Norwegian Church Aid - Afghanistan Program (NCAAP)

Policy Document

Guidelines for Sustainable Use of Groundwater in Afghanistan

- **Case Studies**
- **Overview of Water Resources**
- **Suggestions for Groundwater Management**

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"May Kabul be without gold, but not without snow"
Traditional Afghan proverb.

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Summary

Traditionally, Afghanistan has relied on surface water and groundwater springs and karezes for agricultural irrigation. During recent drought years, the use of deeper groundwater, abstracted via pumped dug wells and boreholes has increased rapidly. Private farmers have drilled many of these new wells and boreholes, but NGOs have also been involved in this activity. In Afghanistan's regulatory vacuum, there is concern that, in some areas, groundwater abstraction rates are already exceeding, or will soon exceed, sustainable groundwater resources.

While the increasing use of pumped wells for irrigation is likely to be an unstoppable process, leading almost inevitably to some degree of overabstraction in some areas, this document is intended to act as a guideline for sustainable groundwater usage. It is hoped that, by adhering to these guidelines, Norwegian Church Aid's partner NGOs can avoid contributing to the overabstraction of Afghanistan's groundwater resources.

It is recognised that these guidelines are based on a rather flimsy and poorly quantified understanding of Afghan hydrogeology. It is also likely that such guidelines will be regarded as rather conservative by many. However, in the absence of any functioning authority regulating or studying groundwater resources in Afghanistan, even some very general guidelines are regarded as better than none at all. The main guidelines offered to prevent overabstraction of the lowland Quaternary and Neogene sedimentary aquifers of Afghanistan, and the derogation of existing groundwater sources are as follows:

(1) The use of groundwater, abstracted by a bucket or handpump, for drinking water purposes has little significance in terms of aquifer water balances. NGOs can promote this activity with a clear conscience.
(2) There should be a presumption against the use of motor-pumped or artesian groundwater for irrigation purposes by NGOs, until a proper management framework exists to license abstractions.
(3) If use of motor-pumped or artesian groundwater for irrigation is absolutely necessary to prevent unacceptable poverty or displacement of populations from their homes, the following guidelines should be observed.
(4) Usage of motor-pumped or artesian groundwater for irrigation should only be temporary, during a drought period. The recipient community should revert to traditional sources (surface waters, karezes, springs) following the drought. This may be achieved by:
    - NGOs promoting awareness of groundwater management issues within the recipient community. Groundwater is a resource that can be used to survive a drought, but it should be allowed to recover afterwards.
    - NGOs signing a contract with the community that usage of pumped groundwater will cease when the drought breaks
    - if the above are not effective, the NGO should consider providing diesel pumps and other equipment as temporary loans, rather than as permanent donations.
(5) All artesian wells must be fitted with a control valve and usage strictly regulated, by agreement with community according to points (3 and 4) above.
(6) Where NGOs plan to use motor-pumped or artesian groundwater for irrigation, a simple risk assessment should be carried out (Appendix 6). This will include:
    - identification of all wells, springs and karezes within 1 km of the proposed well

- assessment of the existing density of abstraction (l/s/km^2) within a 3 km radius (28 km^2) of the proposed well

(7) The proposed irrigation well should not be within 500 m of existing wells, springs or karezes in order to avoid derogation of sources. It should be remembered that wells may be constructed in an area free from existing wells and karezes and the water piped or channelled to the fields or village where it is to be used.

(8) The irrigation well can only be constructed within 500 m of such sources **if**:

- the owners of the wells, springs or karezes are the same community that will benefit from the irrigation water, and have **all** agreed that derogation is acceptable, or
- the owners of wells, springs or karezes have been offered and accepted compensation for derogation in terms of well deepening or provision of alternative water sources, or
- a cogent hydrogeological argument is forwarded, and accepted by NCA, that local hydrogeological conditions will prevent derogation of nearby sources.

(9) New motor-pumped or artesian wells for irrigation should not be constructed if the long term net abstraction density within a 3 km radius of the new well will exceed 1 l/s/km^2, taking into account the abstraction from the new well (i.e. total abstraction within that 3 km radius should not exceed a long term average of 28 l/s). This permissible abstraction density may be lower in desert areas (far from recharge areas) and may possibly be higher near mountain recharge areas and in the immediate proximity of rivers.

It is also noted that use of groundwater for irrigation over a prolonged period *may* carry a risk of soil and groundwater salinisation. As a general rule, groundwater used for irrigation in Afghanistan should have a salinity in class C2 or lower (EC < 750 µS/cm), and an SAR in class S2 or lower (see Appendix 7), *unless* drainage can be shown to be adequate to prevent accumulation of salts in the soil. Groundwater sampled from some sources in Wardak, Ghazni, Zabul, Herat, Badghis and, especially, Kandahar has the potential to cause soil salinisation with prolonged use if drainage is inadequate. Groundwater samples from Dand / Kandahar also contain high boron and residual sodium carbonate, implying some potential to cause soil alkalinisation with prolonged use.

Background

NCAAP is involved in the financing of Water and Sanitation (WatSan)-related projects in Afghanistan, implemented by its partner agencies. The following are the major three implementing partners in this field (although there are other partners):

- Afghan Development Association (ADA): afgdevas@brain.net.pk
- Association for Reconstruction and Energy Conservation in Afghanistan (AREA): area@pes.comsats.net.pk
- Co-operation for Afghan Refugees (CoAR).

The three organisations are involved in using groundwater wells and boreholes to supply drinking and irrigation water to needy communities, but are also aware that any development needs to be sustainable. They are concerned that groundwater abstractions installed during the current drought period should neither

- derogate existing traditional abstractions, nor
- result in long-term aquifer overabstraction

This policy document is intended to address these concerns and provide guidelines as to how groundwater may be utilised to alleviate suffering during a limited period of drought without resulting in damage to aquifer hydrology or traditional patterns of abstraction.

In the apparent almost total absence of hydrogeological data (reports are lost or sequestered by the Ministry of Mines and Industry; the observation well network was destroyed during the war) and of assessments of aquifer water balances, it is very difficult to say for certain whether overabstraction is a genuine concern. Recent, field evidence suggests that it may be a concern in some areas, and NGOs are thus obliged to err on the side of caution when considering groundwater-based irrigation schemes.

In An Ideal World.....

Despite these concerns over groundwater usage, it should be remembered that Afghanistan possesses huge reserves of stored groundwater. Surface waters (rivers etc.) typically respond very quickly to rainfall (filling quickly during rain or snowmelt, and emptying during drought), while groundwater responds much more slowly. It is available in drought periods for much longer than surface water, but takes correspondingly longer to "recover" after the drought breaks. Thus, the use of groundwater for drinking water and irrigation is an *entirely correct* response to a drought situation, when surface water is in short supply, *provided* that any groundwater deficit is allowed to recover following the drought. In an ideal world, Afghanistan would rely largely on surface water during normal years and increasingly on groundwater during drought years.

The concern at present is that there is, in Afghanistan, no system for water management or for licensing groundwater abstractions. In this regulatory vacuum, private landlords and, in some cases, NGOs, in response to drought, are sinking large numbers of irrigation wells and boreholes. It is feared that this is not merely a short-term drought response. Interviews with villagers confirm that they intend to keep irrigation wells in operation following the drought, with a view to increasing the area of land under cultivation. This *may* mean that the aquifer will continue to be in deficit in some areas, resulting in progressively declining groundwater levels.

Groundwater Balance – An Introduction

In its simplest form, the water balance of an aquifer can be expressed by the following formula:

$$Q_{in} = Q_{out} + \Delta S/t$$

Where, Q_{in} = water entering the aquifer (rain, snowmelt, leakage from canals, infiltration of irrigation water, infiltration from rivers, leaking sewers and water mains).

Q_{out} = water discharging from the aquifer (wells, springs, karezes, discharge to rivers/canals, evaporation).

$\Delta S/t$ = change in aquifer storage per unit time (i.e. rate of change of water level).

Expressed in plain speech, this equation states that "What goes in, must come out. If not, there will be a change in water level".

For example, in a drought situation, where Q_{in} decreases due to climatic fluctuations, the water level in the aquifer will decrease. As a result, discharges such as springs and karezes will dry up and, eventually, a new equilibrium will be reached, with the water table at a new, lower level.

Overabstraction

Alternatively, if Q_{out} increases, due to increased abstraction from irrigation wells, the water level will also decrease. Again discharges from springs and karezes will then also decline. There may also be a tendency for Q_{in} to increase slightly, due to increased induced leakage from rivers and canals. Usually, a new equilibrium will be reached, with the water table at a lower level than previously, and with reduced discharge from springs and karezes. In cases of severe overabstraction, a new equilibrium may never be reached and water levels will continue to decline. This is termed *groundwater mining*.

Note, thus, that *overabstraction* encompasses two possible scenarios:

(i) abstraction to such a degree that aquifer water levels fall regionally, causing unacceptable reduction in spring flows, karez flows or drying up of features such as dug wells.

(ii) groundwater mining where abstraction absolutely exceeds recharge, causing sustained falls in groundwater level.

Note that (i) is a somewhat subjective concept. Regulatory authorities need to decide how “unacceptable” reductions in spring flows etc. are defined.

Both forms of overabstraction are undesirable. Note, however, that overabstraction only applies to the *long-term* water balance of an aquifer. A short-term period of overabstraction (e.g. in a drought) *may* be acceptable if one is sure that, in the long-term, recovery of an acceptable water balance will be re-attained.

Derogation

Long-term, *regional* declines in groundwater levels may provide evidence of overabstraction. However, *all* wells and boreholes, even those with very modest abstractions, cause a *local* decline *(drawdown)* in groundwater levels around them. This radial pattern of drawdown is called a *cone of depression.* The drawdown of groundwater levels becomes less with increasing distance from the pumping well. The amount of drawdown depends on the rate of pumping of the well (greater abstraction results in greater drawdown) and the hydraulic properties of the aquifer.

For example, an irrigation well may have a cone of depression of radius 400 m (depending on pumping rate and aquifer properties). If a karez or dug well lies within 400 m of the irrigation well it may suffer a decline in water level. As karezes typically only skim the surface of the water table, and dug wells only penetrate a few metres below it, they are very vulnerable to even small changes in the water table. They may thus be dried out or suffer reduced flow, without any regional overabstraction having occurred. This is called derogation.

In regulated societies, significant derogation of another person’s groundwater source is usually deemed unacceptable. It is either legislated against in water resources law or dealt with by Common Law practices. In cases where derogation is deemed to be in the overall public interest, the derogated party is entitled to compensation or to an alternative water supply.

Water Resources in Afghanistan – An Overview

Climate

Afghanistan suffers extremes of climate, with temperatures up to 50°C in the summer and tens of degrees below freezing in winter in some areas. Table 1 lists basic climatic data for several locations in Afghanistan and Figures 1a,b illustrate seasonal fluctuations in precipitation and open water evaporation (effectively potential evaporation). Annual precipitation is reported to vary between <50 mm/a in the southwest to over 1000 mm/a in the north-eastern highlands (SS Shobair, FAO Peshawar, *pers. comm*. 23/6/01).

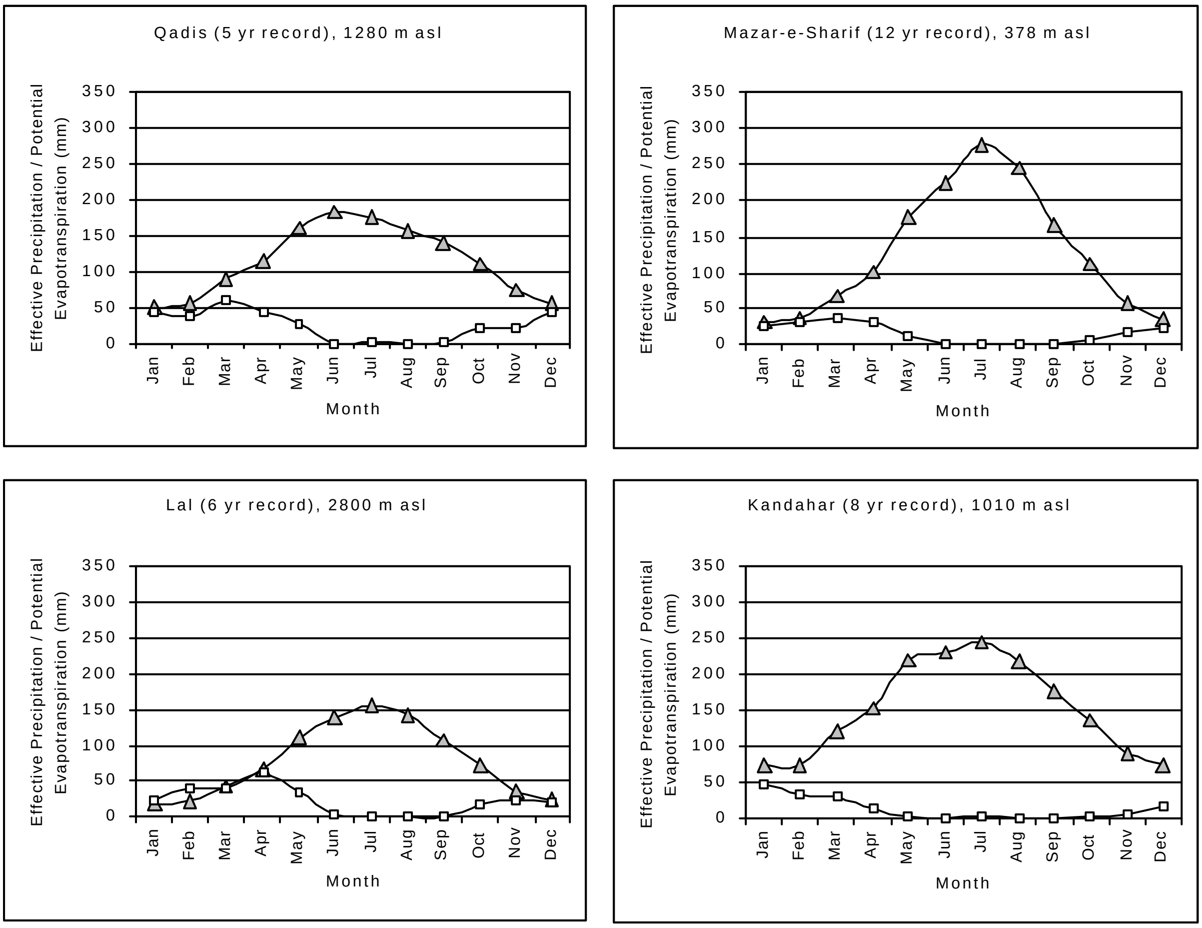


Figure 1a. Seasonal variation of monthly effective precipitation (squares) and potential evapotranspiration (triangles) at Qadis, Mazar-e-Sharif, Lal and Kandahar. After data in Shobair (2001).

Location	**Province**	**Tmax °C**	**Tmin °C**	**R.Hum. %**	**ET_o mm**	**P mm**	**P_{eff} mm**
Qadis	Badghis	30.4 (July)	-2.6 (Jan)	56.1	1372	323	300
Mazar-e-Sharif	Balkh	38.6 (July)	-2.0 (Jan)	57.6	1531	190	181
Lal	Ghor	25.2 (July)	-21.4 (Jan)	77.1	938	282	264
Kandahar	Kandahar	40.4 (July)	0.1 (Jan)	39.4	1812	158	149
Kabul	Kabul	32.2 (July)	-7.4 (Jan)	61.5	1372	303	276
Ghazni	Ghazni	30.8 (July)	-10.7 (Jan)	60.6	1429	292	271
Herat	Herat	36.4 (July)	-2.9 (Jan)	58.3	1732	211	198
Jalalabad	Nangarhar	40.6 (June)	2.6 (Jan)	61.8	1342	171	164

Table 1. Climatic data for selected locations in Afghanistan. T_{max} = mean monthly temperature in month with highest mean temperature, T_{min} = mean monthly temperature in month with lowest mean temperature, R.Hum. = relative humidity (annual mean), ET_o = annual potential evapotranspiration (open water evaporation ??), P = annual precipitation, P_{eff} = annual effective precipitation (it is unclear how this is computed).

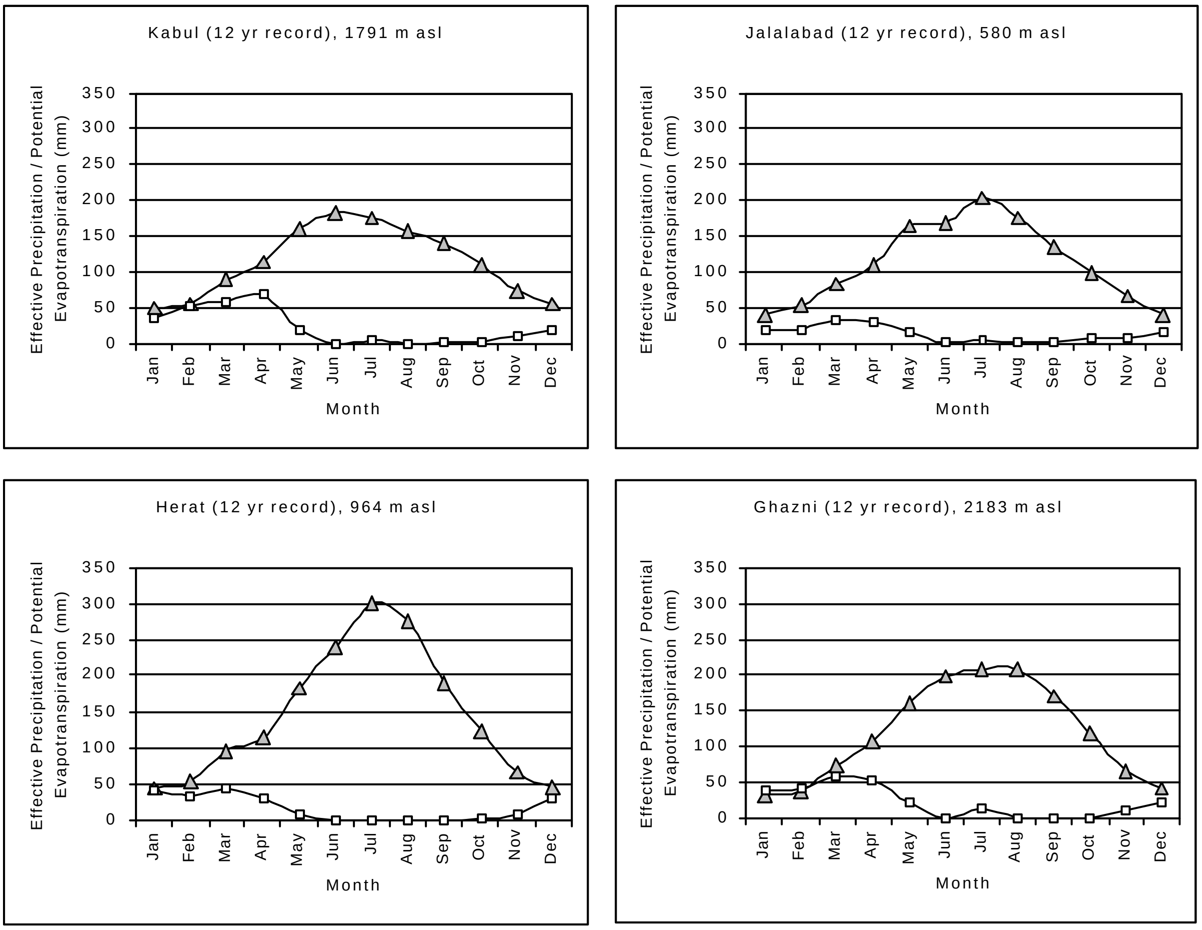


Figure 1b. Seasonal variation of monthly effective precipitation (squares) and potential evapotranspiration (triangles) at Kabul, Jalalabad, Herat, Ghazni. After data in Shobair (2001).

It will be seen everywhere that annual potential evapotranspiration vastly exceeds rainfall at all the stations in Table 1. When considered on a monthly basis, it will be seen that monthly potential evapotranspiration exceeds precipitation for most months of the year (Figures 1a,b). Typically in December-February, potential evapotranspiration and precipitation are similar. Thus, in most of these (lowland) areas, direct recharge of precipitation to groundwater is likely to be extremely low. The most likely period for direct recharge will be around March, where the melting of accumulated snow or frost may temporarily exceed evapotranspiration.

Surface Water

The territory of Afghanistan drains to five main river systems:

(i) the southeastern part of the country drains south to the Indus basin in Pakistan (Kabul, Panjshir, Ghurband, Alishing, Alingar, and Kunar Rivers).

(ii) the north of the country drains to the Amu-Darya River (Kokcha, Amu, Wakhan Rivers), forming the boundary between Afghanistan and the former Soviet Republics of Uzbekistan and Turkmenistan. The Amu-Darya is one of the main rivers draining to the Aral Sea. The progressive and rapid desiccation of the Aral Sea is rightly regarded as an ecological catastrophe, caused in large part by overabstraction and inefficient irrigation of cotton (and other crops) in the former Soviet Republics. Against this background, statements such as the following, expressing a desire to further exploit the Amu River, at the expense of downstream users, should be viewed with considerable concern:

> *"Afghanistan has rich water resources, while Iran, Pakistan and Turkmenistan are using the resources. Building of dams and water diversion systems can turn the tide in the Afghan's favour........(We propose) devising long-term plans covering building of water channels from the Amu River to the south"* (Dr MMM Nedaie, Afghanistan Academy of Science, in *Payem-e-Inkeshaf*, CoAR monthly newsletter, August 2000)
>
> *" The average discharge potential of Afghanistan in general is 55 billion cubic metres in a year. However, it is noted with regret that merely 22 billion cubic metres of the total potential is utilised inside Afghanistan, while the remaining 33 billion cubic metres is poured outside Afghanistan into the territories of Iran, Turkmenistan and Pakistan"* (Engineer Sultan Mahmoud, Head of Hydrology and Water Supply, Ministry of Water and Power, in *Payem-e-Inkeshaf*, CoAR monthly newsletter, August 2000).

(iii) the Helmand River basin drains to the internal basins of Hamun Helmand in western Afghanistan and Hamuni-i-Saberi in eastern Iran, and includes the Arghandab, Tarnak and Ghazni Rivers. The author has little knowledge of the Hamuns, but they are extremely likely to have considerable ecological value.

(iv) The West River basin, including the Harirud, Farahrud, Adreskan and Khash Rivers, also draining towards the Hamuns Saberi and Helmand (and, in the case of the Harirud, north-west towards the Caspian Sea).

(v) The North (Shamal) River Basin, including the Sherin Tagab, Khulm and Sari-Pul Rivers.

Geology

Geological maps and descriptions of Afghanistan are published by the Geological Survey of Germany (Wittekindt 1973, Wittekindt & Weippert 1973). Very simply, the dominant feature of Afghanistan's geology is the existence of ranges of mountains, broadly known as the Hindu-Kush / Kuh-e-Baba ranges of dominantly WSW-ENE trend. These are essentially a continuation of the Himalayan mountain chain, formed in the Tertiary period by the collision of India and Asia. The mountain ridges are dominantly composed of hard (lithified) rocks of pre-Palaeogene age, dominated by metasediments (sandstones, slates, metaconglomerates, limestones, metabreccias, phyllites, slates, schists etc.), with some igneous rocks such as granites. The rocks are faulted, folded and deformed.

The plains surrounding the mountain range and the valleys between the mountain ridges are filled with Neogene and Quaternary (Pleistocene) sediments, which are the products of erosion of the mountains. They comprise alternating layers of pebbles/gravels, sands and silts/clays. They sediments are typically unlithified or partially lithified (although individual hard cemented layers do occur) and not subject to intensive deformation. Adjacent to the mountains, the sediments would be expected to be dominated by coarse deposits such as gravels and pebbles, deposited as the proximal facies of alluvial fans washing down from the mountains. Further away from the mountains, the deposits would be expected to become increasingly dominated by finer sediments such as fine sands/silts (distal facies). Even here, however, layers of coarse material can be found, possibly related to old river channels or glacial melt episodes. The Neogene and Quaternary sediments also contain some volcanogenic deposits such as tuffs and lavas.

Observation suggests that the Neogene sequences contain a generally lower proportion of coarse-grained layers than the Pleistocene, and that they may generally be more compacted / lithified.

Along current river valleys, modern alluvial deposits occur. These can be several tens of metres thick and can be extremely coarse-grained.

Hydrogeology

The geology and climate of the area bear considerable similarities to two other areas studied by the author:

(i) the intermontane trough between the Greater and Lesser Caucasus in Azerbaijan (almost directly geologically analogous to Afghanistan)
(ii) the intermontane trough of the Altiplano, between the Cordilleras Oriental and Occidental of Bolivia.

The following conceptual model of hydrogeology is thus based on:

(a) an assumption of hydrogeological analogy between the above areas and Afghanistan
(b) discussions with local Afghan hydrogeologists (see Appendix 1)
(c) field inspection
(d) the hydrogeological map (Anon 1976)

<u>Groundwater Recharge</u>

Almost all groundwater in Afghanistan will ultimately be recharged by precipitation (rainfall and snowfall). As we have already seen (under "Climate" above), direct recharge of precipitation to lowland areas is likely to be very small, as evapotranspiration greatly exceeds precipitation. The recharge mechanism is likely to be as follows:

(a) pre-Palaeogene bedrocks may be recharged more-or-less directly by infiltration of precipitation at high altitudes where evaporation is less than run-off for many months of the year (and where snow cover may be persistent).
(b) Neogene / Quaternary aquifers are likely to be recharged in foothills by rivers and streams descending from the high mountains and infiltrating into dominantly coarse-grained alluvial fans. The recharge is likely to be highest during snowmelt season. Thus groundwater recharge is highly dependent on quantities of winter snowfall.
(c) further away from the mountains, some recharge to Neogene / Quaternary aquifers is likely to take place by infiltration of water through the bed of perennial rivers.

(d) in irrigated areas, substantial recharge is likely to occur via leakage from irrigation channels.

In regions where precipitation is via the areally distributed direct infiltration of rainfall, calculations of recharge quantities can be made relatively readily. In this situation, where groundwater recharge occurs only in particular zones (mountain foothills and river valleys) and then flows laterally throughout the aquifer complex, estimates of recharge are almost impossible in the absence of detailed river flow profiles etc.

One may attempt to estimate an areally distributed figure for recharge (amount of recharge in foothills divided by area of aquifer fed by such recharge) by examining the response of the aquifer to recharge or drought episodes.

Various agencies have anecdotally reported the following declines in water table level during the drought period:

- In Dand (Kandahar) a decline of c. 6 m in 4 yrs. (1.5 m/yr.), and in Zabul a decline of 2 m in 4 years (0.5 m/year) – *Engineer Hassan, ADA, Kandahar*
- In DACAAR's eastern region 18% of DACAAR's wells (mostly dug wells to 1 or 1.5 m below water table) have dried out over the last 1.5 yrs. This implies a fall of c. 1 m/yr. In Kabul 85% of DACAAR's wells have run dry. Many of these wells (c. 2000 in all) have been deepened by 2-3 m (Thomas Thomsen, DACAAR, Peshawar, *pers. comm.*).
- In the Kabul region, the water table has fallen by 4-6 m in 2 yrs, and in some areas by up to 10 m (AB Afzali, DACAAR, Kabul, *pers. comm.*)
- During the drought (3 yrs. ?), the water table has dropped by 4-5 m in Kabul city, 5-8 m in Kandahar and 2-4 m in Herat (Eng. Ehsanallah, NPO, Kabul, *pers. comm.*).

Given that the largest declines are probably due to the effects of abstraction superimposed upon climatic trends, it seems likely that the climatically-related rate of decline of water table in the Neogene / Quaternary lowland aquifer complexes is in the range 0.5 to 1.5 m/yr. Both seasonal fluctuations and rates of climatic recession are likely to be highest in interfluve areas and lowest in valley areas. If we assume that a decline of 0.5 to 1.5 m/yr. corresponds to one year's deficit of recharge, and if we assume a specific yield (drainable porosity) of some 10% for these rather poorly sorted sediments, this implies a normal areally distributed recharge in the range 50-150 mm/a.

The above is a theoretically rather flawed estimation, and the concept of areally distributing a quasi-linear recharge (in the mountain foothills) is even more dubious, and should be treated with a large pinch of salt.

However, figures of 50-150 mm/a correspond to a maximum renewable resource of 1.6 to 4.8 litres per second per square kilometre in lowland Neogene / Quaternary sediments.

In higher altitude mountain valleys, the rate of recharge would be expected to be higher, due to large areas of mountain slope run-off recharging to valley aquifers of areally limited extent.

Local hydrogeologists (Appendix 1) have estimated the annual areally distributed recharge to Quaternary / Neogene sediments in the Kabul area to be of the order of 250 mm/a. Admittedly, this is in a mountainous area, but the quantity seems intuitively to be very high, given that this figure is higher than typical groundwater recharge over much of Western Europe.

Hydraulic Properties

The pre-Palaeogene bedrocks of the mountain ranges will typically be of rather low permeability. One would expect boreholes drilled in them to yield less than 1-2 l/s. In certain cases, where a borehole strikes an especially permeable fault zone, or a lithology such as limestone / marble, yields would be expected to be significantly greater. Also, where bedrock underlies a Neogene/Quaternary sediment sequence, boreholes completed in the fractured and weathered bedrock surface are reported to yield 5-8 l/s in the Kabul area (Eng. Ameen, AREA, *pers. comm.*).

Quaternary alluvial sediments in the Kabul area (Q_{II}-Q_{IV}), comprising conglomerates, pebbles and gravels are reported have borehole yields of 10-12 l/s. Similar boreholes in the typically finer grained Neogene sediments (siltstones, argillites, some coarser strata) are reported to typically yield 5 /l/s (Eng. Ameen, AREA, *pers. comm.*).

Typical aquifer horizons (alluvial or proluvial sand, gravel and pebbles) are reported, in the Kabul area, to have a typical hydraulic conductivity of 30-60 m/d. This will be reduced if the strata are poorly sorted and have a high content of fines. Sediments will typically be coarser and more permeable nearer mountains, and finer and less permeable at a distance from the mountains.

Groundwater Flow

In undisturbed conditions, the lateral component of groundwater flow would be expected to be from groundwater recharge areas in the foothills of mountain ranges towards discharge areas in the mid- to lower reaches of river valleys or towards desert areas far from the mountains, where water may be discharged via evaporation.

The vertical groundwater flow component would be expected to be downward in groundwater recharge areas in mountain foothills and upward in discharge areas (mid- to lower reaches of river valleys and desert areas).

In mountain foothills, the high topography and permeable nature of the deposits would result in the water table generally being rather deep below ground surface. Further out into the lowlands, the water table might be expected to become shallower.

In recharge areas in mountain foothills, the aquifer deposits would be generally expected to be coarse grained, with relatively high hydraulic conductivity throughout the sequence. Away from the mountain areas, the proportion of fine-grained layers would be expected to increase. Such fine-grained layers may form aquitards, impeding the free upward discharge of groundwater. Artesian heads (i.e. overflowing wells at ground surface) might thus be expected to develop (and are, indeed, observed in regions such as Guzara in Herat province).

Hydrogeochemistry

General Considerations

According to the published hydrogeological map (Anon 1976), the majority of the territory of Afghanistan, especially around the mountainous central massif, is underlain by fresh groundwater of total mineralisation <1000 mg/l, with a hydrochemical composition typically of calcium-magnesium bicarbonate, sodium-calcium bicarbonate or calcium-sulphate-bicarbonate type.

In the low-lying desert areas away from the mountains, there is some tendency to salinisation with mineralisation of >1000 mg/l and up to around 3000 mg/l recorded. This is especially the case in three areas:

- The deserts in the south west of the country: southern Kandahar, Helmand and Nimroz.
- The deserts in the extreme west of the country: western Farah and Herat
- The lowlands in the north of the country, around and to the north of Mazar-e-Sharif.

Salinisation results in a trend to a more sodium-sulphate-chloride-dominated hydrochemistry of groundwater. Even in areas of saline groundwater, fresh pockets or zones of groundwater are reported to occur in valleys of rivers, creeks and ravines.

Salty groundwater is characteristic of areas where the water table is close to the surface. Often, the tendency to salinisation is especially strong in the upper zone of the aquifer, where evapotranspiration may enhance salinity or where recirculated irrigation water recharge accumulates. By casing out the upper section of a borehole, fresh groundwater can be abstracted (at least in the short term) from below any saline horizons.

Water quality is obviously important for the suitability of water for human consumption. In particular, nitrate has shown itself to be an issue of concern where shallow wells have been installed in villages or cities with a high density of latrines. Nitrate is tolerated by most adults without toxic effects. However, concentrations > 50 mg/l may give rise to the potentially fatal condition of methaemoglobinaemia (*blue baby syndrome*) in small infants, if nitrate-rich is used for preparation of milk substitutes or drinks. Nitrate in groundwater may also be up-concentrated due to evapotranspiration in arid climates. High nitrate concentrations may also be good indicators of bacterial contamination.

Water quality is also important for assessing its suitability for agricultural irrigation. In this regard, two parameters are especially important:

- total dissolved solids or salinity (TDS), of which electrical conductivity (EC) is a good indicator.
- sodium absorption ratio (SAR) = $Na^+/((Ca^{++}+Mg^{++})/2)^{0.5}$, where concentrations are in meq/l.

Two other parameters are also of importance:

- concentrations of boron or other elements that may be toxic to plants;
- under some conditions, the bicarbonate excess (in meq/l) relative to concentrations of calcium plus magnesium.

Appendix 7 provides details of the suitability of water quality for agriculture. The SAR and salinity that an irrigated soil can tolerate depends on how well-drained the soil is. In this context, a poorly draining soil can be:

- one where all or most applied water is evapotranspired by plants, such that salts are not leached out of the soil, but accumulate in the root zone (this is likely to be the case in many situations in Afghanistan)
- one which is underlain by low permeability subsoil.

Salinity

- Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. EC < 250 µS/cm
- Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops of moderate salt tolerance can be irrigated with C2 water without special practices. EC > 250 µS/cm, but EC < 750 µS/cm
- High-salinity water (C3) cannot be used on soils of restricted drainage. EC > 750 µS/cm, but EC < 2250 µS/cm
- Very high salinity water (C4) is not suitable for irrigation water under ordinary circumstances. It can be used only on crops that are very tolerant of salt and then only if special practices are followed, including the provision for a high degree of leaching. EC > 2250 µS/cm.

Sodium Absorption Ratio

Waters are divided into four classes on the basis of SAR. The boundaries between the four classes depend on the salinity of the water. Figures for SAR here are cited on the basis of a water with EC = 750 µS/cm. A diagram showing the SAR class boundaries is given in Appendix 7.

- Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of developing harmful levels of exchangeable sodium. SAR < 6 for EC = 750 µS/cm.
- Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils, especially poorly leached soils. Such water may be used safely on coarse-textured or organic soils having good permeability. 6 < SAR < 12 for EC = 750 µS/cm.
- High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage and leaching and addition of organic matter. 12 < SAR < 18 for EC = 750 µS/cm.
- Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil. SAR > 18 for EC = 750 µS/cm.

Driscoll (1986) gives slightly differing advice:

- low SAR 2 to 10: can be used with little danger on all soils. Sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.
- medium SAR 10 to 18: hazardous for use on fine-textured soils that have high cation exchange capacity. May be used on coarse-textured or organic soils with good permeability.
- high SAR 18 to 26: may be harmful to most soils. Requires special soil management, good drainage, high leaching and addition of organic matter. Chemical amendments may be necessary for gypsiferous soils.
- very high SAR over 26: generally not satisfactory for irrigation purposes, except at low salinity (100 to 250 µS/cm at 25^{o}C) and where calcium from the soil or use of gypsum or other mineral additions may make these waters useable.

Boron

Boron is essential to normal plant growth, but the quantity required is very small, and large quantities are harmful. Crops vary greatly in their boron tolerance, but, in general, crops ordinarily grown in Kansas are not adversely affected by boron concentrations of less than 1 ppm (1 mg/l).

Salinisation of Groundwater

If saline groundwater is used for irrigation in arid climates, there may be a risk of groundwater, as well as soil, salinisation. Irrigation water is strongly evaporated and transpired when applied to agricultural land. Dissolved salts are concentrated in the portion of water which is not lost to evapotranspiration, but which may infiltrate the ground and seep down to the water table. This increases groundwater salinity. The same groundwater may then be abstracted and reapplied for agriculture. This "recycling" of groundwater for irrigation may thus result in a progressive increase in soil and groundwater salinity. This is a further argument for preferring surface water (which is generally less saline than groundwater) over groundwater for long-term irrigation purposes.

Analytical Data

During August 2000, Oddmund Soldal (2000) measured electrical conductivity (EC) in selected wells. In Wardak and Ghazni he found the salinity of groundwater to be rather low. EC varied from c. 300 - 600 μS/cm in karezes, with up to 700 μS/cm in groundwater from wells in the lowland area. Measurements made in the Kandahar area are reproduced in Table 2, and here groundwater was found to be somewhat more saline.

Well No.	Yield (l/s)	Depth (m)	Electrical conductivity (μS/cm)
?	7	24	2600
18	7	27	3140
17	10	25 ?	1950
Private	10	50	2000

Table 2. Yield and water quality of wells in the Kandahar area (after Soldal, 2000)

During June/July 2001, the current author sampled 15 groundwater sources. Samples were taken in new 100 ml polyethene bottles, rinsed with filtered sample water. Samples were taken with field filtration via a syringe-mounted 0.45 μm Millipore filter. Samples were transported to the laboratory of the Geological Survey of Norway, Trondheim, where they were treated as follows:

- c. 10-20 ml of sample was taken from the flask and analysed by ion chromatography (IC) for six anions: Br^-, Cl^-, F^-, $SO_4^=$, NO_3^- and PO_4^{3-}. Results for nitrite (NO_2^-) are also quoted but are regarded as invalid due to the warm field sample storage conditions and the long interval before analysis. For similar reasons, results for nitrate (NO_3^-) must also be treated with caution, as possible underestimates of real field concentrations. This quantum was also used for determination of pH and t-alkalinity by titration.
- the remaining 80-90 ml of sample was acidified in the flask with ultrapure concentrated HNO_3 and analysed by inductively coupled plasma atomic emission spectroscopy (ICPAES) for around 30 cationic elements, and metals.

Results are presented in Appendix 5. Table 3 summarises the most important water quality parameters, and also estimates total mineralisation (salinity) by summing the major dissolved species presented in the Table (and assuming that 1 meq/l of alkalinity is equivalent to 61 mg/l HCO_3^-).

Sample	pH	t-Alk	Cl^-	NO_3^-	SO_4^{2-}	Si	Mg	Ca	Na	K	B	Tot.Min.
		meq/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
UK DWS			400	50	250		50	250	150	12	2	
Af 1F	6.81	12.10	23.6	31	27.3	19.7	32.1	174	48.0	2.12	0.600	1096
Af 2F	8.04	3.03	3.6	18	9.23	12.4	14.8	36.5	9.85	1.59	0.036	291
Af 3F	7.91	3.82	7.1	10	12.4	8.62	17.9	47.1	11.0	1.56	0.063	349
Af 4F	7.82	3.59	307	**367**	134	9.84	**63.6**	155	**157**	2.95	0.213	1416
Af 5F	8.01	4.11	8.0	11	13.2	9.28	20.0	48.8	13.4	1.32	0.084	375
Af 6F	7.85	5.69	62.6	14	79.0	6.01	45.8	52.6	58.5	3.18	0.362	669
Af 7F	7.90	3.82	217	**75**	**477**	5.40	**75.6**	93.2	**208**	2.40	0.476	1387
Af 8F	7.74	8.24	169	35	**325**	7.37	**89.7**	89.2	**169**	3.08	0.962	1391
Af 9F	8.13	3.63	9.9	12	41.2	6.50	17.4	38.1	32.3	1.62	0.099	381
Af 10F	7.95	2.98	4.2	7	16.5	5.56	15.2	35.0	11.3	0.83	<0.02	278
Af 11F	7.87	10.16	109	3	**275**	8.46	**66.3**	47.9	**234**	9.29	1.050	1375
Af 12F	7.83	10.35	185	2	**379**	8.33	**70.6**	49.6	**319**	6.56	1.400	1653
Af 13F	7.88	6.47	55.7	24	**301**	5.55	38.3	64.6	**165**	3.17	0.400	1053
Af 14F	7.99	3.76	48.3	23	136	7.28	26.9	39.0	87.2	2.93	0.253	600
Af 15F	7.63	10.99	137	**50**	106	12.1	**92.7**	90.3	112	9.12	1.120	1281

Table 3. Main water quality parameters determined from analyses of 15 water samples from Afghanistan (see Appendix 5 for locations). pH and alkalinity are determined in laboratory. Total mineralisation is estimated by summing the concentrations of the major species. Concentrations are compared with United Kingdom drinking water standards (UK DWS), which are very similar to EU standards. Exceedences are highlighted in bold script.

It will be noted from Table 3 that three samples exceed the drinking water standard for nitrate. Of these, two are in urban areas (Nonga village/Nawa/Ghazni, 367 mg/l; Kabul city, 50 mg/l) and the source of nitrate is very likely to be sewage and leachate from latrines. In such cases, nitrate may be an indicator of pathogenic bacterial contamination. The third high nitrate concentration is from an agricultural area (Toora village/Qalat/Zabul, 75 mg/l) where the source may be fertiliser / manure, or simply leaching of soil nitrogen from ploughing activity. Concentrations of nitrate in the hundred mg/l range may be sufficient to result in blue baby syndrome in young infants. High nitrate concentrations, presumably derived from latrines, have also been noted from studies in Siberia, Moldova, Kosova and Botswana (Banks et al. *in press*).

Exceedences of drinking water standards also occur for salinity-related parameters such as magnesium, sulphate and sodium. These are of lesser health-related concern, although magnesium sulphate can have a laxative effect (possibly unhelpful if diarrhoeal illness is endemic) and excessive sodium may have a negative impact on individuals suffering hypertensive disorders.

Table 4 presents concentrations of major ions converted to milli-equivalents per litre and describes the hydrochemical water type. Table 5 estimates electrical conductivity (EC) from cation / anion sum (1 meq/l cations or anions is equivalent to 100 µS/cm conductivity: Appelo & Postma 1996). Sodium absorption ratio (SAR) is calculated, as is residual sodium carbonate alkalinity (see Appendix 7). The waters are classed according to suitability for irrigation by means of EC and SAR (Appendix 7), and the risk of using water for irrigation is assessed according to EC, SAR, boron concentration and residual sodium carbonate alkalinity.

Sample	pH	t-Alk	Cl^-	NO_3^-	SO_4^{2-}	Mg	Ca	Na	K	Sum anions	Sum cations	IBE	Type
		meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	%	
Af 1F	6.81	12.10	0.67	0.49	0.57	2.64	8.68	2.09	0.05	13.83	13.47	-1.33	Ca-HCO3
Af 2F	8.04	3.03	0.10	0.29	0.19	1.22	1.82	0.43	0.04	3.61	3.51	-1.46	Ca-HCO3
Af 3F	7.91	3.82	0.20	0.16	0.26	1.47	2.35	0.48	0.04	4.44	4.34	-1.15	Ca-HCO3
Af 4F	7.82	3.59	8.66	5.92	2.79	5.23	7.73	6.83	0.08	20.96	19.87	-2.67	Ca-Na-Cl
Af 5F	8.01	4.11	0.23	0.17	0.27	1.65	2.44	0.58	0.03	4.78	4.70	-0.88	Ca-HCO3
Af 6F	7.85	5.69	1.77	0.22	1.64	3.77	2.62	2.54	0.08	9.32	9.02	-1.66	Mg-HCO3
Af 7F	7.90	3.82	6.12	1.21	9.93	6.22	4.65	9.05	0.06	21.08	19.98	-2.69	Na-SO4
Af 8F	7.74	8.24	4.77	0.56	6.77	7.38	4.45	7.35	0.08	20.33	19.26	-2.71	Na-Mg-HCO3-SO4
Af 9F	8.13	3.63	0.28	0.20	0.86	1.43	1.90	1.40	0.04	4.97	4.78	-1.95	Ca-(Mg,Na)-HCO3
Af 10F	7.95	2.98	0.12	0.11	0.34	1.25	1.75	0.49	0.02	3.56	3.51	-0.71	Ca-HCO3
Af 11F	7.87	10.16	3.07	0.05	5.73	5.45	2.39	10.18	0.24	19.02	18.26	-2.03	Na-HCO3
Af 12F	7.83	10.35	5.22	0.04	7.89	5.81	2.48	13.88	0.17	23.49	22.33	-2.54	Na-HCO3
Af 13F	7.88	6.47	1.57	0.39	6.27	3.15	3.22	7.18	0.08	14.70	13.63	-3.76	Na-HCO3-SO4
Af 14F	7.99	3.76	1.36	0.37	2.83	2.21	1.95	3.79	0.07	8.33	8.03	-1.84	Na-HCO3
Af 15F	7.63	10.99	3.86	0.81	2.21	7.63	4.51	4.87	0.23	17.87	17.24	-1.79	Mg-HCO3

Table 4. Major ions, converted to meq/l, from analyses of 15 water samples from Afghanistan (see Appendix 5 for locations). IBE = ion balance error in %.

In Table 4, ion balance errors are all < $\pm$ 5%, indicating the quality of analyses to be extremely good. Water type is variable, but is dominated by calcium bicarbonate in the least saline samples. The soluble cations sodium and magnesium become increasing dominant with increasing salinity. In the more saline samples, sulphate and bicarbonate (rather than chloride) tend to be the dominating anions (which is not untypical for inland semi-arid areas, Parnachev et al. 1999).

Sample	EC	SAR	B	Res NaCO3	Class	Risk	Location	Type	Land use
	uS/cm		mg/l	meq/l					
Af 1F	**1365**	0.79	0.60	0.78	C3-S1	Mod.	CoAR compound/Sayyidabad/Wardak	Dug well	Rural/(urban)
Af 2F	356	0.29	0.04	-0.01	C2-S1	Low	Hoji-Aziz village/Sayyidabad/Wardak	Karez	Rural
Af 3F	439	0.29	0.06	0.00	C2-S1	Low	CoAR compound, Moqur/Moqur/Ghazni	Dug well + bore	Urban
Af 4F	**2042**	2.26	0.21	-9.37	C3-S1	Mod.	Nonga village/Nawa/Ghazni	Dug well	Urban
Af 5F	474	0.34	0.08	0.03	C2-S1	Low	Nr. CoAR compound, Moqur/Moqur/Ghazni	Dug well	Urban
Af 6F	**917**	1.13	0.36	-0.70	C3-S1	Mod.	Shahdo/Qalat/Zabul	Dug well + bore	Agricultural
Af 7F	**2053**	3.10	0.48	-7.05	C3-S1	Mod.	Toora/Qalat/Zabul	Dug well	Agricultural
Af 8F	**1980**	2.37	0.96	-3.59	C3-S1	Mod.	Korkaron/Qalat/Zabul	Dug well	Agricultural
Af 9F	487	0.91	0.10	0.30	C2-S1	Low	Sadukhan/Shinkai/Zabul	Karez	Rural
Af 10F	353	0.34	<0.02	-0.01	C2-S1	Low	Ghogi reservoir, Suhi/Shinkai/Zabul	Spring	Rural
Af 11F	**1864**	3.95	**1.05**	**2.32**	C3-S1	High	Well 2, Mashoor/Dand/Kandahar	Dug well + bore	Agric./ (urban)
Af 12F	**2291**	5.23	**1.40**	**2.06**	C4-S2	High	Well 1, Mashoor/Dand/Kandahar	Dug well + bore	Agricultural
Af 13F	**1416**	3.29	0.40	0.10	C3-S1	Mod.	Karez Bibi village/Kushk-e-Kohna/Badghis	Spring	Urban/(rural)
Af 14F	**818**	2.12	0.25	-0.39	C3-S1	Mod.	Mazrah/Guzara/Herat	Bore (artesian)	Agricultural
Af 15F	**1755**	1.55	**1.12**	-1.15	C3-S1	Mod.	German Club Street/Kabul City	Dug well	Urban

Table 5. Classification of 15 groundwater samples from Afghanistan (see Appendix 5) according to suitability for agriculture. EC = electrical conductivity based on Appelo & Postma's (1996) relation (1 meq/l cations or anions = 100 µS/cm EC). SAR = sodium absorption ratio, Res. $NaCO_3$ = residual sodium carbonate (alkalinity - (Ca+Mg) in meq/l). For classification (C2-S1 etc.) see Appendix 7.

From Table 5, it will be seen that a substantial proportion of sampled waters have a conductivity > 750 µS/cm, placing them in class C3 or C4, rendering them of dubious quality for agricultural irrigation. SAR is generally acceptable. Especially the wells sampled in Dand region are of poor suitability for agricultural irrigation in the long term (high conductivity / salinity, high boron concentrations and a high residual sodium carbonate concentration). The combination of poor water quality and probable overabstraction in Dand region, suggests that use of groundwater for agricultural irrigation in the long term should be strongly discouraged, with a reversion to surface water following the drought. The elevated salinity and boron in the Kabul well (Af 15) may be related to leaking latrines / sewage.

Summary

As a general rule, groundwater used for irrigation in Afghanistan should have a salinity in class C2 or lower (EC < 750 µS/cm), and an SAR in class S2 or lower, *unless* drainage can be shown to be adequate to prevent accumulation of salts in the soil.

From Soldal's (2000) data and data from this study, it will be seen that groundwater sampled from some sources in Wardak, Ghazni, Zabul, Herat, Badghis and, especially, Kandahar has the potential to cause soil salinisation with prolonged use. Groundwater samples from Dand / Kandahar also contain high boron and residual sodium carbonate, implying some potential to cause soil alkalinisation with prolonged use.

Sources of Water

Irrigation in Afghanistan

There are essentially four types of agricultural land in Afghanistan:

- rain-fed agriculture. Typically in upland areas and often on very steep mountain slopes.
- irrigation from surface waters (river-canal systems)
- irrigation from karezes and springs (traditional usage of groundwater)
- lift-irrigation from wells and boreholes. A relatively new method of irrigation, but one which is rapidly expanding.

Relative to the amounts abstracted, the amount of water actually applied to and benefiting the land is relatively small. Some estimates place the efficiency of irrigation as low as 30 % (SS Shobair, FAO, *pers. comm.*). The main reasons for inefficiency are :

- leaking canals
- losses to evaporation
- improper levelling and terracing have irrigated land.

Direct Precipitation

In upland areas, such as the upper valley slopes of Ghor, crops are cultivated on extremely inclined ground. This land is fed only by direct precipitation. As a consequence of the current drought, harvests from such land have been severely affected. Around 80% of land in the Lal area of Ghor is rain-fed. Terracing is not commonly practised.

Surface Water

In both mountain valleys and river valleys in lowland areas, land on and close to the flood plain is irrigated directly from the surface water.

In areas with some topography, water is led off from the river channel upstream of the land to be irrigated by means of a canal or *dewi*, which follows the contours of the topography. Thus, irrigation in such areas can be achieved purely via gravity.

In lowland areas, the use of pumping from the river is becoming increasingly common and NCA's partner organisations have, indeed, assisted communities with the construction of river pumping intakes.

In general, many of the larger streams and rivers in Afghanistan are still flowing, though at a much reduced rate due to the drought. Thus, agriculture is still, to some extent, functioning in river valley areas. The situation may, however, become more critical as the drought progresses. In many river valley flood plains, lift irrigation wells are being sunk to supplement or replace surface water irrigation.

Springs

Springs are locations where the water table intersects the land surface. They are often found in river valleys or in the foothills of mountainous areas. The location of a spring may migrate, depending on the level of the water table. For example, a spring forming the source of a stream in a valley will migrate downstream in periods of low water table and upstream in periods of high water table.

Springs are often utilised by means of gravity flow in pipes or open channels. They may be used for irrigation purposes (as in Ghor) or for drinking water.

In Ghor, springs are often used as drinking water sources. However, they are typically carried from the spring to the point of use in open channels. This allows the possibility of contamination of the water prior to consumption. It would be preferable, in such cases, to enclose the spring in a sealed "spring box" and pipe the water to a reservoir and thence to distribution points in the user community.

In Ghbargi, in Shinkai, a natural spring, some 2 km from the village, has been used for irrigation. Due to low flows caused by the drought, almost the entire flow of the spring is lost via evaporation and leakage from the open channel between the spring and the fields. This situation could be alleviated by a pipeline / reservoir system.

Springs, being fed by a groundwater reservoir, have some resistance to the effects of drought. Like karezes, however (see below), they are essentially in continuity with the water table and will be affected by small drops in the water table, causing decreased flows and /or migration down-gradient. In Ghor, for example, mountainside springs are suffering reduced flows at present.

Karezes

Karezes are, in a sense, artificial underground springs. They are often very old, having been constructed several hundred years ago. They are typically located in proluvial deposits in the foothills or mountain areas, but can be constructed anywhere where the water table is relatively shallow and there is a consistent slope to the terrain.

Traditionally karezes are commenced by digging a well at the upper end of the karez route. This may be up to 20 m deep before the water table is encountered. From this “mother well” an underground karez channel is constructed with a shallow gradient downhill. Wells are dug at 20-30 m intervals along the karez route to allow access during construction. The gradient of the karez is less than that of the topography and, thus, the karez tunnel eventually intersects the ground surface and a flow of groundwater emerges. Karezes may be several kilometres long and have several branches.

Karezes essentially skim water off the top of the water table. This means that, in effect, it is practically impossible to overexploit an aquifer using karezes. On the negative side, they are extremely vulnerable to even relatively small drops in the water table caused by climatic factors or pumping of nearby wells.

Karezes may be used for irrigation and drinking water. Due to declines in water table related to the current drought, flows available for irrigation from karezes have become inadequate in many areas and farming viability is suffering.

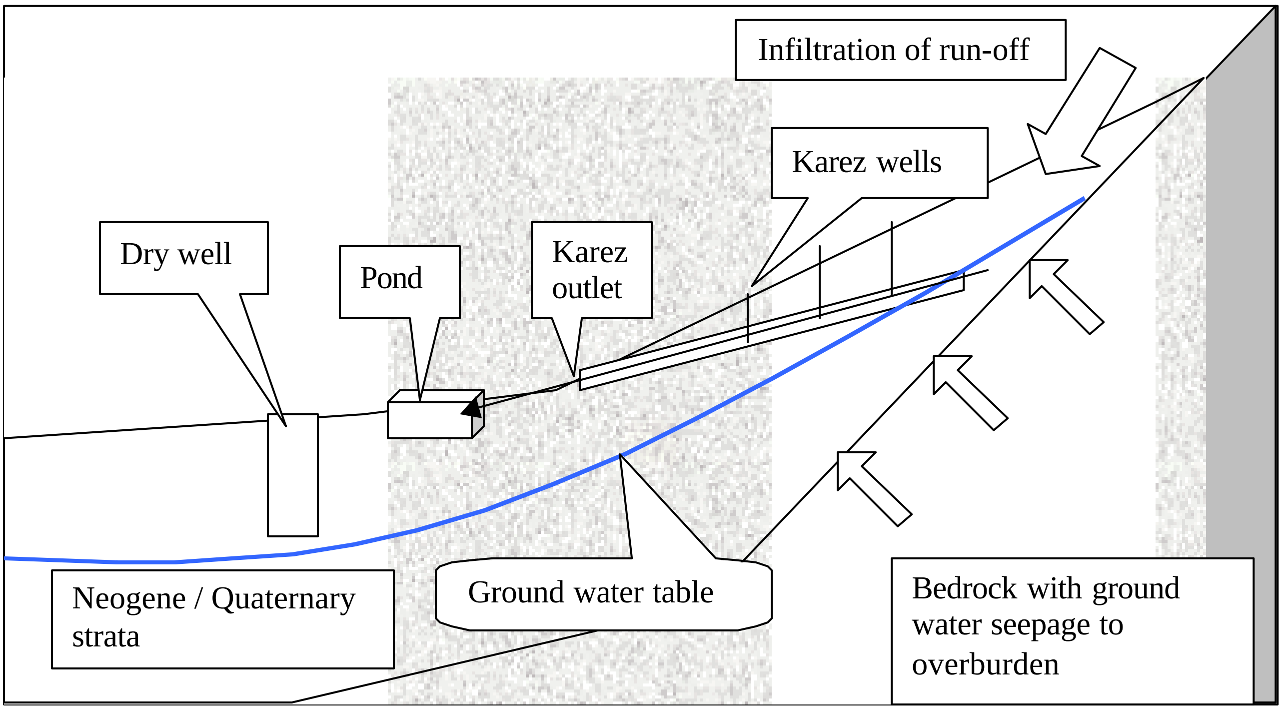


Figure 2. Schematic cross-section of a typical karez (after Soldal 2000).

Karez tunnels are often unsupported, or may have stone roof supports. Due to collapses, karezes require regular cleaning and maintenance. Due to the past 20 years of war in Afghanistan, traditional routines have been disrupted. NGOs have thus focussed on karez rehabilitation and reinstating karez cleaning programs. In most cases, karez cleaning has resulted in increased discharges.

To alleviate karez instability, AREA have started programs in the Herat area to line access shafts with concrete rings and to line tunnels with reinforced concrete ellipses. Masonry is also used to support the intersections of shafts with karezes. Diagrams of such work are found in Appendix 3.

Often, the mouth of a karez may be located over 1 km from the village where the water is used. Typically, an open channel would carry water from the karez to the village or agricultural land, and losses due to seepage or evaporation may be very large. At Karakol and Kurpa village, north of Herat, AREA is constructing filter units and spring boxes at the mouth of the karez, feeding galvanised steel pipe systems to reservoirs and distribution points in the villages.

It should also be noted that, in the portion of the karez that is below the water table, the karez will gain groundwater inflow. In the portion of the karez above the water table, losses will occur. This could be solved by inserting pipe into the karez; slotted pipe in the saturated section to allow water inflow, but plain pipe in the unsaturated section to prevent leakage losses. Lining of karezes with pipe would also reduce the amount of maintenance necessary.

Dug wells

Dug wells may be used either for drinking water (typically fitted with an Afridev-type handpump or a bucket and pulley), or for lift irrigation purposes (typically fitted with a 15-20 Hp diesel suction pump).

Dug wells for drinking water purposes will often be dug at c. 1.5 m diameter and lined either with stonemasonry or with concrete rings. In stable soils they may even be unlined, although, in the author’s opinion, this is undesirable. Depths can reach some 40 m.

Dug wells for drinking water seldom penetrate more than 2 m below the original water table. Thus, they also abstract water from the very top of the aquifer and are vulnerable to climate-related or abstraction-related declines in water table. Wells lined with concrete rings can be deepened by under-digging and then sinking the concrete caisson string. Wells lined with masonry cannot be deepened in this way. Either the masonry must be removed and replaced after deepening, or a narrow diameter borehole must be drilled in the base of the well.

Dug wells for lift irrigation are typically some 4-5 m in diameter and exploited by 15-20 Hp diesel suction pumps, mounted on platforms close to the water table. Occasionally, they are exploited by belt-driven spindle pumps. Lining types may vary and some wells that NCA have funded are completely unlined (undesirable from the point of view of safety and permanence). The best-constructed lift irrigation wells (e.g. ADA’s project in Chaharasiab district of Kabul province) are dug at 5 m diameter and lined with brick masonry down to the water table. Below the water table a caisson structure of lesser diameter (say, 4 m), comprising either concrete rings or brick masonry on top of a single concrete ring, is sunk.

The use of suction pumps for dewatering allows large-diameter lift irrigation wells to be constructed to a maximum of some 6m below the original water table. This modest penetration of the aquifer renders them somewhat susceptible to declines in water table due to drought. Wells fitted with an internal caisson structure may be deepened by digging. Otherwise, lift irrigation wells may be deepened by drilling boreholes in the well base.

The use of diesel suction pumps means that drawdowns in lift irrigation wells are unlikely to exceed 5-6 m. Diesel pumps typically provide flows of some 5 l/s, but the net yield depends on periods of operation. In Chaharasiab, a typical pumping pattern is 4 x 2 hr periods of pumping during the day (net 1.67 l/s on average). In Khansizi and Ser villages of Arghistan, ADA's lift irrigation wells pump at between 12 and 24 hrs/day (net 2.5 – 5 l/s on average). In Mashoor village in Dand, ADA wells typically pump 5-10 hrs per day, but some lift irrigation wells in the area have been known to pump for 10 days non-stop.

Drilled wells (Boreholes)

Boreholes are typically drilled using percussion techniques in Neogene and Quaternary sediments. They may be used for drinking water (fitted with Afridev handpump) or for irrigation.

Boreholes for drinking water are typically drilled at 6-8" diameter and fitted with 4" casing. They are often drilled to 15-20 m below the water table (in fact, 20 m should be a minimum depth below water table) and fitted with an Afridev handpump. Because the borehole penetrates deeper below the water table than a dug well, boreholes are less susceptible to declines in water table. If fitted with a handpump, the amounts of water able to be abstracted are of little significance in terms of the overall aquifer water balance.

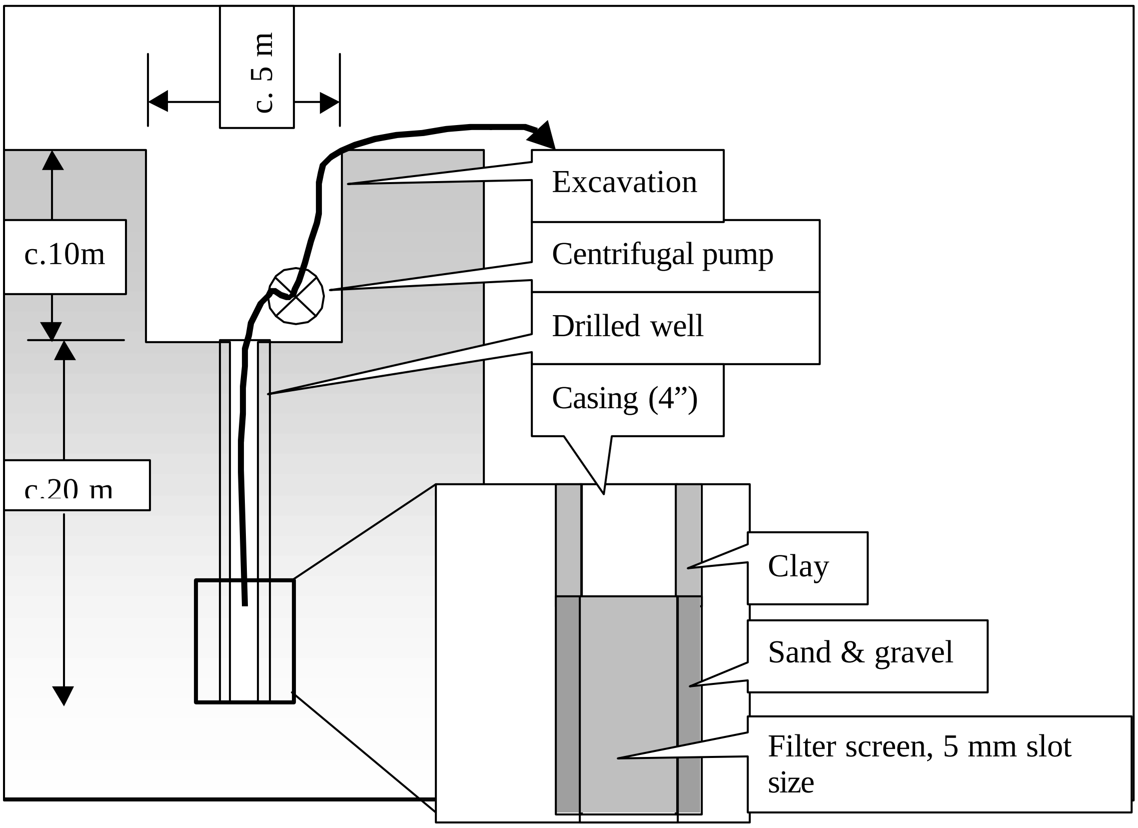


Figure 3. Schematic diagram of a typical dug lift-irrigation well, deepened by use of a borehole (after Soldal 2000).

Boreholes may also be drilled for irrigation purposes and fitted either with a submersible pump or a surface-mounted spindle pump. At AREA's project at Qala-e-Fatoo, south of Kabul, a 61.5 m deep irrigation borehole has been completed with an 18" drilled diameter and 10" casing string. The positive displacement pumps mean that the drawdown and yield are not limited by available suction. Such boreholes can thus achieve very large yields and/or substantial drawdowns.

In some areas, artesian aquifer horizons may exist at depth. In this case, pumps are not required in boreholes, they simply overflow under their own pressure. In Mazrah area of Guzara District (Herat), private irrigation boreholes drilled to 60 – 65 m deep encounter artesian resources of fresh groundwater. Typical yields of some 5 l/s flow uncontrolled 24 hrs/day from these boreholes. Such uncontrolled overflow is extremely undesirable from a water resource point of view.

In Table 6 and Figure 4, it will be seen that, in 1967-68, most land was irrigated either by surface water or by groundwater from karezes or natural springs. Very little land was irrigated by wells and boreholes. This situation is rapidly changing. Lift irrigation is new technology and, although in overall terms it still accounts for a relatively modest share of total irrigated land, its use is growing explosively. This expansion is, ironically, stimulated by the drought and, to some extent, by the activities of NGOs.

Water Management

In theory, responsibility for management of water resources within the Taliban government of Afghanistan is as follows:

- Groundwater Resources: Ministry of Mines and Industry
- Surface Water Resources: Ministry of Water and Power

In practice, however, the ministries lack the resources and technical expertise to adequately manage the resources for which they have responsibility. There appears to be no effective system of permits or licensing drilling or water abstraction in Afghanistan. In this regulatory vacuum, the UN and some NGOs have accepted some responsibility for water resources:

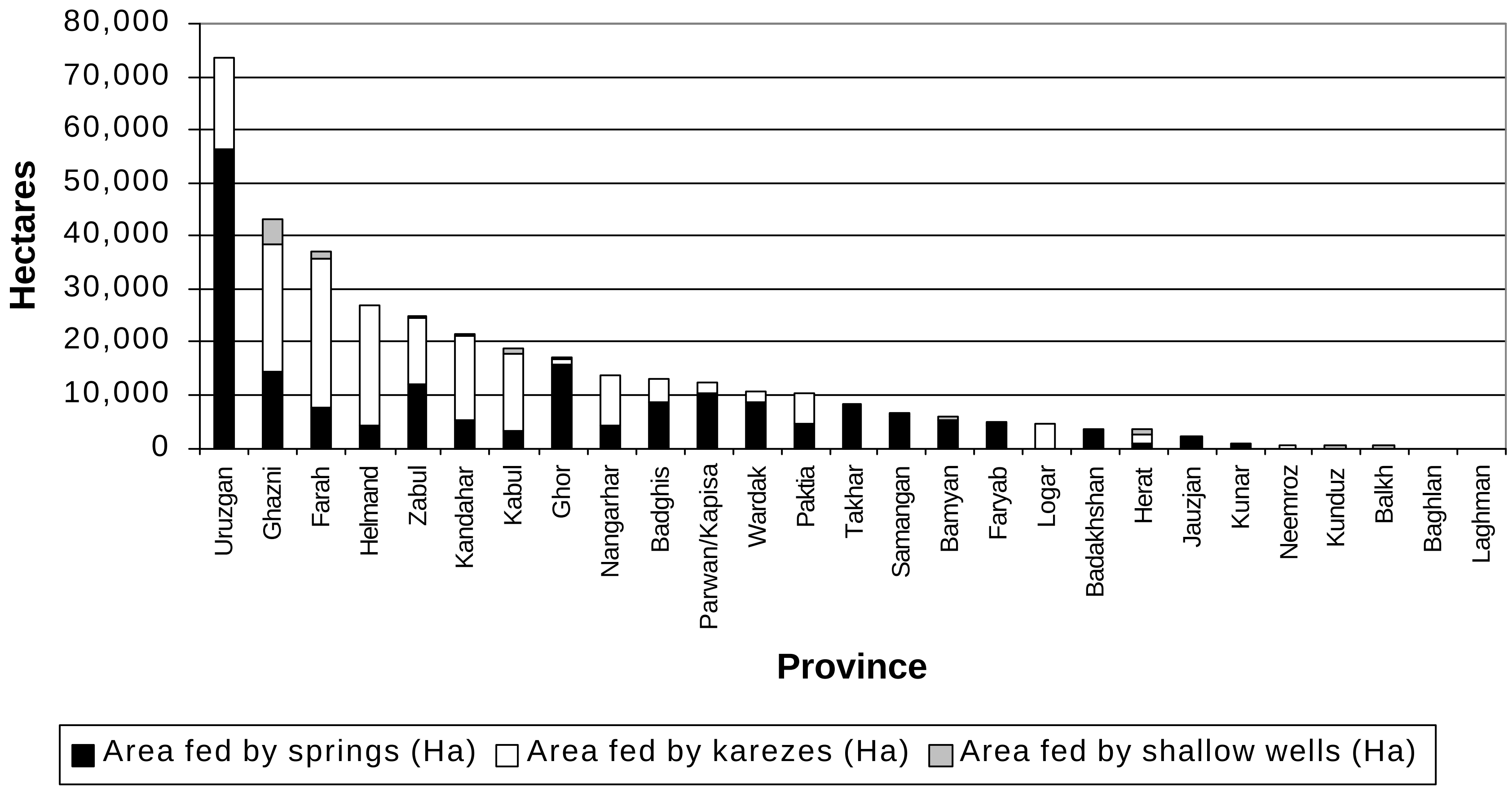
- Urban water supply: Habitat (United Nations Shelter Program)
- Rural water supply: UNICEF, assisted by DACAAR
- IDP camps: these are managed by the Afghan Ministry for Martyrs (!) and Repatriation, with significant input from UNICEF and various NGOs.

These UN and non-governmental agencies are able to some extent to co-ordinate the activities of various actors in the field of water supply. They have not been able, however, to effectively regulate the use of resources.

Table 6. Total number of springs, karezes and shallow wells; area under irrigation from each source; and % of total irrigated land area in each province (ground- and surface water). For each column, bold text marks the top five provinces, italic text the bottom five. After data compiled from the Government of Afghanistan Statistical Yearbook 1980 (data for 1967-68). After Shobair (2000).

Province	**Springs**	**Area (Ha)**	**%**	**Karezes**	**Area (Ha)**	**%**	**Shallow wells**	**Area (Ha)**	**%**	**Total irrigated by ground-water (Ha)**	**% of total**
Uruzgan	**429**	**56,280**	**44.46**	84	**17,550**	13.86	210	80	0.1	**73,910**	**58.4**
Ghazni	**604**	**14,530**	12.37	**1,516**	**23,960**	**20.39**	**636**	**4,680**	**4.0**	**43,170**	**36.7**
Farah	94	7,350	5.85	352	**28,480**	**22.65**	**2,324**	**1,060**	0.8	**36,890**	29.3
Helmand	135	4,320	2.65	276	**22,830**	14.03	60	130	0.1	**27,280**	16.8
Zabul	**756**	**11,990**	19.17	**743**	12,780	**20.43**	148	100	0.2	**24,870**	**39.8**
Kandahar	258	5,310	4.50	**631**	**15,860**	13.45	252	**700**	0.6	21,870	18.5
Kabul	81	3,300	5.73	321	14,760	**25.63**	436	**660**	**1.1**	18,720	32.5
Ghor	**570**	**15,990**	**21.95**	4	710	0.97	263	240	0.3	16,940	23.3
Nangarhar	210	4,360	10.30	495	9,450	**22.32**	15	*10*	*0.0*	13,820	32.6
Badghis	*50*	8,660	**26.01**	30	4,390	13.18	*0*	*0*	*0.0*	13,050	**39.2**
Parwan/Kapisa	165	**10,340**	13.76	83	1,980	2.64	176	50	0.1	12,370	16.5
Wardak	**519**	8,690	**33.95**	336	1,980	7.73	*0*	*0*	*0.0*	10,670	**41.7**
Paktia	392	4,680	8.31	**528**	5,860	10.40	**800**	70	0.1	10,610	18.8
Takhar	288	8,150	13.17	*0*	*0*	*0.00*	**509**	360	0.6	8,510	13.8
Samangan	73	5,840	13.17	7	410	0.92	271	470	**1.1**	6,720	15.2
Bamyan	137	5,350	**23.11**	*0*	*0*	*0.00*	300	540	**2.3**	5,890	25.4
Faryab	79	4,250	3.50	**960**	380	0.31	**867**	270	0.2	4,900	4.0
Logar	169	*170*	0.64	124	4,380	16.44	91	240	**0.9**	4,790	18.0
Badakhshan	82	3,840	6.22	*0*	*0*	*0.00*	54	90	0.1	3,930	6.4
Herat	153	830	0.51	228	1,650	1.01	450	**1,370**	0.8	3,850	2.4
Jauzjan	87	2,060	1.12	2	20	0.01	443	100	0.1	2,180	1.2
Kunar	67	720	3.09	*0*	*0*	*0.00*	*13*	*10*	*0.0*	730	3.1
Nimroz	*2*	*0*	*0.00*	18	320	0.53	140	240	0.4	*560*	*0.9*
Kunduz	*0*	*0*	*0.00*	*0*	*0*	*0.00*	55	540	0.3	*540*	*0.3*
Balkh	92	200	*0.09*	3	*0*	*0.00*	82	50	*0.0*	*250*	*0.1*
Baghlan	*63*	*160*	*0.20*	*0*	*0*	*0.00*	*0*	*0*	*0.0*	*160*	*0.2*
Laghman	*3*	*60*	*0.25*	*0*	*0*	*0.00*	*0*	*0*	*0.0*	*60*	*0.3*
Total	5,558	187,430		6,741	167,750		8,595	12,060		367,240	
Area per unit (Ha)	34			25			1.4				

Figure 4. Hectares land under irrigation from different sources, by Province
(1967-68 data)



Selected Case Studies

Declines in water table level may be due to climatic factors or to abstraction. In the absence of a good observation well network, it can be all but impossible to distinguish between these effects. Indeed, some Afghan hydrogeologists (Engineer Ehsanallah, NPO, 25/6/01, *pers. comm.*) believe that perceived problems of overabstraction may simply be a climatic recession of the water table. Human nature being what it is, those who are affected by the falling water table prefer to have someone to blame, rather than just the weather.

However, several of the following case studies suggest that overabstraction and derogation are probably a genuine concern in some areas of Afghanistan.

Qala-e-Fatoo, c. 10 km south of Kabul, Kabul Province (visited 26/6/01)

Here, agricultural land was previously irrigated by the adjacent Kabul River, which is, to all intents and purposes, dry. AREA have drilled a 61.5 m deep irrigation borehole for watering orchards and vegetables (without water, fruit trees will die, resulting in a loss of capital investment). The rest water level is currently 10.5 m below ground level and the geology comprises pebbles, sands and clays. Besides providing irrigation water, there may be fixed times each day when the local population can collect water for drinking from the borehole. The well will serve some 15 families, who have contributed 20% of the cost of the scheme. Other members of the community, who have not contributed, will have no share in the scheme. Drinking water for the village is typically derived from shallow dug wells that are in the process of drying up.

Query: The well will benefit only a portion of the community, but could have a negative impact on the whole community if drawdown affects water levels in dug drinking water wells. Are those who could afford to pay the 20% share of the project the richer families in the community ? If so, are we benefiting the richer sections at the expense of the poorer ?

Conclusion: Where irrigation schemes are installed, all possible effects on wells, springs and karezes need to be assessed. Irrigation wells should not be installed if they derogate, without compensation, other water sources, especially those accessed by needy sections of the community.

Rahmat Abad Village, Chaharasiab District, Kabul Province (visited 15/7/01)

Here, irrigation water used to be supplied by canals from the Kabul and Logar River systems. ADA have assisted in the construction of at least two dug, 5 m diameter, irrigation wells, serving five families each and c. 4 Ha each. The families prioritised were (a) returning refugees and (b) the poorest families of the community. Wells are pumped for 4 x 2 hour periods per day (8 hrs / day total) at the pump capacity of c. 4-5 l/s. The water table has fallen by 1 m in the last year in both wells, and the wells will be deepened by hand.

The farmers indicate that they will revert to using surface water following the drought, provided that enough is available (pumping costs make use of groundwater an expensive option).

ADA have a policy of not placing lift irrigation wells < 200 m from other wells or karezes, and not placing wells < 30 m from latrines.

In the case of one of the Rahmat Abad wells, a second ADA irrigation well is situated 200 m away (adhering to ADA's internal guideline) from the well, although recently a new private irrigation well was constructed only 150 m away from the well.

In the case of the second Rahmat Abad irrigation well (no. 9), a private irrigation well was also recently constructed only 120 m from the ADA well. ADA believe it is likely that ADA's original lift irrigation wells "advertised" the technology and stimulated the private farmers to construct their own wells.

Irrigation wells in this area (including ADA's) mainly irrigate onions and potatoes for export.

Comment: NGO projects involving groundwater irrigation in needy cases may actually be promoting a potentially unsustainable technology to the private sector. Even though ADA has adhered to its own guidelines regarding well density, there is nothing to stop private individuals subsequently sinking their own wells at unacceptable spacings, resulting in potential derogation and local overabstraction. It is thus likely that groundwater irrigation is, to some extent, an "unstoppable" technology. However responsibly NGOs act, actions of private individuals cannot be controlled.

Suhi Village, Shinkai District, Zabul Province (visited 30/6/01)

At Suhi village, ADA have assisted in the construction of a dug well for irrigation, with total depth 8.5 m. The water table level is at 3.5 m bgl and the drawdown during pumping is some 2.5 m. It is typically pumped on a cycle of 1 hr drawdown followed by 1.5 hrs recovery for a total pumping hourage of 10 hrs/day. The pump discharge is some 2-3 l/s (net average rate = 1.0 l/s). The well irrigates some 100-120 Ha of mixed maize, alfalfa, wheat and orchard.

Pumping is not reported to have any effect on the Ghogi spring area, some 300 m away, but is reported to reduce the flows from another spring some 100 m from the well (the flow recovers following cessation of pumping). The latter spring belongs to the same farmers as use the irrigation wells and thus derogation is not perceived as a problem.

Comments: Documented derogation of a spring on the order of c. 100 m from a typical irrigation well.

Mashoor Area, Dand Province, Kandahar Region (visited 1/7/01)

In this area, just south of Kandahar, irrigation has traditionally been accomplished by use of river water. Before the drought, the water table was only 2 m below ground level (bgl). Two dug irrigation wells (to 9-10 m depth) with boreholes in their base (to a total depth of c. 30m) were sunk with ADA support in the year 2000.

The first well serves some 7 families. The well may pump for 10 days continuously, but tends not to be used so intensively in winter. The water is reported to be slightly salty and may also be reducing (slight smell of H_2S). The nearest other irrigation well is some 5-600 m away. The water table is currently at 9-10 m bgl.

The second well serves 12 families and irrigates some 14 Ha land. The estimated pump discharge is 4-5 l/s, pumping typically 5-10 hrs/day. The water table is now at some 12 m bgl and the pump has recently had to be placed at the very base of the dug well at 9 m bgl.

Drinking water in the village is typically from dug wells some 13-14 m deep which dry up when the irrigation wells are pumping, but which recover when the pumping stops. As these dug wells are owned by the same families operating the irrigation wells, the villagers accept that this is an acceptable price to pay for irrigation water. Families also use the irrigation wells for drinking water.

The families plan to continue to use the wells even after the drought breaks, due to the fact that they perceived the availability of river water as inadequate (available only once every 13-14 days).

In assisting these families to construct irrigation wells, ADA uses the following priorities:

- assisting families with vines and pomegranates (i.e. saving the capital investment that these tree represent)
- assisting recently returned refugees
- assisting the poor/least landed families.

Analyses (Appendix 5, Table 5) have also documented that the water quality from these wells is likely to be unsuitable for long-term irrigation use (risk of salinisation / alkalisation, possibly boron toxicity).

Comment: Derogation of drinking water wells by irrigation wells is documented here, over a distance of tens/hundreds of metres. This can be acceptable provided that the derogated party also receives the benefit of the irrigation well. Provision of irrigation wells is usually not a temporary measure – families will not necessarily revert to traditional irrigation practices once the drought breaks. Assisting of the poorest families in an area is not necessarily the top priority of NGOs. In fact, by assisting families with orchards, they may be assisting the richer families in an area.

Khansizi and Ser Villages, Arghistan District, Kandahar Province (visited 2/7/01)

At Khansizi village, ADA have assisted in the construction of a lift irrigation well, dug to the water table at 4 m bgl, and then with a drilled borehole in the base for another c. 4 m, making a total depth of 8 m. The well benefits 42 families and irrigates some 30 Ha. The well is pumped 12-14 hrs/day at a rate of 4-5 l/s (net abstraction c. 2.5 l/s). Prior to the drought, irrigation water was obtained from the Arghistan River.

Another private irrigation well was situated only 150 m from the Khansizi well, and the owner of this well made a business of selling irrigation water to local farmers. ADA’s well has undermined his business and his well no longer operates.

At the nearby village of Ser, ADA have also assisted in the construction of a lift irrigation well. It comprises a dug well to 6 m, with a drilled borehole in the base to a total depth of 18 m. The well is pumped 12-24 hrs/day. Other private irrigation wells exist in the vicinity and ADA itself have constructed another irrigation well some 470 m away. In the two months since the Ser well was commissioned the water table has sunk 0.5 m. Prior to the drought, irrigation water was obtained from the Arghistan River.

Comment: Should NGOs engage in undercutting the business of private entrepreneurs ? The decline in water table reported at Ser may be related to the high density of irrigation wells in the area resulting in local overabstraction. At Khansizi, the lack of reported water table decline may be related to the fact that the Khansizi well is isolated and not part of a dense well-field.

Shinjan Conflict, Farah Province

In the Shinjan area of Farah Province, ADA report a recent conflict between ADA-funded lift irrigation wells and a village karez. The locality was not visited by the author. The well-field of 19 lift irrigation wells was alleged to have substantially reduced the flow in the village karez. The village karez was situated between 160 and 500 m from the wells. The villagers complained to the "authorities" and all 19 lift irrigation wells were shut down. Eventually, ADA and the villagers were able to reach a compromise and re-open most of the lift irrigation wells (those having the greatest effect on the karez remaining closed).

Comment: Documented instance of derogation of a karez by lift irrigation wells over a distance of hundreds of metres. This appears to be an instance of a negative effect on a general population, with a smaller proportion of the community benefiting from the lift irrigation wells. Some authority obviously does exist to regulate groundwater resources, if villagers are ready to make complaints.

Mazrah Artesian Well-field, Guzara District, Herat Province (visited 6/5/01)

Around Mazrah are a large number of privately-owned artesian boreholes some 60-65 m deep. They overflow, without any means of control, 24 hrs per day, at a rate of up to 5 l/s/borehole. Water is fresh and possibly slightly reducing (indications of high iron concentrations). The wells are used for irrigation purposes.

The spacing between boreholes is as little as 400-500 m, and one farmer estimated that 12 other boreholes existed within a 2 km radius of his own (i.e. 13 wells = 65 l/s in an area of 12.6 km^2, or 5.2 l/s/km^2). All these boreholes were drilled since 2000. Two drilling rigs are currently drilling new boreholes in the same area. Hitherto, there are no obvious problems with declining artesian flow or head, and no shallow wells have suffered a decline in water level.

However, given the calculations proffered under the section on "Groundwater Recharge" above, it seems likely that the aquifer being over-abstracted. One would expect, in the long term, artesian heads and flows to decline to such an extent that pumping becomes necessary. Once pumps are installed, large drawdowns can be achieved and one would thereafter expect an accelerated water level decline. The question of whether the water table in shallow wells would be affected is difficult to answer. If the deep artesian horizon is separated by a very low permeability aquitard from the surface, no effect might be expected. However, if the aquitard is somewhat "leaky", a delayed response may be expected, with shallow wells only being affected after some years.

Prior to drilling these wells, farmers used river water for irrigation. Farmers interviewed stated that they planned to continue to use the artesian water to increase the area of land under cultivation, even after the drought is over.

AREA have suggested that, despite their not having funded any of these boreholes, they might become involved in raising awareness of groundwater management issues amongst farmers; in particular: (a) installing control valves on overflowing boreholes, (b) reverting to surface water usage where possible and only using groundwater where strictly necessary.

Comment: Farmers provided with lift irrigation wells may not revert to irrigation solely by traditional sources once the drought breaks. On the contrary, they may use groundwater to expand the area of land under cultivation (especially in the case of artesian boreholes where there are no pumping costs). Artesian boreholes must be fitted with control valves. NGOs have a role to play in educating farmers in groundwater resource management – uncontrolled exploitation of groundwater resources is not in their collective best interest.

Recommendations for Sustainable Use of Groundwater

Existing Practise

ADA operate a policy of not locating lift irrigation wells within 200 m of other wells or karezes. They also ensure that wells are located 30 m from latrines (Engineer Nasiahmed Beshtas, ADA, Chaharasiab Office, *pers. comm.* 15/7/01).

Empirical Evidence

The case studies presented in the previous section suggest that derogation by lift irrigation wells occurs over a range (radius of influence) of a few hundred metres.

Theoretical Considerations – Derogation

<u>Soviet Formulae</u>

Afghan hydrogeologists (Engineer Ehsanallah, NPO, *pers. comm.*, 25/6/01) utilise the following formulae for calculating the radius of influence (R) of wells. The theoretical basis for the formulae is unclear, but they are believed to derive from the Soviet hydrogeological tradition:

$R = 2.s_w.(K)^{0.5}$ or $R = 10.s_w.(K)^{0.5}$ (it is unclear which geological circumstances pertain to the use of these two rather different formulae).

where
s_w = drawdown in pumping well (m)
K = hydraulic conductivity (m/day)
R = radius of influence of pumping (m).

Given that the hydraulic conductivities of alluvial and proluvial strata are believed to be in the range 30 – 60 m/d (Engineer Ehsanallah, NPO, *pers. comm.*, 25/6/01) and, given that the maximum achievable drawdown with a diesel suction pump is some 6 m, we can construct the following matrix of calculations:

Variant of formula	Hydraulic conductivity (K)	
	K = 30 m/d	K = 60 m/d
$R = 2.s_w.(K)^{0.5}$	66 m	93 m
$R = 10.s_w.(K)^{0.5}$	329 m	465 m

Table 7. Radii of influence of lift irrigation wells, with assumed drawdowns of 6 m, using Soviet formulae in common use in Afghanistan.

Thus, with worst case assumptions, the radius of influence of a lift irrigation well could be as large as almost 500 m.

Theis Equation

The Theis equation calculates the drawdown (s) at radius (r) from a pumping well at time (t) after pumping commenced. The pumping rate is Q, the aquifer transitivity is T and the storage (specific yield) is S.

$s = Q.W(u)/(4\pi T)$

where $u = r^2S/4Tt$

and $W(u) = -0.577216 - \ln(u) + u - u^2/(2.2!) + u^3/(3.3!) - u^4/(4.4!)$...........

For the purposes of calculation, we will assume that

- Q = 5 l/s (0.005 m^3/s)
- hydraulic conductivity = 30-60 m/d
- effective aquifer thickness = 6 m
- T = 180 – 360 m^2/d
- S = 0.01
- t = 12 hours (12 hours on / 12 hours off daily pumping cycle)
- or t = 10 days (prolonged pumping, as was the case at Mashoor)

It will be seen (Table 8) that for aquifer hydraulic conductivities of 30 and 60 m/d, the drawdown is less than 10 cm at distances of c. 130 m after 12 hours pumping. After 10 days, however, the cone of depression (based on s < 10 cm) has expanded to just over 500 m.

In summary, therefore, both the Russian formulae and the Theis equation suggest that an irrigation well can have a radius of influence of around 500 m. Irrigation wells should thus be situation no less than 500 m from other springs, wells or karezes, as a general rule.

Note that if yields exceeding 5 l/s are pumped, the radius of influence may be even larger.

r (m)	K=30 m/d t = 0.5 d	K=60 m/d t = 0.5 d	K=30 m/d t = 10 d	K=60 m/d t = 10 d
10	1.01	0.57	1.59	0.86
20	0.75	0.44	1.32	0.73
50	0.41	0.27	0.97	0.55
100	0.18	0.15	0.71	0.42
150	0.08	0.08	0.56	0.34
200	0.03	0.05	0.45	0.29
250	0.01	0.03	0.37	0.25
300	0.00	0.01	0.31	0.22
350	0.00	0.01	0.26	0.19
400		0.00	0.22	0.17
450		0.00	0.18	0.15
500		0.00	0.15	0.13
750			0.06	0.07
1000			0.02	0.04

Table 8. Calculated drawdown (m) at various distance (r) from an irrigation well pumping at 5 l/s after 0.5 days and 10 days, with aquifer hydraulic conductivity = 30 m/d and 60 m/d. Aquifer thickness is assumed to be 6 m, specific yield = 10 %.

Theoretical Considerations – Overabstraction

It has been seen , under the section “Groundwater Recharge”, that an areally distributed recharge of 50-150 mm/a corresponds to a maximum renewable resource of 1.6 to 4.8 litres per second per square kilometre in lowland Neogene / Quaternary sediments.

If we follow British practice and assume that only 30 to 50 % of this is available for abstraction, then the exploitable resource could range from 0.5 to 2.4 l/s/km^2.

If we assume a compromise, namely that areally distributed recharge is 100 mm/a, and that 30% of this can be abstracted without negative environmental consequences, the maximum exploitable resources in lowland Neogene / Quaternary sediments is 30% x 3.2 l/s/km^2 = 1 l/s/km^2.

In other words, wells should be sited such that the long-term abstraction density does not exceed 1 l/s/km^2. Assuming a hexagonal distribution of wells, the density of abstraction is calculated by:

Abstraction density = $2 . Q / (3 . \tan 30°. L^2)$

where Q = average long term abstraction rate per well
L = average distance between wells

Thus, if Q = 2.5 l/s (5 l/s pump on 12 hr pump cycle) and L = 500 m:

- the area associated with each well is 0.22 km^2
- the abstraction density is 11.5 l/s/km^2.

To achieve an acceptable abstraction density of 1 l/s/km^2, wells with an average abstraction rate of 2.5 l/s need to be situated 1700 m apart.

If we make alternative assumptions about sustainable exploitable resources, average well spacings are found in the Table below:

Abstraction density (l/s/km2)	**L (km) (assuming 2.5 l/s per well)**
0.5	2.40
1	1.70
1.5	1.39
2	1.20
2.5	1.07
3	0.98

Table 9. Average irrigation well spacings (L) to achieve given abstraction densities, assuming an abstraction of 2.5 l/s on average per well, and a hexagonal arrangement of wells.

Of course, if the arrangement of wells is not hexagonal (and it seldom will be), and if the wells are pumped at a lower rate or used for a limited period (e.g. just during drought years), a closer spacing can be acceptable.

From the above, one might conclude, as a rule of thumb, that, in order to avoid overabstraction in a well-field of irrigation wells, spacings between irrigation wells should be on the order of at least 1 km, and ideally more. Ideally, calculations should be made of abstraction density in each individual case.

It should also be noted that the above calculations do not assume that any of the water abstracted for irrigation is recycled to the aquifer via infiltration recharge. Due to the extremely high evapotranspiration rates it is likely that a large proportion of the water applied by flooding of fields is lost via evapotranspiration. If, however, it can be demonstrated that a significant proportion of water is returned to the aquifer via infiltration from canals or fields, then higher abstraction densities can be allowed.

Summary

(1) The use of groundwater, abstracted by a bucket or handpump, for drinking water purposes, has little significance in terms of aquifer water balances. This activity can be promoted by NGOs with a clear conscience.
(2) There should be a presumption against the use of motor-pumped or artesian groundwater for irrigation purposes by NGOs, until a proper management framework exists to license abstractions.
(3) If use of motor-pumped or artesian groundwater for irrigation is absolutely necessary to prevent unacceptable poverty or displacement of populations from their homes, the following guidelines should be observed.
(4) Usage of motor-pumped or artesian groundwater for irrigation should only be temporary, during a drought period. The recipient community should revert to traditional sources (surface waters, karezes, springs) following the drought. This may be achieved by:

- NGOs promoting awareness of groundwater management issues within the recipient community. Groundwater is a resource that can be used to survive a drought, but it should be allowed to recover afterwards.
- NGOs signing a contract with the community that usage of motor-pumped groundwater will cease when the drought breaks
- if the above are not effective, the NGO should consider providing diesel pumps and other equipment as temporary loans, rather than as permanent donations.

(5) All artesian wells must be fitted with a control valve and usage strictly regulated, by agreement with community according to points (3 and 4) above.

(6) Where NGOs plan to use motor-pumped or artesian groundwater for irrigation, a simple risk assessment should be carried out (Appendix 6). This will include:
- identification of all wells, springs and karezes within 1 km of the proposed well
- assessment of the existing density of abstraction ($l/s/km^2$) within a 3 km radius (28 km^2) of the proposed well

(7) The proposed irrigation well should not be within 500 m of existing wells, springs or karezes, in order to avoid derogation of sources. It should be remembered that wells may be constructed in an area free of existing wells and karezes (e.g. a river flood plain) and water piped or channelled in to the fields or village where it is to be used.

(8) The irrigation well can only be constructed within 500 m of such sources **if**:
- the owners of the wells, springs or karezes are the same community that will benefit from the irrigation water, and have **all** agreed that derogation is acceptable, or
- the owners of wells, springs or karezes have been offered and accepted compensation for derogation in terms of well deepening or provision of alternative water sources, or
- a cogent hydrogeological argument is forwarded, and accepted by NCA, that local hydrogeological conditions will prevent derogation of nearby sources.

(9) New motor-pumped or artesian wells for irrigation should not be constructed if the long term net abstraction density within a 3 km radius of the new well will exceed 1 $l/s/km^2$, taking into account the abstraction from the new well (i.e. total abstraction within that 3 km radius should not exceed a long term average of 28 l/s).

(10) An abstraction density lower than 1 $l/s/km^2$ may be appropriate in low-recharge (e.g. desert) areas, far from mountain recharge areas.

(11) A temporary motor-pumped or artesian well for irrigation, resulting in an abstraction density > 1 $l/s/km^2$ *can* be accepted, provided it is known that the new well will be decommissioned following the drought, and that the net abstraction density will revert to a figure < 1 $l/s/km^2$.

(12) A motor-pumped or artesian irrigation well may be permitted to result in an abstraction density greater than > 1 $l/s/km^2$ ***if, and only if,*** a cogent hydrogeological argument is put forward that the recharge to the aquifer is substantially greater than 100 mm/a. In this context, location of irrigation wells in the proximity of regularly or perennially flowing rivers is to be encouraged. In such cases, direct infiltration of river waters to coarse sediments may result in a rapid and high recharge rate to the aquifer. Measures to enhance aquifer recharge (e.g. check dams) are also to be encouraged.

The above form of risk assessment should be adopted by NGO partners working for Norwegian Church Aid (NCA) when evaluating any project involving the use of motor-pumped or artesian boreholes. Written documentation should be available for NCA's inspection that such an evaluation has been carried out and adhered to.

Additionally, in order to preserve groundwater and soil quality, the following guidelines should be adopted:

(13) All wells, springs or karezes potentially used for drinking purposes should be located at least 30 m from latrines or other pollution sources (cattle watering holes, manure stockpiles, rubbish tips etc.)

(14) In villages or towns where the density of latrines or other pollution sources is high, this distance should be increased. In such cases, consideration should be given to locating the drinking water source outside and upgradient of the village, even though this may be less convenient for the consumers (this issue should be discussed openly in a community meeting). The pollution potential from such sources is highlighted by elevated nitrate concentrations found in wells in Nonga village and Kabul city during this study.

(15) Demarcation of wellhead, karez and spring protection zones should be promoted (typically 30 m radius around the source).

(16) Ideally, different users should be separated from the source. For example, flow from a spring or karez can be piped to a reservoir and thence to distribution points for drinking water. A separate pipe can convey water from the reservoir to a livestock watering point.

(17) Use of groundwater for irrigation over a prolonged period *may* carry a risk of soil and groundwater salinisation. The salinity (and ideally also the sodium absorption ratio) of water to be used for irrigation should be determined. As a general rule, groundwater used for irrigation in Afghanistan should have a salinity in class C2 or lower (EC < 750 µS/cm), and an SAR in class S2 or lower (see Appendix 7), *unless* drainage can be shown to be adequate to prevent accumulation of salts in the soil. Groundwater from some sampled sources in Wardak, Ghazni, Zabul, Herat, Badghis and, especially, Kandahar has the potential to cause soil salinisation with prolonged use if drainage is inadequate. Groundwater samples from Dand / Kandahar also contain high boron and residual sodium carbonate, implying some potential to cause soil alkalinisation with prolonged use.

Acknowledgements

Thanks are due to all the staff of Norwegian Church Aid’s Kabul and Peshawar offices, and also to staff of AREA, ADA and CoAR in Peshawar, Kabul, Chaharasiab, Sayyidabad, Moqur, Qalat, Nawa, Shinkai, Arghistan, Kandahar and Herat for their hospitality and interesting discussions. In particular, thanks are due to:

- Faridoon Daudzai (NCAAP Kabul)
- Mohammed Rafi (NCAAP Kabul)
- Aud Elisabeth Wasa (NCAAP Kabul / Peshawar)
- Tor Valla (NCA Oslo)
- Dan Terry and colleagues (IAM, Lal-o-Sarjangal)

for their stimulating company and assistance in the field.

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Wittekindt H & Weippert D (1973). *Geological map of Central and Southern Afghanistan, 1:500,000.* Bundesanstalt für Bodenforschung (Geological Survey of the Federal Republic of Germany), Hannover.

Appendix 1 – Notes from Meetings

22/6/01 – United Nations, Islamabad, Pakistan

Present:

1. Josefa Ojano, Assistant Chief of Mission, UNHCR OCOM Afghanistan, House 24, Street 89, G-6/3, PO Box 1263, ISLAMABAD; Tel: 92-51-2820877; Email: ojanoj@unhcr.ch.
2. Antonio Donini, Deputy Co-ordinator UNOCHA, House 292, Street 55, F-10/4, ISLAMABAD; Tel: 92-51-211467; Email: antonio@undpafg.org.pk.
3. Umer Daudzai, Assistant Resident Representative UNDP, House 293, Street 55, F-10/4, ISLAMABAD; Tel: 92-51-2211451-55; Email: daudzai@undpafg.org.pk.
4. Knut Ostby, Senior Deputy Resident Representative UNDP, House 292, Street 55, F-10/4, ISLAMABAD; Tel: 92-51-2211451-55; Email: knut.ostby@undp.org.
5. NCA: Tor Valla (TV), David Banks (DB), Aud Elisabeth Wasa (AEW)

Discussion:

1. Main centres of IDP migration to Herat and Mazar-e-Sharif. In camps SPHERE standards are not being met. WatSan situation regarded as adequate at Herat camps (OXFAM lead WatSan agency), but situation worse at Mazar (IRC).
2. Recommend intervention at point of origin to prevent IDP migration.
3. General food situation in Afghanistan better than last year, but situation regarding livestock and general ability to cope is worse.
4. In Kandahar, tubewells are used for irrigation water and also for city water supply. Believe groundwater mining is occurring.
5. In some areas there is a tendency to salinisation of soils.
6. Most farming is at a subsistence level or for local markets. The main cash crops are raisins, melons, pistachios and cumin.
7. Recommended further contacts are:
   (a) Hans C Brink, Program Manager FAO Afghanistan, House 8, Street 30, F-7/1, ISLAMABAD; Tel: 2821603 or 2821517.
   (b) Fekare Gebrakal, Afghanistan Rehabilitation Program (ARRP/UNOPS), House 2, Street 58, F-10/3, ISLAMABAD. Tel: 2293251-4; Fax: 2293250.
   (c) Aung Chen, WatSan Co-ordinator, UNICEF.

22/6/01 – ProMIS (UN Program Management Information System), Islamabad, Pakistan

Present:

1. S. Amanullah Shahidi, Resource Officer ProMIS, House 292, Street 55, F-10/4, Islamabad. Tel: 211451-5 ext. 281; Fax: 211450; Email: aman@undpafg.org.pk.
2. NCAAP: AEW/TV/DB

Discussion:

1. ProMIS maintain a GIS based information system of NGO activities and physical features in Afghanistan, including: hydrology (rivers, rainfall etc.), roads, land use, strategic military situation, IDP situation, locations of DACAAR wells. No layers regarding geology or hydrogeology are developed, as yet.
2. Land use maps for the provinces to be visited were ordered by NCA.

22/6/01 – NCA Partner Organisations, NCA Offices, Peshawar, Pakistan

Present:

1. Mr Houdery, Program Director, CoAR.
2. Mr Razziq, Managing Director, ADA
3. Mr Siddiqi, CoAR
4. Mr Ismat, Environmental Planning Director, ADA
5. Mr Kadardan, AREA, Alternative Technology Department
6. Mr Masoom, Director AREA
7. NCAAP: AEW/DB/TV/ Mr Izhaq (NCA Finance) / Mr Ehsan (NCA Program Manager)

Discussion:

1. Traditional water supplies include karezes and dug wells (typically 4x4 m)
2. Partner organisations involved in karez clearance and maintenance
3. There is no common policy for water management in Afghanistan.
4. Declining groundwater levels are observed.
5. In some areas there is perceived to be a conflict between dug wells and karezes.
6. Previously, the water table showed a typical seasonal fluctuation of 1 to 1.5 m.
7. Now, during the drought period, there has typically been a drop in water table level of some 4 m.
8. One good dug well, fitted with a centrifugal pump, pumping 8 hrs/day, can irrigate 5 Ha land.
9. In the case of wells dug on communal land, the local community representatives (shuras or councils) decide on how the water can be used / distributed. The partner organisations work via the shuras (DB note: the shura may be dominated by richer landowners and may not represent the needs of the poorest in the community).
10. The NGOs are examining methods of increased efficiency in use of irrigation water. They believe, however, that increased efficiency will not result in decreased water consumption but an increase in irrigated area.
11. Main techniques for increasing irrigation efficiency involve levelling land to decrease surface run-off and improving construction of open channels. Attempts to promote underground drip irrigation have not been wholly successful due to (a) cost and (b) the high head required to “drive” such systems.
12. Traditional irrigation is by flooding land from a network of irrigation channels. Wheat crops require a minimum of 4-5 floodings per crop, but often 8-9 floodings are applied.
13. Even prior to the drought, some experts were predicting a lack of water by 2004 in Kabul, due to overabstraction.
14. South of Kabul, authorities are granting permits for the construction of wells for the sale of irrigation water to local farmers.
15. Traditional latrines are deep or shallow pits, which are periodically dug out for use as manure on fields.
16. The partner NGOs have no access to laboratory analytical facilities and expressed interest in Oxfam-type test kits.

23/6/01 – DACAAR, NCAAP Offices, Peshawar, Pakistan

Present:

1. Mr Thomas Thomsen, Director, DACAAR (Danish Committee for Aid to Afghan Refugees), 10 Gul Mohar Lane, PO Box 855, University Town, PESHAWAR. Tel: 091-40731 or 44237-843078; Fax: 091-840516. Mobile: 0303-7864040. Email: Dacaar@pes.comsats.net.pk or thomsen@pes.comsats.net.pk.
2. NCAAP: AEW/TV/DB

Discussion:

About DACAAR

1. UNICEF (together with DACAAR) are the lead agency for drinking water in rural areas. UNOPS (UNDP) are lead agency for drinking water.
2. DACAAR have been operational since 1986.
3. DACAAR are the main NGO in the drinking water sector in Afghanistan, performing 70% of rural drinking water work. 3000-4000 wells are installed by DACAAR per year, and, in total, some 22000 wells have been installed (75% dug wells, 25% tubewells). Also, some gravity fed piped schemes have been implemented. DACAAR avoid motorised systems.
4. Some 60% of DACAAR's activity is in the field of drinking water, 40% in the field of integrated agricultural management.
5. In 1999, a WatSan technical working group was established by DACAAR and UNICEF, also involving German AgroAction and the Swedish Afghanistan Committee. Together these organisations account for 90-95% of drinking water activity in Afghanistan. Two subcommittees have been appointed: (a) handpump technology and (b) hygiene education.
6. DACAAR aim to deliver an integrated package of (a) safe drinking water, (b) sanitation and (c) hygiene education. DACAAR have little activity in the field of irrigation water.

DACAAR's Handpump Activities

7. In 1988-89, DACAAR established a hand-pump factory near Peshawar, producing the Afridev design in two versions (a) a cheap (4500 Rupee) light version, with a lift of 20-25 m (the "Kabul" pump) and (b) a standard Afridev version (the "Indus" pump), with a lift of 45-50 m and retailing at 5000 Rupees.
8. Since then, another 7-10 manufacturers have sprung up to satisfy stimulated demand.
9. During the 1990s, the use of the Afridev in Afghanistan as a standard pump, with an efficient spare parts network, has been promoted. UNICEF now recommend the Afridev as the standard handpump for NGO use in Afghanistan.
10. For implementation of handpump projects, DACAAR adhere to the following policy:
    (a) Community involvement (provision of labour, sand/gravel etc.)
    (b) Contract with community guaranteeing public access to pump
    (c) Appoint a *handpump caretaker* from the village
    (d) In case of problems, the caretaker can call upon a *handpump mechanic*, typically responsible for c. 100 wells. The mechanic is trained by DACAAR and provided with a cycle and set of tools. He is paid in wheat per job by the local community.
    (e) All DACAAR wells are regularly inspected by a *handpump inspection team*, employed directly by DACAAR.

11. Handpumps are sources from factories in Pakistan (see above). PVC pipe is sourced from Pakistan or, increasingly, from Iran via traders in Herat. PVC pipe is quality assessed. Cement is sources locally in Afghanistan (from 150 to 220 Rupees/bag). Spare rubber and plastic handpump parts are sourced in Pakistan but can be of highly varying quality and strict quality control is necessary. Local villagers will often choose to purchase the cheapest parts, regardless of quality and durability.

Karezes

12. Karezes are used both for drinking and irrigation water. DACAAR attempt to separate these functions and prefer to use sealed dug wells, fitted with handpumps, for drinking water.
13. Karezes require constant maintenance and are vulnerable to drawdown of the water table.

Dug Wells

14. Dug wells may be constructed to c. 45 m depth, although deaths due to oxygen deficiency have occurred. Dug wells are typically 3-4 times cheaper than boreholes.
15. DACAAR prefers dug wells to boreholes. The former are cheaper and can be deepened if necessary. UNICEF, who implement via the Taliban-controlled General Rural Rehabilitation Department (GRRD), are encouraged to install boreholes, as GRRD operate a drilling rig.

Drilled Boreholes

16. Typical drilling prices in Afghanistan are 350-400 Rp/m in soft strata, 900 Rp/m in hard/strata. In some parts of Afghanistan, where demand is high, prices can reach 18-20 USD/m.
17. Wells or boreholes for drinking water should never be sited near roads. They should be in secluded locations so that women can feel able to access them

Sanitation and Hygiene Education

18. Traditional Afghani sanitation has been based on “unimproved” pit latrines or use of fields. DACAAR’s sanitation activity has involved the installation of single-pit VIP latrines and baths at a limited number of households in each village, in the hope that the “new technology” would spread by recommendation. The program has not been wholly successful as other families have failed to adopt the demonstrated solutions. Double-pit, urine separation latrines have also been trialled.
19. Hygiene education has involved the employment of husband-and-wife (occasionally father-daughter etc.) teams. Current restrictions on employment of women mean that such education programs currently only reach men in Western Afghanistan.

Agriculture and Irrigation

20. The pre-war population of Afghanistan was 15 million. It is now 24 million (excluding 3-4 million external refugees).
21. There are three types of traditional irrigation in Afghanistan: (a) rain-fed irrigation, in high altitude areas especially in Ghor, Badghis, Central Highlands, which has been devastated by the drought, (b) river-fed irrigation on the plains (e.g. Herat River and Helmand River),

which has been less affected by the drought (due to some snow last winter), (c) karez-fed irrigation in the foothills, which is also heavily impacted by the drought.

22. Irrigation based on dug wells and tubewells is a new phenomenon and currently is not extensive, but is spreading rapidly. There is a potential conflict between deep tubewells (which only the richer landlords can afford) and traditional sources (used by the poorer sector of the community).
23. Nomadic land is increasingly being taken over by agriculture. This involves removal of native vegetation on hillsides, ploughing and increased erosion and run-off.
24. DACAAR encourage soil moisture conservation measures such as check-dams.

Declining Water Table

25. Dug wells are normally constructed to 1 or 1.5 m below the water table. In the Eastern Region, 18% of DACAAR dug wells have dried up during the past 1.5 years. In Kabul district, some 85% of wells have become dry.
26. Many wells have required deepening recently. Of 2000 wells deepened by DACAAR recently, the typical extra depth was 2-3 m.
27. The decline in the water table level shows large variations between different locations. In mountainous/hilly districts, a higher proportion of wells have dried up than in plains and valleys.

DACAAR’s Other Activities

28. DACAAR aims to compile at literature base on groundwater in Afghanistan, but most publicly available information is some 20-30 years old.
29. DACAAR also maintain a well database. Hitherto this mainly covers DACAAR wells, but other NGOs are requested to contribute.
30. DACAAR offers WatSan related training to employees of other NGOs.

IDP Camps

31. Regarding IDP camps: the WatSan situation at Herat is believed to be under control. The situation at Mazar is not satisfactory; groundwater is salty.

Further Recommended Contacts:

1. UNICEF Herat – Engineer Qazeem
2. DACAAR Herat – Eng. Aleem
3. DACAAR Jalalabad – Eng. Masoom
4. DACAAR Peshawar – Kerry Jane Wilson (Program Manager, S & W Afghanistan)
    - Eng. Bizmillah Mirsat (Head of Water Supply)
    - Eng. Wahid Dulah (Head of Handpump Technology)
    - Engineer Tameem (Databases)

23/6/01 – Food & Agriculture Organisation of the UN (FAO), FAO Offices, Peshawar, Pakistan

Present:

1. Sayed Sharif Shobair, Irrigation Engineer FAO, 19 AC-03 Gul Mohar Lane, (UPO Box 776), University Town, Peshawar. Tel: 92-91-844721 or 845088. Email: faocrops@psh.brain.net.pk or shobair60@hotmail.com.
2. NCAAP: DB/TV/AEW

Discussion:

1. The FAO irrigation unit is small unit, but has been involved in (a) rehabilitation of over 200 irrigation systems, (b) data collection, (c) policy formulation.
2. FAO are very concerned over the effects of use of groundwater in irrigation on traditional karezes.
3. The drought has reduced the yield of karezes. This has caused folk to dig wells for irrigation. This abstraction causes further derogation to karez systems.
4. Typical traditional irrigation systems are only 30% efficient, with large losses to leakage and evaporation.
5. Irrigation systems have traditionally been managed by *mirabs*. However, many of these have left the country.
6. FAO's activities involve repair of canal structures to minimise losses and the training of new mirabs.
7. No research has taken place into the introduction of more efficient irrigation systems (e.g. drip irrigation).
8. Precipitation ranges from 70 mm/a in southwest to 1000 mm/a in eastern highlands.
9. FAO are not aware of any trend to salinisation due to use of groundwater. However, salinisation has taken place in the Helmand area in connection with an American-funded surface-water irrigation scheme, due to lack of proper drainage.
10. In the north of Afghanistan, snow is harvested, pack with straw in ice wells and used during summer.
11. In other parts of the country, spring run-off is collected in ponds and stored for later use.
12. Afghanistan used to have 130 meteorological stations, but all were destroyed during the war. FAO has established 7 new stations, and DACAAR has also established some stations.

Further Reading:

Shobair SS (1997). *Water Harvesting*. FAO Peshawar, Dec. 1997.
Klemm W (1996). *Water Resources and Irrigation.* FAO Peshawar.

Recommended Contacts:

1. Mr Kawaya Sadr-e-Awlia. Hydrogeologist working in Zarghoon Share in Logar Province.
2. Mr Mohammad Qassem Taheri (Khawaja). Hydrogeologist working in Kolangar village of Logar Province.

24/6/01 – AREA Regional Office, Jalalabad, Afghanistan

Present:

1. Sayed Najibullah, AREA Program Manager Jalalabad, Hada-e-Chaparhar, Opposite Qari Jan Shahid, Reg Shahmard Khan, Jalalabad City.
2. NCA: AEW, TV, DB.

Discussion:

1. Jalalabad city pumps its drinking water from deep wells 3hrs/day. The rest of the time the system is unpressurised (potential for inward leakage of sewage etc. to distribution network - DB).
2. In the Jalalabad area there are two types of well: (a) deep boreholes and (b) shallower dug wells.
3. Deep boreholes may be over 100 m deep. They are typically drilled where the water table is too deep to be exploited by shallow dug wells. In some places the water level may be 60 m deep. AREA only use deep boreholes for drinking water only, not for irrigation. They use handpumps where possible and submersible pumps to reservoirs where the lift is too high for handpumps. One borehole may yield 10 l/s water with a submersible pump.
4. Drilling of boreholes is typically by percussion rig, up to 20" diameter to 50 m depth, reducing below that depth to 15-16". Below the water table, 10" diameter copper-steel (brass?) well-screen is installed. Above the water table, mild steel is used. Typically a 4" submersible pump is installed. Drilling rates vary from 1m/day to 15 m/day, with a typical price of 70 Rp/m. There are often problems retrieving temporary casing from the borehole. Geological records are kept.
5. Shallow dug wells are typically 10-20 m deep. 80% of DACAAR's dug wells have dried out during the drought.

25/6/01 – Meeting with Representatives of CoAR, ADA and AREA, NCA Offices, Kabul, Afghanistan.

Present:

1. NCAAP: Faridoon Daudzai (FD), DB, AEW, TV
2. Seven representatives from CoAR, ADA, AREA

Discussion:

1. AREA policy is not to drill wells any deeper than 60 m, and not to place deep wells in the vicinity of karezes.
2. CoAR do perceive a conflict between deep wells and traditional water sources, especially in Wardak.
3. Some problems of soil salinisation due to use of saline groundwater are observed in Nawa district (Ghazni).
4. Saline groundwater may occur in the upper part of the aquifer, in which case it may be cased out in drilled wells.
5. karez rights may be fairly clearly defined in terms of local law and custom. It may not be possible to extend the head of a karez further back (upslope) without coming into conflict with a neighbouring village's karez rights. Thus, some villages are tending to try and deepen karezes, rather than extend them back
6. Village shuras may be controlled by the richer members of the community and may not represent the needs of the most vulnerable.

25/6/01 – DACAAR, DACAAR Offices, Kabul, Afghanistan

Present:

1. Abdul Baqi Afzali, Chief of DACAAR Kabul Office
2. Engineer Hamidullah, Field Office Manager, Kabul
3. NCAAP: FD, TV, DB

Discussion:

1. DACAAR operate four types of project (a) tubewells for drinking water supply, (b) dug wells for drinking water supply, (c) piped supplies, (d) karez rehabilitation.
2. Use of dug/drilled wells for irrigation typically favours richer landowners over the more vulnerable in a community. Particularly near the Pakistan border adjacent to Quetta, intensive use of groundwater for irrigation has sunk the water table.
3. Saline groundwater tends to occur where the water table is close to the surface. There is no indication of increasing salinity with depth.
4. In most areas, the water table has fallen by 4-6 m in two years. In some areas it has fallen by up to 10m.
5. Many drilling contractors exist in Kabul, Kandahar and Herat. In particular, a contractor named “Recon” (Herat) was named, which has over 10 rigs, including a rotary rig.
6. DACAAR use steel, PE and PVC pipes. 1 m depth of burial is usually enough, regarding winter conditions. Piped spring schemes are capital intensive, but have lower maintenance costs.
7. Locate drinking water sources 15-20 m from latrines.

25/6/01 – Meeting with Hydrogeologists (and others), NCA Offices, Kabul, Afghanistan.

Present:

1. Engineer Ehsanallah, Hydrogeologist, Ministry of Mines & Industry (currently freelancing for Norwegian Project Office NPO)
2. Engineer Safhi (?), Architect, AREA
3. Engineer Ameen, Hydrogeologist, AREA
4. Engineer Qudratallah, Drilling Supervisor, AREA
5. NCAAP: AEW, TV, DB, FD

Discussion:

1. The opinion was expressed that neither deepening nor cleaning karezes will have significant effect on yield (NOTE by DB: the field evidence suggests, however, that cleaning karezes can result in significant yield improvement).
2. The hydrogeologists suspect that irrigation wells do not, in general, have a major effect on karezes as they are typically located at some distance from them.
3. Karezes typically abstract water from proluvial strata in mountain foothills, and occasionally from bedrock.

4. Several (Soviet) formulae are available for calculating the radius of influence (R) of wells. Two of the most commonly used are:
   (a) $R = 2.s.(K)^{0.5}$
   (b) $R = 10.s.(K)^{0.5}$
   (c) where s = drawdown in pumping well (m) and K = hydraulic conductivity (m/day). The theoretical basis for these formulae is unclear, and the two formulae yield rather different results (the latter is five times greater than the former).
5. K = 30-60 m/d in alluvial sands/gravels/pebbles around Kabul. Proluvial strata typically have similar conductivities.
6. Somewhat saline groundwater can be used *in the short term* for irrigating tobacco, tomatoes or vines.
7. A hydrogeological map at scale 1:500,000 is held by the Ministry of Mines, but it is not a public document.
8. Typically, the drought has resulted in water table declines of 4-5 m around Kabul City, 5-8 m in Kandahar and 2-4 m around Herat. These declines are due both to climatic recession and to increased abstraction.
9. There used to be a network of over 40 observation boreholes for water quality and level, but these were destroyed during the war(s).
10. Groundwater resources calculations have been made for Kabul City. It is calculated that the demand of 6000 l/s is balanced by a recharge of 250 mm/yr. Normally, there is a two metre seasonal fluctuation in water table level. In the event of a drought (no rainfall recharge), five years continued abstraction at 6000 l/s would result in the 30 m thickness of productive aquifer being half emptied (i.e. a regional drawdown of 15 m). (NOTE by DB: the influence of Soviet thinking is evident in these calculations, i.e. that natural resources are there to be exploited by humankind to the greatest extent possible. It is assumed that 100% of recharge is available for extraction. In the UK, the Environment Agency is currently setting targets suggesting that only 30%-50% of recharge should be abstracted, in order to avoid depleting small scale private abstractions and environmental features (springs, small streams etc.).
11. In the Quaternary (proluvial) aquifer complexes, some layering of aquifer and aquitard strata may be evident. For example, at Kandahar, the following sequence may be typical (a) sands/gravels to c. 18 m, (b) silts/clays to 60 m, (c) more sands and gravels. The permeable layers are often not laterally continuous, but lens-like. The entire sequence most be regarded as a single complex (i.e. abstractions from lower horizons *may* affect wells in upper horizons).
12. There is general agreement that drilling / digging of deep wells is undesirable and is causing declining groundwater levels.

26/6/01 – United Nations Office for Co-ordination of Humanitarian and Development Activities to Afghanistan, UNCO Offices, Kabul, Afghanistan.

Present:

1. Eliane Duthoit, Regional Co-ordination Officer, Central Region, Shah Mahmood Ghazi Watt, Kabul. Tel: 00-873-761-660-767; Fax: 00-873-761-660-769. Email: eliane.duthoit@undpafg.org.pk.

2. Engineer Salim M. Qayum, Senior Program Assistant, Shah Mahmood Ghazi Watt, Kabul. Tel: 22770 / 26051 / 20445; Satphone: 00-873-761-660-767; Fax: 00-873-761-660-769. Email: salim.qayum@undpafg.org.pk.
3. NCAAP: DB, Faridoon Daudzai (FD)

Discussion:

1. DB & FD informed about planned activities. ED expressed interest in receiving a copy of the Code of Conduct, when produced.
2. Concern was expressed over lack of handpump maintenance in urban areas. In rural areas, the DACAAR maintenance network appears to work well, but in urban areas the community tends not to take responsibility to the same degree.
3. The majority of overabstraction problems due to deep wells are caused by rich (private) landlords, especially in Ghazni, Wardak, Logar and Nergh provinces.
4. Habitat has responsibility for solid waste management in the city of Kabul (although this is of very limited extent), and ICRC have a program for latrine improvement.

Appendix 2 – Itinerary of Field Visits

Date	Province	Locations visited	Comments
26/6/01	Kabul (AREA)	S. outskirts of Kabul Qala-e-Fatoo Gulbagh	AREA dug well in urban area AREA 61.5 m irrigation borehole AREA irrigation bore during drilling
27/6/01	Wardak “ Ghazni “	Sayyidabad Hoji-Aziz village Moqur Gula-Khil (nr Moqur)	CoAR office (dug well / karez) Rehabilitated karez CoAR office (irrigation borehole) Karez in need of pipe scheme
28/6/01	Ghazni (Nawa)	Nonga village near Nonga Nawa village Zarin Khil village	Karez rehabilitation / dug well Dug irrigation well (private) CoAR office Dug well under construction
29/6/01	Zabul (Qalat)	Qalat Shahdo village Toora village Korkaron village Khan village Jaanan village	ADA office Lift irrigation well Lift irrigation well Lift irrigation well Drilling of borehole for handpump Mildly artesian borehole
30/6/01	Zabul (Shinkai)	Sadukhan village Suhi village Suhi village Shinkai River Ghbargi village	Karez rehabilitation Ghogi spring reservoir Dug well for irrigation River platform for pump irrigation Poor karez/spring in need of piping
1/7/01	Kandahar (Dand)	Mashoor (Dand)	Two lift irrigation wells
2/7/01	Kandahar (Arghistan)	Arghistan Khansizi village Ser village Shnakhta village Bareizi village Wachghbarga Kalacha village	ADA office Lift irrigation well Lift irrigation well Drilling of bore for handpump Drilled bore for handpump Karez rehabilitation Karez rehabilitation
3/7/01	Kandahar-Herat		Travel
4/7/01	Herat	Christian Aid AHDA IoM Gowrhashad Begum Maslakh IDP camp	Meeting with Karen Richards Meeting with Engineer Aziz Meeting with Steven Lennon Irrigation borehole (80m) Overview of camp
5/7/01	Herat (Karukh) Badghis (Kushk-e-Kohna)	Mahkiha village Ziarati Baba shrine Makhmali village Makhmali village Karez Bibi village	Karez rehabilitation Dug well under construction AREA sub-office Meeting with villagers Karez rehabilitation
6/7/01	Herat (Guzara)	Mazrah area Assanabad village Bedak village Karakol village	Uncontrolled artesian boreholes “Dry” village “Dry” village with small karez Karez/pipeline scheme

		Kurpa village	Karez/pipeline scheme
7/7/01	Herat-Kabul		Travel by air
9/7/01	Kabul-Mullah Yacob Pass		Travel (13:40 to 01:20)
10/7/01	Mullah-Yacob Pass to Lal-o-Sarjangal	IAM Field Office, Lal	Travel (05:00 to 19:20)
11/7/01	Ghor (Lal)	IAM Clinic at Lal Safid-Ab field office	Dug wells and latrines Overnight at field office
12/7/01	Ghor (Lal)	Upper Four Mills Nawa Jaw Jarbal	Large boxed spring Supposedly "dry" village Supposedly "dry" village
13/7/01	Lal to Kabul		Travel (03:40 to 20:00)
15/7/01	Kabul (Chaharasiab district)	Chaharasiab Elyas Khil village Rahmat Abad village Qala-e-Nishan village	ADA sub-office Lift irrigation well Two lift irrigation wells Lift irrigation well

Appendix 3 – Plans Developed by AREA (Herat) for (a) Typical Karez Rehabilitation Using Concrete Ellipses and (b) a Reservoir and Pipe Scheme from a Karez (or Spring)

Appendix 4 – Statistics on Status of Handpumps, Kabul.

Summary	**Dec-00**	**Jan-01**	**Feb-01**	**Mar-01**	**Apr-01**	**May-01**
Functioning	943	997	1366	1417	1891	1919
Not functioning due to technical problems	435	500	748	742	857	916
Not functioning due to low water table	558	458	483	437	484	423
Total	**1936**	**1955**	**2597**	**2596**	**3232**	**3258**

Appendix Table 4.1. Status of wells with handpumps, Kabul City, December 2000 to May 2001. Data from UNCHS (Habitat) and compiled by Salim Qayum, UNCO, Kabul.

District	**Well depth (m)**	**Water table 21/4/01 (m bgl)**	**Water table 21/5/01 (m bgl)**	**Monthly drawdown (m)**
1	9.30	8.21	8.45	0.24
2	9.26	7.87	8.13	0.26
3	5.88	4.74	4.81	0.07
4	7.49	5.80	6.10	0.30
5	12.24	9.20	9.45	0.25
6	10.07	8.51	8.80	0.29
7	9.30	7.60	7.83	0.23
8	13.60	11.35	11.55	0.20
9	7.20	4.91	5.11	0.20
10	8.96	7.36	7.97	0.61
11	21.87	21.04	21.00	-0.04
12	12.36	11.90	12.02	0.12
15	15.68	14.22	14.55	0.33
16	10.38	7.95	8.24	0.29
Total	**10.97**	**9.33**	**9.57**	**0.24**

Appendix Table 4.2. Change in water table, measured in wells in Kabul City, April/May 2001. Data from UNCHS (Habitat) and compiled by Salim Qayum, UNCO, Kabul.

Water quality was measured in 84 wells in Kabul City and a range of 0 to 130 faecal coliforms per 100 millilitres was found, with an average of 9 faecal coliforms per 100 millilitres. *Data from UNCHS (Habitat) and compiled by Salim Qayum, UNCO, Kabul.*

Appendix 5 – Results of Chemical Analysis of 15 Samples Collected During June/July 2001.

No.	Village/district/province	Depth/ Length	Type	Surrounding land use
Af1	CoAR compound/Sayyidabad/Wardak	D = 12 m	Dug well	Rural/(urban)
Af2	Hoji-Aziz village/Sayyidabad/Wardak	L = 2 km	Karez	Rural
Af3	CoAR compound, Moqur/Moqur/Ghazni	D = 70 m	Dug well + bore	Urban
Af4	Nonga village/Nawa/Ghazni	D = 40 m	Dug well	Urban
Af5	Nr. CoAR compound, Moqur/Moqur/Ghazni	D = 15 m	Dug well	Urban
Af6	Shahdo/Qalat/Zabul	D = 83 m	Dug well + bore	Agricultural
Af7	Toora/Qalat/Zabul	D = 10 m	Dug well	Agricultural
Af8	Korkaron/Qalat/Zabul	D = 10 m	Dug well	Agricultural
Af9	Sadukhan/Shinkai/Zabul	L = 1 km	Karez	Rural
Af10	Ghogi reservoir, Suhi/Shinkai/Zabul	N/a	Spring	Rural
Af11	Well 2, Mashoor/Dand/Kandahar	D = 30 m	Dug well + bore	Agricultural/ (urban)
Af12	Well 1, Mashoor/Dand/Kandahar	D = 30 m	Dug well + bore	Agricultural
Af13	Karez Bibi village/Kushk-e-Kohna/Badghis	N/a	Spring	Urban/(rural)
Af14	Mazrah/Guzara/Herat	D = 65 m	Bore (artesian)	Agricultural
Af15	2 blocks east of NCA office, German Club Street/Kabul City	D = 10 m	Dug well	Urban

Collection datesAf1-3=27/6/01; Af4=28/6/01; Af5-8=29/6/01; Af9-10=30/6/01; Af111-12=1/7/01; Af13=5/7/01; Af14=6/7/01; Af15=15/7/01.

Appendix Table 5.1. Details of sample locations of 15 water samples taken in June/July 2001.

		Norges Geologiske Undersøkelse 7491 TRONDHEIM Tlf.: 73 90 40 00 Telefaks: 73 92 16 20			
Analysis Date	**Job No.**	**Sample ID**	**Sample Date**	**pH**	**t-Alkalinity**
				pH	**mmol/l**
02/08/2001	1-294/01	Af 1F	27.06 2001	6.81	12.10
02/08/2001	2-294/01	Af 2F	27.06 2001	8.04	3.03
02/08/2001	3-294/01	Af 3F	27.06 2001	7.91	3.82
02/08/2001	4-294/01	Af 4F	28.06 2001	7.82	3.59
02/08/2001	5-294/01	Af 5F	29.06 2001	8.01	4.11
02/08/2001	6-294/01	Af 6F	29.06 2001	7.85	5.69
02/08/2001	7-294/01	Af 7F	29.06 2001	7.90	3.82
02/08/2001	8-294/01	Af 8F	29.06 2001	7.74	8.24
02/08/2001	9-294/01	Af 9F	30.06 2001	8.13	3.63
02/08/2001	10-294/01	Af 10F	30.06 2001	7.95	2.98
02/08/2001	11-294/01	Af 11F	01.07 2001	7.87	10.16
02/08/2001	12-294/01	Af 12F	01.07 2001	7.83	10.35
02/08/2001	13-294/01	Af 13F	05.07 2001	7.88	6.47
02/08/2001	14-294/01	Af 14F	06.07 2001	7.99	3.76
02/08/2001	15-294/01	Af 15F	15.07 2001	7.63	10.99

Appendix Table 5.2. Determinations of pH and t-alkalinity for 15 samples of groundwater from Afghanistan. Analysed by Norges Geologiske Undersøkelse (NGU), Trondheim, using *Radiometer Titralab 94 / Glass electrode pHC 2701-8 "Red Rod", according to Norwegian Standard NS 4720 and NGU Standard NGU-SD 3.7B (correponds to former Norwegian Standard NS 4754).*

	Norges Geologiske Undersøkelse 7491 TRONDHEIM Tlf.: 73 90 40 00 Telefaks: 73 92 16 20						
Sample ID	**F^-**	**Cl^-**	**NO_2^-**	**Br^-**	**NO_3^-**	**PO_4^{3-}**	**SO_4^{2-}**
	[mg/l]	**[mg/l]**	**[mg/l]**	**[mg/l]**	**[mg/l]**	**[mg/l]**	**[mg/l]**
AF1 27.06.01	0.09	23.6	< 0.05	< 0.1	30.6	< 0.2	27.3
AF2 27.06.01	0.14	3.58	< 0.05	< 0.1	18.2	< 0.2	9.23
AF3 27.06.01	0.12	7.11	< 0.05	< 0.1	9.83	< 0.2	12.4
AF4 28.06.01	0.09	307	< 0.05	1.19	367	< 0.2	134
AF5 29.06.01	0.13	7.98	< 0.05	< 0.1	10.6	< 0.2	13.2
AF6 29.06.01	0.20	62.6	< 0.05	0.18	13.9	< 0.2	79.0
AF7 29.06.01	0.22	217	< 0.05	0.59	75.0	< 0.2	477
AF8 29.06.01	0.35	169	< 0.05	0.54	34.5	< 0.2	325
AF9 30.06.01	0.12	9.91	< 0.05	< 0.1	12.3	< 0.2	41.2
AF10 30.06.01	0.06	4.23	< 0.05	< 0.1	7.12	< 0.2	16.5
AF11 01.07.01	0.63	109	< 0.05	0.26	3.31	< 0.2	275
AF12 01.07.01	0.68	185	< 0.05	0.44	2.27	< 0.2	379
AF13 05.07.01	0.95	55.7	< 0.05	0.10	23.9	< 0.2	301
AF14 06.07.01	0.43	48.3	< 0.05	0.12	22.9	< 0.2	136
AF15 15.07.01	0.22	137	< 0.05	0.26	50.2	< 0.2	106

Appendix Table 5.3. Determinations of anionic species for 15 samples of groundwater from Afghanistan. Analysed by Norges Geologiske Undersøkelse (NGU), Trondheim, using a *Dionex Ion Chromatograph 120 DX*. Nitrite (NO_2^-) determinations regarded as invalid due to long elapsed time between sampling and analysis.

Sample ID	Si	Al	Fe	Ti	Mg	Ca	Na	K	Mn	P	Cu	Zn	Pb	Ni
	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
Af1	19.7	<0.02	<0.01	<0.005	32.1	174	48.0	2.12	0.0147	<0.1	<0.005	0.0886	<0.05	<0.02
Af2	12.4	0.0232	0.0107	<0.005	14.8	36.5	9.85	1.59	0.00102	<0.1	0.00916	0.0205	<0.05	<0.02
Af3	8.62	<0.02	<0.01	<0.005	17.9	47.1	11.0	1.56	<0.001	<0.1	<0.005	<0.002	<0.05	<0.02
Af4	9.84	<0.02	0.0107	<0.005	63.6	155	157	2.95	0.0415	0.110	0.0121	1.16	<0.05	<0.02
Af5	9.28	<0.02	<0.01	<0.005	20.0	48.8	13.4	1.32	<0.001	<0.1	0.00593	0.0337	<0.05	<0.02
Af6	6.01	<0.02	<0.01	<0.005	45.8	52.6	58.5	3.18	0.00219	<0.1	<0.005	0.0558	<0.05	<0.02
Af7	5.40	<0.02	<0.01	<0.005	75.6	93.2	208	2.40	0.00219	0.167	<0.005	<0.002	<0.05	<0.02
Af8	7.37	<0.02	<0.01	<0.005	89.7	89.2	169	3.08	0.00175	0.126	<0.005	0.00300	<0.05	<0.02
Af9	6.50	0.0328	<0.01	<0.005	17.4	38.1	32.3	1.62	0.00102	<0.1	<0.005	0.00366	<0.05	<0.02
Af10	5.56	<0.02	<0.01	<0.005	15.2	35.0	11.3	0.825	0.00422	<0.1	<0.005	0.0153	<0.05	<0.02
Af11	8.46	<0.02	<0.01	<0.005	66.3	47.9	234	9.29	0.00175	0.128	<0.005	0.0308	<0.05	<0.02
Af12	8.33	<0.02	<0.01	<0.005	70.6	49.6	319	6.56	0.00160	<0.1	<0.005	0.0147	<0.05	<0.02
Af13	5.55	<0.02	<0.01	<0.005	38.3	64.6	165	3.17	0.00102	0.122	0.00539	0.0270	<0.05	<0.02
Af14	7.28	<0.02	<0.01	<0.005	26.9	39.0	87.2	2.93	<0.001	<0.1	<0.005	0.0162	<0.05	<0.02
Af15	12.1	<0.02	<0.01	<0.005	92.7	90.3	112	9.12	0.00248	0.147	<0.005	0.128	<0.05	<0.02

Sample ID	Co	V	Mo	Cd	Cr	Ba	Sr	Zr	Ag	B	Be	Li	Sc	Ce	La	Y
	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]	[mg/l]
Af1	<0.01	<0.005	<0.01	<0.005	<0.01	0.0737	1.52	<0.005	<0.01	0.600	<0.001	0.0436	<0.001	0.0806	<0.01	<0.001
Af2	<0.01	<0.005	<0.01	<0.005	<0.01	0.0291	0.270	<0.005	<0.01	0.0358	<0.001	<0.005	<0.001	<0.05	<0.01	<0.001
Af3	<0.01	<0.005	<0.01	<0.005	<0.01	0.0448	0.273	<0.005	<0.01	0.0632	<0.001	0.0246	<0.001	<0.05	<0.01	<0.001
Af4	<0.01	0.00518	<0.01	<0.005	<0.01	0.0632	2.20	<0.005	<0.01	0.213	<0.001	0.0386	<0.001	0.0980	<0.01	<0.001
Af5	<0.01	<0.005	<0.01	<0.005	<0.01	0.0465	0.319	<0.005	<0.01	0.0842	<0.001	0.0274	<0.001	<0.05	<0.01	<0.001
Af6	<0.01	<0.005	<0.01	<0.005	<0.01	0.0236	0.615	<0.005	<0.01	0.362	<0.001	0.0436	<0.001	<0.05	<0.01	<0.001
Af7	<0.01	0.00533	<0.01	<0.005	<0.01	0.0347	1.63	<0.005	<0.01	0.476	<0.001	0.0330	<0.001	<0.05	<0.01	<0.001
Af8	<0.01	0.00518	<0.01	<0.005	<0.01	0.0380	1.73	<0.005	<0.01	0.962	<0.001	0.0766	<0.001	<0.05	<0.01	<0.001
Af9	<0.01	<0.005	<0.01	<0.005	<0.01	0.00687	0.487	<0.005	<0.01	0.0989	<0.001	0.0140	<0.001	<0.05	<0.01	<0.001
Af10	<0.01	<0.005	<0.01	<0.005	<0.01	0.0115	0.348	<0.005	<0.01	<0.02	<0.001	0.00950	<0.001	<0.05	<0.01	<0.001
Af11	<0.01	0.0110	<0.01	<0.005	<0.01	0.0190	1.53	<0.005	<0.01	1.05	<0.001	0.0855	<0.001	<0.05	<0.01	<0.001
Af12	<0.01	0.0105	<0.01	<0.005	<0.01	0.0187	1.68	<0.005	<0.01	1.40	<0.001	0.0917	<0.001	<0.05	<0.01	<0.001
Af13	<0.01	<0.005	<0.01	<0.005	<0.01	0.0291	1.60	<0.005	<0.01	0.400	<0.001	0.0419	<0.001	<0.05	<0.01	<0.001
Af14	<0.01	<0.005	<0.01	<0.005	<0.01	0.0242	1.05	<0.005	<0.01	0.253	<0.001	0.0224	<0.001	<0.05	<0.01	<0.001
Af15	<0.01	0.00785	<0.01	<0.005	<0.01	0.247	1.32	<0.005	<0.01	1.12	<0.001	0.207	<0.001	<0.05	<0.01	<0.001

Appendix Table 5.4. Determinations of a range of elements for 15 samples of groundwater from Afghanistan. Analysed by Norges Geologiske Undersøkelse (NGU), Trondheim, using a *Thermo Jarrell Ash ICP 61* (Inductively Coupled Plasma Atomic Emission Spectrometer).

Appendix 6 – Risk Assessment Form: Motor-Pumped Wells and Boreholes for Groundwater Abstraction.

1. Location of Proposed Well

Province... District..
Village... Grid. Ref. ....

2. About the Proposed Well

Depth..(m) Diameter..(m)
Expected rest water level................(m bgl) Expected maximum drawdown.........(m)
Expected peak yield........................(l/s) Expected mean net yield..................(l/s)

3. Expected Geology

.... to........... m below ground level (bgl)
.... to........... m below ground level (bgl)
.... to........... m below ground level (bgl)
.... to........... m below ground level (bgl)
.... to........... m below ground level (bgl)

4. Derogation ? - List of All Wells, Springs and Karezes within 1 km

Name	Type (karez, drinking water well, irrigation well, spring)	Distance and direction from new well (m)	Current water level or flow

The new well must be > 500 m from the above sources. If it is less than 500 m away, a clear justification must be given that no unacceptable derogation will occur.

Justification / calculations:

5. Overabstraction ? List all motor-pumped or artesian wells within a 3 km radius.

Name	Distance and direction from new well (m)	Max. pumping rate $= P_{max}$ (l/s)	Hours pumping per day = H	Mean net yield (l/s) $= \frac{H \times P_{max}}{24}$
Total net yield (l/s), excluding new well $= T_{ex}$				
Abstraction density excluding new well $= D_{ex} = T_{ex}/28$ (l/s/km^2)				
Proposed new well	0 m			
Total net yield (l/s) including new well $= T_{in}$				
Abstraction density including new well $= D_{in} = T_{in}/28$ (l/s/km^2)				

If $D_{in} < 1$ l/s/km^2 the new well should not result in overabstraction
If $D_{ex} < 1$ l/s/km^2 but $D_{in} > 1$ l/s/km^2, the new well should only be constructed as a temporary measure, to be decommissioned after the drought
If $D_{ex} > 1$ l/s/km^2, the local aquifer may already be overabstracted and no new well should be built.

<u>Exceptions to the above guidelines can be made if local hydrogeological considerations or calculations suggest that the proposed abstraction will be sustainable</u>:

Responsible (name)................................ (signed)..

(date)...................... (organisation)............................

Appendix 7 – Water Quality and Irrigation

The following is downloaded from the Kansas Geological Survey web-site at:
http://www.kgs.ukans.edu/General/Geology/Sedgwick/gw07.html

Chemical Constituents in Relation to Irrigation

The following discussion of the suitability of water for irrigation use is adapted from Agriculture Handbook 60 of the U. S. Department of Agriculture (U. S. Salinity Laboratory Staff, 1954).

The development and maintenance of successful irrigation projects involve not only the supplying of irrigation water to the land but also the control of salt and alkali in the soil. The quality of irrigation water, irrigation practices, and drainage conditions are involved in salinity and alkali control. Soil that was originally non-saline and non-alkaline may develop saline and alkaline character if excessive soluble salts or exchangeable sodium are allowed to accumulate in the soil as the result of improper irrigation or soil-management practices, or inadequate drainage.

In areas of sufficient rainfall and ideal soil conditions the soluble salts originally present in the soil or added to the soil with water are carried downward by the water and ultimately reach the water table. The process of solution and transportation of soluble salts by water moving through the soil is called "leaching." If the amount of water applied to the soil is not in excess of the amount needed by plants, there will be no downward percolation of water below the root zone and mineral matter will accumulate at that level. Impermeable zones in the soil near the surface can retard the downward movement of water, resulting in water logging of the soil and deposition of salts. Unless drainage is adequate, attempts at leaching may not be successful, because leaching requires the free passage of water through and away from the root zone.

The characteristics of water for irrigation that seem to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other principal cations (magnesium, calcium, and potassium); (3) concentration of boron or other elements that may be toxic to plants; and (4) the bicarbonate concentration, under some conditions, as related to the concentration of calcium plus magnesium.

The total concentration of soluble salts in irrigation water can be adequately expressed in terms of electrical conductivity for purposes of diagnosis and classification. Electrical conductivity is a measure of the ability of the ionised inorganic salts in solution to conduct an electric current, and is usually expressed in microSiemens per centimetre (µS/cm) at 25° C. The electrical conductivity can be determined accurately in the laboratory, or an approximation of the electrical conductivity can be obtained by multiplying the total milliequivalents per litre (meq/l) of calcium, magnesium, sodium, and potassium by 100 (Appendix Table 7.1). In general, water having a conductivity below 750 microSiemens per centimetre is satisfactory for irrigation insofar as salt content is concerned, although salt-sensitive crops may be adversely affected by irrigation water having an electrical conductivity in the range of 250 to 750 microSiemens per centimetre. Water having a range of 750 to 2,250 microSiemens per centimetre is widely used, and satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water having a conductivity of more than 2,250 microSiemens per centimetre is not common, and very few instances can be cited where such waters have been used successfully.

Appendix Table 7.1 -Factors for converting parts per million (mg/l) of mineral constituents to milliequivalents per litre (meq/l).

Cation	**Conversion factor**	**Anion**	**Conversion factor**
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	0.0823	SO_4^{--}	0.0208
Na^+	0.0435	Cl^-	0.0282
		NO_3^-	0.0161
		F^-	0.0526

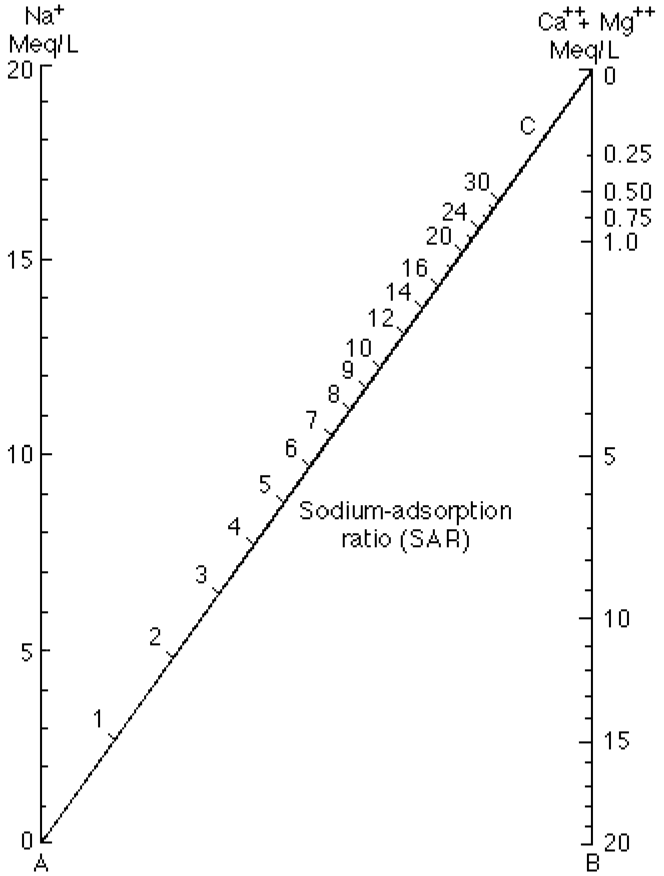
In the past, the relative proportion of sodium to other cations in irrigation water usually has been expressed simply as the percentage of sodium among the principal cations (expressed in meq/l)--the percent sodium, so called. According to the U. S. Department of Agriculture the sodium-adsorption ratio (SAR), used to express the relative activity of sodium ions in exchange reactions with soil, is a better measure of suitability of water for irrigation with respect to the sodium (alkali) hazard. The sodium-adsorption ratio may be determined by the formula

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}},$$

where the ionic concentrations are expressed in milliequivalents per litre.

The sodium-absorption ratio may be determined also by use of the nomogram shown in Appendix Figure 7.1. In using the nomogram to determine the sodium-absorption ratio of water, the concentration of sodium expressed in milliequivalents per litre is plotted on the left-hand scale, and the concentration of calcium plus magnesium expressed in milliequivalents per litre is plotted on the right-hand scale. The point at which a line connecting these two points intersects the scale for the sodium-absorption ratio indicates the sodium-adsorption ratio of the water. When the sodium-adsorption ratio and the electrical conductivity of a water are known, the classification of the water for irrigation can be determined by plotting these on the diagram shown in Appendix Figure 7.2.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of developing harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils, especially poorly leached soils. Such water may be used safely on coarse-textured or organic soils having good permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage and leaching and addition of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.



Appendix Figure 7.1 - Nomogram for determining sodium-adsorption ratio of water.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops of moderate salt tolerance can be irrigated with C2 water without special practices. High-sanity water (C3) cannot be used on soils of restricted drainage. Very high salinity water (C4) is not suitable for irrigation water under ordinary circumstances. It can be used only on crops that are very tolerant of salt and then only if special practices are followed, including the provision for a high degree of leaching.

Boron is essential to normal plant growth, but the quantity required is very small, and large quantities are harmful. Crops vary greatly in their boron tolerance, but, in general, crops ordinarily grown in Kansas are not adversely affected by boron concentrations of less than 1 ppm.

In water having a high concentration of bicarbonate, there is a tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated as a result of evaporation and plant transpiration. This reaction ordinarily does not go to completion, but when it does, there is a reduction in the concentration of calcium and magnesium, and, therefore, a relative increase in sodium. The calcium and magnesium are precipitated as carbonates, and any residual carbonate or bicarbonate is left in solution as sodium carbonate. The potential amount of such residual sodium carbonate may be computed

$(Na_2CO_3) = (CO_3^{-} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$,

where the ionic concentrations are expressed as milliequivalents per litre.

On the basis of limited data and using the concept of residual sodium carbonate described above, the Department of Agriculture has concluded that water having more than 2.5 meq/l of residual sodium carbonate is not suitable for irrigation. Water containing 1.25 to 2.50 meq/l of residual sodium carbonate is marginal, and water containing less than 1.25 meq/l can be safely used for irrigation.

In appraising the quality of an irrigation water, first consideration must be given to salinity and alkali hazards by reference to Appendix Figure 7.2. Then consideration should be given to other characteristics such as content of boron and other toxic elements and of bicarbonate, any one of which may change the quality rating. The use of water of any quality must take into account such factors as drainage and management practices.

Appendix Figure 7.2 - Diagram showing suitability of water for irrigation. Points plotted on diagram are analyses from Sedgwick County, Kansas.