GROUNDWATER RESOURCES AND USE IN THE UPPER WATERSHEDS AREA OF THE SYR DAR'YA AND AMU DAR'YA CATCHMENTS OF THE CENTRAL ASIAN REPUBLICS

Short-term Hydrogeological Consultancy to Sub-Project 7 of EU TACIS Programme: Water Resources Management and Agricultural Production in the Central Asian Republics
(WARMAP Project)

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LIST OF ABBREVIATIONS/UNITS

l/s	litres per second
m/a	metres per year
mm/a	millimetres per year
MCM/a	million cubic metres per year
tcmd	thousand cubic metres per year
mg/l	milligrammes per litre
mmole/l	millimoles per litre
g/l	grammes per litre
CIS	Commonwealth of Independent States
TACIS	Technical Assistance Programme to the Commonwealth of Independent States and Georgia
WARMAP	European Union Water Resources Management and Agricultural Production Programme in the Central Asian Republics
Oblast	Administrative province, divided into *Raion* (regions)

EXECUTIVE SUMMARY

This consultancy reports on the groundwater resources, current utilisation and some water quality issues in the upper watersheds project area of the Syr Dar'ya and Amu Dar'ya rivers. Data were collated with the assistance of national agencies in the Republics of Kyrgyzstan, Tajikistan and Uzbekistan. Practically all groundwater development is centred on unconsolidated Quaternary and Pliocene river valley, piedmont alluvial fan and intermontaine basin deposits. Although the complex solid geology serves an important role as adjacent recharge hinterland, most of the aquifers are located in arid to semi-arid zones, across which flow rives fed by rainfall, snow-melt or glacier-melt in the upper high mountain catchments. The hydrogeological setting therefore comprises local lateral recharge combined with inflows from rivers and canal/field irrigation systems in hydraulic connection with underlying aquifers.

There are no reports of over-abstraction at present development levels. The principal threats to the groundwater resource lie in Man's activities, and point-source pollution problems associated with urbanisation, industrial, mining and mineral processing plants have been noted. Although irrigation is by volume the main consumer of groundwater, its use for public supply is universal, most urban areas, provincial towns and many rural communities relying exclusively on this source of domestic and drinking water supply. Consequently protection of aquifers used for public supply is vital both for public health and economic reasons. Proposals are made for technical cooperation on groundwater protection, data management and water/wastewater licensing issues as part of Phase 2 of the present TACIS WARMAP programme.

1. INTRODUCTION

1.1 Background-The Problem

The Aral Sea Basin,a huge inland-draining lake system located in the desert areas of Central Asia, is centred on the Aral Sea, which was the world's fourth largest lake in area in 1960. The sea and its surrounding delta areas are suffering a major man-made environmental catastrophe because inflows from its two main river systems, the Amu Dar'ya and Syr Dar'ya have drastically diminished as a result of expanded irrigation water use, principally in the lower reaches of both river systems. Between 1960 and 1993 the sea's level declined at an average rate of 0.5 m/a, causing a reduction in surface area of nearly 50% and in volume of over 70% [1]. The reduction in inflow has led not only to the loss of productive fisheries due to a major and continuing increase in the Aral's salinity, from 10 to over 30 g/l, but also the demise of a regionally significant navigation and marine transportation system. The effects have been devastating on the ecologically and economically important wetlands of the two delta systems where it is estimated that 85% had disappeared by the late 1980's due to desiccation and subsequent desertification. A variety of serious public health problems have been reported in the areas adjacent to the Aral associated either directly with the increase in wind-blown salt and dust or with poor water supply and sanitation infrastructure in the irrigated areas [1].

83% of the Aral Sea's drainage basin of 1,800,000 km² is located in the five CIS Central Asian republics of Uzbekistan, Kazakhstan, Kyrgyzstan, Turkmenistan and Tajikistan (hereafter called the five basin states) and the remainder in Afghanistan and Iran. Recent assessments of the predicament of the Aral Sea and its surrounding areas have led to the recognition that the problems are manifestations of catchment-wide water resource management problems affecting all five basin states. This has prompted a number of political initiatives which have included:

- the signing by all five basin states in February 1992 of an agreement on the joint management and protection of interstate water resources
- the signing by all five states in May 1993 of a 10-year agreement on cooperative efforts to improve the Aral region
- the forging of international links with developed countries and requests to multinational organisations for help with Aral Sea problems

The Water Resources Management and Agricultural Production Programme in the Central Asian Republics (WARMAP), which is part of the EU-financed Technical Assistance Programme to the Commonwealth of Independent States and Georgia (TACIS), is one such project directed at identifying problems in the basin as a whole. More details on the objectives and structure of the WARMAP Programme, which includes sub-projects throughout the five-state basin area, can be found in Reference [II].

1.2 Terms of Reference

The information referred to in this report was collected as Task 6 of Sub-Project 7, whose general objective is to draw up proposals for mitigation of the numerous environmental, economic and human health problems that occur in the upper watersheds of the Amu Dar'ya and Syr Dar'ya catchments. The expected outputs of the Sub-Project comprise the collation and preliminary assessment of data on a number of environment and economic indicators and a set of proposals for a second phase to provide appropriate and sustainable measures and guidelines that can improve the management of the natural and anthropogenic systems at both national and regional levels. The terms of reference both for Sub-Project 7 and for this specific input on groundwater resources and utilisation are set out in Appendices 1A and 1B respectively.

Groundwater information was being collated prior to and during the visit by local professionals from the principal hydrogeological institutes in Uzbekistan (Uzbekgidrogeologia Corporation) and Kyrgyzstan (Kyrgyzgidrogeologia Survey), and this report concentrates on data and meetings from those two republics. It was not possible to establish contact with the Tajik counterpart organisation at the time of the visit as political unrest in and around Dushanbe prevented effective contact and any field visits by any project staff to Tajikistan Republic. However some groundwater data has been collated and provided under the coordination of the Tajikistan Hydrometeorologival Service. Only a small part of the upper watersheds lies in Kazakhstan Republic (c.5 % of one *Oblast*), and for many purposes it can be regarded as an adjunct to Tashkent *Oblast*. Some information is provided from the published hydrogeological map of the Republic. A contact name and institute is given in the list of information sources for future reference.

2. BRIEF DESCRIPTION OF SUB-PROJECT 7 STUDY AREA

2.1 Physiography

The upper watersheds area of Sub-Project 7 has been defined for project purposes both topographically and meteorologically. It comprises all land above 800m. in the Amu Dar'ya and Syr Dar'ya river catchments, approximately coinciding with the 50% snowfall probability line. However physiographically the area contains a number of intermontaine basins of which the most important is the Fergana Valley (Figure 2.1), and several of these have a lower elevation than 800m. The project area of approximately ...... km² encompasses all of the territory of Tajikistan, much of Kyrgyzstan and significant upland areas of eastern Uzbekistan and southern Kazakhstan. It is edged to the west and north by the desert steppes of the Turan lowlands. At the time of the

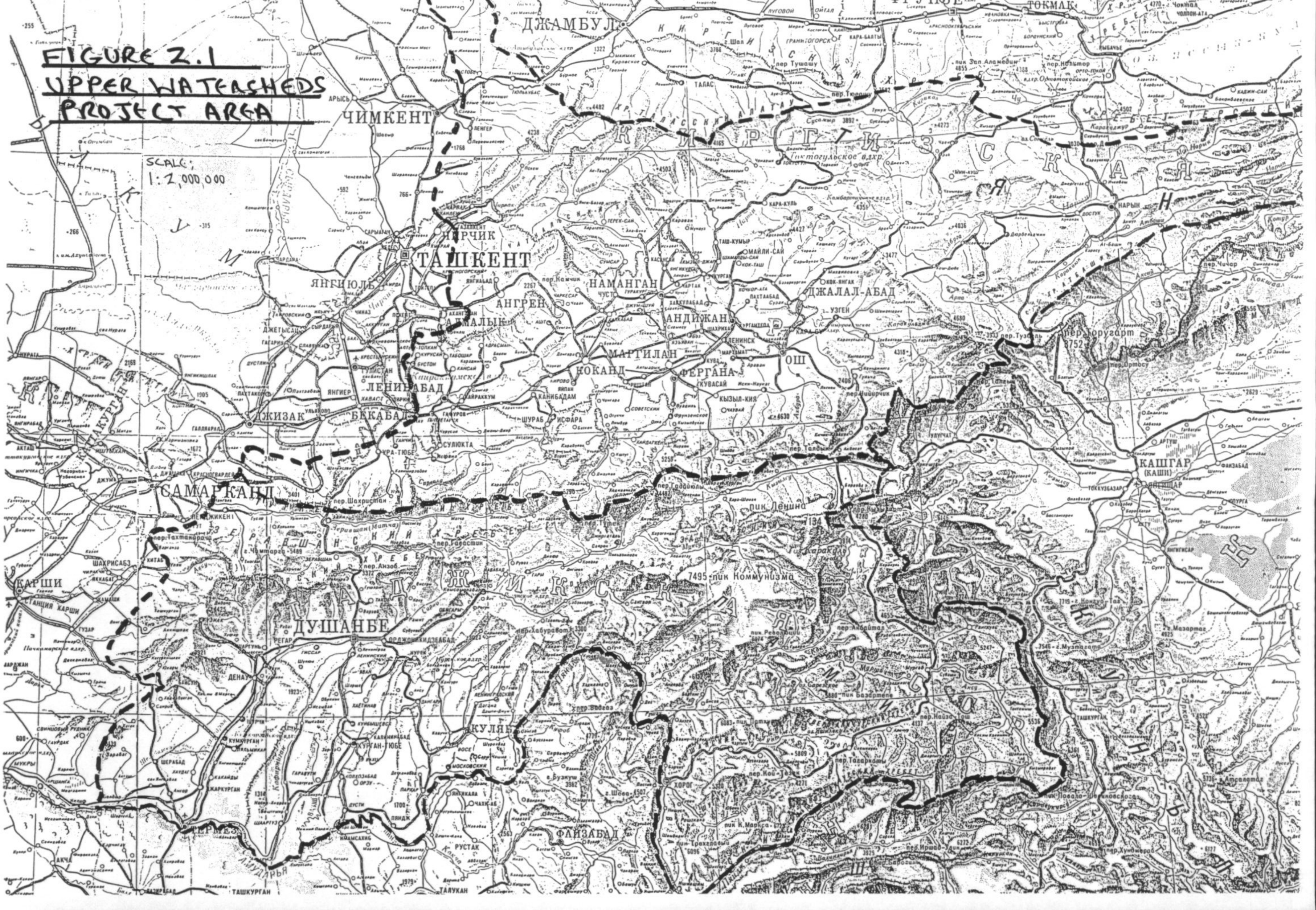


FIGURE 2.1
UPPER WATERSHEDS
PROJECT AREA
SCALE:
1:2,000,000
ДЖАМБУЛ
ТОКМАК
ЧИМКЕНТ
ТАШКЕНТ
ЧИРЧИК
ЯНГИЮЛЬ
АНГРЕН
АЛМАЛЫК
НАМАНГАН
АНДИЖАН
ДЖАЛАЛ-АБАД
МАРГИЛАН
ФЕРГАНА
КОКАНД
ОШ
ЛЕНИНАБАД
БЕКАБАД
ДЖИЗАК
САМАРКАНД
КАРШИ
ДУШАНБЕ
КУЛЯБ
КУРГАН-ТЮБЕ
ТЕРМЕЗ
ФАЙЗАБАД
НАРЫН
КАШГАР
(КАШИ)
пик Ленина
7495 пик Коммунизма
ТАЛАС
ТАШКУРГАН
ХОРОГ

visit, comparative maps of the upper watersheds project area and administrative boundaries were still in preparation, but an approximate indication of the main *Oblasts* concerned in each Republic is shown in Table 2.1.

TABLE 2.1 Administrative provinces (*Oblast*) within Sub-Project 7's area

Republic	*Oblast*	Reference Number	Approx. % *Oblast* within project area
Uzbekistan	Tashkent	511	60%
	Namangan	506	100%
	Andijan	502	100%
	Fergana	512	100%
	Djizak	504	10%
	Kashkadarya	505	30%
	Surkandarya	509	95%
Kyrgyzstan	Chiu	-	15%
	Issyk-Kul	-	15%
	Narin	201	70%
	Djalal-Abad	203	100%
	Osh	202	100%
Kazakhstan	South Kazakhstan	101	5%
Tajikistan	Leninabad	301	100%
	Hatlon	302	100%
	Rejon	303	100%
	Badashan	304	100%

Note: very limited areas (<5%) of the *Oblasts* of Syr Dar'ya and Samarkand (Uzbekistan) and of Talas and Issyk-Kul (Kyrgyzstan) are also located within Sub-Project 7's area

2.2 Climate

General information on climate, soils, land-use, agricultural production, water pollution and water-related public health issues was still being collated at the time of the visit. The amount and distribution of precipitation in the project area is likely to be extremely variable, as the region encompasses intermontaine plains (such as Fergana), valleys (such as the Chirchik and Narin valleys) and piedmont areas, together with both the foothills and main massifs of a number of important mountain ranges, including the Tien Shan, Pamir, Kyrgyz, and Zerafshan Ranges. Both elevation and rain-shadow effects will be important in such varied relief. However precipitation as snowfall or rain even in the high ranges is not great; annual values are less than 600 mm/a over more than 75% of the area of Kyrgyzstan for instance (Figure 2.2), and much of the project area is likely to have annual rainfall in the range 150-600 mm/a. Certainly most of valley axes and intermontaine plains are arid or semi-arid. Figure 2.3 from a companion project report [Reference III] shows mean monthly rainfall and potential evapotranspiration 1881-1980 for Fergana, a central station in the main intermontaine plain. Potential evaporation exceeds rainfall for 10 months of the year, and even in January and February, with precipitation values less than 25mm/month, the availability of excess rainfall for recharge or runoff is likely to be small in the intermontaine basins and lower river valleys themselves, where rain-shadow effects are pronounced. Precipitation is greater at higher elevations; the ranges of 1500-4000m in Djalal-Abad and eastern Osh in Kyrgyzstan and in western Surkandariya for instance receive more than 800mm/a rain and snowfall.

3. GEOLOGY & HYDROGEOLOGY

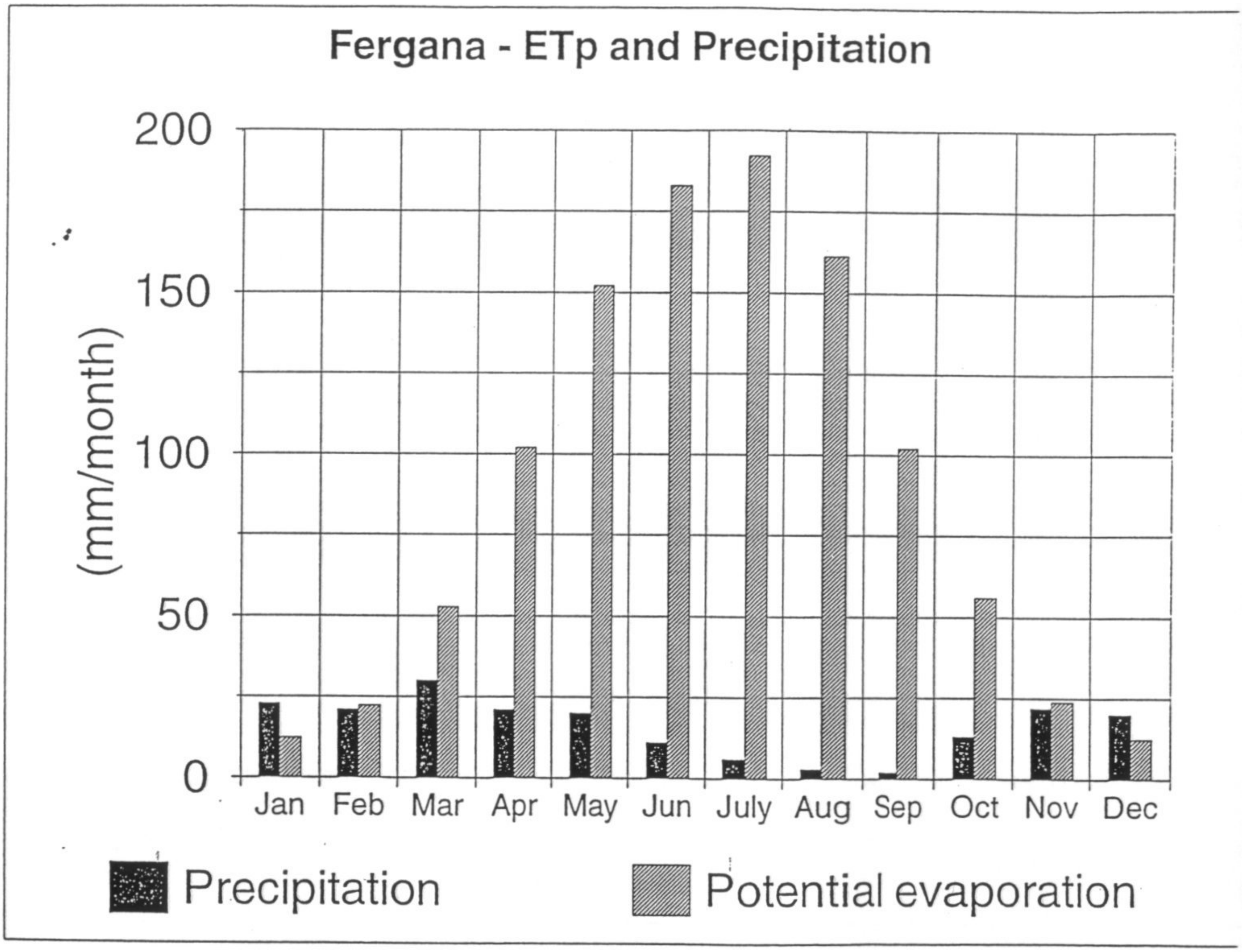
3.1 Geology

The project area has an extremely complex geology, encompassing as it does much of one of the world's most important orogenic belts. Rocks are present at outcrop from the entire stratigraphic column, from Proterozoic to Quaternary. Intensely folded and faulted cordillera of Lower Palaeozoic rocks characterise most of the high cordillera in Kyrgyzstan, south Kazakhstan and eastern Uzbekistan. The cores of a number of anticlinal ranges and anticlinoria for instance form the massifs of the Tien Shan and Zerafshan ranges, In northern Kyrgyzstan. the Kyrgyz mountains represent an extensive area of migmatisation and igneous intrusion which stretches eastward from Djalal-Aabad *Oblast* south of Lake Issyk-Kul towards the Tien Shan. Metamorphism of the shales, siltstones, sandstones, conglomerates, marls and limestones in the succession has occurred during successive orogenies.

Formations of Mesozoic age occur on the flanks of the major anticlinal systems, and Cretaceous and Jurassic rocks outcrop extensively in Osh and Namangan/Andijan/Fergana *Oblast* around and

FIG 1

FIGURE 2.3.



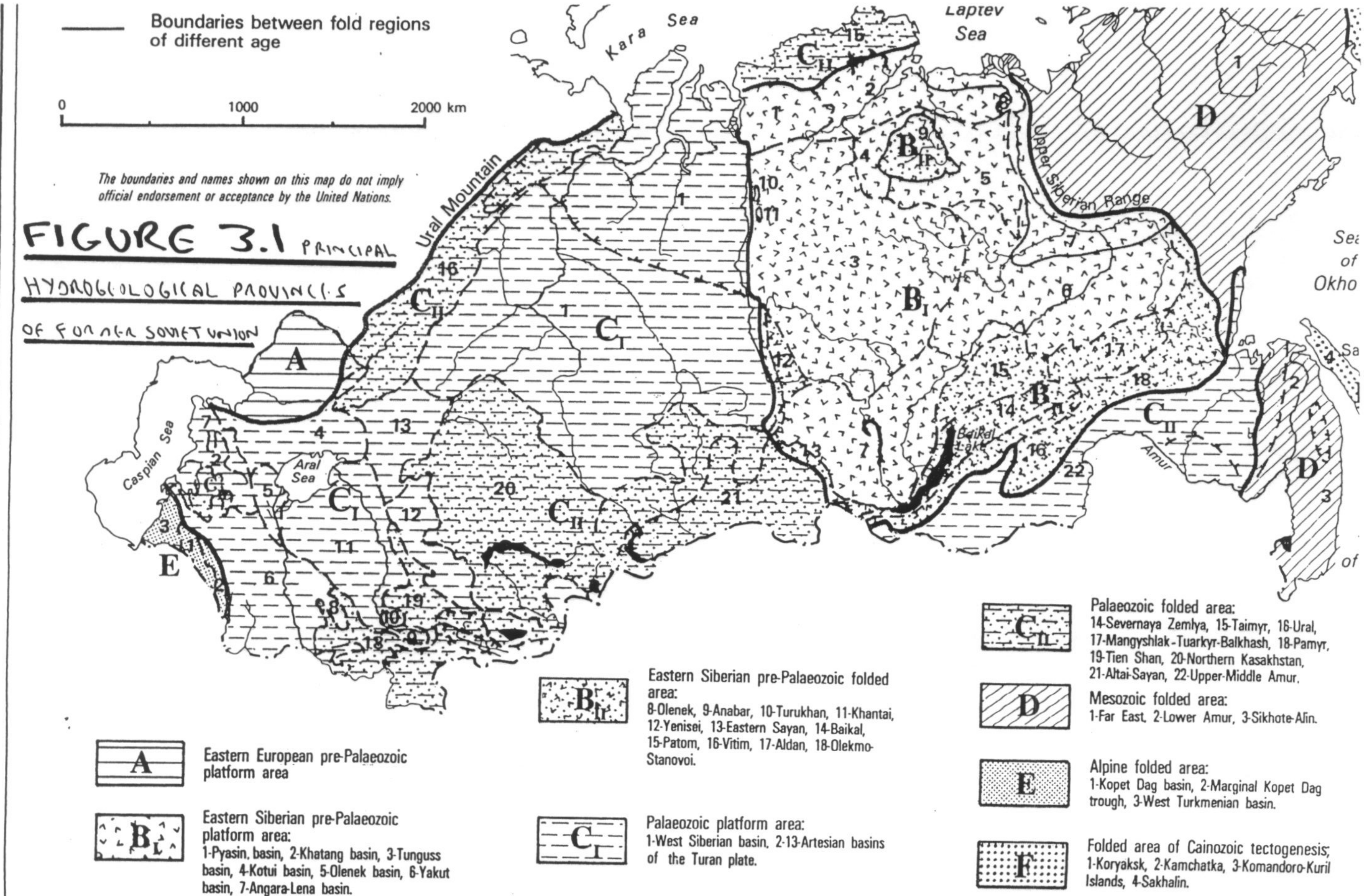


FIGURE 3.1 PRINCIPAL HYDROGEOLOGICAL PROVINCES OF FORMER SOVIET UNION

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MAY 1985

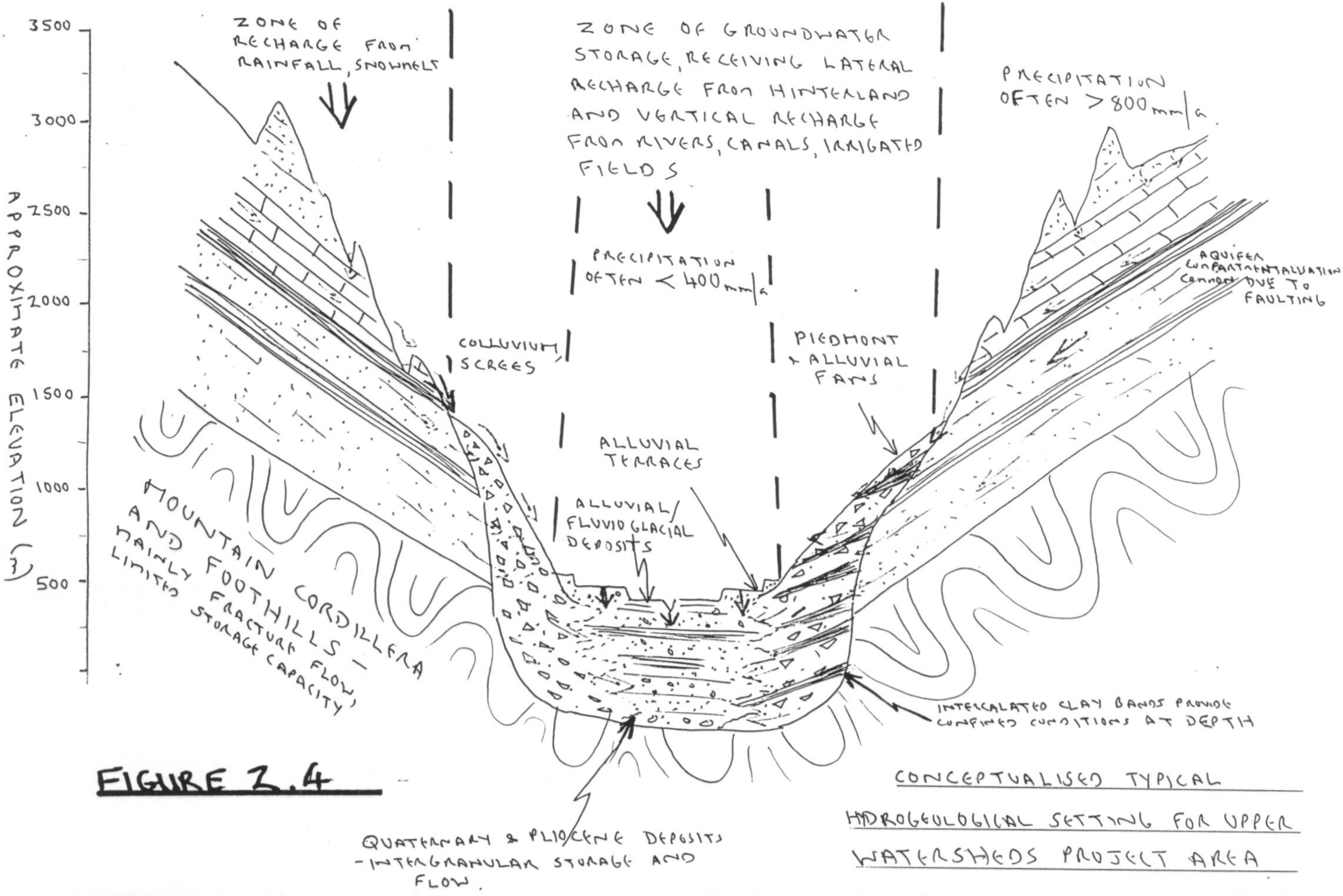


FIGURE 3.4

CONCEPTUALISED TYPICAL HYDROGEOLOGICAL SETTING FOR UPPER WATERSHEDS PROJECT AREA to the east of the Fergana valley.

The lower slopes and valleys of the entire region are characterised by Quaternary and Pliocene alluvial and fluvioglacial deposits, which form valley fills, intermontaine basins and coalescing piedmont alluvial/colluvial fans. These unconsolidated deposits are typically heterogeneous, with grain sizes ranging from cobbly fanglomerates through pebble beds, gravels, sands, some silts to clays, the latter being discontinuous but fulfilling an important role as confining/semi-confining beds. Minor silty loessic beds of eolian origin are also present. In the upper valleys, these alluvial and fluvioglacial deposits can be extremely thick, due to glacial overdeepening and subsequent deposition (eg >400m in the Chirchik valley, Ref IX).

More detail than this rudimentary summary of such a geologically complex region can be found in Refs IV, VIII and IX.

3.2 Regional hydrogeological setting

The entire project area is located in the Palaeozoic fold region of Central Asia, which has been classified as one of the principal hydrogeological provinces of the Asian part of the former Soviet Union [Figure 3.1, Ref VIII]. While the geology is extremely complex, the hydrogeology can be simplified into two main units, (a) the mountain cordilleras and flanking foothills and (b) intermontaine basins, river valleys and piedmont alluvial/colluvial fans. Figure 2.4. is a sketch section typifying the groundwater system and flow/recharge components in the upper watersheds project area.

3.2.1 Mountain cordilleras and foothills:

This unit comprises all consolidated rocks flanking and underlying unit (b) and includes formations from upper Mid-Tertiary to Proterozoic age, metasediments and metavolcanics and all igneous rocks. Although the group comprises a wide variety of different rock types, from karstic limestones through porous sandstones to dense metamorphics and igneous intrusions, their hydrogeological role is similar because their occurrence at the higher elevations, topography and the land-use at these altitudes together make them the precipitation recharge zones for all fresh groundwater. The most favourable conditions for recharge are cited [Refs. IX, XI, XII] to occur between the elevations of 1500-3500m, where precipitation, either as rainfall or snowfall is at a maximum. Cited equivalent recharge values in this zone for Uzbekistan range from up to 375 mm/a in limestones, 250-280 mm/a in older sedimentary or fractured igneous formations, 95-155 mm/a in metasediments down to 30-95 mm/a in Mesozoic or younger sediments [Ref IX].

These values appear to be on the high side considering both the precipitation/evapotranspiration regime and the likely significant runoff component of effective rainfall from steep mountain slopes. However, a field visit to the small mountain catchment of Little Chimgan in the Chirchik valley did lend support to some of these figures. The catchment, located about 10 km south of the Charvak Reservoir, has an area of about 35-40 km^2 and comprises bedded limestones against a granitic intrusion, with the former predominating (see Photo Figures 2.5A,B). The catchment ranges from about 1400m to 3300m, and the entirely spring-fed stream[1] draining the catchment had a baseflow at the time of the visit (23 July, considerably post-snowmelt, no antecedent rainfall for at least 15 days) of about 450 l/s. This equates to around 11-13 l/s/km^2 or 345-410mm/a although no information is available on the spring recession during the remaining half of the dry season..

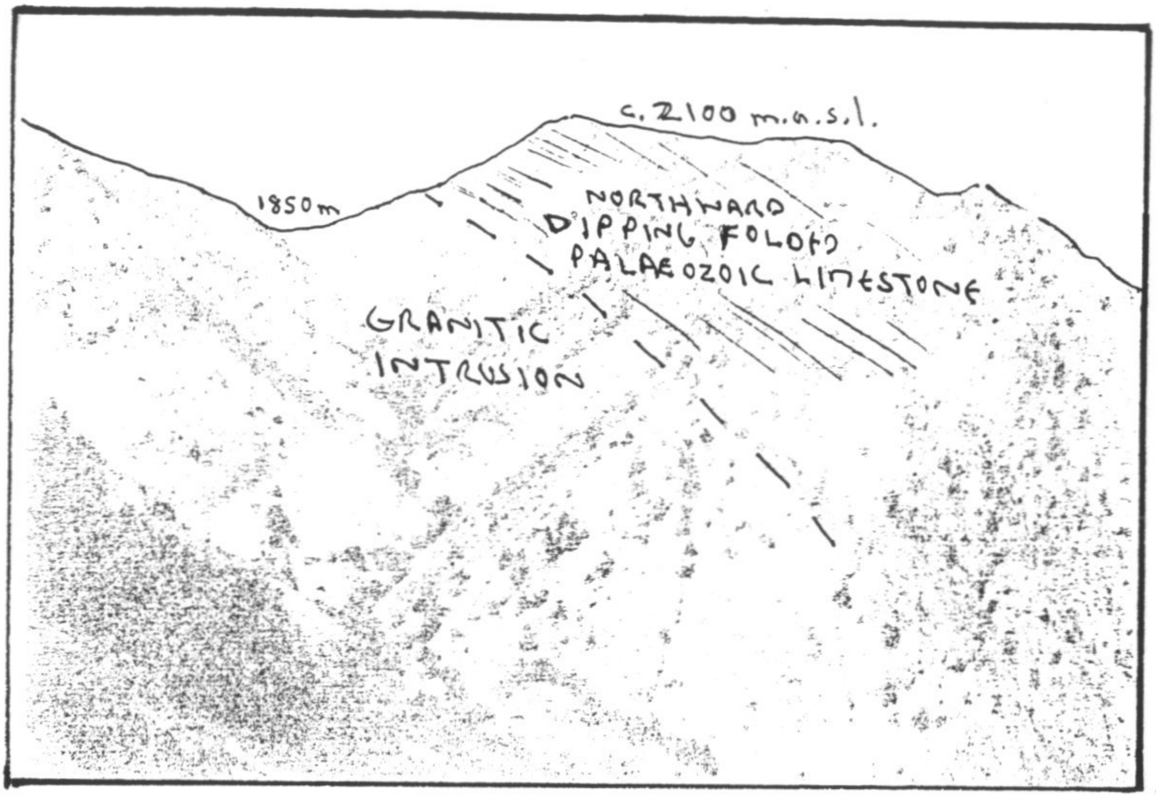
Analysis of mean monthly springflow histograms which have been used to identify the intake area of a number of spring-fed mountain streams [Refs XI, XII] confirm the general mechanisms and role of these formations in the groundwater recharge regime. The highest (glacial melt) recharge areas (at 3200-3500m) have a later peak flow period than snow-melt (2,500-3,200m) and rainfall/snow-melt (<2500m) altitude/aspect zones; these peak in March/April, May/June and June/August respectively. For the larger sub-catchments of the Syr Dar'ya, this would (in a natural flow regime, uninfluenced by irrigation system withdrawals) have the combined effect of flattening and extending the baseflow recession as the river emerged from its upper catchment. Thus rivers draining the high cordilleras provide extensive opportunities for groundwater recharge throughout much of the summer as well as during the autumn rainfall period.

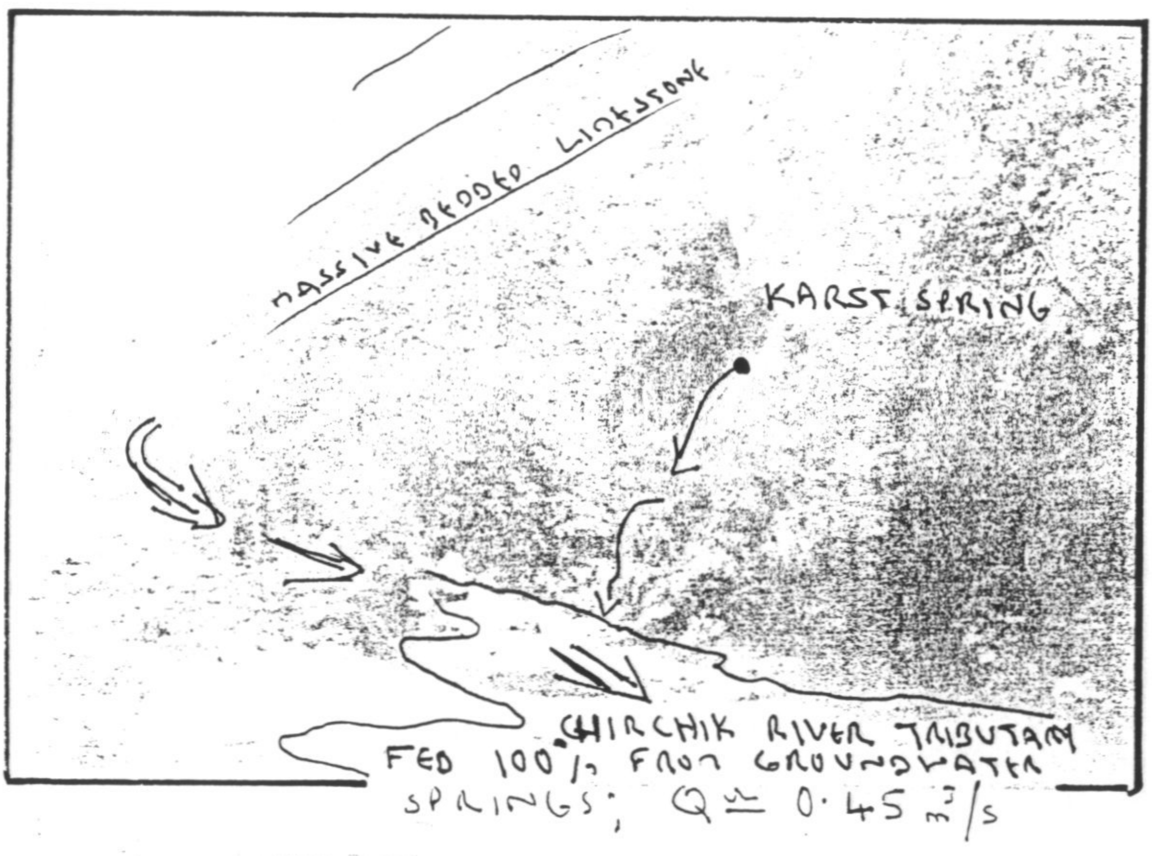
In some karstic terrains and in zones heavily dislocated by faulting, it is reported that spring flows can be significant; exceptionally yields of 2,000-3,000 l/s have been reported from karst springs in Narin basin in Kyrgyzstan and of 5-20 l/s elsewhere from fracture zones. It is also possible that in some layered permeable formations deep circulation systems may contribute groundwater to the unconsolidated aquifers at lower elevations by upward leakage. In Tajikistan, Cretaceous/U.Tertiary sandstones and limestones in the northern part of Leninabad *Oblast* are cited as one of the 30 principal aquifer systems of the republic.

3.2.2 Intermontaine basins, river valleys and piedmont alluvial/colluvial fans:

This unit comprises all lower slope unconsolidated or poorly consolidated/cemented alluvial, fluvioglacial glaciolacustrine and eolian deposits (Photo Figures 2.6 A,B,C). Deposits are generally Quaternary to Pliocene in age, and occur in a number of geomorphologically distinct

[1]A water sample taken from high-level limestone spring in this catchment had a measured electrical conductivity (SEC) of 185μS/cm^2, equivalent to a total dissolved solids content of about 130 mg/l


c. 2100 m.a.s.l.
1850m
NORTHWARD DIPPING FOLDED PALAEOZOIC LIMESTONE
GRANITIC INTRUSION


MASSIVE BEDDED LIMESTONE
KARST SPRING
CHIRCHIK RIVER TRIBUTARY
FED 100% FROM GROUNDWATER
SPRINGS; Q ≃ 0.45 m³/s

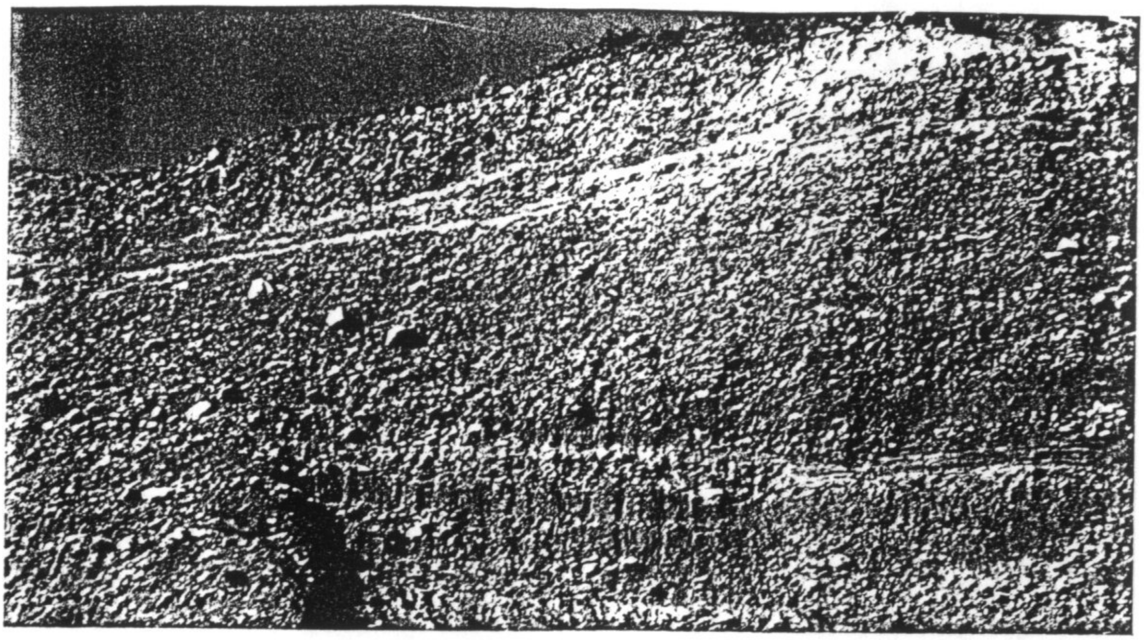


FIGURE 2.6.C

UNSATURATED ZONE OF VALLEY RIVER DEPOSITS, CHIRCHIK

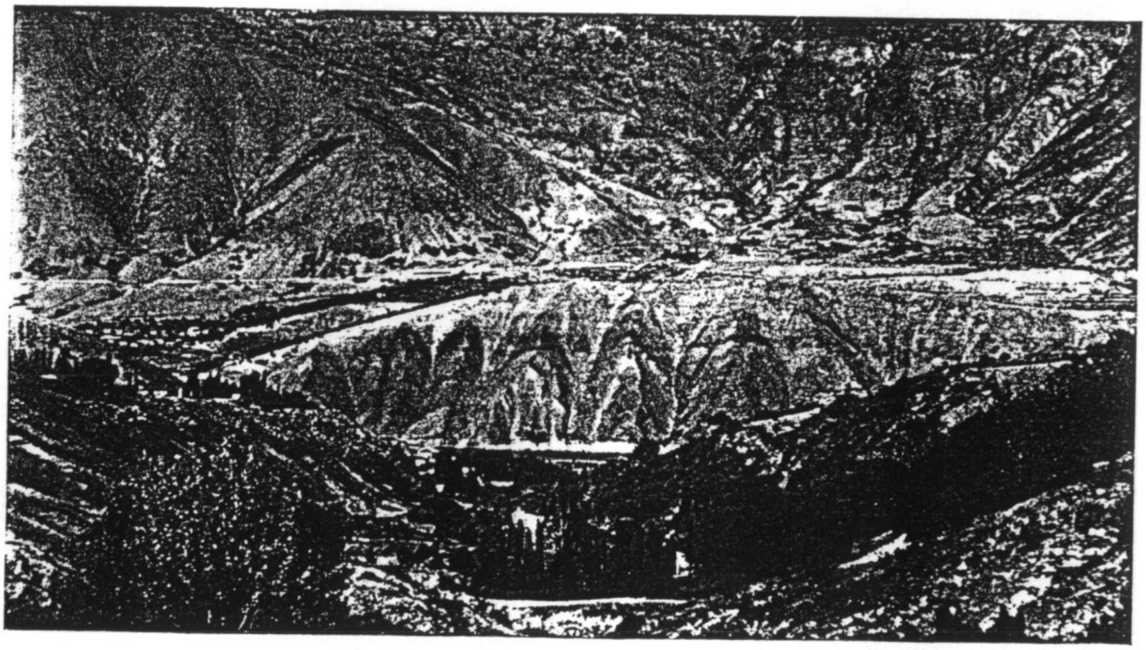


FIGURE 2.6.B

COALESCING PIEDMUNT ALLUVIAL FANS, CHIRCHIK VALLEY

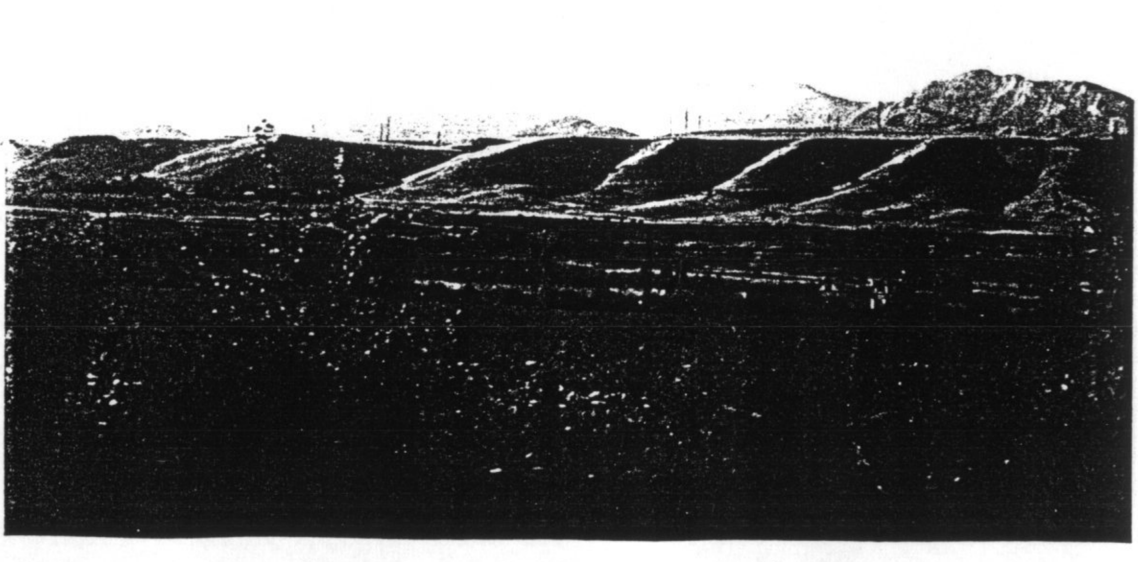


FIGURE 2.6A

INTERMUNTAINE BASIN RIVER TERRACE DEPOSITS, CHIRCHIK.

depositional environments. These include sinuous river valley alluvium, intermontaine tectonic or sedimentary basins, foothill or mountain front alluvial fans, fluvio-glacial eskers, glacial moraines, colluvium, coarse glacial lake deposits and wind-accumulated loess. Their location at low altitude, in arid or semi-arid climatic conditions, their frequently coarse granulometry, their often high effective porosity and their thickness combine to provide them with the role of storage medium. These formations accept either lateral recharge as spring flow or runoff from adjacent (or underlying) consolidated rock formation or vertical recharge as seepage from rivers/canals or over-irrigated field systems. The volume of such deposits is not known, but an indication of their relative importance can be assessed from Figure 2.7 which is derived from the hydrogeological map of Kyrgyzstan. The cumulative area of Quaternary and Pliocene fresh groundwater-bearing deposits in the republic estimated to be nationally close to 40,000 km², of which perhaps 40% is considered irrigable.

In some valleys where glacial deepening has occurred, these deposits can be deep, 100-300m thick. The Pskent area of the Upper Chirchik basin for instance has artesian and semi-artesian alluvial/fluvioglacial aquifers at 200-400m depth. So although the lateral width of the Quaternary aquifer system can be quite limited away from major intermontaine basins such as the Fergana and the Narim valleys, saturated aquifer volumes can still be significant.

Quaternary and Pliocene formations are regarded as the principal exploitable aquifers throughout the upper watersheds of the Syr Dar'ya and Amu Dar'ya basins, being cited exclusively in Uzbekistan and Kyrgyzstan and with only one exception in Tajikistan.

Both confined and unconfined conditions are encountered, but it seems likely that in many locations the Quaternary aquifer is lens-like, with semi-unconfined and semi-confined conditions occurring due to lateral impersistence of confining clay beds or mudflow/lahar intercalations. The system is reported to be prolific, with yields of up to 100 l/s and specific capacities of up to 50 l/s/m.

It is reported, and was widely considered during meetings and interviews that bed leakage from rivers/canals and irrigation field losses contribute importantly to recharge, alongside that from snowmelt streams and lateral inflow. This is a key feature of the groundwater system and should be considered alongside the observation that there is no evidence from the monitoring systems in Kygyzstan, Tajikistan or easternmost Uzbekistan of declining water levels in either the Syr Dar'ya or Amu Dar'ya basins due to over-abstraction. The latter point was made by Dr Tolstihin and Dr Tarasenko (Chief Hydrogeologist and Chief Geologist at the Kyrgyzstan Hydrogeological Survey), in the 1991 review report on groundwater in Kyrgyzstan [X] and in the project local specialist review for Tajikistan.

More descriptive detail is given in Refs V, VII, VIII and IX, and a part translation of the features most salient in the upper watersheds is provided in Appendix U.

4. GROUNDWATER RESOURCES AND THEIR PRESENT UTILISATION

Data on the present status of groundwater development in Uzbekistan, Kyrgyzstan and Tajikistan were collated by staff at Uzbekgidrogeologia Corporation, Kyrgyzstan Hydrogeological Survey and Tajik Hydrometeorological Service respectively. These data are provided in detail as Appendix sets U, K and T. Here only selected information fro the tables is quoted to provide an overview on the status of groundwater development in the upper watersheds of these three basin republics.

4.1 Soviet resource classification system

It may be useful first however to describe the resource classification which was adopted under the Soviet system, which continues as a standard method, and which is rather different from that utilised in Western Europe. There are 4 classes in the system; A, B, C1 and C2, in decreasing order of certainty;

A: This is the quantity at which pilot or production wells have been tested. A typical array would have both pumping and observation wells, and there would be a constant rate pumping test of c.6 days duration. A comprehensive file of well information (on aquifer type, thickness, lithology, static water level, screened section, pumping test results etc) is usually available. These are used to evaluate aquifer characteristics (transmissivity, storage coefficient, leakage, boundary conditions) and, together with results of physico-chemical water analysis, an abstraction regime for development is designed. There is a high degree of confidence in the cited resource volume, which would be analogous to the 'safe yield' in Western Europe.

B: This is the yield from a number of similar wells in the same area, and the aquifer and well characteristics are studied less precisely, often by extrapolation or interpolation from nearby test wells. There is no definite relationship between A and B, but the latter is typically 50% of the former. Together A and B are regarded as proven or certified resources.

C1: The C1 value is less borehole-oriented, and comprises an estimate of the available resource in a more generalised sense. Aquifer discharges are approximated by testing or extrapolation and techniques may include the Darcy equation to estimate flow through

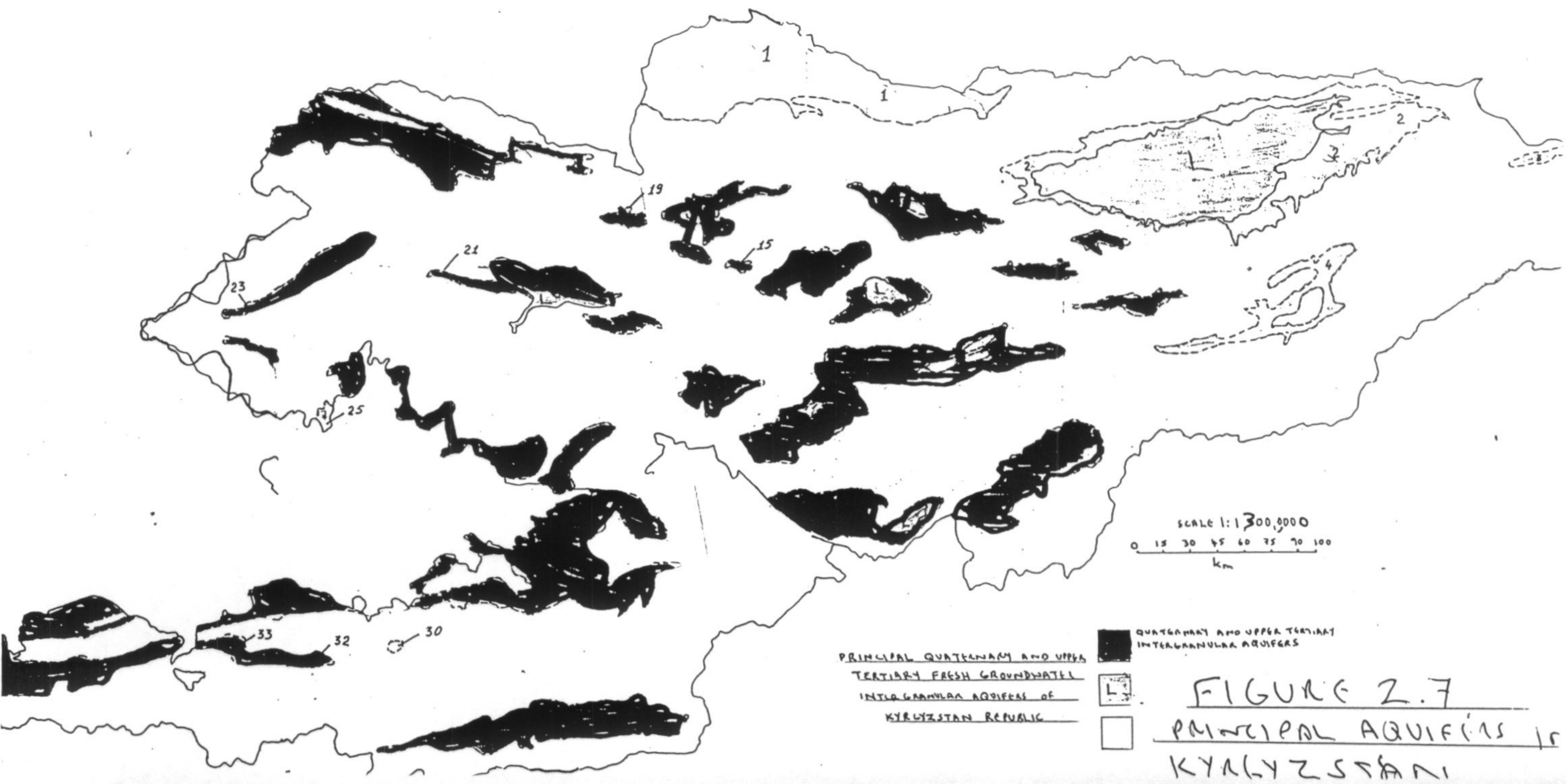


FIGURE 2.7
PRINCIPAL AQUIFERS IN KYRGYZSTAN

aquifer cross-sections. Water quality is assessed but not in respect of its stability over time. Groundwater abstraction is estimated by analogy with similar areas. C1 class can be regarded as having been assessed but not in detail.

C2: This is the least certain resource volume, and is used for reconnaissance-level estimation purposes where there are only limited field data available. Hydrologic, meteorologic or geologic approximations are employed eg estimates of permeability based on probable average grain size, effective rainfall from precipitation minus pan evaporation. The water quality is assessed on the basis of single samples. The values of A+B+C1 are deducted from the calculation and the balance is called C2 *ie* A+B+C1+C2=ΣReserves.

This classification is very practical for aquifer development purposes, but some care is needed in interpreting the resultant totals for total resource estimation, as the global figure will include both A and C2 values with their widely different degrees of confidence and precision.

4.2 Resources and current use in Kyrgyzstan Republic

See Appendix Tables K1-K3 which refer to the 3 Oblasts corresponding principally with the Syr Dar'ya basin. Certified (A+B), assessed (C1) and estimated (C2) resources in 1994 in the 11 principal Quaternary river valley, intermontaine basin or alluvial fan aquifer systems amount to about 690-700 MCM/a, depending on the data table used, which compares with a national total for 1991 of about 1865 MCM/a. Most of the balance is likely to be located in the extensive Chiu piedmont and alluvial plain aquifer around Bishkek, located outside and north of the Syr Dar'ya Basin. There are several features of note in the water resource and utilisation statistics;

(i) Of the 690-700 MCM/a, about 80% is certified or assessed, so this resource assessment may be regarded as conservative. This is corroborated by 2 observations; (a) actual abstraction is 486 MCM/a of which only 263 MCM/a is certified and yet (b) the Kyrgyz Hydrogeological Survey confirmed that there are no reports of over-exploitation from any aquifer in Kyrgyzstan. However, it is equally important to note that much of the resilience of aquifer levels to abstraction is likely to be due to increased induced leakage from surface water sources, either naturally through river beds or via irrigation systems (canal and field losses). Future increases in abstraction would be reflected in commensurate reductions in baseflow where there is scope for bed leakage to replenish aquifer storage.

(ii) Only two out of every five wells in the project area have certified use

(iii) Almost 2200 boreholes are in operation by 580 users in the Syr Dar'ya basin. This compares with a national total in 1991 of 5864 [Ref X], so the Syr Dar'ya catchment encompasses around a third of all abstraction and a third of all the wells in Kyrgyzstan.

(iv) While arable irrigation is the prime user of groundwater by volume (50%), it is clear that one very important use of groundwater is public water supply, with 40% of all abstraction being used for this purpose.

It was not possible in the time available to quantify the relative importance of groundwater for domestic drinking water supply, other than in general terms, but some indication of its essential role can be made. Bishkek and all principal provincial towns are supplied from groundwater via boreholes or spring capture systems. About 35% of the 1994 national population of 4.5 million is urban (see Appendix table K4), so perhaps about 1.6 million urban dwellers depend for drinking water on groundwater supplies. Furthermore many rural dwellers in the Osh, Djalal-Abad and Chiu *Oblasts*, where two-thirds of the rural population is located, are also likely to depend on boreholes for drinking water purposes, because these areas are also where most of the groundwater irrigation is concentrated. Staff at the Krgyz Hydrogeological Survey estimated that perhaps 80% of the population of Kyrgyzstan depends on wells, springs or galleries for drinking water supply. This places a special quality demand on the aquifers used for potable purposes and makes protection of sources an important public health concern.

4.3 Resources and current use in Tajikistan Republic

These data are presented in Appendices T1-T3 and were collated during the latter part of July but it was not possible to discuss them with Tajik hydrogeologists as political unrest impeded travel to Dushanbe. 30 important aquifer systems are reported on, 29 of which are Quaternary unconsolidated deposits. Forecast resources, thought to be equivalent to the C1+C2 resource classification in use elsewhere in the project area, are estimated to total 8548 MCM/a, equivalent to about 70 m^3/s, of which 2,750 MCM/a (c.87 m^3/s) is listed as exploitable (thought to be equivalent to A+B classes). Actual abstraction (date of figures unknown) stands at 2086 MCM/a or 76% of exploitable reserves, and again no problems of local over-abstraction are cited.

It is notable that all 30 main aquifer systems provide groundwater for public supply (domestic and drinking water purposes) and in one third of cases that is cited as the principal use. Tajikistan's population in 1990 was 5.36 million, 31% of which is urban [Ref XIII]

4.4 Resources and current use in Uzbekistan Republic

Collated figures for Uzbekistan refer to the 7 *Oblasts* corresponding to the upper watersheds project area; these are in both the Syr Dar'ya and Amu Dar'ya basins, but it should be noted that

TABLES 4.1A,B: PRELIMINARY OVERVIEW OF GROUNDWATER RESOURCES, USE AND PUBLIC SUPPLY DEPENDENCY IN UPPER WATERSHEDS PROJECT AREA, SYR DAR'YA & AMU DAR'YA BASINS

COUNTRY	ESTIMATED GW RESOURCE MCM/a	A+B CLASS EXPLOITABLE RESOURCE MCM/a	C1+C2 RESOURCE MCM/a	ANNUAL ABSTRACTION MCM/a	RATIO OF A+B RESOURCE TO ABSTRACTION EXPRESSED AS % (3÷5*100%)	NO. OF WELLS IN OPERATION
1	2	3	4	5	6	7
KAZAKHSTAN	-	-	-	-	-	-
KYRGYZSTAN	702*	467	235	524	89	860
TAJIKISTAN	11,298	2,750	8,548	2,086	132	4243
UZBEKISTAN	4,625	2,731	1,894	4,148**	66	15240
TOTALS MCM/a	16,625	5,948	10,677	6758	88	20343

* Excludes uncertified resources ** excludes 7 lowland aquifer systems and 892 MCM/a abstraction for soil waterlogging prevention or drainage

COUNTRY	ESTIMATED ANNUAL VOLUME USED FOR PUBLIC SUPPLY MCM/a	% TOTAL ANNUAL GW ABSTRACTION USED FOR PUBLIC SUPPLY
KYRGYZSTAN	281	40%
UZBEKISTAN	1633	32%

substantial areas of Kashkadarya, Tashkent and especially Djizak *Oblasts* comprise lowland plains which are outside the project area. This has complicated the data collation, and Appendix Tables U1A,B although reproduced, should not be regarded as reliable indicators of reserves and use in the project area. Instead such data have been taken from Appendix Tables U2-U4, which catalogue details of the 37 main aquifer systems in the 7 *Oblasts*. A further refinement to the total figures excludes from the 37 systems 7 of those lowland plain aquifers which are clearly outside (west of) the project area; these are the deposits 23, 24, 26, 34, 35, 36 and 37. The collated Certified (A+B), assessed (C1) and estimated (C2) resources in 1994 in the remaining 30 aquifer systems are all located in Quaternary and Pliocene river valley, intermontaine basin or alluvial fan systems. According to the data supplied in Appendix U3 these together amount to 4625 MCM/a. (Note; there remain inconsistencies in the data supplied, as this global figure does not agree with the sum of used and not used resources in Appendix U4, the latter totalling 7061 MCM/a). Actual abstraction is assessed at 5040 and 5026 MCM/a in Appendices U2 and U3 respectively, of which 892 MCM/a consists of soil waterlogging prevention and drainage.

According to the data presented in Appendix U4, groundwater for public supply (domestic and drinking water) totals about 1633 MCM/a or 32% of all groundwater used, and it is again clear that groundwater plays a pivotal role in providing domestic and drinking water supply both to urban and rural communities. Table U6 sets out sources of public water supply for the major urban centres in eastern Uzbekistan. All 7 provincial capitals are entirely or predominantly groundwater dependent and almost 40% of the supply to Tashkent is similarly derived, so in these urban areas alone perhaps more than 2.1 million inhabitants rely on groundwater for domestic supply.

4.5 Upper watersheds resource overview

The data on groundwater reserves and actual abstraction has been collated in Tables 4.1A,B. to provide a summary of resources and current utilisation levels in the project area, but it must be stressed that the overview is no more than preliminary. Not only do the data include some areas outside the upper watersheds, and exclude other areas (eg the relevant sector of South Kazakhstan *Oblast*), but also there are internal inconsistencies in some of the tabulated data that need to be resolved. These *caveats* made, the tables indicate that estimated groundwater reserves (A+B+C1+C2) are of the order of 16,600.MCM/a, equivalent to about 527 m³/s, of which about 31% or c. 6,760 MCM/a is exploited. The pattern of use and the aquifer setting prompt a number of comments relevant to land and water management in the upper watersheds:

- While, by volume, the main use of groundwater is for irrigation, principally of field and orchard crops, there is clearly a very high dependence throughout Uzbekistan, Kyrgyzstan and Tajikistan on groundwater for domestic and drinking water supply. About a third of all groundwater pumped in Uzbekistan and Kyrgyzstan is used for this purpose, with a similar or higher figure likely for Tajikistan. The high socio-economic and public health value of this water use places a premium on the protection of quality and on the sustainability of aquifer production. The provision of alternative supplies would be inherently much more expensive, because for viable alternatives (more distant unpolluted aquifers/spring systems or treated river water) both substantial capital investment for the engineering works and higher maintenance costs for system operation would be involved.

- The nature of the principal aquifer system, the Quaternary and Pliocene deposits, will require sophisticated water resources management. It is widely reported that recharge for these aquifers, most of which are geographically limited by topography or geomorphology, is partly dependent on river and canal bed leakage and on infiltration of excess irrigation from field systems. The wide range of elevations of the catchments supplying summer flows provides a prolonged high baseflow period in many river tributaries to the Syr Dar'ya and Amu Dar'ya and so despite the aridity of the river valleys and the intermontaine plains, surface water is amply available for most of the year. This means that groundwater levels, especially in the phreatic aquifer systems, will be relatively insensitive to increased abstraction, because the resultant increased drawdowns will provide storage volume which will induce more leakage from surface water systems. This occurs both to shallow watertable aquifers and, more slowly by leakage, to deeper semi-unconfined systems where the hydraulic head permits. The compensatory leakage will affect summer baseflows because that also coincides with the peak demand for irrigation by groundwater. If a pattern of steadily increasing abstraction developed, the effect will be cumulative downstream

- Similarly, the effects of pollution of surface waters in this hydrogeological environment has an important bearing on groundwater quality. One of the advantages of abstraction from groundwater is that its quality is relatively stable compared to the frequent transient effects that characterise river abstractions. Even where there is hydraulic connection and bed leakage, such transients, often of only a few hours or days duration have little effect because of the large storage in intergranular groundwater aquifer systems. Equally though, any long-term deterioration in river water quality will eventually be reflected in any connected aquifers, and any such degradation will persist long after improvements to river quality have been attained.

- While it is important not to over-interpret the figures in Tables 4.1A,B due to their preliminary nature, it does appear that in the upper watersheds, at the present stage of groundwater development there is less exploitable groundwater resource available in Uzbekistan than in either Kyrgyzstan or Tajikistan. In Uzbekistan actual annual abstraction (excluding soil drainage areas) is already 50% greater than A+B 'safe yield' resources and is 90% of A+B+C1+C2 resources. This contrasts with Kyrgystan and Tajikistan, where current abstractions are much closer to, or within, the 'safe yield' resource estimates. Taking the upper watersheds project area as a whole, current total pumping is about 14% greater than combined A+B resource.

The combination of these three factors; high dependence on groundwater for public supply, current abstraction rates already larger than the A+B exploitable resource and strong surface water/groundwater interaction are likely to constrain the scope for substitution. of surface water resources by groundwater as a possible strategy option for resource reallocation at an international scale. There may however be opportunities for groundwater resource reallocation at a national level by internal agreements, for instance to safeguard the public health role of clean groundwater as a source of domestic and drinking water supply.

On a more general note, there is clearly much detailed information available from the hydrogeological survey departments, especially in Uzbekistan, where it is estimated that the two national monitoring networks jointly exceed 34,500 wells. The figures collected cover the fields of resource, evaluation, abstraction and water quality, and are so numerous as to be very difficult to use for surveillance or trend analysis, and impossible to collate for integrated river basin water management purposes. The Uzbekistan data for instance was collected from different sources and contained significant inconsistencies, which Uzbekgidrogeologia themselves acknowledge to be not uncommon. There appears to be a case for a data management project perhaps using one of the smaller republics such as Kyrgyzstan as a pilot area. This would allow the very comprehensive data which has been (and at a reduced scale continues to be) collected to be organised in such a way that it could provide state and river basin water resource managers with more effective decision-making tools.

5. WATER QUALITY CHARACTERISTICS

Similar features were reported on natural groundwater quality from each of the 3 main republics, so for convenience they will be treated together. The effects of human activities on water quality are being assessed in another WARMAP project task, so these features will only be referred to in brief. Typical macro-element compositions are reported in Appendix sets K, T, and U.

Baseline major ion chemistry throughout the project area reflects the effects of residence time and interaction with the host rock through which recharging groundwater has passed. Thus some sinuous shallow river valley alluvial/fluvioglacial deposits such as Faizabad-Kalaidasht-Dashtirabat in Tajikistan and the Kugart River valley in Kyrgyzstan show the low mineralisation typical of a rapid recharge shallow aquifer, with chloride and sulphate concentrations generally below 100mg/l. Deeper systems, and those where confining conditions have impeded circulation start to show increased hardness with calcium and magnesium greater than 150 and 75 mg/l respectively and associated sulphate concentrations from 750 to more than 1300 mg/l. This is especially the case where the aquifer is composed of, or receives recharge from a hinterland of Upper Tertiary formations, because these are frequently gypsiferous. High sulphate appears to be a greater problem than salinity, and chloride values are generally below the 250 mg/l WHO guideline value (although there are exceptions such as Lyakat-Savat and the Syr Dar'ya valley itself, where the chloride content may reflect recharge of surface water which is itself salinised upstream from the Fergana intermontaine basin). In contrast a number of aquifer deposits show sulphate concenrations in excess of the WHO guide level of 400 mg/l (eg Kasansai, Narin, Chirchik-Keles, Sherabab in Uzbekistan, Kirsorovat, Golodnostep, Lyakat-Sovat in Tajkistan).

A useful 1990 review of groundwater resources and quality [Ref X] in Kyrgyzstan reports on almost 2350 analyses from over 1350 wells and 93 sources of pollution, and provides valuable detailed information on natural water quality and groundwater pollution problems encountered. The report refers to 5864 wells, 103 springs and 39 infiltration galleries in operation nationally in 1990. The review cites examples of groundwater quality deterioration from human activities. In Bishkek, elevated high nitrate and chromium concentrations are reported from the area of an agricultural machinery factory due to inadequate effluent disposal facilities, and other urban and industrial landfill leachate problems are alluded to. A number of point pollution incidents are reported from mining and minerals processing plants. High cyanide and sulphate from tailings lagoons seepage, together with high nitrate (presumably from oxidation in the unsaturated zone of cyanide salts used in ore processing additives) are noted. The review recommends that plants should be equipped with adequate treatment facilities for generated wastes, better wastewater re-use technologies including closed cycle techniques and education of industrialists and the public in environmental protection issues.

In Tajikistan, mining, industry, food processing, construction materials, cattle breeding farms, irrigated agriculture and urbanisation are cited as the main polluting activities. Noteworthy examples of diffuse pollution from agriculture were cited as the Dalversin (east of Samarkand), Nau-Kostakoz, Karakchikum-Kanibadam and Isfara aquifers (south of Dushanbe) all with mineralisation in the range 1000-3300 mg/l and nitrates 20-110 mg/l. Ore processing effluent have been problematic, one effluent leakage incident produced samples with 5400 mg/l mineralisation and sulphate concentrations over 3000 mg/l. An industrial pollution incident example from a nitrogen fertiliser plant produced extremely high concentrations of nitrogen compounds (ammonia 630-2675 mg/l, nitrite 33-182 mg/l and nitrate 10-133 mg/l).

6. PROPOSALS AND RECOMMENDATIONS ON GROUNDWATER MANAGEMENT IN THE UPPER WATERSHEDS

On the basis of the groundwater information supplied during the visit, there appears at present to be little evidence of groundwater resource depletion in the upper watershed project area. There are for instance no reports of over-abstraction from any of the counterpart agencies contacted. However, some concern has been expressed over contamination problems from industrial, mining and mineral processing activities, and high sulphates and nitrates are widely cited as the product of pollution from agricultural sources, both in diffuse form as a result of leaching from (over)irrigated land and as point pollution from intensive livestock and poultry-rearing units. High sulphate is also a natural wate quality problem in some aquifers where echarge has passed through gypsiferous Upper Tertiary formations. It therefore appears that degradation of the groundwater resource is more likely to occur as a result of water quality deterioration than from over-abstraction.

From discussions held with counterpart staff at meetings in Tashkent and Bishkek, three possible areas of institutional support arose: techniques of protection of potable groundwater sources, data management and water/wastewater management. These areas of interest could form the basis of a groundwater resource management element of the second phase of the WARMAP project

6.1 Protection of potable groundwater sources

The heavy dependence throughout the upper watersheds on groundwater for domestic and drinking water supply has already been pointed out; around 2.1 million city dwellers alone in Uzbekistan, perhaps 80% of all domestic supplies in Kyrgyzstan and public supply abstraction from all 30 of Tajikistan's main aquifers all testify to the pivotal public health and economic roles played by groundwater in the region. Protection of the aquifers feeding public supply wells is therefore a vital water resource management role. There was at meetings held with local agencies a general appreciation of the need for a protection policy in respect of potable supply sources, and considerable interest both in the kinds if measures already adopted in Western Europe and elsewhere with the same objective and also in the use of the tools which would enforce such a policy. Uzbekistan for instance has produced large scale national vulnerability maps, but has not used them for any policy development or land-use planning purposes.

Institutional support for the development of national groundwater protection policies appears strong and could take the following form:

- identification of the objectives of a national policy
- moves to standardise policy objectives amongst the Central Asian republics
- development of policy tools along the lines already successfully implemented in Western Europe, North America and in some states in Latinamerica and the Caribbean These tools include *inter alia* hazard identification and pollution load assessment surveys, land zoning by aquifer vulnerability mapping and source protection zone delineation, development of institutional, planning and legal sanctions to control activities hazardous to potable supplies

Training needs could be metthrough in-house institutional support and include a workshop, drawing for instance on the expertise of WHO-PAHO, which has considerable experience in the field of groundwater protection, having organised with the aid of professional presenters similar events throughout Latinamerica, the Caribbean and in Southeast Asia.

6.2 Data management

The system of groundwater monitoring in the Central Asian republics is enormous; Uzbekistan alone has twin systems covering more than 34,500 wells. However it appears that although very comprehensive in its areal coverage, this system is not well attuned to the needs of basin-wide resource management, and the fact that in the main it is still a paper record (apart from a pilot project in Karakulpakstan) makes data synthesis for planning and predictive purposes virtually impossible. It is proposed that support be given to helping key institutions in each republic establish, in parallel, a groundwater data management system using modem interactive databasing programmes, with a subsidiary/secondary option to interface with a GIS system which would help manipulation and visualisation of the data for national resource planning and management. Training needs could be met by accompanied visits to agencies in Western Europe where such techniques are in operation on a routine basis, and also to a number of emerging nations where simple systems are being developed in tune with local needs.

6.3 Water/wastewater management

There is some concern that the system of planning and regulation implicit in the centralised command economy of the former Soviet Union is falling into disuse in the new post-Soviet liberalised economic climate. It is essential to ensure that in respect of groundwater, due concern is paid to the recquirement to reconcile competing, sometimes contradictory demands for the use of the land surface with the need to protect and maintain the integrity of underlying and down-gradient groundwater resources.

The approach adopted in most countries has been to institute some form of licensing, whereby water users and water/effluent disposers alike are required to carry out their business according to certain technical criteria, standards or conditions as set out in a user-specific licence. The polluting potential of any activity at the land surface and the vulnerability and scarcity of the resource are reflected in the conditions attached to the licence. Charging mechanisms can also be utilised to favour particular uses of groundwater, such as for public supply, in accordance with strategic policy objectives. These may include improved waste handling, storage or treatment for particular industrial effluent. The licensing authority and its surveillance/regulatory function are usually self-supporting, financed from part of the licence charges. Such a licensing system would perform one of the legal and executive roles of national policies put in place to ensure that the value of the water resource is truly accounted in the economy.

It is therefore proposed that consideration be given to assisting institutional development of a water and wastewater regulatory system based both on valuing abstracted groundwater resources and pricing/controlling practices which could threaten those resources.

6.4 Other recommendations

The ToR of the this consultancy did not include assessment of institutional operational needs, but there did appear to be a need in both the Hydrogeological Surveys visited for some modest improvement in computing facilities (PCs, printers, software) and in basic hydrogeological field items such as field water level and physico-chemical measuring equipment. Investment in these basic facilities has virtually ceased since the republics' independence.

7. ACKNOWLEDGEMENTS, LIST OF INFORMATION SOURCES

Most of the information gleaned during the visit was obtained with the help of local professional hydrogeologists, who provided both their time at numerous meetings and compiled data to reinforce the resource assessment, current development stage and water management sections. Thanks are due to the following individuals:

Uzbekistan:

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Mr Alibert Shapiro	Senior hydrogeologist, Uzbekgidrogeologia Corporation, 64 Morozov Street, Tashkent Tel. 3712-627592

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Kyrghyzstan:

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Tajikistan:

Akmal Akhmadov	via data coordinator Sirozjidin Aslov, Tel 3772-278383 Home, 3772-340830 Bus; based in Tajik Hydrometeorological Service, Dushanbe

Dr Rakmanov, assistant director of the KSRII, was particularly helpful during two visits to Bishkek, and the services of Ms Taissia Oleinikova, interpreter at WARMAP, were invaluable. It was not possible in the time available to establish contact with hydrogeologists in Kazakhstan Republic, but for future reference, the following professionals could provide access to hydrogeological information on the Republic;

Prof. V.Veselov	Director, Institute of Hydrogeology and Hydrophysics (IHH), National Academy of Sciences, 94 Ch.Valikhanov Street, Alma-Aty 480100. Tel. 3272-614609, Fax 3272-696116, E-mail VLADIMIR @SU.ALMA-ATA.ITPM.IHH

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Appendix 1: Terms of reference for short-term expert on agro-hydrology

Subject:

Advisory services to the WARMAP Project, relative to the execution of the Sub-Project 7 "Integrated Land and Water Management in the Upper Watersheds" during the 1st implementation phase of six months (February/July 1995) with special regard to activities 1.3 (Use of surface water resources for irrigation and other purposes), 1.4 (Use of groundwater resources for irrigation and other purposes), 1.6 (Evaluation of techniques and methods of irrigation) and 4.2 and 4.3 (Measures for the improvement of land and water management) of the general Terms of Reference of the Sub-project.

Duties of the expert:

- To give backstopping to the local experts in the collection of the necessary data with regard to:
  - the actual use of available water resources for irrigation purposes;
  - the actual practices of irrigated and rainfed agriculture in the valleys and lower mountain ranges (up to 3,500 m) of the upper watersheds;
  - conveyance and field losses in irrigation systems; irrigation efficiency;
  - specific problems in irrigation (salinity; pollution in general; transport of contaminants in soil and groundwater).
- To evaluate actual methods of water use in irrigation for their water consumption and environmental impact. Amounts of water used; impact of soil quality; degradation of water quality in the irrigation-drainage cycle etc.
- To evaluate actual methods of rainfed agriculture and their impact on environment (soil and water degradation/conservation).
- To define integrated approaches to sustainable soil and water conservation, including irrigated and rainfed areas.
- To define together with the erosion expert and sub-project team leader, pilot areas where such an integrated approach can be field tested.

The expert will assist the sub-project leader in the preparation of proposals for long-term strategies with regard to integrated land and water management, including institutional aspects.

The expert will execute his work in the WARMAP offices in Tashkent and make field trips to the areas of interest. The findings will be put down in a report in the English language, which will be submitted to the Project not later than June 31, 1995. The draft of this report will be presented to the project by the expert before his departure from Tashkent.

APPENDIX 1A 12-4-1995

WARMAP-Project

Terms of reference for Sub-project 7

Subject:

The execution of works related to Sub-project 7 "Integrated Land and Water Management in the Upper Watersheds" during the 1st implementation phase of six months (March/July 1995).

Objective of the first phase:

The present situation with respect to land and water management in the upper watersheds has been analyzed, immediate measures defined and detailed proposals for the continuation of the study formulated.

Strategy for the first phase:

The first phase of the Sub-project will concentrate on the collection and analysis of those data which are needed for a general understanding of the land and water management issues in the upper watersheds region and its impacts on the quantity and quality of downstream water resources.

Due to time constraints, the Sub-project will in this phase use mainly data in elaborated form, such as presented on maps and compiled in research reports and yearbooks, etc. Occasionally, additional data may be collected where needed and easily available. Data verification in the first phase will depend mainly on common sense and intuition of the responsible experts, rather than on statistical evaluation. An evaluation will be made whether the second phase of the project can depend on existing data or eventual additional data (e.g. via satellite images) should be collected.

The analysis of the collected information will be limited to the description of the main characteristics of the land and water management system, its functioning and its specific problems. The analysis will be followed by recommendations for immediate action and proposals for further study to be executed in the second phase of the project.

(In the second phase of the project, it is foreseen to make a more profound analysis of the land and water management system, including the social-economic and technical evaluation of envisaged strategies and measures, using dynamic modeling and computerized GIS techniques).

Results to be achieved (including data requirements and planned analysis steps):

1. **Information on the availability and present use of land and water resources has been collected and analyzed.**

   1.1 Collect and analyze data on natural and climatic features.

   Data requirements:

   (a) Basic information on the geomorphology of the region (maps; short text).
   (b) Topographic maps 1:500,000 of the region (bigger scale if required).
   (c) Map of hydrometeorological stations.
   (d) Rainfall and evapotranspiration data in elaborated form (main stations:

monthly totals for the last 40+ years as far as available; isohyetal maps, etc.).

(A large part of (c) en (d) data will be collected under sub-project 2b (check!!)

Analysis steps:

(a) Geomorphologic description of the region.
(b) Relief map of the region indicating mountains, rivers, roads, cities, etc.).
(c) Assessment of existing mapping of spatial variation of rainfall.
(d) Tables and/or graphs of time variation (annual cycle; time series) of rainfall (mean monthly values for main stations; 10% dry and wet year; cycle of dry and wet years for selected stations; trends) and evapotranspiration.

1.2 Collect data on land use and relate them to soil, topographic and climatic conditions.

Data requirements:

(a) Soil maps (1:500,000, 1:1,000,000) of the region (oblast level); information on relative soil characteristics.
(b) Information on soil suitability for growing different crops.
(c) Data on actual land use, related to topographic, soil, climatic, etc. conditions.

(Land use maps are only available on 1:10,000; too big, not usable!)

Analysis steps:

(a) Assessment of existing soil maps and the soil classification for their suitability for erosion and land use (irrigation) evaluation.
(b) Compilation of land use statistics (related to soil, topographic and climatic conditions, etc., as far as the data allow).

1.3 Quantify available SW resources and their use for irrigation and other purposes.

Data requirements:

(a) Map of discharge stations in the upper watershed region.
(b) Stream flow records of main discharge stations (average monthly discharges; average year, 10% dry year, 10% wet year).
(c) Other SW sources.
(d) Data on water use by different branches of the economy (for irrigated agriculture in the growing season and outside the growing season, annual data for industry, domestic water supply, fish farming, etc.); location.
(e) Socio-economic output data (irrigation revenues, number of people connected to piped drinking water supply, hydroelectricity generated, etc.).

(Activities (a) and (b) will be executed by sub-project 2b. Check!)
(Activity (e) might be executed by sub-project 4. Check!)

Analysis steps:

(a) Quantification of available resources in space and time.
(b) Analysis of trends in SW availability.
(c) Quantification of SW use for different purposes.
(d) Quantification of reuse of drainage and waste water.
(e) Preliminary analysis of the economic value of water for different purposes.

1.4 Quantify available GW resources and their use for irrigation and other purposes.

Data requirements:

(a) Hydrogeological maps with location of main aquifers.
(b) Characteristics of main aquifers (Short geohydrological description; hydraulic characteristics; water quality).
(c) Location and exploitation data of wells (number, depth, exploitation regime; discharge; yield (summary per aquifer).
(d) Information on groundwater-level development of main aquifers (summary).

Analysis steps:

(a) Short description of main aquifers / maps.
(b) Quantification of available resources and identification of exploitation potential (including quantity and quality aspects).
(c) Quantification of the actual exploitation of aquifers (location of wells; yearly production; seasonal variation of discharge).
(d) Identification of specific problems with regard to exploitation (over-exploitation, water quality, costs aspects, etc.).

1.5 Collect and analyze information on the water management system.

Data requirements:

(a) Schematic general description of river basin water management systems (rivers, dams, irrigation systems, drainage canals, etc.; location on maps; capacity) including location and extension of irrigation areas.
(b) Schematic description of main irrigation systems (lay-out, hydraulic capacity, maintenance state, operation (supply or demand), operation costs, etc.); Summary of minor irrigation systems.
(c) Description of reservoir management (criteria for release of water, actual release statistics).

Analysis steps:

(a) Schematic presentation of main hydraulic systems.
(b) General evaluation of technical and operational aspects of the main irrigation systems.
(c) Evaluation of operational aspects of reservoir management.
(d) Evaluation of interrelations between different water uses and eventual conflicts.

1.6 Collect and analyze data on the techniques and methods of irrigation.

Data requirements:

(a) Data on the irrigation techniques used in the main irrigation schemes, differentiated according to crops.
(b) Conveyance and field losses in main irrigation schemes.
(c) Cropping intensity data.
(d) Data on crop water use and irrigation efficiency (compiled per irrigation scheme and differentiated according to crops).
(e) Information on specific problems with regard to irrigation (salinity, water-

logging, etc.).

Analysis steps:
(a) Assessment of relation between irrigation efficiency, irrigation methods and other characteristics.
(b) Graphic presentation of results; mapping.
(c) Evaluation of water balance aspects in representative systems within the upper watershed region.

2. Information on the extent of flooding, erosion and mud-flows has been collected.

2.1 Evaluate the runoff formation process.

Data requirements:
(a) Map of snow-observation stations in the upper watershed region.
(b) Data on snow cover (start of the melting period, snow cover at the end of the melting period; monthly progress).
(c) Discharge data as collected under 1.3(a) and 1.3(b)

Analysis steps:
(a) Reconstruction of snow melt process and snow-covered area in an average year, 10% dry year, 10% wet year (dry and wet expressed in terms of available water resources).
(b) Presentation in map form.
(c) Graphical presentation of the time behavior of the snow melt process in the different catchments (Syrdarya or Amudarya).
(d) Relation between snow melt and discharge in graphical form (area of snow cover against volume of discharge for each river basin).

2.2 Evaluate actual flood risk in relation to hydrometeorological conditions and reservoir management.

Data requirements:
(a) Reservoir release statistics.
(b) Statistics of flood occurrence and extension.
(c) Statistics of flood damage.

Analysis steps:
(a) Assessment of the relation between runoff formation, reservoir management and flooding.
(b) Assessment of the relation between flood occurrence, flood intensity and flood damage.

2.3 Evaluate the extent of erosion and the risk of mud-flow in combination with flooding risks.

Data requirements:
(a) Data on the extent of erosion and erosion intensity.
(b) Maps on erosion sensitivity.
(c) General information on land-use practices in (non-irrigated agriculture and uphill cattle ranching

(d) Statistical data on forest coverage; deforestation; reforestation efforts.
(e) Statistical data on sediment load of rivers (monthly averages in selected stations).
(f) Statistical data on the impacts of erosion (land loss, etc.).
(g) Statistical data on mud-flow occurrence and its impacts.

Analysis steps:
(a) Assessment of the causes and implications of erosion and mud-flows.

2.4 Evaluate the existing flood and erosion hazard management system (complex of technical and organizational measures to avoid or limit damage from erosion, mud-flows and flooding).

Data requirements:
(a) Description of technical and organizational aspects of the flood warning systems.
(b) Description of existing measures to prevent or limit erosion and mud-flows.

Analysis steps:
(a) Assessment of the effectiveness of the existing flood warning systems.
(b) Assessment of the effectiveness of the existing erosion and mud-flow protection measures.

3. Information with respect to water quality and pollution has been collected and analyzed.

3.1 Assess the present state of water quality in the region.

Data requirements:
(a) List of water quality stations and their location (map?).
(b) Records of water quality in elaborated form (selected elements: average quarterly values for different (5 year) time periods; min.; max., trend).
(c) Specific information on the water quality of reservoirs (water quality parameters, annual variation).

Analysis steps:
(a) Water quality classification of the water resources in the region.
(b) Quantification of restriction of water use, due to inappropriate water quality.

3.2 Identify and map main sources of soil and water pollution.

Data requirements:
(a) Statistics on the use of agrochemical products; quantity and type of chemicals and location of use.
(b) Location and production statistics of mining operations.
(c) Location and production statistics of the most important industries.
(e) Location and population estimates of towns (maps with urban centers and their population; population per oblast or smaller admin. units.

Analysis steps:
(a) Identify and analyze the risk of pollution.
(b) Analyze the environmental effects of pollution.

3.3 Identify possible economic and health aspects of inadequate water quality.

Data requirements:
(No special data required).

Analysis steps:
(a) Assessment of limitations of water use for different purposes, due to inadequate water quality.
(b) Identify possible health hazards related to poor water quality.

4. Short-term options to improve land and water management have been identified and preliminary strategies outlined.

4.1 Analyze socio-economic trends and their relations to land and water management.

Data requirements:
(a) Statistic data on economic development of irrigated agriculture (per sub-basin or per oblast, whatever available).

Analysis steps:
(a) Assessment of the interrelation between socio-economic development and quantity and quality aspects of land and water management.

4.2 Identify measures for immediate action and prepare eventual proposals.

Measures for improvement of land and water management (water saving, water quality protection, storage and transfer, erosion protection, etc.) have to be identified and should be considered either for immediate implementation or for further study.

4.3 Develop basic strategies for the improvement of land and water management.

Strategies should be developed that guarantee a long term improvement of land and water management. Such strategies should include outlines for the improvement of daily water management and irrigation practices, investment policies, institutional set-up, etc. In this phase, the strategies will not yet be analyzed for their socio-economic implications.

5. An activity planning for the next 18-month phase has been compiled and necessary resources estimated.

5.1 Identify overall goal, purpose and activities of the next project-phase and prepare detailed plan of operations, including allocation of resources.

A detailed, but realistic plan of operations should be provided based on the experiences of the 1st project phase. Due attention should be given to the logical relations between activities, results and project objectives.

5.2 Identify additional projects in relation to WARMAP with respect to land and water management in the upper watersheds.

To identify study or advisory measures that are necessary to improve land- and water management, but do not fit within the framework of the WARMAP for logical, budgetary or organizational reasons.

5.3 Assess training needs of staff in the local participating institutions and recommend a training program.

The qualification of available local staff should be related to the plan of operations of the next project-phase. Discrepancies between requirements and qualifications should be eliminated by training.

5.4 Design integration of processed information with MIS.

The structure of a GIS for integrated land and water management has to be established and interfaces with the to be proposed MIS be defined..

WARMAP-Project

Sub-project 7

Terms of reference for the employment of a short term expert on hydrogeology

Subject:

Advisory services to the WARMAP Project, relative to the execution of Sub-project 7 "Integrated Land and Water Management in the Upper Watersheds" during the 1st implementation phase of six months (February/July 1995) with special regard to activity 1.4 (Quantification of available GW resources and their use for irrigation and other purposes) of the general Terms of Reference of the Sub-project.

Duration of the assignment:

17 May - 21 June 1995

Duties of the expert:

- To give backstopping to the local experts in the collection of the necessary data with regard to:
  - the general hydrogeology of the upper watersheds region and the location of the main aquifers;
  - the characteristics of the main aquifers (hydrogeology, hydraulic characteristics, water quality parameters, etc.);
  - location and exploitation of wells;
  - groundwater level and groundwater quality developments.
- To identify the main aquifers of the upper watersheds region and select those aquifers relevant for the upper watersheds water management. Basis for the selection are the hydrogeological maps and global data on overall yield of the specific aquifers, next to their socio-economic importance for any form of water supply, including irrigation.
- To assist the local experts in the description of the characteristics of the selected aquifers (general hydrogeological description, hydraulic characteristics, water quality characteristics). A summary of the remaining aquifers has to be provided.
- To quantify available resources in terms of seasonal and areal availability. Seasonal availability: Variation of the exploitation over the year, according to specific water use needs; areal availability: Most economic placement of wells, avoiding local over-exploitation.
- To quantify the actual use of GW resources for different types of water use (agriculture, domestic and industrial water supply, etc.) for all selected aquifers.
- To identify specific exploitation problems such as aquifer over-exploitation, decrease of water quality, high exploitation costs, etc. in the different aquifers.
- To assess the present exploitation of the GW resources, comparing it with the exploitation potential and taking into account optimal exploitation and water quality aspects.

- To make recommendations for the rational exploitation of available resources. Such recommendations should include water quantity (maximum sustainable exploitation) and water quality (maximum availability of good quality resources) aspects.

The expert will execute his work in the WARMAP offices in Tashkent and make field trips to the areas of interest. The findings of the expert will be put down in a report in the English language, which will be submitted to the Project not later than June 31, 1995. The draft of this report will be presented to the project by the expert to the project before his departure from Tashkent.

Annexes:

- Terms of Reference for Sub-project 7
- Task description 6, "Groundwater potential and groundwater use"

APPENDIX K1 CATALOGUE OF MAIN AQUIFER SYSTEMS IN SYR DAR'YA BASIN OF REPUBLIC OF KYRGYZSTAN, 1994

NO.	NAME & LOCATION	TYPE/ SETTING	DEPTH INTER-VAL m.B.G.L	S.W.L m. B.G.L	STRAT. AGE	LITH-OLOGY & SATD. THICKNESS	DEVEL START DATE	RESOURCE BY CERTIFICATION CLASS MCM/a				
								A	B	C1	C2	ΣA+B+ C1+C2
1	2	3	4	5	6	7	8	9	10	11	12	13
Certified groundwater reserves in aquifers of Narin Oblast												
A1	N.Kugart River valley,16km SW Kazarman	River valley	4-13	4	aQ III-IV	boulder/ gravels+sandy alluvm13m	1987	0.8	0.8	-	-	1.6
A2	Saragastinkoye, SE of Ketmer-Tubinskaya basin, 2km N Saragata	"	10-30	10	aQ IV	boulder/ gravels+sandy alluvm30m		-	2.4	-	0.7	3.14
Certified groundwater reserves in Fergana aquifer system												
B1	Karayngyrskoye, Noorlensky & Bazar-Kurgansky districts	"	40-135	40-105	apQ III-IV	boulder/coarse gravels+sandy alluvm135m	1974	38.5	26.4	0.8	127.7	219
B2	Kugartskoye, L.Kugart & Chongetu rivers	"	15-480	24-30	apQ III-IV	boulder/coarse gravels+clay sands500m	1970	152.8	56.9	-	-	209.8

Appendix K1 continued;

B3	Kurshabskoye,30km E of Kara Syy	"	5-50	5	apQ II-IV	Boulder bed, coarse gravel 30-60m	1964	6.9	2.6	23.8	-	33.2
B4	Madunskoye,13km E of Osh	"	2-15	2	apQ III	Boulder bed, coarse gravel 15m	1967	5.5	1.7	1.6	-	8.9
B5	Tachtekskoye,6km SE Kuzul-Kiya	Intermont aine basin	20-135	12	apQ IV	boulder/coarse gravels+sandy alluvm, clay sand100-150m	1973	-	7.9	-	-	7.9
B6	Oshskoye, 0.8km S of Osh	River valley	3-18	3	aQ IV	boulder/ gravels+sandy alluvm18m	1972	-	11.1	-	-	11.1
B7	Akburinskoye, N end of Osh	"	9-27	9	aQ IV	boulder/ gravels+sandy alluvm27m	1973	-	10.0	42.0	-	52.0
B8	Karaba-Kokjarskoye, Naykatsky Kadamjaysky districts	Piedmont fan	35-180	+20-6	apQ III-IV	boulder/coarse gravels+sandy alluvm150-200m	1990	12.3	34.6	-	-	46.9
B9	Tuya-Muyonskaye	Alluvial fan	50-200	+6-100	pQ I-III	boulder/coarse gravels+clay sand100-250m	1991	46.8	48.6	-	-	95.3

Appendix K1 continued;

Uncertified groundwater reserves in aquifers of Narin Oblast												
1	Baejozskoye at Baetooka	Piedmont fan	-	-	apQ III-IV	Coarse pebbly gravel	1975	-	-	-	-	-
2	Atbashanskoye at Bolshevik	"	-	-	pQ III	Coarse gravel with clay	1976	-	-	-	-	-
3	Karakoynsky,E Ajbas hinsky district	"	-	-	apQ II-III	Boulderbeds, coarse gravels	1986	-	-	-	-	-
Uncertified groundwater reserves, Fergana aquifer system												
4	Karayngykskaya valley	River valley	-	-	apQ III-IV	Boulderbeds, coarse gravel, sand clay,50m	1961	-	-	-	-	-
5	Kara-Kull	"	-	-	aQ IV	Boulderbeds, coarse gravels, 30m	1978	-	-	-	-	-
6	Osh-Karasyisky oasis	"	-	-	apQ III-IV	Boulderbeds,s andy clay,30m	1981	-	-	-	-	-
7	Oshsky & Djalal-abadsky water intakes	River valleys, intermont aine basins , alluv. fans	-	-	apQ II-IV N2-Q1	Boulderbeds, coarse gravels conglomerates 50-300m	1960-1987	-	-	-	-	-

APPENDIX K2 SUMMARY TABLE OF GROUNDWATER USAGE IN SUB-PROJECT 7 AREA OF KYRGYZSTAN REPUBLIC, 1994

OBLAST	GROUNDWATER USE IN MCM/a						
	PUBLIC WATER SUPPLY	INDUSTRIAL	ARABLE IRRIGATION	LIVESTOCK/ PASTURE IRRIGATION	TOTAL SUPPLIED	TRANS-MISSION LOSSES*	TOTAL ABSTRACTION
1	2	3	4	5	6	7	8
TOTAL RESOURCE							
NARIN	30.9	4.2	29.2	3.1	67.4	1.9	69.3
DJALAL-ABAD	59.3	2.6	76.5	7.1	145.5	4.9	150.4
OSH	190.4	20.7	248.0	30.2	489.3	35.0	524.3
% OF TOTAL SUPPLIED AFTER LOSSES(2+3+4+5=6)	40%	4%	50%	6%	100% 94%	- 6%	- 100%
CERTIFIED PART OF TOTAL RESOURCE							
NARIN	0.3	0.8	1.1	0.2	2.4	-	2.4
DJALAL-ABAD	59.3	2.6	25.5	0.7	88,1	1.7	89.8
OSH	55.9	9,6	101	5.9	172.4	11.6	184.0
% OF USE FROM CERTIFIED RESOURCE	61%	63%	51%	23%	-	38%	53%

* Transmission losses may occur adjacent to or en route to user, a proportion of which will recharge either directly or via surface watercourses

APPENDIX K3 NUMBERS OF WELLS IN SUB-PROJECT 7 AREA OF KYRGYZSTAN REPUBLIC, 1994

SOURCE TYPE	OBLAST	AQUIFER SYSTEM	NUMBER OF SOURCES			
			SINGLE WELLS	WELLS IN GROUPS	TOTAL	NO. OF WELLS WITH CERTIFIED USE
BOREHOLE	NARIN	NARIN ARTESIAN SYSTEM	203	64	267	2
BOREHOLE	DJALAL-ABAD	FERGANA ARTESIAN SYSTEM	545	261	806	397
BOREHOLE	DJALAL-ABAD & OSH	OTHER DISTRICTS IN THESE OBLASTS	832	273	1105	461
	TOTALS FOR SYR DAR'YA BASIN		1580	598	**2178**	860
% OF ALL WELLS IN PROJECT AREA WITH CERTIFIED USE					39%	
% OF ALL WELLS IN PROJECT AREA IN KYRGYZ FERGANA VALLEY					37%	

APPENDIX K4 POPULATION STATISTICS FOR KYRGYZ REPUBLIC

YEAR	TOTAL POPLN (millions)	URBAN (millions)	RURAL (millions)	URBAN %	RURAL %
1985	3.96	1.51	2.47	38	62
1991	4.42	1.68	2.74	38	62
1992	4.48	1.70	2.79	38	62
1993	4.50	1.69	2.82	37	63
1994	4.46	1.59	2.87	36	64

Reference; I Krivonosova in Kyrgyzstan Chronicle #28 (84) 12-18 July 1995, Bishkek

OBLAST	% 1994 TOTAL POPLN	NAT.POPLN GROWTH %
OSH	31.6	2.3
DHJALAL-ABAD	18.4	2.3
CHUI	16.7	0.7
BISHKEK	13.4	0.1
ISSYK-KUL	9.5	1.3
NARYN	5.9	1.9
TALAS	4.5	1.9
K.REPUBLIC	100	1.6

APPENDIX K5 LEGEND EXTRACT FROM HYDROGEOLOGICAL MAP OF REPUBLIC OF KYRGYZSTAN

From *Technical Atlas of Kyrgyzstan*, Moscow 1987-see pp50-51 for distribution

A. Groundwater in Quaternary formations, including deep and confined conditions; principally intergranular flow.

1.	aQ	L.Quaternary-Recent sand, gravel & pebble/cobble beds; rare sandy clay
2	ap,pQ	L.Quaternary-Recent alluvium; (a) pebbly/cobbly gravel, layered with sandy loams (b) loessial silts with gravel lenses
3	lQ	M.Quaternary-Recent coarse lacustrine deposits; sands, coarse gravels, loams, pebble beds
4	gQ	M/U.Quaternary coarse glacial deposits; cobbles, pebbles, gravels, sands
5	f,fpQ	M/U.Quaternary fluvioglacial deposits; cobbles, pebbles, gravels, sands, silty sands

B. Groundwater in Tertiary & Mesozoic formations, mainly intermontane and piedmont molasse-type deposits with extensive evaporitic beds

6	N-Q	U.Pliocene-L.Quaternary interstratified conglomerates, sands, pebbly sandy clays
7	N	stratified U.Tertiary gravelly conglomerates, sands with gypsum & salt horizons
8	P	U.Tertiary marl & limestone with gypsum & salt, sandy clay in upper part
9	K	Cretaceous conglomerates, sandstones, shales, gypsiferous marls, limestones, heterogeneous sandstones & conglomerates
10	J	Jurassic interbedded sandstones, shales, coal horizons
11	T-J	Jurassic-Triassic conglomerates with sandy shales

C. Palaeozoic & older sedimentary, metamorphic and effusive formations

12	PZ	U.Palaezoic terrigenous & carbonate formations; conglomerates, sandstones, shales, limestones
13	PZ	U/M.Palaeozoic carbonate & terrigenous formations; limestones, sandstones, shales
14	PZ	M.Palaezoic terrigenous, metamorphic, volcanic formations; sandstones, conglomerates, shales, phyllites, quartzites, limestones, marbles, volcanics
15	PZ	L.Palaeozoic terrigenous & volcanic & metasediments; sandstones, conglomerates, shales, slates, phyllites, quartzites, limestones, marble, volcanics
16	P-C	Precambrian mainly metasediments and metavolcanics; marble, limestones, volcanics
17	γPZ	Igneous intrusives; granite, porphry, quartz-porphyry, granodiorite, diorite

APPENDIX T1 RESOURCE CHARACTERISTICS & CURRENT USE OF MAIN AQUIFERS OF REPUBLIC OF TAJIKISTAN

NO	NAME OF AQUIFER DEPOSIT	RESOURCE POTENTIAL $000m^3/d$	EXPLOIT-ABLE RESERVES $000^3/d$	ACTUAL ABSTR-ACTION $000^3/d$	AGE	SWL (m)	MAX WELL DEPTH S (m)	NO.OF WELLS	TYPE OF USE
1	DALVERSIN	629	372.1	527	apQII-III	0-40	180	260	IRR,PS
2	KIRSOROVAT	37	82.7	41	K2-P	5-+8	100	16	IRR,PS,IND
3	GOLODNOSTEP	290	-	369	apQII-III	1-20	100	224	IRR,PS
4	SAMGAR	615	588.7	298	apQII-III	12-45	100	152	IRR,PS
5	KAMYSHKURGAN	1825	388.4	716	apQII-III	5-50	300	544	IRR,PS
6	SYRDAR'YA	712	155	306	apQIV	0-12	120	24	IRR,PS
7	LYAKAT-SAVAT	333	85	169	apQII-III	42-51	200	136	IRR,PS,IND
8	NAU-KOSTAKOZ	2770	871	1339	apQII-III	1-40	250	335	IRR,PS
9	KARAKCHIKUM-KANIBADAM	1632	490	379	apQII-III	5-30	120	215	IRR,PS,IND
10	ISFARA-LYAKAN	383	216.8	234	apQII-III	5-19	100	151	IRR,PS,IND
11	SHAKHRISTAN	571	181.7	239	apQII-III	0-40	150	233	IRR,PS
12	ZERAFSHAN	1624	85.3	79	apQII-III	1-10	100	61	IRR,PS,IND
13	REGAR	551	252.3	123.8	apQIII-IV	2-44	100	149	IRR,PS,IND
14	KHANAKIN	1189	76.9	99.8	apQIII-IV	20-65	120	174	PS,IRR,IND

	APPENDIX T1 CONTINUED:								
15	DUSHANBE	1200	503.8	117.2	apQIII-IV	0-23	100	280	PS,IND,IRR
16	KAFIRNIGAN	2760	1086.6	44.4	apQIII-IV	2-20	100	142	PS,IND
17	FAIZABAD	62	7.1	39.9	apQII-III	10-15	120	60	IRR,PS
18	KALAIDASHT	163	101.6	0.1	apQII-III	2-+2	75	30	IRR,PS
19	DASHTIRABAT	39	22.1	32.1	apQII-III	+2.5-+2.6	180	10	IRR,PS
20	KUIBYSHEV	415	673	19.6	apQIII-IV	2-10	100	64	PS,IND
21	KURGANTYUBE	1301	223.7	36.2	apQIII-IV	4-6	50	82	PS,IRR
22	NIJNEVAKSH	214	-	42.2	apQIII-IV	4-9	40	146	PS,IRR
23	BESHKENT	182	-	4.3	apQIII-IV	2-4	50	34	PS
24	NIJNEKAFIRNIGAN	680	83.6	19.6	apQIII-IV	3-6	35-80	40	PS,IND
25	KHOVALING	87	87.3	62.9	apQII-III	41-66-+40	180	58	IRR,PS
26	MUMINABAD	73	42.4	13.6	apQII-III	15-41	120-150	51	IRR,PS
27	YAKHSUI	475	541.3	82.6	apQIII-IV	58-73	150	150	IRR,PS
28	KZYLSUI	1705	36.3	252.0	apQIII-IV	10-45	150	286	IRR,PS
29	MOSKOVSKOE	430	146.8	16.8	apQIII-IV	0-7	70	79	PS,IND
30	PARKHAR	472	133.7	12.5	apQIII-IV	2-4	85	55	PS,IND
	TOTALS:	23419	7535.2	5715.6	-	-	-	4243	-

IRR= IRRIGATION USE, PS=PUBLIC DRINKING WATER SUPPLY, IND= INDUSTRIAL USE

APPENDIX T2 WATER QUALITY CHARACTERISTICS OF MAIN AQUIFERS OF REPUBLIC OF TAJIKISTAN

NO.	NAME OF AQUIFER DEPOSIT	AGE	SAMPLE DEPTH INTER-VAL (m)	CONCENTRATION IN mg/ll						
				DRY RES	SO4	Cl	NO3	NO2	NH4	TOT.HDNESS MMOLE/L
1	DALVERSIN	apQII-III	4-170	0.3-1.1	11-506	11-461	1-9	-	-	.001-.01
2	KIRSOROVAT	K2-P	7-92	0.6-1.5	121-780	14-78	3-90	-	-	.001-.02
3	GOLODNOSTEP	apQII-III	3-90	0.5-3.6	12-1177	32-1134	1-7	-	-	.001-.01
4	SAMGAR	apQII-III	35-89	0.1-1.7	10-996	7-170	1-9	-	-	.001-.01
5	KAMYSHKURGAN	apQII-III	16-260	0.7-2.0	220-1030	42-354	1-50	-	-	.001-.04
6	SYRDAR'YA	apQIV	5-110	1,1-2.5	495-1300	99-284	2-55	-	-	.003-.02
7	LYAKAT-SAVAT	apQII-III	50-185	0.2-3.7	12-1177	32-1137	2-7	-	-	.001-.01
8	NAU-KOSTAKOZ	apQII-III	40-270	0.3-4.3	13-1857	14-315	1-35	-	-	.001-.02
9	KARAKCHIKUM-KANIBADAM	apQII-III	30-110	0.5-4.2	19-1319	21-362	2-700	-	-	.003-.05
10	ISFARA-LYAKAN	apQII-III	20-90	0.9-2.7	394-1685	28-191	1-8	-	-	.006-.03
11	SHAKHRISTAN	apQII-III	40-140	0.3-0.4	8-43	3-11	2-6	-	-	.004
12	ZERAFSHAN	apQII-III	20-90	0.3-0.6	-	-	-	-	-	-
13	REGAR	apQIII-IV	50-90	0.3-0.9	35-227	2-26	7-64	0-0.3	0-1.25	.003-.009
14	KHANAKIN	apQIII-IV	52-110	0.3-0.7	25-114	3-55	7-100	0-0.1	0-0.3	.003-.009

	APPENDIX T2 CONTINUED:									
15	DUSHANBE	apQIII-IV	25-90	0.2-0.6	14-116	2-35	0-50	0-0.1	0-2.5	.004-.007
16	KAFIRNIGAN	apQIII-IV	12-94	0.2-1.3	14-515	3-117	5-45	0-0.2	0-1.25	.003-,014
17	FAIZABAD	apQII-III	40-110	0.3-0.6	12-69	3-72	0-39	0-0.1	0-0.6	.004-.007
18	KALAIDASHT	apQII-III	75-105	0.3-0.4	8-36	0-9	0-9	0-0.2	0-1.2	.002-,003
19	DASHTIRABAT	apQII-III	100-165	0.3-0.4	14-36	0-9	0-5	0-0.2	0-1.2	.003-,006
20	KUIBYSHEV	apQIII-IV	20-90	0.6-1.6	180-629	96-301	0-6	0-0.1	0-0.7	.004-,007
21	KURGANTYUBE	apQIII-IV	16-45	0.6-1.7	173-667	83-216	3-109	0-90	0-125	.002-.016
22	NIJNEVAKSH	apQIII-IV	24-35	1.1-1.4	324-417	149-147	18-43	0	0-0.5	.01-.014
23	BESHKENT	apQIII-IV	20-40	0.6-0.7	147-173	106-115	4-13	0-0.1	0-9.1	.006-.007
24	NIJNEKAFIRNIGA N	apQIII-IV	10-70	0.3-1.1	39-326	14-92	0-55	0-0.1	0-0.9	.002-.011
25	KHOVALING	apQII-III	35-170	0.3-0.4	2-18	4-9	4-10	0-0.2	0-0.4	.003-.04
26	MUMINABAD	apQII-III	60-122	0.3-0.4	3-20	3-18	2-8	0-0.1	0-0.2	.004
27	YAKHSUI	apQIII-IV	23-140	0.3-1.3	19-426	9-206	3-37	0-0.3	0-3.6	.002-.014
28	KZYLSUI	apQIII-IV	30-140	0.6-1.2	346-387	32-255	2-19	0-0.1	0-0.7	.01-.013
29	MOSKOVSKOE	apQIII-IV	15-65	0.3-0.4	41-74	4-40	0-11	0-0.1	0-1.2	.003.004
30	PARKHAR	apQIII-IV	20-80	0.6-1.3	95-267	19-180	0-58	0-0.3	0-1.0	.006-.013

APPENDIX U1 GROUNDWATER ABSTRACTION AND TYPE OF USE IN 7 UPPER WATERSHEDS OBLASTS OF UZBEKISTAN REPUBLIC, 1993

OBLAST/ PROVINCE	GROUNDWATER USE IN 000m³/d					TOTAL FOR EACH OBLAST /PROVINCE IN 000m³/d [2+3+4+5+6]	APPROX % EACH OBLAST WITHIN PROJECT AREA
	PUBLIC DRINKING WATER SUPPLY	INDUSTRIAL	ARABLE CROP IRRIGATION	LIVESTOCK /PASTURE IRRIGATION	WATER-LOGGING PREVENTION /DRAINAGE		
1	2	3	4	5	6	7	8
TASHKENT	2247.4	632.9	37.6	-	247.7	3165.6	60%
NAMANGAN	876.2	77.9	1083.4	-	643.3	2680.8	100%
ANDIJAN	1060.8	131.4	488.3	844.5	844.5	3369.5	100%
FERGANA	3591	1606.9	3598	-	3808.6	12604.5	100%
DJIZAK	382	14.5	42.7	33.1	257.2	729.5	10%
KASKADARIA	336	1.3	176.5	7.2	-	521	30%
SURKHANDARIA	473.5	38.4	200.7	1.6	4.8	719	>95%
USE TOTALS:	8966.9	2503.3	5627.2	886.4	5806.1	23789.9	-
7 OBLAST USE %	38%	10%	24%	4%	24%	100%	-

APPENDIX U2 ADOPTED GROUNDWATER RESERVES BY TYPE OF USE IN 7 UPPER WATERSHEDS OBLASTS OF REP. UZBEKISTAN 1993

OBLAST/ PROVINCE	GROUNDWATER USE IN 000m³/d										TOTAL FOR EACH OBLAST 000m³/d	
	PUBLIC DRINKING WATER SUPPLY		INDUSTRIAL		ARABLE CROP IRRIGATION		LIVESTOCK /PASTURE IRRIGATION		SOIL DRAINAGE			
	A	NA	A	NA	A	NA	A	NA	A	NA	A	NA
TASHKENT	2183.7	63.6	234.3	43.3	34.9	2.6	-	-	90.2	157.6	2543.1	267.1
NAMANGAN	2637.7	115.8	47.9	60.6	3.0	987.8	50.8	399.4	442.6	200.7	3182	1764.2
ANDIJAN	720.4	278.8	18.9	-	100.5	387.4	-	-	129.1	-	968.8	666.2
FERGANA	1525.8	145	389.8	457.9	727.6	1155.5	-	-	83.2	2237.6	2726.4	3996
DJIZAK	494.9	-	14.6	-	42.7	-	35.1	-	20.2	-	607.4	-
KASHKADARJA	519.3	0.8	1.4	-	141.2	35.4	2.3	-	-	0.5	664.2	36.7
SURKANDARJA	818.7	112.1	3.7	34.7	4.8	195.8	-	-	-	4.8	827.2	347.5
USE TOTALS:	8900.6	716.2	710.4	596.6	1054.7	2764.5	88.2	399.4	765.2	2601.1	11519.1	7077.7
7 OBLAST USE %, A & NA	77%	10%	6%	8%	9%	39%	1%	6%	7%	37%	100%	100%
% OF TOTAL ASSESSED RESOURCES ADOPTED AND NON-ADOPTED:											62%	38%

A: Adopted groundwater resource NA: non-adopted groundwater resource

APPENDIX U3 CATALOGUE OF GROUNDWATER RESOURCES IN 7 UPPER WATERSHEDS OBLASTS OF UZBEKISTAN REPUBLIC, 1993

#	AQUIF. SYSTEM	RIV. BAS-IN	AGE	LITHO-LOGY	REF. NO.	ADOPTION CLASSIFICATION					ACTUAL ABSTR $000m^3/d$
						A	B	C1	C2	Σ	
	1	2	3	4	5	6	7	8	9	10	11
	FERGANA RAION:										
1	MAILESUI	SD	Q	BP	25	7	-	-	-	7	253
2	KARAUNGUR	"	Q	BP	32	11.5	8.3	-	-	19.8	115
3	ALTYARK-BESHALYK	"	Q	BP	13	233.4	361.4	194.1	13.9	802.7	2356.2
4	ANDIJAN-SHAKRISTAN	"	Q	BP	14	4.5	30.4	49.4	-	84.3	814.5
5	OSH-ARAVAN	"	Q	BP	32	101.8	206.4	162	941.7	1411.9	858.8
6	ALMAS-VARZYK	"	Q	BP	1178	68.8	25.9	24.3	-	119	619.3
7	KASANSAI	"	Q	BP	N24	-	2.3	5.5	-	7.9	137
8	KUKUMBAI	"	Q	BP	N24	-	3.2	1.7	-	4.9	6
9	NANAI	"	Q	BP	-	-	-	-	-	-	38.2
10	ISKOVOT-PISHKARAH	"	Q	BP	36	68.4	71.9	-	-	140.3	536.1
11	CHUST-PAP	"	Q	BP	-	-	-	-	-	316.8	132.2

SD=SYR DAR'YA R., SK= SURKANDARIYA R, KK=KASHKADARIYA R, CC=CHIRCHIK R.; .Q=QUATERNARY; BOULDER BEDS, PS=PEBBLY SAND BEDS, P= PEBBLE BEDS,SG= SANDS & GRAVELS

APPENDIX TABLE U3 CONTINUED:

#	AQUIF. SYSTEM	RIV. BAS-IN	STR AT. AGE	LITHO-LOGY	REF. NO.	ADOPTION CLASSIFICATION					ACTUAL ABSTR 000m³/d
						A	B	C1	C2	Σ	
	1	2	3	4	5	6	7	8	9	10	11
12	NAMANGAN	"	Q	BP	19	2.6	19.2	11.3	32.0	65.1	297.2
13	NARYN	"	Q	BP	1264	398.5	107.5	55.8	264.4	826.2	596.3
14	SYRDAR'YA	"	Q	BP	22	33.3	1218.5	719.1	-	1970.9	296
15	CHIMION-AUVAL	"	Q	BP	4232	241.0	246.4	181.9	57.0	726.3	1123.7
16	YARMAZAR	"	Q	BP	4756	129.6	155.5	-	60.5	345.6	878.7
17	ISFARA	"	Q	BP	26	26.3	12.1	-	-	38.4	242.6
18	SOKH	"	Q	BP	28	236.2	203.8	25.6	-	465.6	2248.3
19	SYRDAR'YA	"	Q	BP	22	175.0	1226.9	1422.7	-	2824.5	67.7
	TASHKENT & ENVIRONS:										
20	CHIMGAN MASSIFS	CC	Q	PS	1155	5.1	4.0	4.0	-	13.1	7
21	CHIRCHIK FTHILLS RB	"	Q	PS	-	-	-	-	-	-	4.3
22	CHIRCHIK FTHILLS LB			PS	-	-	-	-	-	-	42.2
23	CHIRCHIK-KELES DIV.	"	Q	PS	32	0.3	9.9	17.6	-	27.9	92.4
24	CHIRCHIK	"	Q	PS	19	995.8	589.8	341.3	106.1	2033.1	2191.9

#	AQUIF. SYSTEM	RIVER BASIN	STRAT. AGE	LITHOLOGY	DOC. REF. NO.	ADOPTION CLASSIFICATION					ACTUAL ABST $000m^3/d$
						A	B	C1	C2	Σ	
25	AKHANGARAN	A	Q	PS	9	395.7	521.3	340.3	187.1	1444.4	830.3
	GOLODNOSTEP:										
26	PREDGORNDE	SD	Q	PS	1275	58.7	68.3	32.4	-	159.4	125.3
27	SANJAR	"	Q	PS	1276	79.6	156.7	70.1	-	306.4	179.0
28	RAVAT	"	Q	PS	N10	9.7	11.5	5.4	47.3	73.9	31.7
29	ZAAMIN	"	Q	PS	N1064	27.7	43.9	9.5	74.4	155.6	158.9
	SURKANDARYA:										
30	BAISUN-PASHKHURDA MASSIF	SK	Q	P	9956	23.8	14.0	8.6	13.5	59.9	130.0
31	S.SURKANDARYA	"	Q	P	9728	82.9	72.6	19.7	75.4	250.6	483.0
32	S.SURKANDARYA	"	Q	P	N34	22.3	35.7	61.8	26.3	146.1	183.9
33	SHERABAB	"	Q	P	N864	9.8	11.8	21.6	-	43.2	142.1
	KASHKADARYA:										
34	MOUNTAIN MASSIF	KK	Q	SG	1137	-	0.6	77.8	-	78.4	83.1
35	KITAB-SHAKRISYABZ	"	Q	SG	8993	216.8	215.2	-	-	432.0	315.2
36	PRAVOBEREGNOE	"	Q	SG	1016	22.7	40.8	-	22.9	86.4	115.8
37	LEVOBEREGNOE	"	Q	SG	-	-	-	-	-	-	5.16

APPENDIX TABLE U4 CATALOGUE OF GROUNDWATER UTILISATION ACCORDING TO AQUIFER SYSTEM IN 7 UPPER WATERSHEDS OBLASTS OF UZBEKISTAN REPUBLIC, 1993

#	AQUIF. SYSTEM	RIVER BASIN	HY-GEOL REGIME	TOTAL RESERVE		TYPE OF WATER USE -ADOPTED-					TYPE OF WATER USE -NOT ADOPTED-				
				USED	NOT USED	PDWS	IND'L	ACI	L/PI	WP/D	PDWS	IND'L	ACI	L/PI	WP/L
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1				258	-	7	-	-	-	-	78.9	28.7	13.6	-	-
2				115	-	19.8	-	-	-	-	26.3	3.6	65.2	-	-
3				2352.6	-	470.9	145.2	166.6	-	-	-	-	166.6	-	1212.6
4				914.5	-	84.2	-	-	-	-	173.6	76	308.6	-	-
5				857.8	554.1	609.4	18.9	100.5	-	129	-	-	-	-	-
6				619.3	-	79.7	0.3	39	-	-	-	-	469.5	-	30.7
7				137	-	46.4	1.5	1.3	-	-	-	-	87.8	-	-
8				5.4	-	4.4	-	0.5	-	-	-	-	0.5	-	-
9				38.2	-	-	-	-	-	-	7.5	-	30.7	-	-
10				536.1	-	133.4	-	6.9	-	-	-	-	394.4	-	-
11				132.2	-	-	-	-	-	-	97.8	30	4.8	-	-
12				277.2	-	65.1	30.6	0.1	-	-	10.8	30.6	0.1	-	169.9

APPENDIX U4 CONTINUED

#	AQUIF. SYSTEM	RIVER BASIN	HY-GEOL REGIME	TOTAL RESERVE		TYPE OF WATER USE -ADOPTED-					TYPE OF WATER USE -NOT ADOPTED-				
				USED	NOT USED	PDWS	IND'L	ACI	L/PI	WP/D	PDWS	IND'L	ACI	L/PI	WP/L
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13				596.4	212.9	333.7	15.5	1.9	-	275.2	-	-	-	-	-
14				296	1274	97.7	-	1	-	197.4	-	-	-	-	-
15				1123.7	-	333.3	99.9	551.5	-	41.6	-	-	-	-	97
16				878.7	-	202.6	143	-	-	-	-	391.3	139.6	-	2.1
17				242,6	-	38.4	-	-	-	-	16.8	2.9	135.8	-	48.6
18				2248.3	-	465.6	-	-	-	-	128.2	63.6	713.5	-	877.3
19				67.7	2756.8	15.1	1.6	9.5	-	41.6	-	-	-	-	-
20				7	6.1	4.3	0.7	2	-	-	-	-	-	-	-
21				4.3	-	-	-	-	-	-	4.3	-	-	-	-
22				42.2	-	-	-	-	-	-	41.1	1.1	-	-	-
23				92.4	-	27.9	-	-	-	-	18.2	42.2	2.6	-	-
24				2191,9	-	1570.2	354,5	27.3	-	81.1	-	-	-	-	157.6

APPENDIX U4 CONTINUED

#	AQUIF. SYSTEM	RIVER BASIN	HY-GEOL REGIME	TOTAL RESERVE		TYPE OF WATER USE -ADOPTED-					TYPE OF WATER USE -NOT ADOPTED-				
				USED	NOT USED	PDWS	IND'L	ACI	L/PI	WP/D	PDWS	IND'L	ACI	L/PI	WP/L
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25				830.3	614.2	581.3	234.3	5.6	-	9.1	-	-	-	-	-
26				125.3	34.1	78.5	4.7	8.1	33.9	-	-	-	-	-	-
27				179	66.8	145.6	9.8	12.9	-	10.8	-	-	-	-	-
28				31.7	52.1	31.3	-	0.4	-	-	-	-	-	-	-
29				158.9	9.6	127	-	21.3	1.2	9.4	-	-	-	-	-
30				30	29.9	25.7	0.3	4.1	-	-	-	-	-	-	-
31				483	-	250.6	-	-	-	-	60.9	29.8	141.6	-	-
32				163.4	-	142	3.4	0.7	-	-	-	-	16.8	-	-
33				142.1	-	43.2	-	-	-	-	51.2	4.9	37.4	-	4.8
34				83.1	-	2.9	0.6	74.9	-	-	-	-	3.6	-	-
35				315.2	116.8	274.8	0.4	37.7	2.3	-	-	-	-	-	-
36				115.8	-	57.4	0.4	28.6	-	-	-	-	27.4	-	0.5
37				5.2	-	-	-	-	-	-	0.8	-	4.3	-	-

APPENDIX U5 INDICATIVE MAJOR ION ANALYSES OF GROUNDWATER IN PRINCIPAL AQUIFER UNITS OF 7 UPPER WATERSHEDS OBLASTS OF REPUBLIC OF UZBEKISTAN

#	AQUIFER SYSTEM	RB*		TYPICAL VALUES mg/l							
			pH	Ca	Mg	Na+K	HCO3	SO4	NO3	Cl	TDS**
1		SD	7.5-8.1	40-100	20-30	10-50	170-250	60-170	1-6	10-20	300-500
2		"	7.8-8.2	30-50	20-50	10-20	150-210	30-50	2	10	200-400
3		"	7.7-8.2	10-20	10-20	20-30	1-11	90 –	1-2	10	200
4		"	7.8-8.2	40-50	30-40	100	100	300	2	30	600-700
5		"	7.2-7.4	40-60	10-80	40-150	80-410	80-90	-	20-130	300-800
6		"	7.9-9.8	8-90	20-60	20-60	80-100	60-100	-	10-20	200-400
7		"	7.2-8.3	61-122	37-64	58-84	70-317	184-414	0-4	23-48	480-850
8		"	7.8-8.5	36-62	37-54	100	32	270-283	-	162-165	666-714
9		"	-	-	-	-	-	-	-	-	-
10		"	7.4-8.2	40-70	200-500	10-80	230-260	70-270	-	10-50	300-700
11		"	7.9-9.8	90	8	20-60	80-200	60-100	-	10-20	200-400
12		"	8.0	48-73	28-55	256-358	189-265	105-296	-	18-22	339-600
13		"	7.3-8.6	40-150	10-40	3-13	6-38	30-450	1-3	20-150	300-1000
14		"	7.4-8.2	16-21	5-6	-	37-104	3-4	2-4	76-104	236-260
15		"	7.2-8.0	6-12	2-6	20-70	130-310	120-350	3-24	10-50	300-800
16		"	-	-	-	-	-	-	-	-	-

APPENDIX U5 CONTINUED

17		"	8.3	30	40-100	30	100-300	200	-	10-40	600
18		"	7.4	20-30	10	10-20	90-100	70-100	-	10	180-260
19		"	6.7	100	40	100	100-200	300-400	-	30-100	600-800
20			6.2-8.4	1-15	3-5	1-15	50-90	1-15	-	1-98	110-170
21			7.2-8.3	30-120	30-69	1-15	153-354	147-252	-	1-48	400-850
22			7.1-8.3	4-26	9-18	6-31	130-200	26-86	-	6-28	213-352
23			7.0-8.4	16-172	6-191	18-45	43-360	8-1098	-	6-252	200-1994
24			7.2-8.3	32-124	69	10-40	153-354	147-292	24	22-48	437-850
25			7.7-8.4	34-116	8-17	13-48	49-201	49-238	1-15	9-27	182-576
26		SD	8.0	72	43	103	220	350	-	25	720
27		"	8.4-8.7	50-80	30-50	50-100	110-200	190-360	2-8	38-40	430-740
28		"	7.6-7.8	40-150	40-80	70-80	200-240	210-520	-	20-30	500-600
29		"	8.0-8.1	40	40	30	220	100	-	10	360
30			7.2-8.2	400-900	200-400	200-500	300	200-400	-	100-400	600-800
31			7.4	100	10	40	100	200	-	20	1500
32			7.1-7.6	100-200	20-40	50-70	200-300	300-400	-	20-40	600-900
33			7.9-8.0	10-30	10-40	20-200	100-200	200-700	-	300-600	400-1200
34			7.5-8.1	200-400	-	20-200	300	30	-	10	300
35			6.8-7.0	60-80	-	10-30	200-300	30-40	-	10	300-500

APPENDIX U5 CONTINUED											
36			6.9	300	300	100	200	200	-	200	500
37			7.6	500	300	200	200	300	-	400	800

RB River Basin;
SD Syr Dar'ya

TDS mineralisatio n, estimated as dry residue.

APPENDIX U6 GROUNDWATER USE FOR URBAN DRINKING WATER SUPPLY TO PROVINCIAL CITIES IN 7 UPPER WATERSHED OBLASTS OF REPUBLIC OF UZBEKISTAN

#	OBLAST	CITY	POPULATION (1990)	APPROX TOTAL VOL OF SUPPLY m^3/s	PER CAPITA SUPPLY l/p/d	APPROX. VOL. SUPPLIED. FROM GROUND WATER m^3/s	% OF SUPPLY FROM GROUNDWATER
1	TASHKENT	TASHKENT	2,100,000	22-23	925	8.5	38%
2	"	ALMALIK	115,000	2.5	1878	2.5	100%
3	ANDIJAN	ANDIJAN	300,000	c.3	864	2.7	90%
4	NAMANGAN	NAMANGAN	340,000	4	1016	4	100%
5	FERGANA	FERGANA	185,000	1	467	1	100%
6	DJIZAK	DJIZAK	120,000	0.7	504	0.7	100%
7	KASKADARJA	KARSHI	185,000	1.5	700	1.5	100%
8	SURKHANDARJA	TERMEZ	105,000	0.7	576	0.7	100%
	ESTIMATED POPULATION DEPENDENT ON GROUNDWATER IN MAJOR URBAN CENTRES: **2,120,000**						

APPENDIX .. ABSTRACT FROM HYDROGEOLOGICAL DESCRIPTION OF REPUBLIC OF UZBEKISTAN (REFERENCE IX, page 36)

HYDROGEOLOGY

Hydrogeologically the territory of Uzbekistan Republic is divided into 2 provinces, the piedmont and foothill mountain areas and the valley-lowlands. The areas of intensive development of fresh groundwater resources are in the mountains. On the plains, there is groundwater but with high salinity and limited resources.

Piedmont and foothill mountainous province

This province is divided into mountain systems, foothills/piedmont and intermontaine valleys.

Mountains: These comprise a very complex nucleus of tectonisd anticlinal structures. Here one can find fissure and karst-fissure water in carbonate rocks, fissure water in metamorphic shales, sandy shale formations and volcanosedimentary deposits and intergranular flow in some terrigenous complexes of Mesozoic rocks. Groundwater derives from the infiltration of precipitation, the intensity of which depends on the lithology of the rocks and the amount of precipitation, which itself varies with elevation and geographical location. The most favourable conditions for groundwater recharge are found between the elevations of 1,500-3,500m, where the greatest amount of precipitation is observed. This zone is characterised by maximum groundwater flow rates(*recharge?*): for carbonate rocks their value reaches 12 $l/s/km^2$, for sedimentary or magmatic complex it is 8-9 $l/s/km^2$, for metamorphic sandy shale it is 3-5 $l/s/km^2$ and for terrigenous Mesozoic/Cenozoic it is 1-3 $l/s/km^2$. The minimum values of groundwater flow rate(*recharge*) are observed in all water containing rocks below 1500m elevation because here the amount of atmospheric precipitation is rather low, and the evaporation rate is considerable. Groundwater resources of mountain areas in Uzbekistan are about 105 m^3/sec as follows;

31.4 %	Tashkent District (Tashkent Oblast)
23.8	Sukhandariya Oblast
13.5%	Kashkadariya Oblast
11.6%	Zerafshan District (Navoyi Oblast)
6.7%	Nurata-Turkestan District (Bukhara),
5.25%	Hungry Steppe (Djizak),
5.9	Namangan, Andijan and Fergana Oblasts,
<2%	central Kzyl-Kum desert.

Over 80% of the total dynamic resources contribute to surface water courses The resources occur in fracture flow or karst fissure system and as sub-channel flows (*underflow?*) of mountain river valleys. While these are important for water supply, their withdrawal will directly affect the amount of surface water flow and the resources of groundwater in foothills and intermontaine areas.

Piedmont/foothills: are represented by low rows of hills which flank intermontaine areas, formed as synclinal basins, often artesian. In this area, phreatic and confined groundwater (recharge) derives both from precipitation and inflow of subsurface water. They supply mainly adjacent artesian basins. The rocks are principally sandy clays which form piedmont/foothills and are weakly saturated. The quality of subsurface water is variable, from fresh to brine. In Kokural piedmont plain, fresh artesian water flows from sandy gravel sediments at the depth of 100m and more. The water resources are estimated as 1.0 m^3/sec and are the main source of public water supply and pasture irrigation. The typical discharge of a borehole is 10-15 l/s. In the foothills of Zerafshan confined gravel and pebble aquifers produce mainly fresh and slightly saline water. The resources are negligible. Borehole discharge is up to 10-15 l/s and is used for public water supply and livestock watering. The total amount of dynamic reserves of groundwater in the foothills is about 295 m^3/sec.

Intermontaine and river valleys: Mountain massifs are separated by river valleys and intermontaine basins which are represented by synclines. The axes of almost all such plains are coincide with the river valleys. In the intermontaine plains, phreatic and confined groundwater occurs. Quality and quantity is different depending on the recharge conditions, circulation and on discharge. In central parts of depressions, groundwater with increased salinity predominates, due to difficult conditions for groundwater flow. Fresher water in Quaternary deposits are referred to peripheral fans and to the so-called gravel/shingle tongues in the loam layers (central Fergana, eastern part of Hungry Steppe)

Artesian waters are derived from Mesozoic and Tertiary deposits and vary both in quantity and quality. In sandy, pebbly strata of the Upper Tertiary, freshwater occurs but is scarce. In Lower Tertiary deposits, highly saline and very often thermal waters are mainly found.

Groundwater reserves of intermontaine basins are many times more than the demands of public water supply and industrial water supply (*sic*). Within intermontaine basins and river valleys, water of Quaternary formations of different genesis is of great practical value. Considerable reserves of fresh groundwater (90-95%) are formed in the basins, mainly due to losses of surface water from rivers, canal and field irrigation system. River valleys are formed by alluvial gravel/pebble formations (main rivers) and older alluvial loams, sands, gravels and pebble beds, and the thickness of such deposits is 100-300m. A very productive flow of groundwater can be found there. The formation of groundwater flow starts at the exit of rivers from the mountain region and down along the valley the reserves increase continuously due to losses from the river itself, from the irrigation network and irrigated lands and from groundwater flow from the mountain streams (*sai*) and from the surrounding mountainous ranges. Discharges of boreholes can be up to 100 l/s per more with the specific discharge(*specific capacity?*) of up to 50 l/s/m.

Fergana valley is rich in groundwater. Productive reserves of groundwater are 289 m^3/s as recharge. When withdrawal of groundwater is high, surface water decreases by 250 m^3/s. Intensive use of groundwater will result in reduction of evaporation from shallow groundwater levels, will improve the capacity of saline soils and will provide increased water resources by a value which is close to the value of evaporation from the groundwater level (40 m^3/s). In the basin of Chirchik and Akhangaran Rivers, about 140 m^3/sec is formed, namely 90 m^3/sec in Chirchik, 33 m^3/sec in Akhangaran, 14 m^3/sec in Syr Darya. Water levels are found mainly at 1-5m in depth. Borehole yields can be about 180 l/s. Groundwater is mainly lost to river channels, irrigation collector drains and by evaporation from the water table. In the Pskent area (*uppermost river valley of Chirchik*), semi-artesian and sometimes artesian water is found in pebble beds at a depth of 200-400m. Productive renewable reserves of the water are 1.3 m^3/sec. Single borehole discharges reach 50 l/s and more.

The total productive reserves of groundwater which are suitable for public water supply and irrigation in Hungry Steppe are about 32 m^3/sec. The largest reserves of groundwater are in the northeastern part of Hungry Steppe, where the confined water level is at 5-400m deep.

Between the basins of Syr Darya and Amu Darya rivers there is a transition zone which includes the valley of Sanzar River, Gallja'aral, Koitash, Koshrabad, Nurata and Arnasai depressions and surrounding northern and southern ranges of Nurata Mountains. In the valley of Sanzar River, there are fresh groundwater is highly developed, and the reserves are 3 m^3/sec. Single borehole discharge is up to 50 l/s. In Gallja'aral Koitash and Koshrabad depressions, there are small reserves of groundwater. Water is of mixed salinity, from fresh to brackish. Discharge of a single borehole is 5-10 l/s, seldom 15 l/s. The total productive reserves of groundwater here are estimated as 7.1 m^3/sec. In Nurata tectonic basin, freshwater is mainly found in pebbly sands, loams and sandstones. Borehole discharge are up to 25 l/s. The total reserves of groundwater are 1.7 m^3/sec. Water of such tectonic basins can be used for irrigation and rural water supply.

In the middle part of Zerafshan basin (Zerafshan intermontaine valley) and in the lower part of it (Bukhara and Karakul oases) groundwater is widespread. Reserves of the present day Zerafshan river valley are 95 m^3/sec and are derived from losses of river, canals and irrigated lands. In the irrigated zone of Karakul and Bukhara oases, groundwater is found at a depth of 1.5-3 m. The salinity varies from slightly saline to saline. Productive reserves of groundwater are estimated at 38 m^3/sec. This water can be used for public water supply and as additional source for irrigation. In Kitab-Shakhrisjabskaya inland depression, about 8 m^3/sec of good quality water can be taken from gravel/pebble deposits, the borehole discharge being about 25 l/s.

Fresh, slightly saline and saline groundwaters are found in the middle reaches of Kashkadariya River, in Upper Tertiary sandstones. Water here is confined and at a depth of 20-50 to 105m. Borehole discharges are typicaly about 5 l/s. Reserves of this water (2 m^3/sec) can be used for agriculture, livestock watering and industrial supply. In the valley part of Kashkadariya basin, including Karshy Steppe, saline confined water is found in marls, limestones of the Lower Tertiary and sandstones of the upper Cretaceous. The artesian boreholes have about 25 l/s discharge. The depth of aquifer level increases from north towards the south and west from 100-150 to 300-450m. Reserves of this water (about 1.5 m^3/sec) can be used for pasture irrigation and industrial supply.

Sukhandariya and Sherabad river basins are characterised by uneven distribution of fresh and slightly saline groundwater. On the eastern bank of the Sukhandariya river, there is no groundwater of regional distribution and suitable for use. Fresh groundwater is spread within the alluvial fans and flows into western valleys of Sukhandariya river and lower parts of the valley. Productive reserves of groundwater from those fans are 17 m^3/sec. Within the lower part of Sukhandariya river valley, fresh and slightly saline ground water is found along the river bed. The estimated reserves of groundwater here are about 3.5 m^3/sec and those of the whole valley 16 m^3/sec. Water level is at different depths (from 1-2 to 10-15m). Typical borehole discharges are about 15 l/s. In the Sherabad river fan, fresh water occurs in the form of lenses of fresher water in sandy beds at 100m depth.Reserves of this water are about 0.3 m^3/sec. Discharges of single boreholes when withdrawn are about 25 l/s. Within the Baisoun group of intermontaine basins in Ghyssar mountains, groundwater is confined mainly to saline water in Cretaceous deposits which are at 300 m depth. The reserves are unknown, but it is assumed that they may be enough to water pasture regions. Freshwater is found in the zone of fractures or faults and locally in Quaternary deposits.

APPENDIX U7 SUPPLEMENTARY NOTES ON GROUNDWATER IN REPUBLIC OF UZBEKISTAN

This information was supplied by Dr Sorokina Iraida; who heads the Hydrogeological Dept of SANIIRI at meetings on 17 & 18 July 1995.

Groundwater investigation & evaluation:

This role is carried out by Uzbekgidrogeologia Corporation, which is a dependency of the Ministry of Geology, and this reflects a functional division between groundwater investigation and resource definition on the one hand and groundwater operations and day-to-day management on the other. The latter role is undertaken by different organisations under the umbrella of the Ministry of Water Resources Development. Uzbekgidrogeologia Corporation (UC) is responsible for initial resource identification, through field mapping and aquifer testing programmes, and also for the quantification of groundwater quality and quantity. It applies a 4-tier system of resource assessment which was said to be Soviet-wide; classes A, B, C1 and C2:

The system in effect takes account of the unavoidable uncertainties in the safe yield from a given groundwater system during its early period of exploitation, when the data base is small and there may be inadequate information on aquifer geometry, boundary conditions or recharge mechanisms. Water is assessed in response to a demand, and the quantity required is then compared with the volume of water available in classes A & B. [This important point was subsequently checked in Kyrgyzstan, where a similar system operates; see final text of report section 4.1.

Operational organisation of groundwater abstraction:

Like other water related applied research or planning and design institutes, such as Vodproect, Uzgiprovodkhoz, Uzgipromeliostroi, SANIIRI is a dependency of the Ministry of Water Resources Management (MWRM). Its present role in Uzbekistan is therefore one of technical advice to MWRM in the operation of water systems.

Actual field operations involving groundwater development are controlled by 13 operational units, which are geographically organised, one for each *Oblast*. These are field units responsible for land drainage and reclamation issues, and monitoring of water level and some simple water quality surveillance for agricultural purposes is carried out to support this function. The monitoring network is vast, numbering about 34,000 wells, located only in the irrigated areas; typical network density is about 1 well to 200 ha. Measuring frequency for water levels is every 10 days, with water sampling in April, July and October, corresponding to spring pre-seeding flooding for desalinisation purposes, mid-crop and post-crop periods. Quality sampling can be for major ions (Ca, Mg , Na with K, Cl, HCO_3, SO_4) if considered necessary, but is generally just for total mineralisation (evaporated dry residue) and Cl. Recently the number of analyses has declined due to reagent shortages. The data are compiled by each field unit into regular reclamation digests which include sections, with maps at 1:100,000 and 1:200,000 on water level, semi-artesian head where applicable, water and soil salinity. As well as monitoring, the field units have a surveillance function, which arises both from detection of adverse trends from the monitoring network, and from their agricultural extension service function, in that farmers can report to the field units the development of waterlogging or salinity increases.

A third element in water management infrastructure operated through MWRM comprises a series of administration departments. These are organised by topic rather than geographically, and cover, amongst other topics, irrigation, land reclamation, canal/river pumping stations, waterlogged land dewatering.