drilled in this aquifer.

- In the Shirin Tagab River valley as well as its tributary, the Qaysar River, the fluvial sand and gravel are saturated with fresh groundwater. The water supply systems for Maymana, Shirintagab, and Dawlatabad are based on wells tapping this aquifer.

Aeolian – Proluvial Complex: A large part of the Amu Darya (Northern) Plain is underlain by aeolian sand and loess, which either cover or are interstratified with the basin deposits in the central Piedmont Area of the basin. This complex overlies the Neocene series of clay, siltstone, marl and sandstone which also contains gypsum and salt. Oil and gas exploration drilling in this area has indicated that both shallow and deeper aquifers contain brackish and saline groundwater. The UNDP (1985) noted that in the whole area between the Amu Darya River to the north and the line of the towns/cities of Dawlatabad-Sheberghan-Balkh-Khulm in the south, conditions are not favorable for groundwater development.

2.4 Declining Water-Level History

There has been a great deal of verbal and written discussion about declining groundwater levels as a result of the present drought, and in some areas due to what may well be the over-abstraction of groundwater for irrigation usage. In the absence of systematic monitoring in specific river basins, most evidence is anecdotal. The following are some excerpts from the Norwegian report (2002).

- DACAAR Eastern Region: 18% of DACAAR's wells (mostly hand dug to 1 to 1.5m below the water table) have dried up over the past 1.5 years (report date April 2002).

- DACAAR noted that in the Kabul region, the water table has fallen 4-6m in 2 years and in some areas up to 10m.

- During the 3+ year drought, the water table has dropped 4-5m in Kabul City, 5-8 m in Kandahar, and 2-4m in Herat (Personal communication by Norwegian Aid with Eng. Ehsanallaj, NPO, Kabul).

- In Dand (Kandahar) there was a decline of c. 6m in 4 years (1.5 m/yr), and in Zabul a decline of 2m in 4 years (0.5m/yr) (Personal communication by Norwegian Aid with Eng. Hassan, ADA, Kandahar).

2.5 Past Studies of Groundwater Recharge

While there has been no in-depth country wide evaluation of aquifer/groundwater recharge, several NGOs, consulting firms, and Afghanistan Governmental Departments have conducted studies to evaluate the magnitude of groundwater recharge in specific areas. **Figure 2** is a mean annual precipitation map for the country (FAO, 1996) and **Figure 6** shows the extent of snow cover in late January and early February 2002.

The predominant groundwater recharge mechanisms include the following:

- The Quaternary and Neocene aquifers are recharged via infiltration from rivers and streams descending from the high mountains and infiltrating into the coarse grained alluvial fans. It is in these same geologically controlled locales (alluvial fans) that many karezes have been installed over the centuries. This recharge mechanism is probably the highest during the snowmelt season. In some river valleys, direct recharge of precipitation in lowland areas occurs from snowmelt in the winter and spring seasons.

- There will also be a component of recharge from the bounding higher elevation bedrock systems to the unconsolidated and semi-consolidated Quaternary and Neocene aquifers.

- The bedrock aquifer systems, which comprise a vast land area in Afghanistan, rely on the direct infiltration of precipitation for recharge. This recharge will vary depending on the degree of fracturing, altitude, and relative amounts of precipitation/evapotranspiration.

- The carbonate rock aquifer systems, from which large springs emerge, particularly on the northern flank of the Hindu Kush, are probably recharged from the direct infiltration of precipitation.

- The unconsolidated aquifer systems in the southern and northern desert parts of the country receive very little recharge due to the very low annual precipitation and high rate of evapotranspiration.

FAO, 1996

The 1996 FAO study estimates that the country-wide groundwater recharge in a year of average precipitation is in the range of 18,000 million m^3. This is based on the assumption that 10% of precipitation serves to recharge groundwater systems and is equivalent to 76,000 liters per day/km^2 (lpd/km^2)

Norwegian Aid, 2002 Reference to Afghanistan Government Studies

The Norwegian Aid 2002 report notes that local hydrogeologists have estimated annual recharge to the Quaternary and Neocene aquifers in the Kabul City area to be in the range of 250 mm/year. This is equivalent to 690,000 lpd/km^2 which is a very high estimate for recharge in this semi-arid environment.

Norwegian Aid, 2002

The Norwegian Aid study used the rate of water level decline to calculate a normally areally distributed recharge rate for the Neocene-Quaternary aquifer systems along the Kabul and Helmand tributary river systems. Water level declines over a 1-year period of drought have been in the range of 0.5 to 1.5m/yr. Norwegian Aid assumed a specific yield of 10% to arrive at a 50 to 150 mm/yr. range of recharge.

This recharge range is equivalent to 138,000 to 414,720 lpd/km^2 for the Quaternary and Neocene Aquifer systems. These figures are considered to be very high and correlate more closely with recharge rates for glacial aquifer systems in the eastern United States in areas that receive over 1000mm of precipitation annually.

Norwegian Aid further notes that in higher altitude mountain valleys, the rate of recharge is expected to be higher, due to large areas of mountain runoff contributing to valley aquifers of limited extent.

3.0 GROUNDWATER USE AND AVAILABILITY BY RIVER BASIN

3.1 Methodology

Groundwater recharge for aquifer systems in the five principal river basins has been estimated by two methods. The first approach was to utilize the FAO (1996) method of estimating groundwater recharge as a fixed percentage (10%) of average annual precipitation in a specific river basin. In this study, a higher rate or percentage of average annual precipitation for recharge was applied to the unconsolidated and semi-consolidated Quaternary and Neocene aquifer systems, as well as for the carbonate rock systems, and a lower rate of recharge for consolidated bedrock systems. In addition, in this study, the amounts of groundwater recharge were separated out by river basin for the unconsolidated and consolidated aquifer systems.

Additionally, in this study, areas such as the Registan Desert and the Dashte-E-Margo Desert in the lower Helmand River basin were assumed to have no groundwater recharge because of the very low precipitation in these deserts (50 to 100mm/yr.) and high rates of evapotranspiration. These two deserts comprise about 95,000 km^2.

For the Western Flowing Rivers, recharge was estimated at 2% to 4% of precipitation because of the overall low annual precipitation and high evapotranspiration rates in these river basins.

In the final analysis, the FAO and this study's estimates were compared with a compilation of estimates summarized by the World Bank in a 2003 report.

Groundwater use is mostly for irrigation purposes in Afghanistan. Municipal and village usage, although primarily from groundwater, is considered to comprise a much smaller percentage of overall groundwater use. For example, in the Kabul River Basin groundwater use for irrigation is estimated at 450Mm^3/yr. Whereas water use for drinking purposes for a population of about 5 million in this basin would be in the range of 20 to 40Mm^3/yr., representing about 5 to 10% of the agricultural irrigation usage of groundwater.

In this study, irrigation application was estimated at 7,000 to 8,000 m^3/hectare on an annual basis.

3.2 Kabul River Basin and Indus Tributaries

3.2.1 Kabul River Basin

The area of the Kabul River basin in Afghanistan is 54,000km^2 and it includes the provinces of Parwan, Kapisa, Laghman, Kunar, Wardak (partial), Kabul, Loghar, and

Nangharar. The principal tributary rivers include the Panjsher-Ghorband Rod, Alingar-Alishing-Nuristan Rod, Kunar Rod, Logar-Maydan Rod, and the Kabul-Surkh Rod.

The unconsolidated to semi-consolidated Quaternary and Neocene Age sediments comprise the most prolific and developed aquifer systems in the basin. The Quaternary deposits consist of unconsolidated conglomerates, pebbles, sand, clays and silt up to +/- 50m in thickness. The Neocene deposits consist of unconsolidated to semi-indurated sediments up to +/- 400m in thickness.

There are four principal Quaternary and Neocene aquifer systems in the Kabul River Basin. These include the:

- Logar Basin to the south
- Kabul River Basin in the Kabul City area including the Paghman area to the west
- Parwan Basin associated with the Shamali Plain to the north of Kabul and the Panjsher River Basin and its tributaries
- Jalalabad Basin

The areal extent of these Quaternary and Neocene Age unconsolidated and semi-consolidated aquifer systems is on the order of 8,400 km^2 in the Kabul River basin.

Consolidated bedrock units consist principally of crystalline and igneous rocks and some sedimentary rocks such as sandstones, siltstones, conglomerates, and limestones. These bedrock units are largely unexplored.

Irrigation Groundwater Use - Kabul River Basin (Shobair, 2001)											
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**Percent from GW**
Parwan	165	10,340	13.7	83	1980	2.6	176	50	0.1	12,370	16
Kapisa	No Data	-	-	No Data	-	-	No Data	-	-	-	-
Laghman	3	60	<1	0	0	0	0	0	0	60	<1
Kunar	67	720	3	0	0	0	13	10	0	730	3
Wardak	519	8,690	34	336	1,980	7.7	0	0	0	10,670	42
Kabul	81	3,300	5.7	321	14,760	26	436	660	1.1	18,720	32
Logar	169	170	0.6	124	4,380	16	91	240	0.9	4,790	18
Nangharar	210	4,360	10.3	495	9,450	22	15	10	0	13,820	33
								Total Area =		**61,160ha**	

Recharge Estimates

A total of about 61,000 ha are irrigated from groundwater sources (karezes springs and wells) in this area. This represents an annual demand of about 450 Mm^3.

Precipitation in the Kabul Basin is in the range of 200 to 500mm/year. Precipitation in the mountains is higher and can be up to 1,500mm/year. The 1965 FAO report estimates potential evapotranspiration (PET) at 1,610mm/year. The FAO estimate of annual recharge using 400mm/year as average annual precipitation is 2,200 Mm^3/yr.

In this study, average annual precipitation was taken to range from 300mm (lowland areas) to 500mm (mountain areas), and recharge to comprise 15% of precipitation for the unconsolidated units which occur in the lowland areas and 5% of precipitation for the bedrock units which occur in the mountainous areas.

Geologic unit	**Area (km^2)**	**Precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	45,600	5% of 500 mm	1,140
Unconsolidated	8,400	15% of 300 mm	380
Total	54,000		1,520

These estimates of groundwater recharge indicate that for the Kabul Basin at large, groundwater recharge is in excess of irrigation withdrawals. However, the recharge estimate for the unconsolidated aquifer systems in the river valleys (380Mm^3/yr), where most of the groundwater withdrawal takes place, is actually less than the groundwater withdrawal estimate (450Mm^3/yr.), indicating that there are probably sub-basins where groundwater withdrawals exceed recharge.

3.2.2 Southeastern Basins (Indus River Watershed)

The Southeastern Basins have an area of 18,664km^2 and include the provinces of Paktika, Khost, and Paktya. The principal tributary rivers include the Gomol Rod and Shamal Rod.

The unconsolidated to semi-consolidated deposits of Quaternary and Neocene Age occur in limited areas along river valleys. Consolidated bedrock units include mostly Paleocene Age sedimentary rocks and some crystalline and igneous rocks.

Irrigation Groundwater Use - Southeastern River Basins - Indus (Shobair, 2001)											
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**% from GW**
Paktya	392	4,680	8.3	528	5,860	10	800	70	<1	10,610	19
								Total Area =		**10,610 ha**	

Recharge Estimates

A total of about 10,500 ha are irrigated from groundwater sources (karezes, springs and wells) in this area. This represents an annual demand of about 80Mm^3/yr.

The FAO estimate of annual groundwater recharge for the 19,000km^2 basin using an average precipitation of 350mm/yr is 670Mm^3/yr.

In this study, average annual precipitation was also taken to be 350mm (range of 300 to 400mm/year) and recharge to comprise 10% of the average annual precipitation for the unconsolidated aquifer systems and 5% for the consolidated bedrock aquifer units.

Geologic unit	**Area (km^2)**	**Precipitation**	**Annual Recharge (Mm^{3}yr.)**
Consolidated	15,000	5% of 350mm	260
Unconsolidated	4,000	10% of 350mm	140
Total	19,000		400

This study's estimate of groundwater recharge for the unconsolidated aquifer systems of 140Mm^3/yr is about double the estimated groundwater withdrawal number of 80Mm^3/yr indicating the potential for additional withdrawals.

3.3 Helmand River Basin

The Helmand River Basin is subdivided into the Eastern Helmand and the Western Helmand basins.

3.3.1 Eastern Helmand Basin

The area of the eastern Helmand basin is 72,200km^2 (excluding the Registan Area) and it includes the provinces of Ghazni, Paktya (part), Paktika (part), Zabul, and Kandahar (part). The principal tributary rivers include the Ghazni, Tarnak, Arghistan-Lora and Arghandab.

The unconsolidated and semi-consolidated Quaternary and Neocene deposits along major river valleys comprise the most prolific aquifers in this basin. Carbonate rock aquifers of Cambrian and Jurassic Age occur in the lower Tarnak River Basin, and in parts of the Arghistan and Arghandab River Basins (**Figures 4 and 5).**

Consolidated bedrock units consist principally of crystalline and igneous rocks and sedimentary rocks such as sandstones, siltstones, conglomerates.

Irrigation Groundwater Use - Eastern Part of Helmand River Basin (Shobair, 2001)												
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**% from GW**
Ghazni	604	14,530	12	1,516	23,960	20	636	4,680	4	43,170	37
Zabul	756	11,990	19	743	12,780	20	148	100	<1	24,870	40
Kandahar	258	5,310	5	631	15,860	13	252	700	<1	21,870	18
									Total Area =	**89,910 ha**	

This figure has probably changed over the past 5 to 10 years in the eastern Helmand River Basin because of the recent installation of many hundreds of irrigation wells particularly along the Tarnak and Ghazni River valleys (personal Communication with Ministry of Mines & Industry, DACAAR and other government and NGO persons).

Recharge Estimates

Given the recent but significant development of drilled wells along the Tarnak River and Ghazni-Moqor highway, at least 100,000ha, if not more, are irrigated from groundwater sources (karezes springs and wells) in this area. This represents an annual demand of about 750Mm^3.

The Registan Area (South of Kandahar Province) was not factored into the recharge calculations because of the very low annual precipitation in this region.

The FAO estimate of annual recharge using 250 mm/yr annual precipitation is 1,800Mm^3/yr. In this study, average annual precipitation was taken to be 250mm (range 200 to 350mm). The geologic units have been broken out into consolidated, and unconsolidated deposits.

Geologic unit	**Area (km^2)**	**% of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	51,000	5% of 250mm	640
Unconsolidated	21,000	10% of 250mm	530
Total	72,000		1,170

The estimated annual groundwater recharge (1,170Mm^3/yr.) is somewhat greater than the estimated usage (750Mm^3/yr.). However, as much of the irrigation usage is derived from unconsolidated aquifer systems, the current estimated annual usage (750Mm^3/yr.) may well exceed the estimated annual recharge (530Mm^3/yr.) for these unconsolidated aquifer systems. These river basins require hydrogeological investigations to assess sustainability at current and projected future rates of withdrawal.

Navar Closed Basin

The Navar Depression, a closed fresh water basin with no outlet, lies due west of the town of Ghazni. The area of this closed depression is about 1,600km^2 and much of the low land area in this basin is underlain by Quaternary Age deposits. The average annual precipitation is from 400 to 500mm.

Because this basin has no outlet, a recharge rate of 25% of precipitation was used in the groundwater recharge analysis. Recharge is estimated at 180Mm^3 per annum.

This closed basin represents an important ecological resource as it is located on a major flyway for migratory birds. It is our understanding that there is very little groundwater use in this closed basin for irrigation purposes. Any development of groundwater within this closed basin should be planned carefully and ecological water needs should be a major consideration.

3.3.2 <u>Western Helmand Basin</u>

The area of the Western Helmand Basin is 118,660km^2 and includes Oruzgan and Helmand Provinces and parts of Wardak, Bamyan and Ghor Provinces. The principal tributary rivers include the Helmand and the Musa Qal'eh Rud.

Unconsolidated to semi-consolidated aquifer systems of Quaternary and Neocene Age are present along major river valleys and also in a large area in the southern part of the Helmand River basin in the Dashte–E–Margo Desert. This desert receives on the order of from 50 to 100mm/year of precipitation and large areas are reportedly underlain by brackish to salty groundwater. Areas of fresh groundwater occur along the Helmand River in this southwest desert.

There is an extensive area in the Middle Helmand River Basin in Oruzgan Province underlain by Permian Age Limestone as well as smaller areas to the northeast up to Wardak Province (**Figure 4).** Consolidated Bedrock units consist principally of crystalline and igneous rocks and sedimentary rocks such as sandstones, siltstones, and conglomerates. These bedrock units have not been explored in detail.

Irrigation Groundwater Use - Western Part of Helmand River Basin (Shobair, 2001)

Province	Springs			Karezes			Shallow Wells			Total Groundwater	
	No.	Area (ha)	%	No.	Area (ha)	%	No.	Area (ha)	%	Area (ha)	% from GW
Oruzgan	429	56,280	44	84	17,550	14	210	80	<1	73,910	58
Helmand	135	4,320	2.6	276	22,830	14	60	130	<1	27,280	17
									Total Area =	**101,190 ha**	

Oruzgan Province has the largest area in the country under irrigation from groundwater sources (springs, karezes and open wells). This is principally due to the topographic relief and geologic formations that favor spring development and the utilization of karezes for groundwater extraction. The current state of groundwater development from deep drilled wells has not been established.

Recharge Estimates

A total of about 100,000ha are irrigated from groundwater sources (karezes, springs and wells) in this area. This represents an annual demand of about 750Mm^3.

For the purpose of this recharge analysis, the Lower Helmand Basin has not been included due to the low average annual precipitation in this part of the basin and expected very low recharge rates. The principal recharge mechanism in the Lower Helmand River valley will be infiltration of surface water from the Helmand River.

The Upper Helmand Basin was assumed to be about half of the western Helmand basin or 62,000km^2. It comprises an area characterized by important surface water and groundwater resources, especially in Oruzgan Province. There are limestone/carbonate rock aquifer systems in this upper basin that are largely unexplored and unconsolidated and semi-consolidated Quaternary and Neocene aquifer systems.

Precipitation in this part of the river basin is in the range from 150 to over 500mm/yr., with the highest precipitation in the upper northeast reaches of the basin where the mountains receive snowfall. An average annual precipitation of 300mm/year was used in the recharge analysis for the upper Helmand River Basin.

The FAO estimate of annual recharge is 1,850Mm^3/yr. For this study it was assumed that 10% of the 300mm/yr. precipitation would recharge the unconsolidated and carbonate aquifer systems and 5% the consolidated bedrock units

Geologic unit	**Area (km^2)**	**% of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	37,000	5% of 300mm/yr	560
Unconsolidated and Carbonate	25,000	10% of 300mm/yr	750
Total	62,000		1,310

This study's recharge estimate of 1,310Mm^3/yr. is lower than FAO's (1,860Mm^3/yr.) estimate. The analysis indicates that groundwater use for irrigation (750Mm^3/yr.) is lower than annual recharge and thus the potential exists for increased groundwater development for irrigation usage in the upper part of the Helmand basin.

3.4 Western Flowing Rivers

The Western Flowing Rivers are broken out into the rivers that drain into the Seistan Depression (Khash, Farah and Adraskan) addressed in report section 3.4.1 below, and the Hari Rud covered in report section 3.4.2.

3.4.1 <u>Western Flowing Rivers Draining to Seistan Depression</u>

The area of the Western Flowing Rivers (Khash, Farah, and Adraskan) draining to the Seistan Depression is 108,201km^2. These rivers are located in Southern Herat, Farah, Southern Ghor, and Northern Nimroz Provinces.

The unconsolidated and semi-consolidated Quaternary and Neocene Age sediments comprise the best aquifers in this basin particularly adjacent to river courses. Consolidated bedrock units are principally crystalline and igneous rocks and sedimentary rocks such as sandstones, siltstones, and conglomerates. These bedrock aquifer systems have not been explored in any detail and are considered to comprise marginal aquifers.

Irrigation Groundwater Use - Western Flowing Rivers (Shobair, 2001)

Province	Springs			Karezes			Shallow Wells			Total Groundwater	
	No.	Area (ha)	%	No.	Area (ha)	%	No.	Area (ha)	%	Area (ha)	% from GW
Herat included in Hari Rod River Basin											
Ghor included in Hari Rod River Basin											
Farah	94	7,350	6	352	28,480	23	2,324	1,060	1	36,890	29
Nimroz	2	0	0	18	320	<1	140	240	<1	560	1
								Total Area =		38,000 ha	

Recharge Estimates

A total of about 38,000ha are irrigated from groundwater resources (karezes, springs and wells) in this area. This represents an annual demand of about 300Mm^3/yr.

Precipitation in the Western Flowing Rivers basin is in the range from 50 to 300mm/yr. with the highest precipitation in the upper northeast reaches of the river basin in the mountainous areas. An average precipitation of 150mm/yr. was used in the recharge analysis

The FAO estimate of annual recharge using 150mm/yr. as average annual precipitation is 1,600Mm^3/yr. for the basin area of 108,000km^2.

In this study, recharge estimates were developed by geologic formation. The geologic units were broken out into unconsolidated aquifers with a higher potential for recharge and lower permeability consolidated rock aquifers with a lower potential for recharge. Because of the desert environment and very high evapotranspiration and potential evapotranspiration rates, lower rates of potential recharge were estimated for these river basins in the analysis as compared to other river basins in the country. An estimate of 2% of precipitation serving to recharge the consolidated rock aquifer units was applied and for the unconsolidated units, 4%.

Geologic unit	**Area (km^2)**	**% of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	52,000	2% of 150mm/yr	160
Unconsolidated	56,000	4% of 150mm/yr.	340
Total	108,000		500

The annual groundwater use for irrigation is estimated to be 300$Mm^{3.}$ This study's recharge estimate (500Mm^3/yr.) is considerably lower than FAO's estimate of 1,600Mm^3/yr. If agricultural groundwater use is indeed 300Mm^3/yr., then irrigation usage, which is predominantly in areas underlain by unconsolidated sediments, may well be approaching this study's estimate of annual recharge of 340Mm^3/yr.

3.4.2 Hari Rud River Basin

The area of the Hari Rud River Basin in Afghanistan is 39,000km^2 and it includes the provinces of Central Ghor and Herat.

Quaternary Age unconsolidated gravels, pebbles, and sand with interbedded layers of clay and silt are present with a total thickness in the range of 100 to 150m. The maximum thickness of Quaternary deposits is found in areas of alluvial fans of Buton and Karah and along river bed areas. Neocene Age unconsolidated to semi-consolidated deposits also occur in the basin.

Consolidated Bedrock units consist principally of crystalline (phyllite, gneiss, schist, and marble) and igneous rocks and sedimentary rocks (sandstone, marls, conglomerates and limestone).

Irrigation Groundwater Use - Hari Rod River Basin (Shobair, 2001)											
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**% from GW**
Ghor	570	15,990	22	4	710	1	263	240	<1	16,940	23
Herat	153	830	<1	228	1,650	1	450	1,370	<1	3,930	2.4
									Total Area	**20,870 ha**	

The Hari Rud River Basin was studied in the early 1970s (ERCON, 1972). The objectives of this study were to assess hydrogeological conditions in the basin, estimate groundwater reserves, and assess the feasibility of irrigating 16,500 hectares by groundwater irrigation.

The ERCON study concluded that the groundwater reserves in the Hari Rud Valley were in the range of 4,000 Mm^3 and the dynamic or rechargeable reserves were estimated at 1,100Mm^3/yr. ERCON recommended that, of this amount, 700Mm^3/yr. could be withdrawn for irrigation purposes.

A total of about 21,000ha are irrigated from groundwater resources (karezes, springs and wells) in this area. This represents an annual demand of about 160Mm^3.

Precipitation in the Hari Rud Basin is in the range of 150 to 350mm/yr. and the precipitation is highest in the mountainous regions of the drainage basin in the eastern and central parts. An average precipitation of 250mm/yr. was used in the development of recharge estimates for the basin.

The FAO Estimate of annual recharge, using 250mm/yr. as average annual precipitation, is 980Mm^3/yr. for the 39,000km^2 basin. This study's recharge calculations are outlined below.

Geologic unit	**Area (km^2)**	**% of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	26,000	5% of 250mm/yr.	320
Unconsolidated	13,000	10% of 250mm/yr.	320
Total	19,000		640

This study's recharge estimate (640Mm^3/yr.) is lower than the FAO estimate (980Mm^3/yr.) and ERCON's estimate (1,100Mm^3/yr.). However, all of the annual recharge estimates are considerably higher than estimated groundwater use for agricultural irrigation (160Mm^3/yr.) indicating the potential to develop additional groundwater in this basin for irrigation purposes.

3.5 Northern Flowing Rivers

The first hydrological surveys in the Northern Regions of Afghanistan were conducted in the Mazar-i-Sharif area by H. Jackly: "Hydrology of the Area of Mazar-i-Sharif, 1954". Reportedly, a hydrogeological survey in Northern Afghanistan by the Oil and Gas Exploration, Department of Mines and Industries, assisted by Soviet specialists, started in

1959. The first reports on these investigations were written by A. F. Kallnitzky in 1960 and 1961.

The Northern River Basins are underlain by extensive carbonate rock/limestone aquifer systems and many of the river systems receive baseflow from springs issuing from these aquifers (Murghab, Maymana (Shirin Tagab), and Balkh Rivers). The lowland areas are underlain by unconsolidated to semi-consolidated deposits of Quaternary and Neocene Age. These river systems, in most years, die in the desert and do not reach the Amu Darya River.

The area of the Northern Rivers basin is 114,787km^2 and includes the provinces of Badghis, Faryab, Saripul, Jawzjan, Balkh, Samangan, and northern parts of Ghor and Bamyan Provinces. The principal Tributary rivers from west to east include the Murghab Rod, Shirin Tagab, Saripul, Balkh and Khulm.

The unconsolidated to semi-consolidated Quaternary (conglomerates, pebbles, sand, clay and silt) and Neocene Age sediments occur over the northern portion of this river basin.

A large portion of the Northern Plain is comprised of aeolian sand and loess, which either cover or are interstratified with the basin deposits in the central Piedmont Area of the basin. This complex overlies the Neocene series of clay, siltstone, marl and sandstone deposits which also contains gypsum and salt. Oil and gas exploration drilling in this area has indicated that both shallow and deeper aquifers contain brackish and saline groundwater. UNDP (1986) has noted that in the area between the Amu Darya River to the north and the line of the towns/cities of Dawlatabad-Sheberghan-Balkh-Khulm in the south, conditions do not appear favorable for groundwater development.

Areas in the highland/mountainous areas are underlain by Cretaceous-Paleocene Age carbonate rock aquifer systems. These aquifer systems are characterized by large capacity springs that form the headwaters of many of the rivers and streams that drain the northern flanks of the Hindu Kush range **(Figures 4 and 5).**

Consolidated Bedrock units consist principally of crystalline and igneous rocks and sedimentary rocks such as sandstones, siltstones, and conglomerates.

Irrigation Groundwater Use - Northern Basin (Shobair, 2001)											
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**% from GW**
Badghis	50	8,660	26	30	4,390	13	0	0	0	13,050	39
Jawzgan	87	2,060	1	2	20	<1	443	100	<1	2,180	1
Faryab	79	4,250	3	960	380	<1	867	270	<1	4,900	4
Saripul	No Data	-	-	No Data	-	-	No Data	-	-	No Data	-
Balkh	92	200	<1	3	0	0	82	50	<1	250	<1
Samangan	73	5,840	13	7	410	1	271	470	1	6,720	15
								Total Area =		**27,100 ha**	

Recharge Estimates

A total of about 28,000ha are irrigated from groundwater resources (karezes, springs and wells) in this area. This represents an annual demand of about 210Mm^3.

In the Northern Basin, precipitation is in the range of 150 to 400mm/yr. An average precipitation of 250mm/yr. was used in the development of recharge estimates for the 115,000km^2 basin.

The FAO estimate of annual recharge is 2,900Mm^3/yr. This study took into consideration the geologic units in the basin that have been broken out into consolidated, unconsolidated, and carbonate or limestone rocks. As the northern part of the basin is characterized by unconsolidated Quaternary and Neocene aquifers which likely contain brackish to saline groundwater, only half of the area underlain by these units was considered in the recharge analysis (27,000km^2).

Geologic unit	**Area (km^2)**	**% of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	10,000	5% of 250mm/yr.	130
Unconsolidated	27,000 (half)	10% of 250mm/yr.	680
Carbonate Rocks	53,000	10% of 250mm/yr.	1,330
Total	115,000		2,140

The annual groundwater use for irrigation is estimated to be 210Mm^3/yr. The FAO recharge estimate (2,900Mm^3/yr.) and this study's estimate (2,140Mm^3/yr.) when compared to groundwater use indicates the potential for developing significant additional supplies of groundwater for irrigation in the Northern Basin.

3.6 Amu Darya River Basin

The Northeastern River basins along with the Kabul River Basin receive the highest precipitation and some of the higher elevation mountain areas contain snow throughout the year (**Figure 6**). The three river systems (Surkhab (Kunduz), Kokcha and Wakhan) are all fed from the higher elevation snow melt. On the basis of a recent FAO study (Shobair, 2001); the Amu Darya River basin is the least irrigated river basin from groundwater sources. The area of the Amu Darya Basin in Afghanistan is 90,893km^2 and it includes the provinces of Baghlan, Kunduz, Takhar, and Badakhshan.

Unconsolidated to semi-consolidated deposits of Quaternary and Neocene Age comprise the principal aquifers in the Basin. A large area in the upper reaches of the Kunduz River

Valley is underlain by Cretaceous and Paleocene Limestone Rocks, as well as some lowland areas in the vicinity of Baghlan and Kunduz (**Figure 4).**

Consolidated Bedrock units consist primarily of crystalline and igneous rocks and sedimentary rocks such as sandstones, siltstones, and conglomerates particularly in the southeast and eastern parts of the river basin (Wakhan and Kokcha Rivers).

Irrigation Groundwater Use - Amu Darya River Basin (Shobair, 2001)												
Province	**Springs**			**Karezes**			**Shallow Wells**			**Total Groundwater**	
	No.	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**No.**	**Area (ha)**	**%**	**Area (ha)**	**% from GW**
Badakhshan	82	3,840	6	0	0	0	54	90	<1	3,930	6.4
Kunduz	0	0	0	0	0	0	55	540	<1	540	<1
Takhar	288	8,150	13	0	0	0	509	360	<1	8,510	14
Baghlan	63	160	<1	0	0	0	0	0	0	160	<1
								Total Area =		**13,140 ha**	

Recharge Estimates

A total of about 13,000ha are irrigated from groundwater resources (springs and wells) in this area. This represents an annual demand of about 100Mm^3.

Precipitation in the Amu Darya Basin is in the range of 200 to 1,500mm/yr. The precipitation is highest in the mountain areas, particularly in the southeast mountainous part of the basin and up to 1,000mm/yr. in the northern part of Badakhshan Province. An average precipitation of 500mm/yr. was used in the development of recharge estimates for the basin.

The FAO recharge estimate for the 90,893km^2 basin is 4,500Mm^3/yr. This study's estimates were developed for the consolidated and unconsolidated geologic units and using a more conservative percentage of recharge from precipitation for the bedrock units (5%) than FAO.

Geologic unit	**Area (km^2)**	**%of precipitation**	**Annual Recharge (Mm^3/yr.)**
Consolidated	63,000	5% of 500mm/yr	1,570
Unconsolidated/Carbonate	28,000	10% of 500mm/yr	1,400
Total	91,000		2,970

The annual groundwater use for irrigation is estimated to be 100Mm^3/yr. The FAO recharge estimate (4,500Mm^3/yr.) and this study's estimate (2,970Mm^3/yr.) indicate a significant surplus of groundwater reserves in this river basin given the very low groundwater use and clearly a potential for developing significant groundwater resources for irrigation in this Northeastern Basin.

3.7 Summary

Kabul River Basin

While the estimates of groundwater recharge for the Kabul Basin indicate that groundwater recharge is in excess of irrigation withdrawals, this study's recharge estimate for the unconsolidated aquifer systems in the river valleys (380Mm^3/yr.) is actually less than the 450Mm^3/yr. groundwater withdrawal estimate, indicating that there are probably sub basins where groundwater withdrawals exceed recharge.

This is a river basin which requires an evaluation of aquifer sustainability for the basin at large and more importantly in each of the sub basins.

For the southeastern tributaries of the Indus River Basin, this study's estimate of groundwater recharge for the unconsolidated aquifer systems of 140Mm^3/yr. is about double the estimated groundwater withdrawal number of 80Mm^3/yr. indicating the potential for additional withdrawals.

Eastern Helmand Basin:

The estimated annual groundwater recharge of 1,170Mm^3/yr. is somewhat greater than the estimated usage of 750Mm^3/yr. However, as much of the irrigation usage is derived from unconsolidated aquifer systems, the current estimated annual usage of 750Mm^3/yr. may well exceed the estimated annual recharge of 530Mm^3/yr. for these unconsolidated aquifer systems. These river basins require more in-depth hydrogeological investigations to assess sustainability at current and projected future rates of withdrawal.

Western Helmand Basin:

The estimated annual recharge of 1,310Mm^3/yr. for the upper part of the Western Helmand River Basin is considerably larger than the estimated groundwater use for irrigation of 750Mm^3/yr. Thus, the potential exists for increased groundwater development for irrigation usage in the upper part this basin.

Overall, the Middle and Upper Helmand River Basin likely has the potential for additional groundwater development on the basis of groundwater use and this recharge analysis. This is another basin where a detailed hydrogeologic assessment of groundwater use and sustainability should be given priority.

Western Rivers Basin:

The recharge estimate of 500Mm^3/yr. for the basin at large is somewhat higher than the estimated irrigation groundwater use of 300Mm^3/yr. However, recharge for the unconsolidated aquifer units (340Mm^3/yr.) is comparable to irrigation usage. Overall, this basin appears to have a limited potential for natural groundwater recharge primarily because of low annual average precipitation and high evapotranspiration rates.

Hari Rud:

The recharge estimate (640Mm^3/yr.) for this basin when compared to the 160Mm^3/yr. estimated irrigation usage indicates the potential to develop additional groundwater in this basin for irrigation purposes.

Looking at the Helmand River Basin and the five Western Flowing Rivers as a whole, the following is a comparison of the World Bank, FAO and this study's analyses of groundwater recharge for these basins:

World Bank, 2003:	3,800 Mm^3/yr.
FAO, 1996:	5,230 Mm^3/yr.
This Study, 2003:	3,620 Mm^3/yr.

Northern Flowing Rivers:

The annual groundwater use for irrigation of 210Mm^3/yr. is considerably lower than groundwater recharge estimates of 2,900Mm^3/yr. (FAO) and 2,140Mm^3/yr. (current study) indicating the potential for developing significant additional supplies of groundwater for irrigation purposes in the Northern Basin.

Amu Darya Basin:

The annual groundwater use for irrigation estimated at 100Mm^3/yr. is much lower that groundwater recharge estimates of 4,500Mm^3/yr. (FAO) and 2,970Mm^3/yr. (current study) indicating a significant surplus of groundwater reserves in this river basin and clearly a potential for developing the use of groundwater resources for irrigation in the Amu Darya Basin.

Looking at the Northern Flowing Rivers and the Amu Darya Basins as a whole, the following is a comparison of the World Bank, FAO and this study's analyses of groundwater recharge for these basins:

World Bank, 2003:	1,500 Mm^3/yr.
FAO, 1996:	7,400 Mm^3/yr.
This Study, 2003:	5,110 Mm^3/yr.

4.0 RECOMMENDATIONS

4.1 Recognized Groundwater Problems

Major groundwater impacts that may be occurring in Afghanistan include:

1. Long-term reduced groundwater recharge due to deforestation and poor land-use practices in the watersheds at large;

2. Water-level drawdown impacts from increased deeper tube well pumpage in the eastern Helmand River tributaries, the Kabul River Basin, and in some urban centers;

3. The drying up of shallow wells and karezes from this deeper tube well pumpage; and

4. Undocumented water quality impacts in the urban and town areas from improper wastewater disposal, poor drainage, and chemical spills and disposal practices.

The nature and magnitude of these impacts to the principal aquifer systems in the country have not been defined or quantified in detail. However, anecdotal evidence of water-level impacts from the increasing use of deep drilled wells, particularly in the eastern Helmand basin and Kabul River basin has been provided in several reports and studies over the past several years. Impacts to shallow sources of groundwater supply including hand dug wells and karezes has been attributed to the increased development of the groundwater resources in these basins as well as to the 5+ year drought.

Urban centers such as Kabul, Kandahar, and others that rely solely on groundwater as a source of drinking water supply, have reportedly experienced the lowering of groundwater levels and the drying up of shallow wells and karezes. Water quality conditions and impacts have not been evaluated in any detail in either rural or urban settings.

Groundwater recharge has also been impacted over the decades by the continued deforestation of all of the watersheds in the country.

4.2 Groundwater Issues

Some of most pressing issues include:

1. The traditional sources of irrigation from groundwater sources are gravity feed (karezes and springs) and shallow hand-dug open wells. Deeper drilled wells have become more common-place along the eastern Helmand Basin river systems and in the Kabul Basin. Abstraction from deeper drilled wells has resulted in the lowering of water levels in shallow hand-dug wells and has also impacted karez

systems which basically skim the top of the water table. Resolution of these conflicting abstraction systems, possibly by developing separation distances between traditional groundwater abstraction systems and new deeper drilled wells, is a consideration.

2. Over-abstraction is clearly a concern in the Kabul, eastern Helmand and Western Rivers basins. Studies are required to refine the safe sustainable yield estimates in these three basins (and sub basins) and for that matter for all of the minor and major river systems in Afghanistan. Such evaluations and determinations are precursors to the development of management plans for the groundwater resource.

3. Management systems clearly need to be incorporated in the local, provincial and regional governance process. And while policies and regulations from the national government might be a consideration, at the end of the day, there will need to be local buy-in to management policies and implementation. Enhancement of traditional methods of water management by Mirabs and Wakils needs to be explored for water management particularly in rural areas.

4.3 Scientific Studies

Data gaps are immense, but are slowly being filled in. Various International Organizations such as GTZ, USAID, JAICA, the UN and many NGOs such as DACAAR etc. are conducting water point surveys, evaluating groundwater quality, instituting water-level monitoring (particularly in the Kabul Basin) and beginning to develop the framework for groundwater management models in the Kabul Basin. The FAO has an on-going survey of inventorying land under irrigation by water source. There is clearly the need to initiate scientific studies by river basin and sub basin that will entail:

- Basic groundwater data compilation (well details; water levels; water quality; pumpage; and aquifer characteristics)
- Aquifer and river basin/sub basin oriented investigations and monitoring of water levels, pumpage, and water quality
- Groundwater recharge and aquifer/basin sustainability assessments;
- Detailed well inventories and withdrawal estimates by well and basin;
- For key basins, the development of models that will allow an assessment of the impacts of different management practices.

4.4 Management

From a management perspective, the following areas need to be considered and ultimately addressed:

- Abstraction regulations;
- Well permitting and construction regulations

- Integrated river basin management approaches
- Watershed management protection, reforestation and recharge enhancement

Drilling and pumping equipment technology often gets ahead of management approaches. Afghanistan can certainly learn from India and neighboring Pakistan (particularly Baluchistan province) and other countries where inexpensive deep drilling technologies and deep well submersible pumps allow for the rapid installation of irrigation wells and the withdrawal of significant quantities of groundwater for irrigation purposes. In these instances, the hardware technology is often decades ahead of the realization and political will to institute management practices and sustain groundwater systems.

4.5 Initiation of Programs

1. Initiate basic and practically oriented scientific studies by river basin that focus on groundwater availability; recharge characteristics and sustainability, and management alternatives;

2. Begin to consider and develop the elements of some form of regulation for well drilling, well construction guidelines, and groundwater abstraction.

3. Develop a focus on education related to conservation and water use, watershed care and reforestation, and enhancement of groundwater recharge through local small scale technologies.

4. Initiate a program to explore the development potential of bedrock aquifer systems in the country beginning with the carbonate rock systems.

5.0 ACKNOWLEDGEMENTS

We would like to acknowledge the many individuals who assisted in our 2003 study and evaluation and generously provided information sources, reports and data. These include: Stan Hall from Unicef; Eric Viala and David Craven from DAI who provided input and prepared some of the Figures, DAI who retained me for the initial work in 2003; Mir Mohammed Sediq the Minister of Mines and Industry; FAO's office in Kabul, the United States Geological Survey (USGS); the UN mapping group in Kabul AIMS, and countless Afghanis who shared their culture, zest for life and experiences with me during my stay in their country.

6.0 REFERENCES

ERCON - Engineering and Resources Consultants. 1972. Hydrogeological Investigation of the Hari Rud Basin between Marwa and Ghuryan, Afghanistan. Phase 2 Report, vol. 2A: Hydrogeology. Prepared for the Ministry of Agriculture and Irrigation.

FAO, 1965. Report on Survey of Land and Water Resources, Afghanistan. Volume 1: General Report, Volume II: Geology, Volume III: Hydrology, Volume IV: Soils, Volume V: Water Control – Irrigation – Power Potential. Rome 1965.

FAO, 1996. Afghanistan, Promotion of Agricultural Rehabilitation and Development Programmes, Water Resources and Irrigation. FAO Project TCP/AFG/4552. November 1996. AREV

FAO, 1999. Provincial Landcover Atlas of Islamic State of Afghanistan. Utilization of Remote Sensing for the Inventory and Monitoring of Agricultural Land in Afghanistan. FAO Project AFG/90/002. March 1999.

FAO, 2001. Dr. Sayed Sharif Shobair. Current Drought Situation in Afghanistan. August 2001.

Government of Afghanistan, 1978. Hydrogeological Yearbook, 1975. Water and Soil Survey Department, Ministry of Water and Power, June 1978.

Malyarov, E. P. and V. M. Chmyriov. 1976. Scheme of Hydrogeological Zoning of Afghanistan. 1976.

McClymonds, N.E., 1972. Shallow Groundwater in the Zamin Dawar Area, Helmand Province. Afghanistan. Open File Report. United States Geological Survey, under the auspices of the United States Agency for International Development.

Norwegian Church Aid – Afghanistan Program (NCAAP), 2002. Guidelines for Sustainable Use of Groundwater in Afghanistan. April 2002.

Organization for Surveying & Cartography. 1984. National Atlas of the Democratic Republic of Afghanistan. Geokart Poland. 1984

Sammel, E. A., 1971. Groundwater Reconnaissance in the Argandab River Basin near Kandahar, Afghanistan. Open File Report. United States Geological Survey, under the auspices of the United States Agency for International Development.

Sir M. MacDonald & Partners and Hunter Technical Services, LTD. 1972. Agricultural Development Bank Project – Consultant Services for Minor Irrigation Rehabilitation and Groundwater Development. Report Prepared for Royal Government of Afghanistan, Ministry of Agriculture and Irrigation. July 1972.

Radojicic, S. 1976. Report on Deep Well Locations in Certain Places of Kabul and Ghazni Provinces. Afghanistan Rural Water Supply Project. June, 1976.

Radojicic, S. 1978. Report on Possible Provision of Drinking Water for the Places of Gereshk, Qala-i-Kah, Anardara, Khake Safed, Fararod, Gulestan, Bakwa, Kohsan and Obe. Report Prepared for Republic of Afghanistan. Kabul 1978.

UNICEF, 1976. Hydrogeological Survey in Kabul Province. Kabul 1976.

UNICEF, 1982. Hydrogeology of Kabul Basin. Prepared by Vlastimil Myslil and M. Naim Eqrar. April 1982

UNICEF, 1976. Hydrogeological Survey in Loghar Province. Republic of Afghanistan, UNICEF Rural Water Supply Project.

United Nations. 1986. Ground Water in Continental Asia (Central, Eastern, Southern, South-Eastern Asia). Natural Resources/Water Series No. 15.

USGS. Jones, James R. 1971. Program of Groundwater Resources Investigation for the Helmand-Arghandab Valley Authority, Afghanistan. U. S. Geologic Survey Administrative Report, Lashkar Gah, December 1971.

World Bank, 2003. Water Resource Development in Northern Afghanistan and Implications for Amu Darya Basin

WHO/Unicef. 1979. Balkh-Aqcha Regional Water Supply Scheme – Report on Groundwater Potential. Report Prepared for Republic of Afghanistan, Ministry of Public Health. Kabul, 1979.

Table 1: Summary of Groundwater Use and Recharge Estimates By River Basin			
River Basin	**Groundwater Usage (FAO) Mm^3/yr**	**Recharge Estimate FAO, 1996 Mm3/yr**	**Recharge Estimate VUA, 2003 Mm3/yr.**
1. Kabul	450	2,200	1,520
(Unconsolidated Aquifers Only)	***450***		***380***
Indus Basin	80	670	400
Total Kabul/Indus	**530**	**2,870**	**1,920**
2. Helmand			
2a. Eastern Basin	750	1,800	1,170
(Unconsolidated Aquifers Only)	***750***		***530***
2b. Western Basin	750	1,850	1,310
Total Helmand Basin	**1,500**	**3,650**	**2,480**
3. Western Flowing Rivers			
3a. Western Rivers	300	1,600	500
(Unconsolidated Aquifers Only)	***300***		***340***
3b. Hari Rud	160	980	640
Total Western Flowing Rivers	**460**	**2,580**	**1,140**
4. Northern Basin	210	2,900	2,140
5. Amu Darya	100	4,500	2,970
Amu Darya and Northern Basins Combined	**310**	**7,400**	**5,110**
Total for Afghanistan	**2,800 Mm^3/yr**	**16,500 Mm^3/yr**	**10,650 Mm^3/yr**

FIGURES

Figure 1: River Basin of Afghanistan (DAI, 2003)

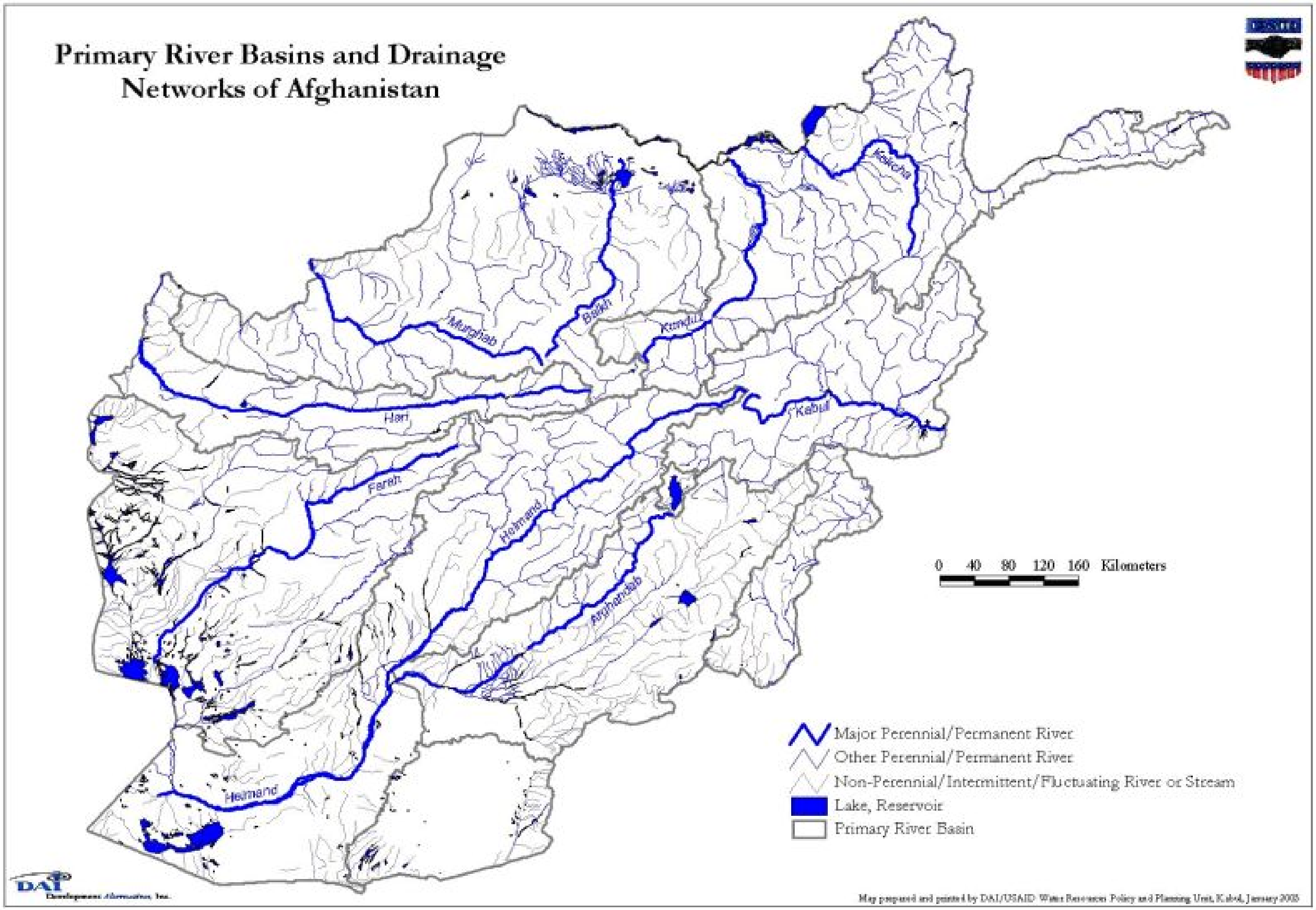


Figure 2: Mean Annual Precipitation Distribution – Afghanistan (Geokart, 1984)

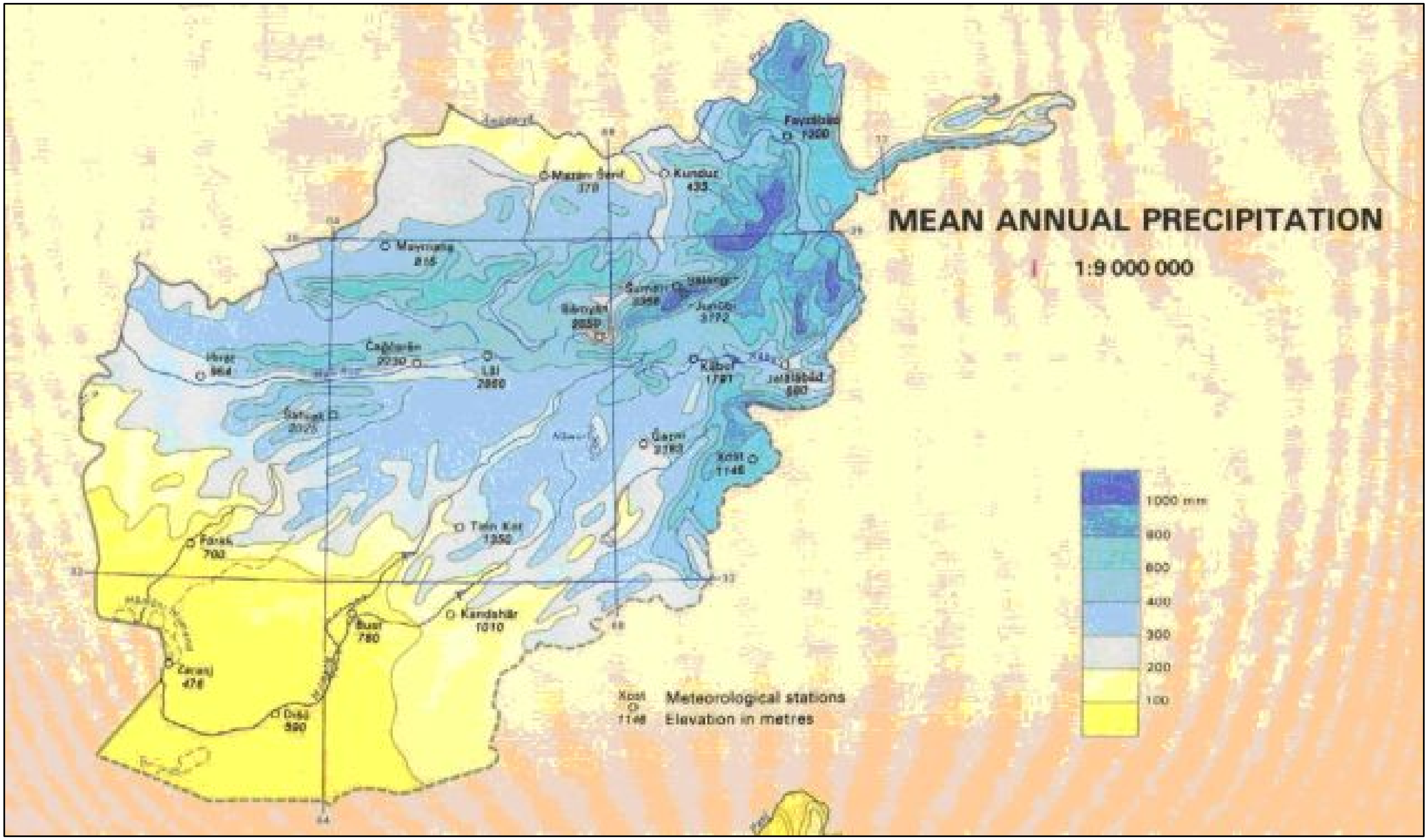
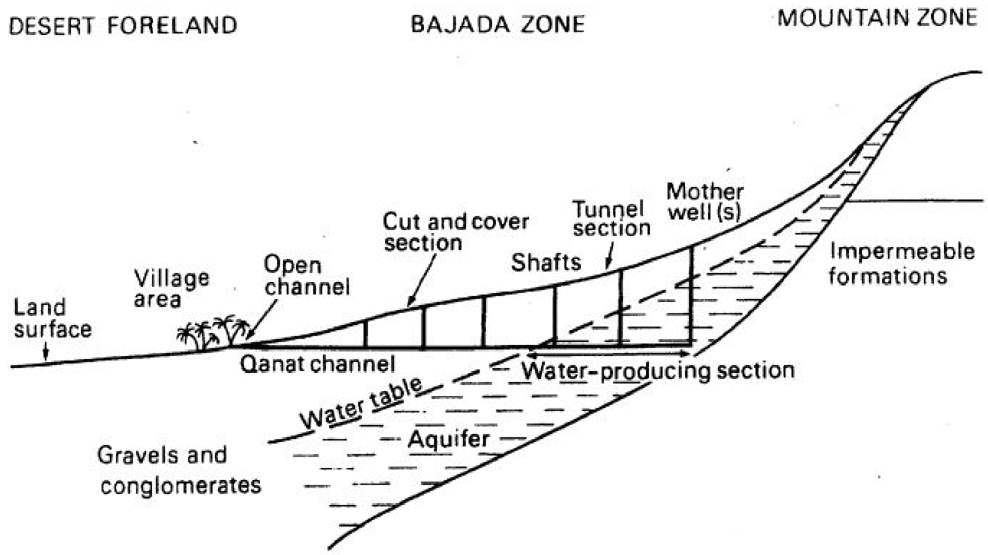


Figure 3: Cross section of a Karez



(Source: "The Warm Desert Environment" by Andrew Goudie and John Wilkinson, 1977)

Figure 4: Geologic Map of Afghanistan (Geokart, 1984)

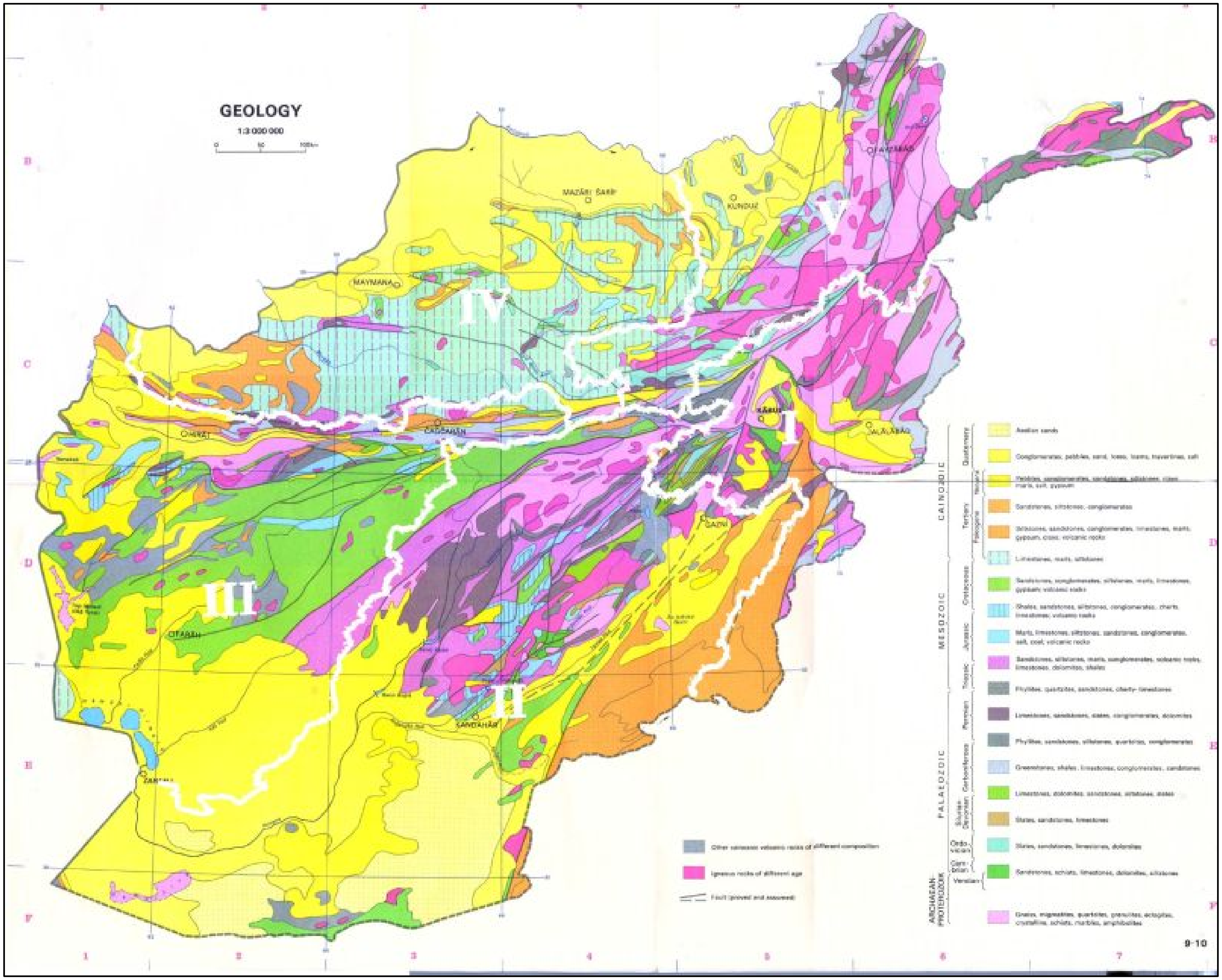


Figure 5: Geomorphology of Afghanistan (Geokart, 1984)

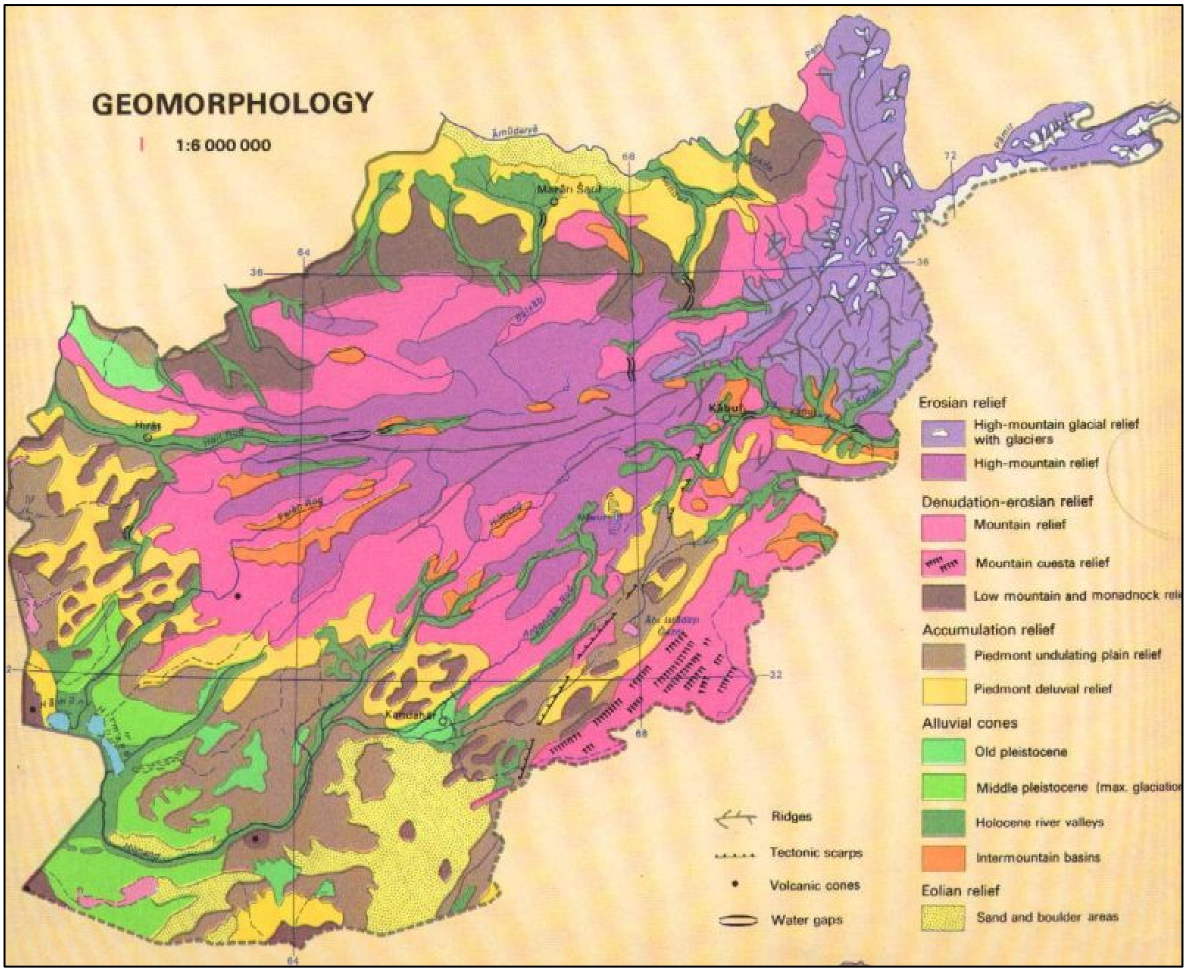
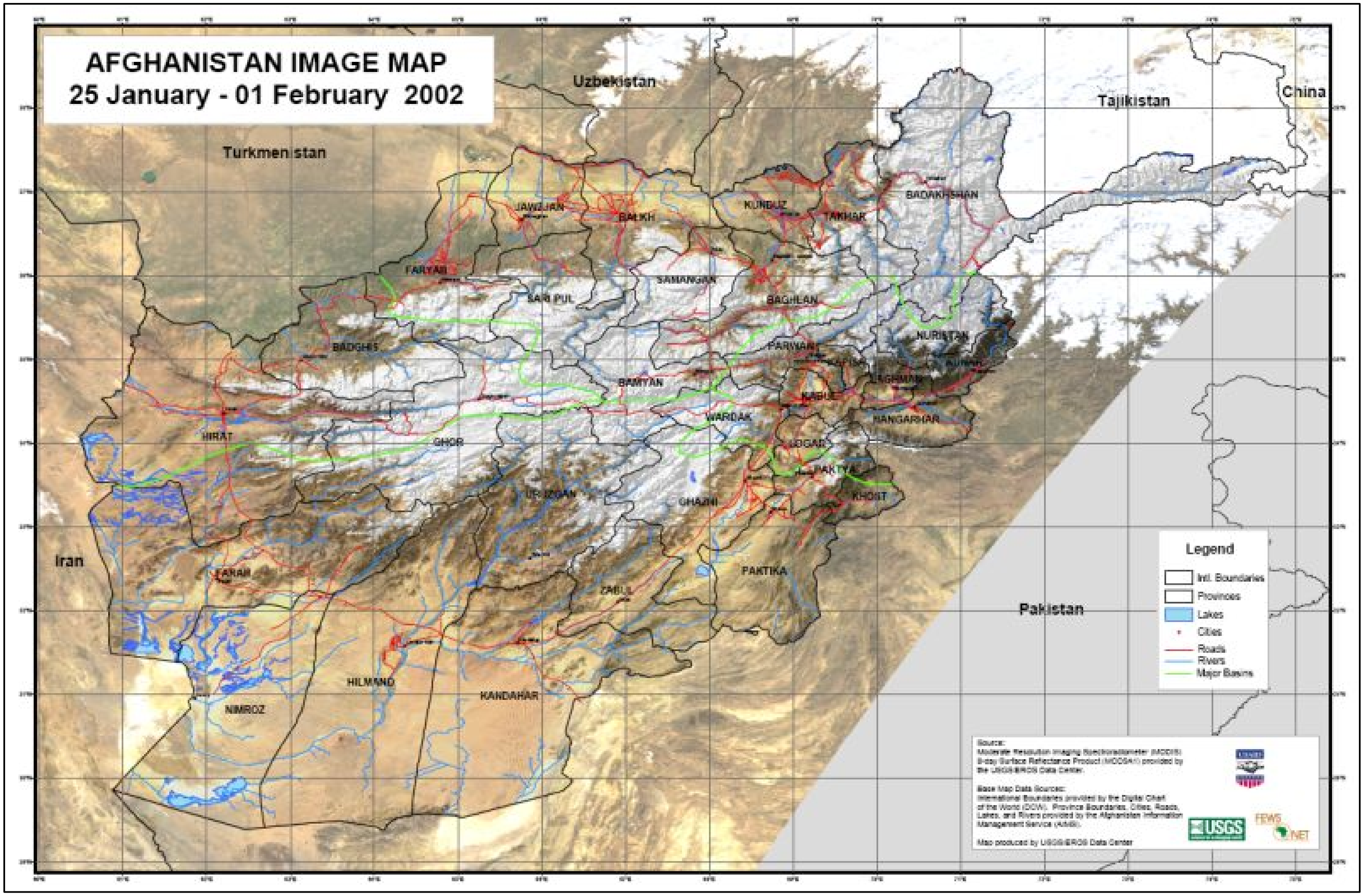


Figure 6: Satellite Image: January – February 2002, showing the extent of snow cover (DAI, 2003)



APPENDIX 1

PHOTOS

Photo 1:Logar River

Photo 2: Kunduz River

Photo 3: Village in the Hindu Kush Range

Photo 4: Salang Tunnel in the Hindu Kush Range

Photo 5: Aerial view of a Karez well systems and irrigated fields

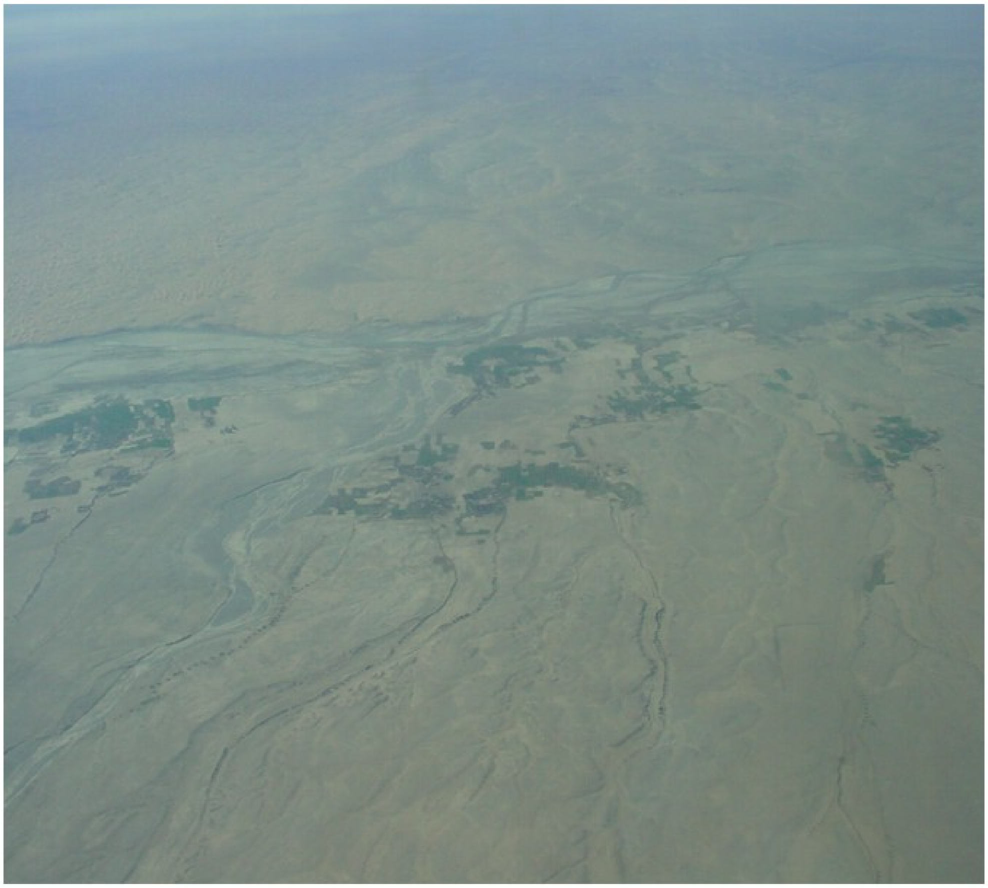


Photo 6: Aerial view of a Karez system and irrigated fields

Photo 7: Hand dug open well

Photo 8: Outlet of a Karez system

Photo 9: Outlet of a Karez system