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DFID Project No. R7134

Groundwater vulnerability and urban activity assessment: the Bishkek, Kyrghyzstan case-study

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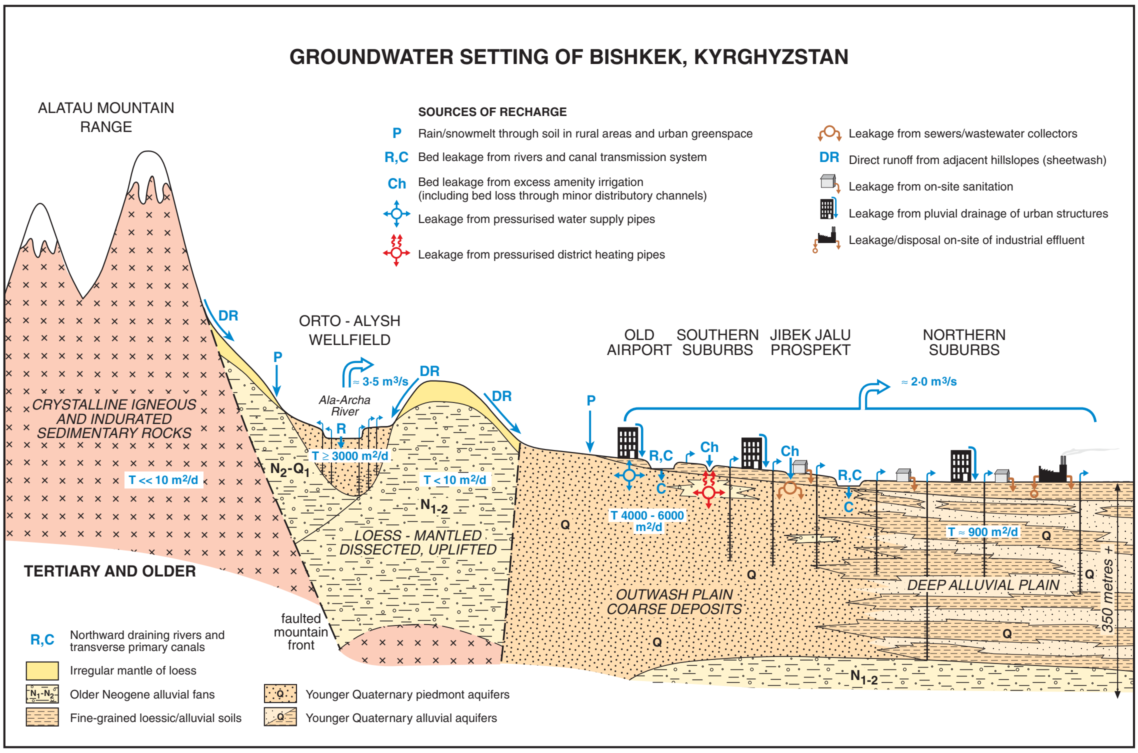

Natural Environment Research Council

BGS International®
British Geological Survey
Keyworth
Nottingham NG12 5GG
United Kingdom

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Groundwater vulnerability and urban activity assessment: the Bishkek, Kyrghyzstan case-study

B. É. Ó Dochartaigh[1], B. L. Morris[1], R. G. Litvak[2], E. J. Nemaltseva[2] , I. Podubnaia[2] and G Tolstihin [3]

[1] British Geological Survey Hydrogeology Group
[2] Kyrghyz Scientific & Research Institute of Irrigation Groundwater Modelling Laboratory
[3] Kyrghyz Hydrogeological Survey

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Front cover illustration: Groundwater setting of Bishkek, Kyrghyzstan

Keyworth, Nottingham, British Geological Survey, 2000

Executive Summary

A pragmatic groundwater risk assessment for groundwater protection and urban development planning purposes is described for the city of Bishkek, capital of Kyrghyzstan. The city is 100% aquifer dependent for potable, domestic, commercial and industrial water supplies which are provided by both intraurban and periurban wellfields. The urban groundwater setting is hydrogeologically complex, with a laterally heterogeneous multi-aquifer system tapped by urban wells at widely different depths. The coarse alluvial and fluvio-glacial deposits comprising the aquifers have high transmissivities and significant vertical permeabilities. The risk assessment needed to take account of the vulnerability of aquifers at significant depths of up to 150 m. Using simple GIS techniques and working with available data, a map showing areas of low, moderate and high vulnerability together with a plan of potentially hazardous activities was produced collaboratively by British Geological Survey and Kyrghyz Scientific and Research Institute for Irrigation teams. The interaction between these two themes has provided the groundwater resource-planning map. This is the key plan required for the second stage of this project, in which urban groundwater protection policies are evolved and guidelines developed for more general use.

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1. BACKGROUND

1.1 Project Overview

This is the first technical report of the DFID-KAR project on Groundwater Protection and Management for Developing Cities (R7134). The goal of this project is to increase sustainability of groundwater used for public water supply in cities, and its purpose is the improved protection of aquifers from urban/industrial activities (see project log framework, Appendix 1). The project commenced on 1 October 1998 and is for 3 years duration. Outputs from the project are centred on work in two case-study cities and include:

(i) Aquifer vulnerability and contaminating activity assessments

(ii) Training of collaborators in techniques of assessment for groundwater protection

(iii) Development of guidelines for sustainable management of urban aquifers, generalised for wider use

The project aims to use the experience of the case studies, which are in two contrasting developing city settings, to develop appropriate tools and planning guidelines. These are based on the urban water management principles and strategies advocated in the World Bank policy paper on Groundwater in Urban Development (Foster *et al*, 1998, also a DFID-supported project R6307). In outline, each case study produces a draft groundwater resource planning map which is evolved through the medium of groundwater vulnerability and pollution risk assessments. The map is then used together with a concise draft set of policy options to provide a working document with which to engage urban stakeholders.

The cities of Bishkek in Kyrghyzstan and Narayanganj in Bangladesh were selected for the case-studies because they represent common urban groundwater development environments and socio-economic situations where water quality deterioration could have serious economic consequences (Morris *et al,* 1994). The hydrogeological setting of Bishkek (on a piedmont/alluvial outwash plain aquifer) and of Narayanganj (deep coastal plain multi-aquifer) are both frequently encountered, especially in the South, Central and East Asian regions, so the results of the study can be generalised to many more cities of similar type. The cities contrast with each other socio-economically, as Kyrghyzstan is an ex-command economy in transition, while Bangladesh is an industrialising developing world economy. There are thus opportunities for lessons to be learnt in the development of practical sustainable development policies in quite different socio-economic settings.

The project's timetable in each city divides into two stages:

(i) Collation of available information, its technical evaluation and incorporation into a resource risk assessment. These permit production of thematic maps that summarise the key management issues for urban groundwater.

(ii) Development of a draft set of policy options and liaison with key stakeholders who are affected by, and can influence, how groundwater is developed and how the subsurface in each city is managed to meet the urban needs of water supply, waste disposal and urban engineering[1].

This report describes the first-stage activities to produce thematic maps in the Bishkek case study.

[1] During the first stage, the identification and engagement of urban stakeholders has been an aim in each of the case studies

1.2 The Bishkek Case Study

The project partner in Bishkek, Kyrghyzstan is the Kyrghyz Scientific and Research Institute for Irrigation with a project team from the Groundwater Modelling Laboratory (KSRII-GML). Secondary assistance in the form of data provision has come from the Kyrghyz Hydrogeological Survey (KHS), from the municipal water services agency Bishkek Vodocanal (BV) and from the Water Resources Branch of the Department of Water Economy (DWE-WRB). These organisations are also important stakeholders, BV being the supplier of almost all of the city's water for domestic, industrial, commercial and heating purposes, KHS being their principal technical consultant and DWE-WRB being a national water planning agency whose remit includes the capital. UK project support includes technical advice and training and is provided by the British Geological Survey (BGS).

The Bishkek case study started in December 1998. Its inception is described in BGS project report WD/98/75C (Morris, 1998) and the first 12 months progress in a KSRII report (Litvak et al, 1999).

Bishkek is the capital city of the Kyrghyz Republic, a former republic of the USSR and an independent state since 1991. The city lies on the outermost northern flanks of the foothills of the Alatau range of the Tien Shan mountains at an elevation of 725-900 m above sea level. The population of Bishkek is approximately 600,000.

The city is the country's industrial centre and has witnessed changes since independence, notably the decline of the once-dominant Soviet military-industrial sector, and the increase in small private businesses, often with foreign investment. Nationally, mining, mineral processing and agriculture remain important economic activities, the last-named now also largely characterised by small individual producers following the demise of state and collective farms.

2. PRAGMATIC GROUNDWATER RISK ASSESSMENT FOR URBAN PLANNING

2.1 Rationale for Using Simple Risk Assessment Tools for Aquifer Management Purposes

Criteria which have influenced how outputs from a resource risk assessment stage can be made appropriate for use at a subsequent policy development and aquifer management stage include:

(i) *Must use available data:* The project is resourced only to use existing information, which is the typical situation for groundwater protection in most small fast-developing cities. This places a premium on identification of either basic data arrays already collected for other purposes, or simple parameters easily collated from operational records. In Bishkek, the standard of basic hydrogeological data appears to be good, being comprehensive in parameters covered (geology, hydrogeology, water levels, location of wells etc), internally consistent and relatively up to date (mostly less than 20 years old). Only in the area of routine monitoring is the available data array weak, so that trends in aquifer usage and water quality are unknown.

(ii) *Transparency of tools employed:* The tools used need to be simple and robust if they are to be generalised to many different city situations. This will facilitate their uptake by making the process relatively rapid, low cost and easy to undertake with limited human, technical and financial resources. For example, while GIS is used in this case-study to permit easy overlay of thematic material for map production, the number of stages is small enough and the ranking system simple enough for manual overlay techniques to have been employed if local resources had so dictated.

(iii) *Comprehensible to stakeholders:* In many cases important and influential stakeholders involved in urban water management decisions do not have a technical background either in engineering or in resource planning. Professional hydrogeological expertise in city water management is rare, even where groundwater is a major urban resource. This is almost certainly the case in Bishkek, where urban water management decisions do not appear to involve resource-knowledgeable institutions like the KHS or KSRII. Thus while the underlying rationale may be subtle, and the technical background complex, an urban water management discussion document needs to be simple, clear and concise enough to engage municipal decision-makers with a minimum of technical jargon. The groundwater pollution threat assessment tools developed in a related DFID project (R6863) are an example of this approach, and have been used in the data collation and planning work of this case-study (Calow *et al,* 2000 and Appendix 2 of this report).

These criteria (must use available data, must be simple to apply but technically robust; results must be easily visualised by the intelligent layman) have guided how a risk-based assessment can be adopted. The chosen approach employs the interaction between hazard from contaminant load and aquifer vulnerability to determine the risk of pollutants reaching the aquifer (Figure 2.1).

The risk can then be conceived as the interaction between:

(i) the aquifer pollution vulnerability resulting from the natural characteristics of both the aquifer and the strata separating it from the land surface, and

(ii) the contaminant load that is, will be or might be applied to the sub-surface as a result of human activity.

Adopting such a scheme, it is quite possible to have high contaminant load but no significant pollution risk because the aquifer's intrinsic vulnerability is low, and vice versa. As the intrinsic vulnerability relates only to the properties of the aquifer with its overlying layers, and not to the properties of the potential contaminants (because these are numerous and highly variable), the approach is most helpful when dealing with persistent mobile contaminants not readily susceptible to attenuation. As such, the scheme is necessarily a pragmatic approximation because "general vulnerability to a universal contaminant in a typical pollution scenario is a meaningless concept" (Andersen, 1987).

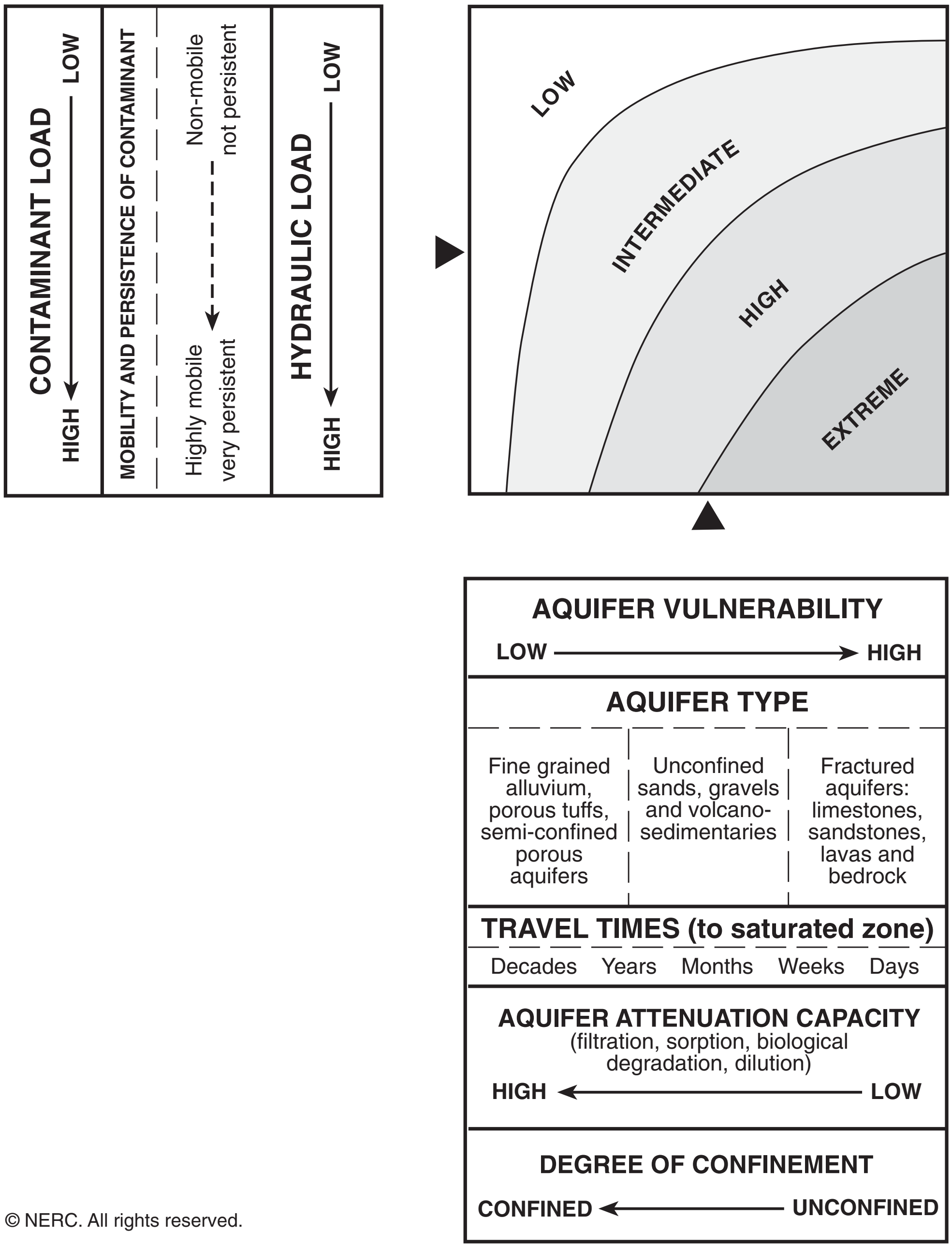


Figure 2.1 Conceptual scheme of groundwater pollution risk (modified from Foster & Hirata, 1988)

For the purposes of developing groundwater protection and management policies, the assessments of aquifer vulnerability and contaminant load are presented in the form of a groundwater resource planning map (GRPM). This is derived from a groundwater vulnerability map (GVM) and a potentially hazardous activities map (PHAM).

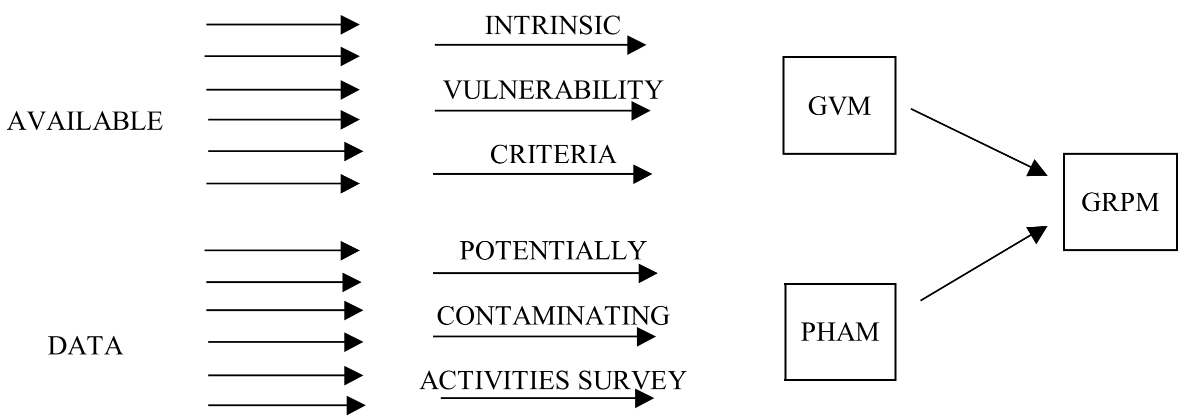


Figure 2.2 Evolution of component parts of a groundwater resource-planning map (GRPM)

2.2 Interaction of Aquifer Vulnerability and Hazard from Contaminant Load

2.2.1 General description

Intrinsic groundwater vulnerability arises from the natural characteristics of the aquifer and any overlying strata. As described in the previous section, groundwater vulnerability is distinct from pollution risk, which is controlled by the contaminant load that may be applied to the sub-surface environment as a result of human activity[2].

Assessing groundwater vulnerability requires an appraisement of the sensitivity of the groundwater system to being adversely affected by an imposed contaminant load. To a great extent, aquifer vulnerability is a function of the accessibility of the saturated zone to pollutants and the attenuation capacity of the overlying strata.

While a wide range of human activities generate some contaminant load on aquifers, often only a few activities are responsible for the major groundwater pollution hazard. There have been many attempts to produce comprehensive lists of activities that are potential sources of groundwater pollutants, and to classify these by type. One such classification system (from Foster and Hirata, 1988) is given in Table 2.1.

The aim of a risk assessment of this type is to identify the most vulnerable aquifers, or parts of aquifers, and the activities that cause the greatest pollution hazard in those areas. The final GRPM will therefore serve to focus attention on those areas and activities so as to prompt prioritisation of

[2] Groundwater pollution risk is defined as the probability that groundwater in an aquifer will become contaminated to concentrations above the corresponding WHO guideline value for drinking water quality; it can be expressed either quantitatively as a numerical probability or, more commonly, in qualitative terms (low, moderate, high, extreme).

groundwater monitoring, enactment of voluntary controls and, if necessary, regulation in those areas most at risk.

Table 2.1 Classification of potentially polluting industrial types

Activity codes for industry types			
0*	Administration/retail	13	Pulp and paper
1	Iron and steel	14	Soap and detergents
2	Metal processing	15	Textile mills
3	Mechanical engineering	16	Leather tanning/processing
4	Non-ferrous metals	17	Food and beverages
5	Non-metallic minerals	18	Pesticides/herbicides
6	Petrol and gas refineries	19	Fertilisers
7	Plastic products	20	Sugar and alcohol
8	Rubber products	21	Electric power
9	Organic chemicals	22	Electric and Electronic
10	Inorganic chemicals	23	Fuel filling stations
11	Pharmaceuticals	24	Other**
12	Woodwork		

* Includes all service/tertiary activities not likely to generate a significant pollution load

** *Other* includes any industrial activity that may be potentially polluting and is not covered by the other 23 codes.

3. URBAN GROUNDWATER SETTING OF BISHKEK

3.1 Overview

The groundwater setting is shown conceptually in Figure 3.1, and includes the following key features which are described in more detail in the following section:

- A semi-arid climate but extensive opportunities for recharge from rivers draining the nearby Alatau range of the Tien Shan Mountains.

- A complex unconsolidated fluvioglacial/alluvial aquifer system of Quaternary age which is in excess of 350 m thick in northern districts of the city.

- Strong lateral and vertical variability. As a first approximation the system fines laterally northwards away from coarse clastic piedmont deposits composed of coalesced alluvial fans fronting the foothills into more stratified deep alluvial plain sediments.

- Unconsolidated sediments provide intergranular flow conditions, and there is hydraulic connection with surface flow in snow-melt rivers and associated canal systems, especially across the southern piedmont area where the aquifer system is considered to be both unconfined and to possess strong vertical connectivity.

- More complex semi-confined conditions are present in the northern part of the city where 3 aquifer systems have been identified by other resource investigation projects. Scope for significant pumping-induced vertical leakage exists, especially in the southern parts of Bishkek where where low permeability horizons in the alluvial tract are thinner and less numerous.

Features of the urban water infrastructure imposed upon this hydrogeological system include:

- 100% dependence on groundwater for drinking water, industrial and heating water needs.

- A very extensive piped water infrastructure (pressurised hot water as well as drinking water mains, plus piped sewerage), widespread use of on-site sanitation in single/two-storey residential areas and significant amenity irrigation of communal parts of residential areas.

- Supply wells located in a highly productive but very localised periurban valley-fill wellfield (Orto-Alysh production wellfield) and also throughout the urban area, at various depths.

- Urban wells screened extensively in middle aquifer (typically >120 m intake depth), but the lower part of the upper aquifer (40 m-120 m) also widely tapped.

3.2 The Groundwater System

The geological setting underlying Bishkek is comprised of an alluvial sequence fining-outward from the flanks of the Tien Shan Mountains northwards towards the plain. In the southern part of the city the geology is a relatively homogeneous sequence of coarse-grained clastic alluvial fan cobbles, gravels and sands. To the north the geology comprises a multi-layered system, with numerous low permeability silt and clay-rich horizons interspersed with higher permeability sands and fine gravels. Generic examples of the hydrogeological setting are shown in Figure 3.2 (from Mathers and Zalasiewicz, 1993). The Bishkek situation displays features of both semi-arid and wet fans, in keeping with its locally low average rainfall of approximately 450 mm/a (reference Bishkek meteorological station records 1979-1988) but mountainous non-arid hinterland.

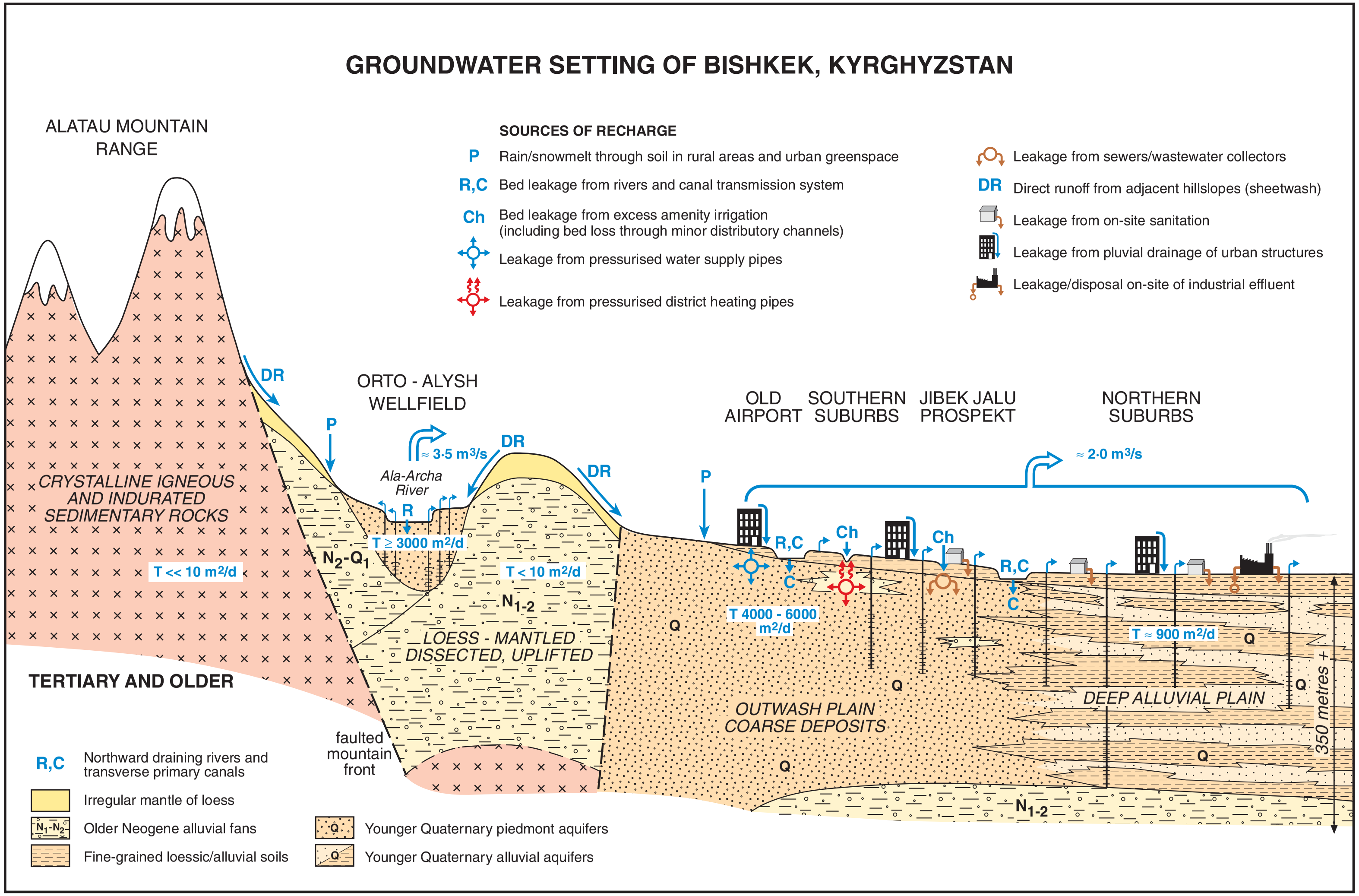


Figure 3.1 **Groundwater setting of Bishkek, Kyrghyzstan**

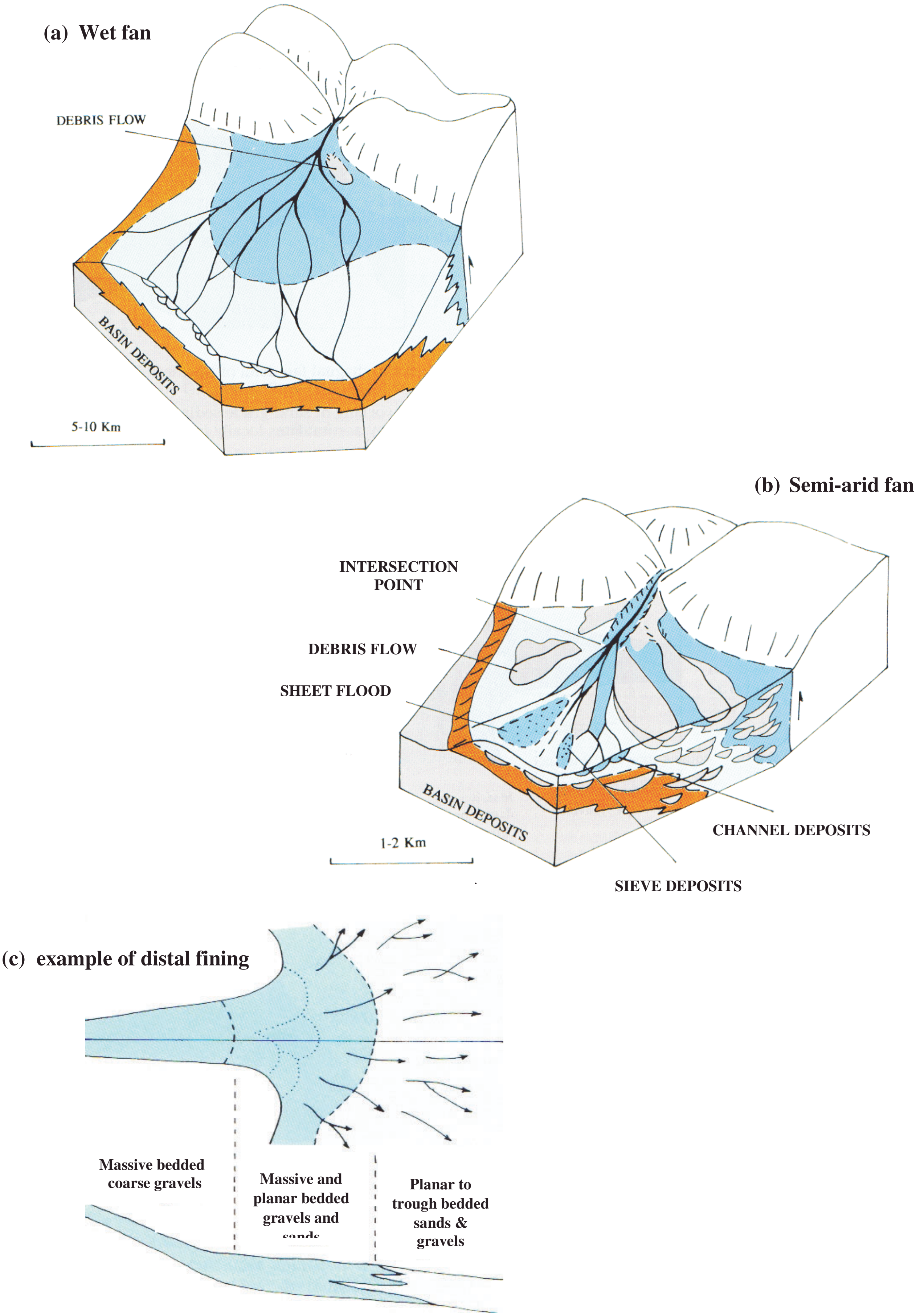


Figure 3.2 **Typical morphology of alluvial fans (from Mather and Zalasiewicz, 1993)**

Based on a combination of pumping test results and inspection of drilling returns, Kyrghyz hydrogeologists divide the aquifer system into three: an upper, middle and lower aquifer. The boundaries between the aquifer divisions are taken as laterally mappable low permeability horizons. In the northern part of the city low permeability horizons are important features, but they decrease in thickness and number towards the south, where they are rare and laterally discontinuous, or absent. However, a small number of pumping tests in the southern part of the city revealed variations in groundwater pressure head with depth. Largely because of these results, the three-fold aquifer divisions are extrapolated southwards across this area. The divisions do not appear to be sustainable beyond the southern suburbs, where the system can be approximated to a single coarse clastic facies providing unconfined aquifer conditions. A schematic diagram of this hydrogeological system is shown as Figure 3.3

In the northern part of the city, the upper aquifer is often unofficially sub-divided into two. The shallow part of the upper aquifer consists across much of the area of dominantly low permeability deposits with patchy thin high permeability lenses. The lower level, to a maximum of about 120 m depth, is characterised by thicker (c. 25 m) lenses of higher permeability deposits interspersed by low permeability layers. Data from very shallow (less than 10 m deep) agricultural wells show that groundwater in the upper zone is already significantly contaminated, reportedly with high nitrates and bacterial contamination.

Kaplinsky (1977) conducted water balance studies based on seasonal groundwater level changes for the Chu valley, of which the Bishkek area forms part. These suggested recharge from precipitation to be about 10% (approximately 45 mm) in the northern half of the city where the water table is shallow, but possibly only about 2% (<10 mm) away from the rivers in the piedmont recharge zone. Instead the main contributions to rural recharge come from irrigation losses (c.200 mm/year). River underflow is an important water balance element (c.20% of river flow volume) and so bed losses may also be a significant additional source of recharge.

Urbanisation almost invariably increases recharge (Foster *et al*, 1993, BGS and SAGUAPAC 1994, 1997). Although unstudied in Bishkek, significant additional recharge from the urban infrastructure is almost certainly occurring, and it is quite likely that such sources now significantly exceed the natural recharge from precipitation, especially in the southern half of the city. The extensive piped water infrastructure (potable supply, district heating and sewerage) together with infiltration losses from garden watering and on-site sanitation (estimated by KSRII to be as high as 400 mm/year), signifies that recharge of urban origin is probably well in excess of natural infiltration.

Thus human activities at the land surface are exerting major controls on both the quantity and quality of local recharge to the Bishkek aquifer system.

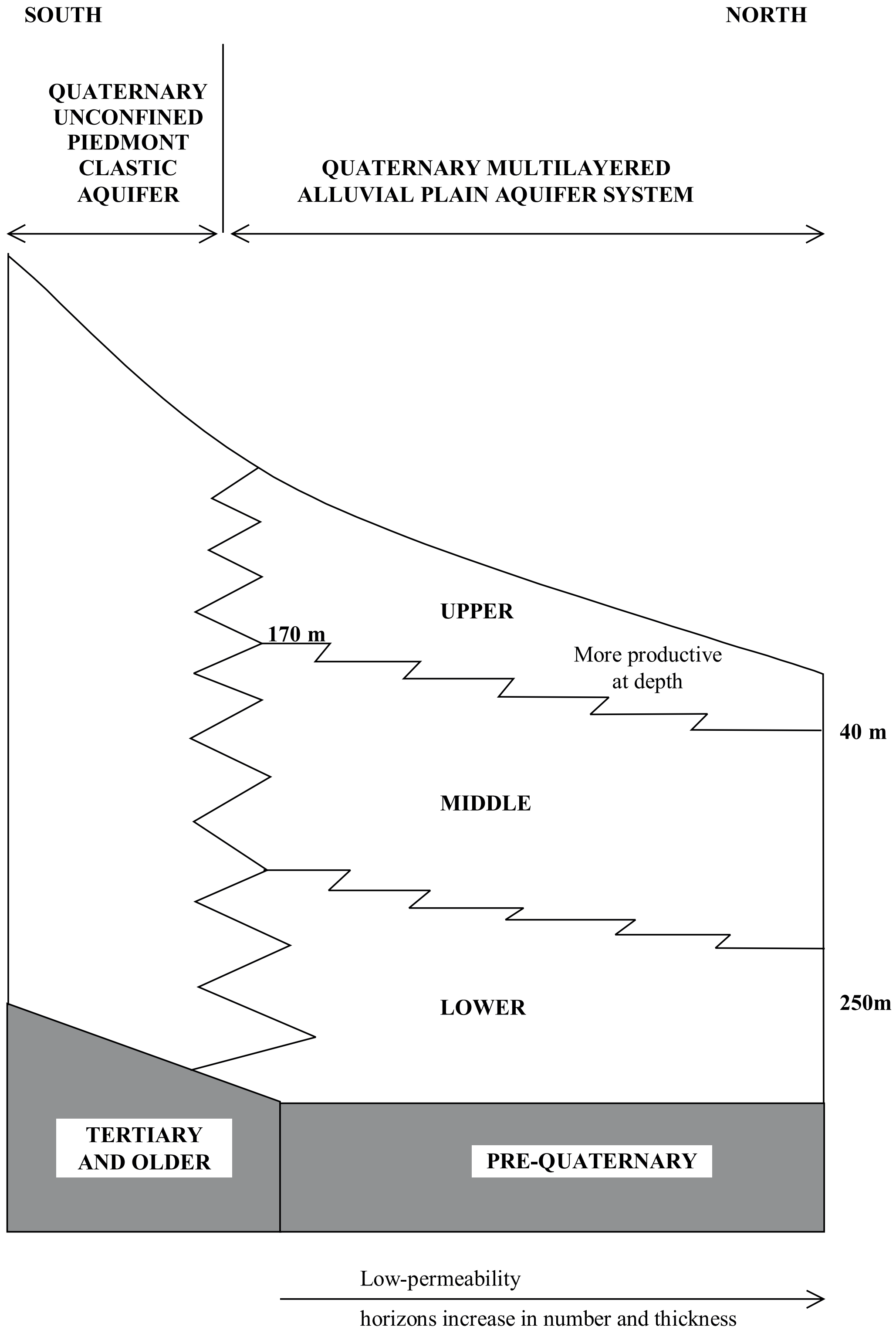


Figure 3.3 Schematic diagram of hydrogeological system underlying Bishkek

The aquifer is also divided into a recharge and a discharge zone, along the line where the groundwater level in the upper aquifer is between 2.5 and 3 mbgl. The area to the north of this line, which lies in the northern part of the city, is termed the discharge zone, where groundwater discharges to rivers. In its natural state this area is marshland. The area to the south of the line is the zone of 'groundwater flow formation' (Figure 3.4), in which recharge can occur because the phreatic surface is below the level of evapotranspirative uptake by vegetation.

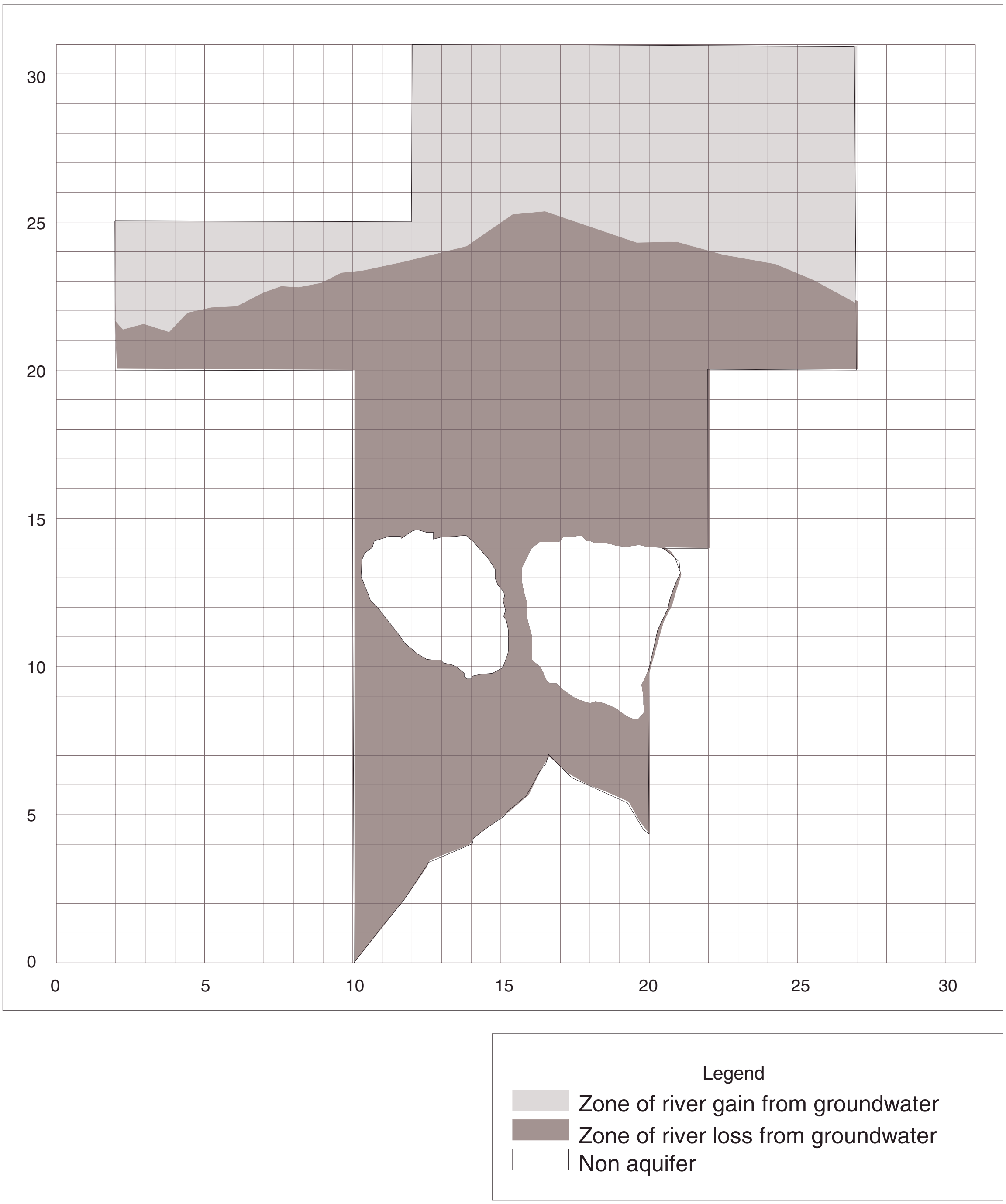


Figure 3.4 Zones of upper aquifer groundwater recharge and discharge

3.3 Groundwater Developmental Setting

Figure 3.5[3] shows the basic physical features of the city and indicates the direction and extent of expansion during the last quarter-century. The extent of urban expansion in the late 1980s is not shown at the extreme east and west of the city due to limitations in available map cover, but is not considered to be extensive. Most expansion has occurred on the northern, southern and south eastern fringes of the city.

Large-scale groundwater abstraction for piped public water and industrial supplies is drawn from the lower part of the upper aquifer and from the lower two aquifers. It is not clear whether the groundwater potential in the upper zone of the upper aquifer is too low to support large abstractions, whether this aquifer was formerly exploited but abandoned due to contamination, or whether policy required all urban state wells to abstract from deeper than 40 m. There are an unknown (but probably quite small) number of private wells, largely for irrigation and non potable-use industrial purposes, some of which may be abstracting from the shallow contaminated zone.

The majority of abstraction boreholes operated by Bishkek Vodocanal, the municipal water supply agency, are described as public water supply. However, such boreholes do not function only for potable supply. They may provide water for both domestic and industrial processes, and there are also three separate reticulated systems for domestic water. One supplies cold water (domestic potable use), one supplies hot water taps (domestic non-potable use) and one supplies hot water for radiators (non-potable district heating use), the last of which appears to be a closed (non-consumptive) system which is operated only during the winter. All come under the description 'public water supply'. The private urban water use categories are less important both in number and volume of water pumped; a small number of factories have private wells, for potable or non-sensitive water supplies and there are also small numbers of private domestic and public municipal irrigation wells. Non Vodokanal-operated supplies for commercial premises, hospitals and large state administrative buildings appear to be insignificant.

The wastewater disposal system comprises a piped sewerage element, to which industrial, commercial, apartment and public buildings together with some low-rise residential housing are connected, and a dispersed on-site sanitation element in many low-rise residential areas. The relative importance and geographical extent of the latter is not well documented, but may be significant. A wastewater treatment plant receiving domestic and industrial sewered effluent is located on the northern fringes of Bishkek.

Supply well water level and water quality trends within the municipal area are unknown as apparently no regular monitoring is carried out apart from some microbiological testing. Even the latter may be limited to the distribution system rather than the pumped raw water supply.

At an early stage in the project, an urban groundwater questionnaire was completed. The questionnaire was devised as a tool for planning by DFID-KAR project R6863, and is used to assemble available urban water management information in a concise overview format. The questionnaire proved to be a helpful aid to organising data collection, and also served to highlight areas where key information is deficient or absent. It is reproduced as Appendix 2, and is likely to be used again in the second stage of the project along with the groundwater pollution threat diagnostic program which was the other main product of DFID-KAR Project R6863 (Calow *et al*, 2000).

[3] Urban expansion in the 1980s on the east and west margins of the project area is under-represented as map cover is unavailable in those districts.

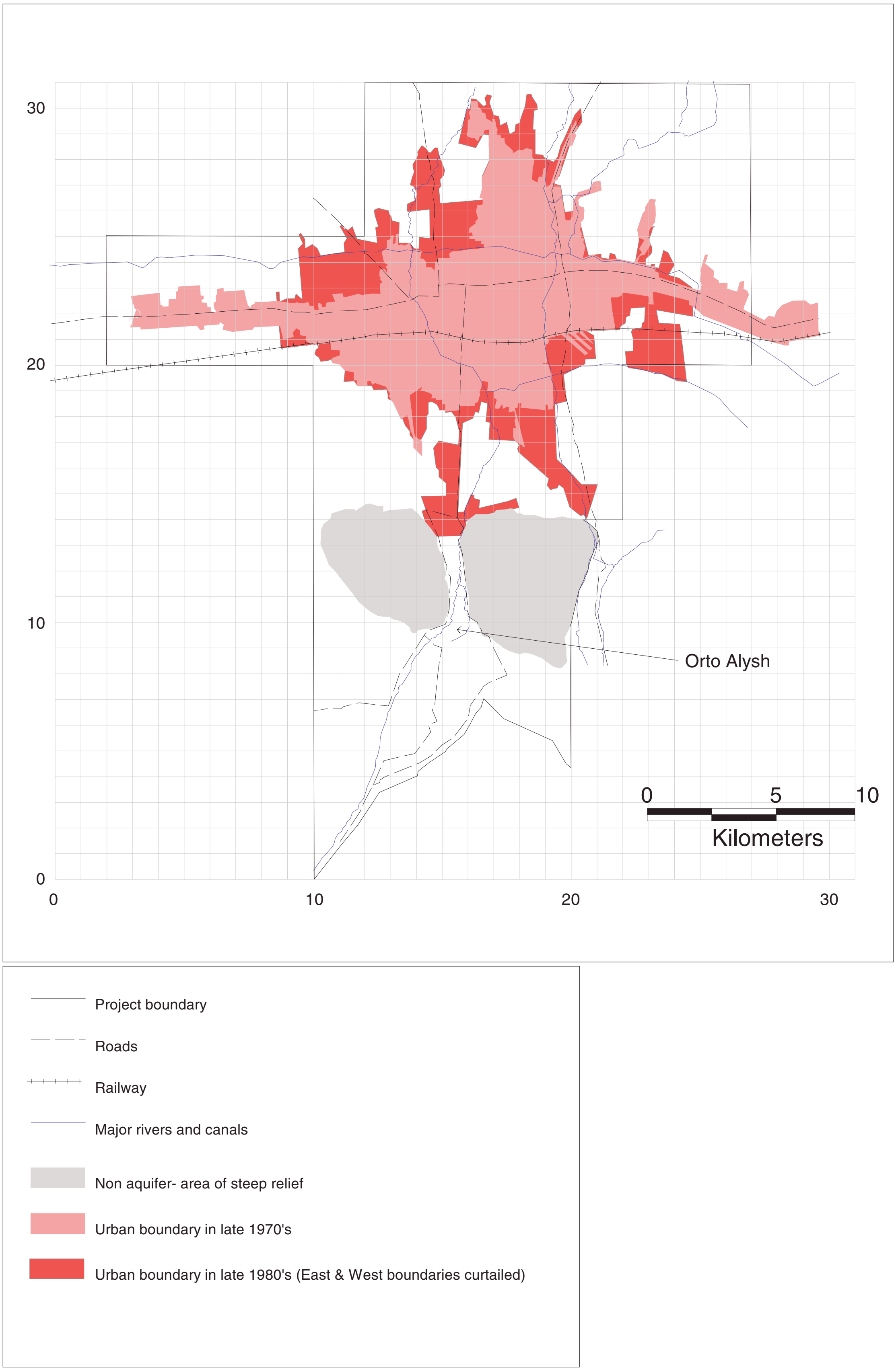


Figure 3.5 Main physical features of Bishkek

4. APPLICATION OF RISK ASSESSMENT SYSTEM TO BISHKEK SETTING

4.1 Selection of Which Part of Aquifer System Risk Assessment to Apply to

Given the complex hydrogeological system, with a single unconfined aquifer beyond the southern suburbs and a multi-layer three-aquifer system below much of the city, there is a need to define which parts of the system the vulnerability assessment refers to. This is controlled by

(i) the pattern of abstraction (existing and potential future regimes) and

(ii) the likely degree of vertical connection between different aquifers.

In the south, the intrinsic vulnerability is considered to apply to the whole saturated thickness of aquifer material, because the predominantly coarse nature of constituent sediment lenses is likely to result in relatively high vertical permeability and strong vertical connectivity. Thus all of the aquifer tapped by the Orto-Alysh wellfield is included. Further north, the vulnerability assessment applies principally to the lower part of the upper aquifer between 20 and 120m depth, because this is tapped by about a third of the 155 public supply and potable-use industrial wells that were in use in 1999. However, by implication, the assessment also applies to the upper part of the middle aquifer down to about 150 m. This is because the degree of physical separation of the upper from the middle aquifer by an aquitard layer is not well defined, so that in the south-central parts of the city (south of Jibek Jalu Prospekt) this division may be arbitrary because intervening aquitard layer(s) are thin and/or discontinuous. The borehole logs along four cross-sections shown in Appendix 2 illustrate this observation. About 55% of the in-use public supply and potable-use industrial wells have screens present above 150 m depth and so draw at least some of their water from this productive zone of the multi-aquifer system (Figure 4.1).

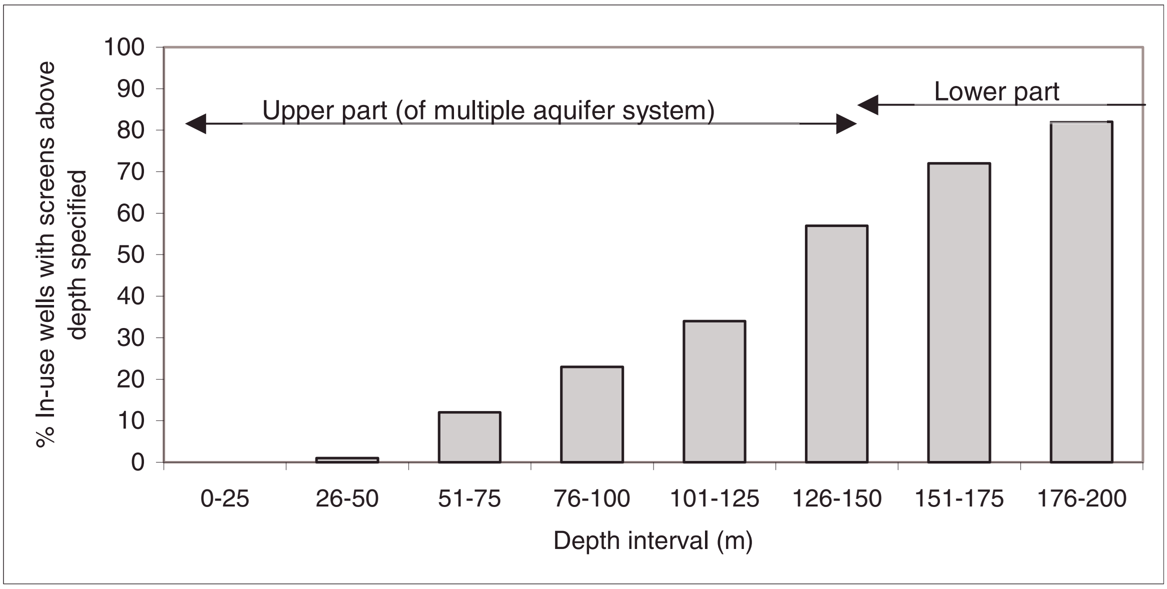


Figure 4.1 Depths to top of screened interval of in-use public supply and potable-use industrial wells in Bishkek

Assessment of the vulnerability of this upper part of the aquifer complex is important because of the likely major role of vertical leakage in the system, although in the absence of a properly calibrated digital groundwater model of the city, the significance of such leakage is difficult to quantify accurately.

4.1.1 Demonstration of likely importance of vertical leakage in contaminant movement

An order-of-magnitude estimate can be calculated using available values and applying it as a sample calculation to just the southern part of the multi-aquifer system, where known head differences and a water table below 2.5-3.0 m show that downward leakage of shallow groundwater is likely to occur to deeper levels. This zone comprises an area of approximately 40 km^2 corresponding to the Ala-Archinsky type of cross-section and occupying the central part of the city parallel to the Jibek Jalu Prospekt.

The magnitude of downward leakage from the upper aquifer to the middle aquifer can be estimated using the Darcy flow equation:

$$Q_v = \frac{k_v \ x \ I \ x \ A}{86{,}400}$$

Where:

Q_v = downward leakage in cubic metres /second [m^3/s]

k_v = mean vertical permeability in metres/day: this is estimated to be not less than 0.01 = K_h which from pumping test value of transmissivity of 4,000-6,000 m^2/d for a saturated thickness of c.350 m is approximately 15 m/d. $k_v = 0.01\ k_h = 0.15$ m/d

I = vertical hydraulic gradient dh/dl in which:
dh is the mean head difference in metres (estimated to be not less than 1.0 m)
dl is the distance in metres between the mid-point of the lower part of the upper aquifer and the top of the middle aquifer (90-55 = 35 m)

A = the area of positive head (40 km^2 or 40,000,000 m^2)

$$Q_v = \frac{(0.15\ x\ 1/35\ x\ 40{,}000{,}000)}{86{,}400}$$

$$\mathbf{Q_v = 2.0\ m^3/s}$$

This volume is approximately the same as the estimated pumped abstraction from all of the boreholes in the urban part of Bishkek, and shows that theoretically vertical leakage is quite capable of providing the entire volume of water pumped from wells in Bishkek. The actual system is no doubt much more complex, with the city wellfields likely to be tapping water of two origins:

(i) interception of throughflow from the thick coarse piedmont deposits to the south, and

(ii) locally induced leakage enhanced by the increased vertical head differences present within the composite cones of drawdown of the wellfields.

Nevertheless, the calculation demonstrates the important role of leakage in the system, and the consequent importance of safeguarding groundwater quality in the upper aquifer.

The lower parts of the Bishkek alluvial system below about 150 m below ground level also merit vulnerability assessment, not least because they are so widely utilised that they constitute the principal aquifer for potable supply purposes. Their depth and the high volume of storage in the system make for a much slower response to anthropogenic sources of pollution entering the land surface or shallow subsurface. Nevertheless, their key role in water supply requires policy guidelines. A subsequent technical report is under consideration to provide a simple vulnerability scheme adequate to underpin policy development needs, possibly based on depth to the lower part and a calculation of recharge transit time (see Figure 4.3).

4.1.2 Assessing the degree of dependence of public supplies on upper aquifer

Inspection of the borehole design statistics for the 135 Vodokanal public water supply wells and 20 private potable-use industrial wells which were in production in 1999 showed that over half (85) have screens present above 150 m depth (see above). They are therefore drawing some of their water from the upper part of the aquifer system. Given the complex multiple aquifer system, not all of these 85 wells would be equally vulnerable, because some will also be screened in the middle aquifer. The most vulnerable would be those boreholes with significant (>5m length) screen open in the upper aquifer.

Interpretation by KSRII-GML of the borehole cross-sections shown in Appendix 3 shows that although the base of the upper aquifer falls away from the mountain front towards the north-east, it does so much less steeply than the land surface. The result is that the base of what has been classified as upper aquifer is more than 150 m below ground level on the southern margin of the city, but less than 50 m below ground level on the north-eastern edge (see contours in Figure 4.2).

Thus the aquifer utilisation is quite complex. Across much of the northernmost third of the city, a relatively shallow screen setting of 60-90 m in a production borehole would tap the middle aquifer, but across the southernmost third such a setting would be located near the top of the saturated zone of the upper aquifer.

It is important for groundwater protection policy formulation to know what proportion of current production wells might be tapping the (relatively vulnerable) upper aquifer. Moreover, knowing their locations provides an opportunity to select key sites for groundwater quality monitoring purposes, because in the absence of dedicated observation boreholes, these wells are likely to be the first to show the effects of any significant downward movement of urban recharge. Water quality indicators from deep public supply wells in the Bolivian city of Santa Cruz have for instance been successfully employed in this way to demonstrate the rate of movement and extent of urban recharge to deep aquifers underlying that city (BGS and SAGUAPAC 1994, 1997).

Figure 4.2 shows the depth below ground level of the base of the upper aquifer together with the location of the 45 public supply and potable-use industrial boreholes that have screen lengths open in the upper aquifer, i.e. above this surface. The screen lengths are also indicated. These 45 boreholes comprise more than one in four (29%) of all the wells currently in use and it can be observed that more than half have a significant (30 m or more) screen length open in the upper aquifer. Thus the upper aquifer is significantly utilised for public/potable water supply, even though this appears not to be the local perception.

For water quality monitoring purposes selection could be made, for instance, from the 29 wells with more than 20 m of screen open in the upper aquifer.

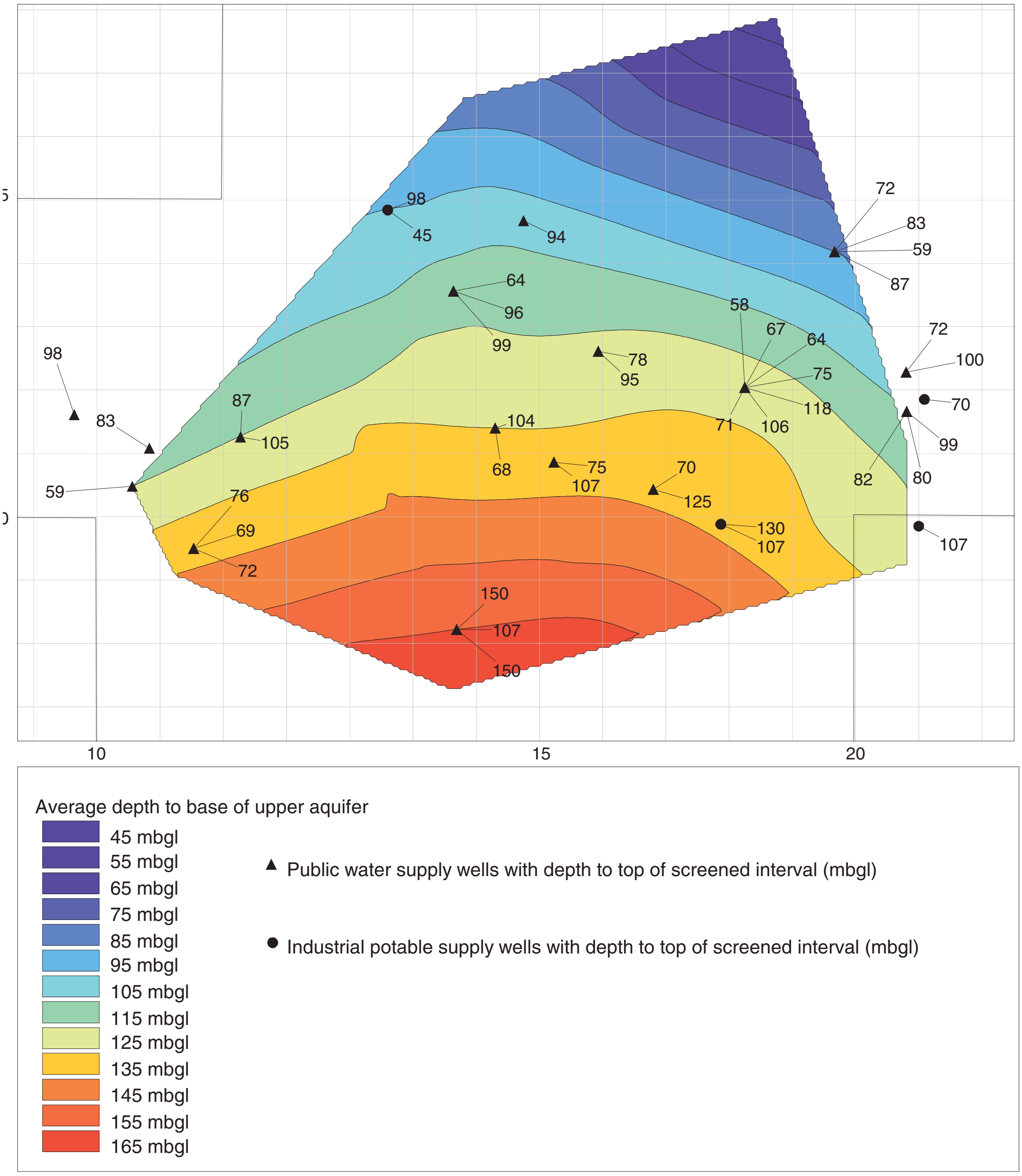


Figure 4.2 Public supply and potable-use industrial wells tapping the upper aquifer in Bishkek

4.2 Methodology for Producing a GVM for the Upper Aquifer (0 to c. 120 m) of Bishkek.

4.2.1 Identifying, collecting & collating existing data

The three staff of KSRII-GML in Bishkek largely carried out the collection and collation of existing data. The resources of KSRII-GML are limited, both in human terms and practically (the topic area is potentially very large). Much of the available information is unpublished and held by different organisations, including KHS and BV. A flowchart showing the information sources and the themes of the various maps produced in this report is shown in Figure 4.3 to provide an overview.

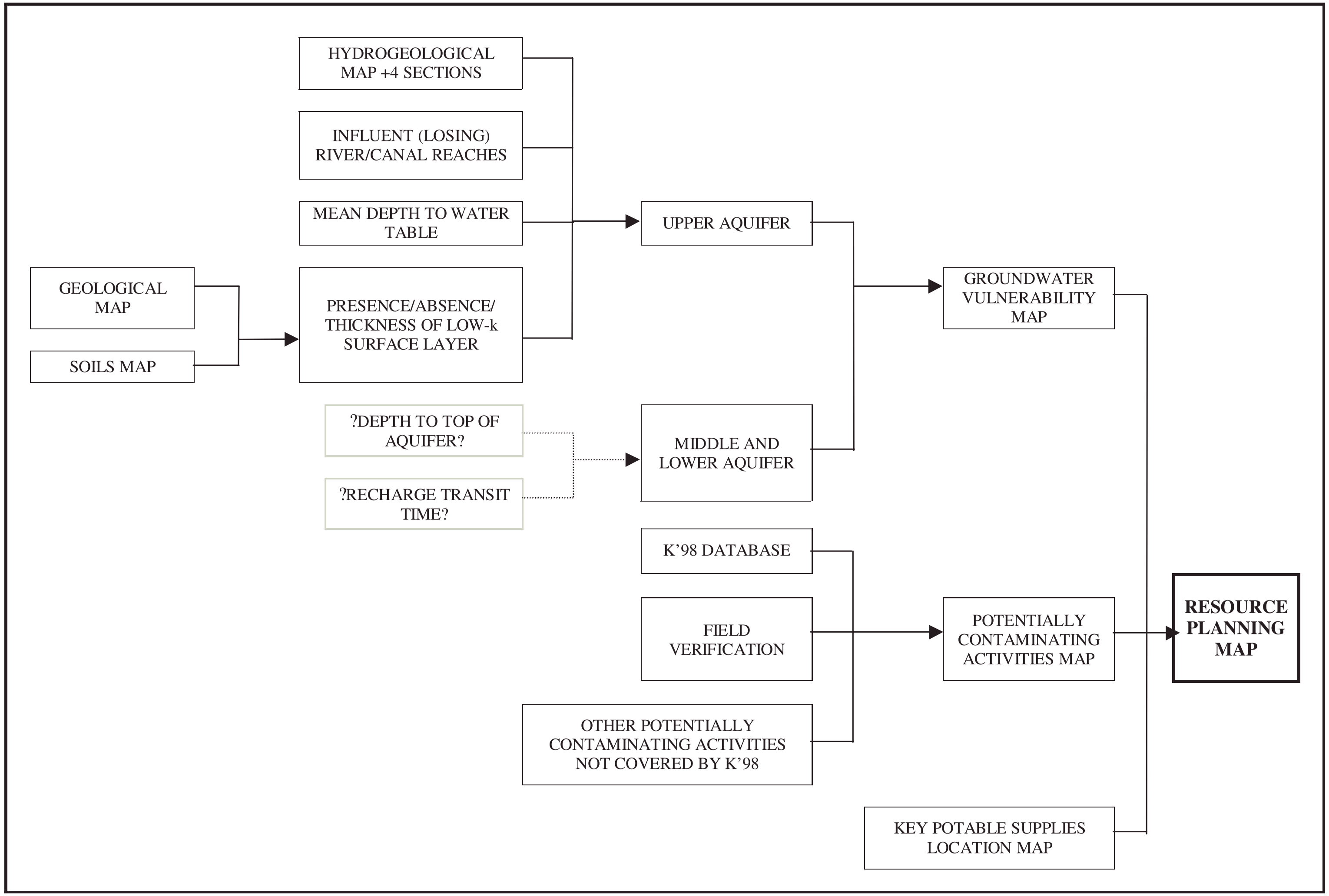


Figure 4.3 Maps required to produce final 'general-user' resources plan

4.2.2 *Data collected*

- Location and details of abstraction wells in Bishkek and in the Orto Alysh well-field to the south of the city. Details include depth of well, construction, rest and pumped water levels in depth below datum (but not datum level), abstraction volume, storage and specific capacity, and water use classified by 5 codes. (Source: BV)

- Various maps & cross sections of the geology and hydrogeology of the Bishkek area, including lithology/chronostratigraphy (Lianov & Anor 1995, Crishenko & Anor 1964), piezometric levels in the productive part of the upper aquifer (c. 40 – 130 m depth), aquifer recharge and discharge areas and hydrogeochemistry (Lianov & Anor 1995, Krivchenko & Anor 1980), groundwater levels in the shallow part of the upper aquifer in the northern part of the city (Source: net of agricultural wells 3 to 10 m deep: map drawn for winter 1986 (Krivchenko & Anor 1986), and groundwater levels to the south of the two hills in the Orto Alysh area (Bondar & Anor 1989).

- A cross section of the city showing aquifer lithology and marking the location of wells along the section. The lithology was inferred by KHS geologists partly from inspection of cuttings during drilling and partly from the results of geophysical surveys. The cross section also shows the division of the system into three aquifers: an upper, middle and lower, based on differences in water pressure observed during three pumping tests. The aquifer divisions are extrapolated along the level of observed/inferred low permeability layers. (Source: KHS).

4.2.3 *Lithological cross section*

To accompany the map layer showing the geological classifications in the project area, four cross-sections were drawn comprising well logs at semi-regular intervals along the section lines (shown on the map comprising Figure 4.4). The well logs illustrate the representative lithology at each interval along the section. The lithological data were taken from geological cross-sections drawn by KHS, and also show the boundaries between the aquifers as defined by KHS. Each well log also shows the position of the well screen in one particular well at that point on the section, as an indication of the level of water intake. The wells are numbered according to the KHS reference system, also used by KSRII for this project. Where the selected well log lies off the section line, the approximate grid reference for the point on the line orthogonal to the well is given (in project co-ordinates). These cross-sections are reproduced in Appendix 3 and proved most useful aids to understanding how the aquifer system had been conceptualised previously, as well as providing the means by which a surface approximating to the base of the upper aquifer could be constructed (see next section).

4.2.4 *Specifying the layers of data needed for the Groundwater Vulnerability Map (GVM); their application and relative importance*

The data needed for the GVM are largely prescribed by the general concepts of groundwater vulnerability mapping, by the assessment of the particular situation in Bishkek and by the technical data (in the form of maps and well records) which are currently available for the city. The following were identified as key criteria controlling aquifer vulnerability in Bishkek:

- **The presence & thickness of a low permeability surface layer** which will act to restrict infiltration of pollutants to the underlying aquifers and so protect them;

- **The geology of the aquifers**, and specifically their ability to transmit contaminants laterally and vertically from point of ingress;

- **The depth to water table** (thickness of the unsaturated zone) because the presence of a thick unsaturated zone extends the residence time of infiltrating recharge and provides a medium for various attenuation processes to occur

- **Influent reaches of rivers/canals** crossing the project area., because linear recharge of contaminated river water can be a significant groundwater quality hazard

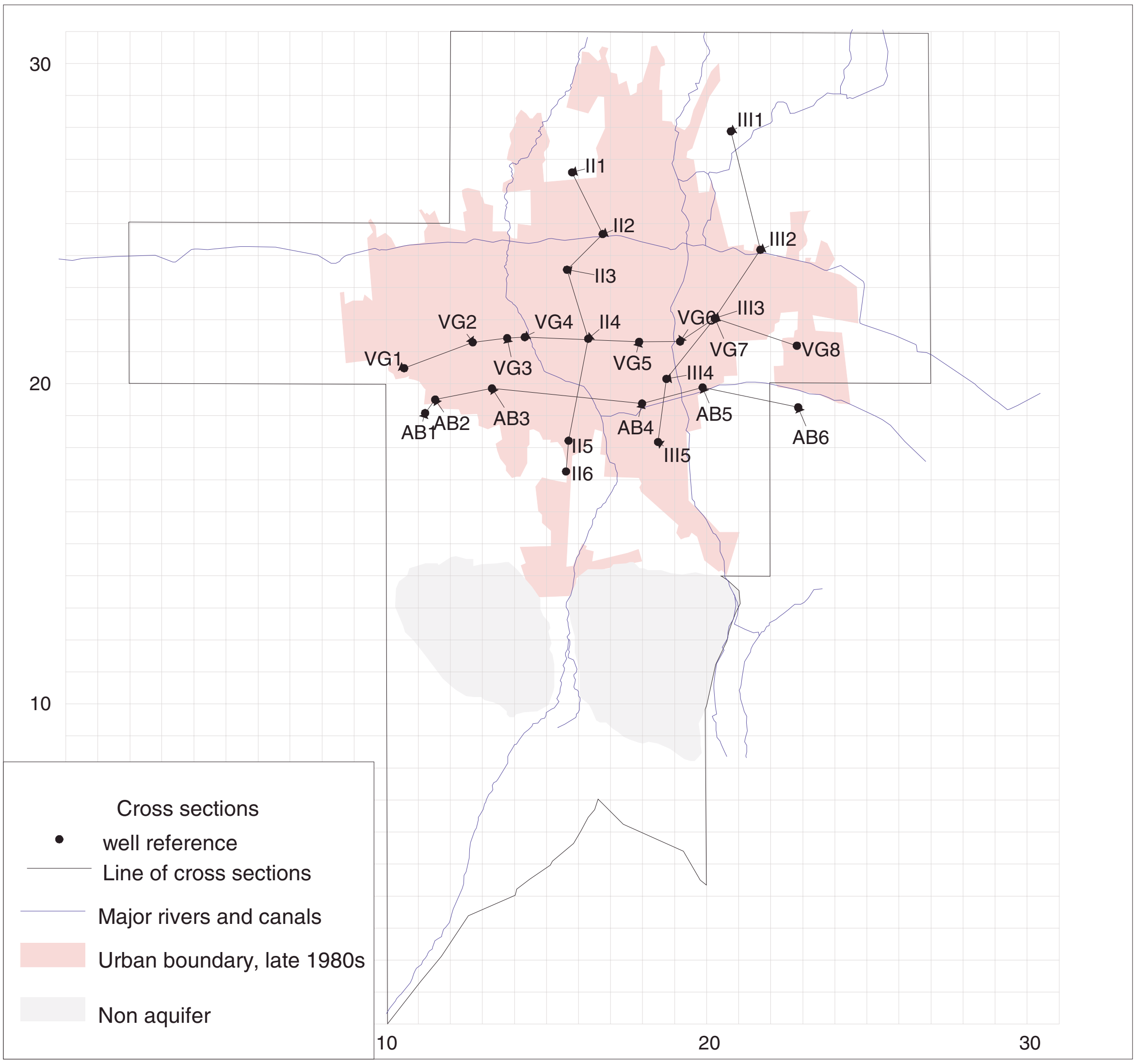


Figure 4.4 Map showing lines of borehole log cross-sections.

The classification of zones representing the relative groundwater vulnerability within each criterion was finalised during discussion with KSRII staff. The zones are defined in section 4.2.7

4.2.5 Specifying the techniques and software for producing the GVM

The production of a groundwater vulnerability map is an ideal task for a geographical information system (GIS). A GIS is a linked spatial and attribute database, within which data can be queried to reveal spatial patterns. Currently there are two commonly available PC-based GIS systems: ArcView and MapInfo. For the purposes of this project it was decided to use MapInfo and the add-on software

Vertical Mapper. The latter allows the creation of raster-type grid data layers, which can be overlain and analysed for spatial patterns using processes that are not available for MapInfo vector-type data. MapInfo was chosen for the task mainly for reasons of ease of uptake, as KSRII had no previous experience of GIS use.

Each groundwater vulnerability criterion is classified into a number of zones reflecting relative susceptibility. Each zone is given a weight according to the relative impact on groundwater vulnerability. A map of the zones for each criterion is produced within the GIS as a theme, with attribute information describing the zones and the weighting given to each. These themes can be displayed singly over a base map showing the physical features of the project area, or combined to produce a composite map of relative groundwater vulnerability in which each polygon is in effect an area with the same point-score total/weighting.

4.2.6 Producing a project base map

It became apparent at the start of the project that accurate maps of the Bishkek area are not easily available. For various, partly political, reasons a standard co-ordinate reference system based on the USSR-wide metric grid mapping array was not employed for any of the historical source maps available for use by the project team. Instead maps were drawn to individual reference systems, which may often not be available, or not be clear, to the present-day map user. Before starting to produce any of the groundwater vulnerability data layers, a project co-ordinate reference system and base map were produced.

The resultant metric grid encompasses the project area of Bishkek and is a 31 km x 31 km square. The origin of the grid corresponds with a known latitude-longitude co-ordinate. The basemap (Figure 3.5) shows the main physical features of the city: project boundary, railway, roads, rivers and canals, simplified areas of high relief, the approximate boundaries of the urbanised area in the 1970s, and the municipal boundary of the city in the 1980s. For a technical description of the methods used to produce the base map see Appendix 4.

4.2.7 Producing maps of each of the component themes of the GVM

The GVM is designed to illustrate those areas of the aquifer which are intrinsically vulnerable to contamination. These areas are composite zones arising from the interaction of the four criteria listed in section 4.1.3, where each zone represents a different relative intrinsic vulnerability of the aquifer. The four component themes of the groundwater vulnerability map, with vulnerability classifications and vulnerability ‘scores’ for each parameter, are shown in Table 4.1 below.

The vulnerability themes were produced as vector-based maps in MapInfo and then converted to raster-based grids using Vertical Mapper. For each layer, polygons according to the zones classified above were digitised in MapInfo, and attribute data about the polygons in each theme were entered into the layer’s attribute table. Each theme was then converted to a raster-type grid in Vertical Mapper, each cell of which can display the weighting representing relative groundwater vulnerability of the component zones. The individual grids were superimposed by adding the weightings, to produce a composite map displaying the zones of relative groundwater vulnerability across the project area. The four thematic component maps are shown in Figure 4.5a,b and the resultant composite map in Figure 4.6. For technical details of the methods used in MapInfo and Vertical Mapper, see Appendix 4.

The composite map was then reclassified into areas of upper aquifer high, moderate or low vulnerability using the point-scoring system in Table 4.2 and is shown as Figure 4.7.

Table 4.1 **Point scoring system adopted for the GVM of the upper part of the Bishkek aquifer system**

Vulnerability Theme	Classification (i.e. component zones)	Relative Vulnerability	Vulnerability Score
Presence of low permeability surface layer	0 – 5 m thick	High	3
	5 – 10 m thick	Low	1
	Non-aquifer	Negligible	0
Geological units	Karabaltinsky	High	3
	Panfilovsky	Moderate	2
	Ala-Archinsky	Low	1
	Neogene alluvial inliers to south of city (non-aquifer)	Negligible	0
Depth to groundwater	0 – 5 m	Very High	4
	5 – 10 m	High	3
	10 – 50 m	Moderate	2
	> 50 m	Low	1
	Non-aquifer	Negligible	0
Surface hydraulic conditions	Zone of influent rivers	Moderate	2
	Recharge zone, no influent rivers	Low	1
	Groundwater discharge zone and non-aquifer	Negligible	0

Table 4.2 **Groundwater vulnerability map classification**

Sum of 4 component theme scores	Vulnerability classification of upper part of aquifer system
0	NON-AQUIFER
1-6	LOW
7-8	MODERATE
9-11	HIGH
12	EXTREME

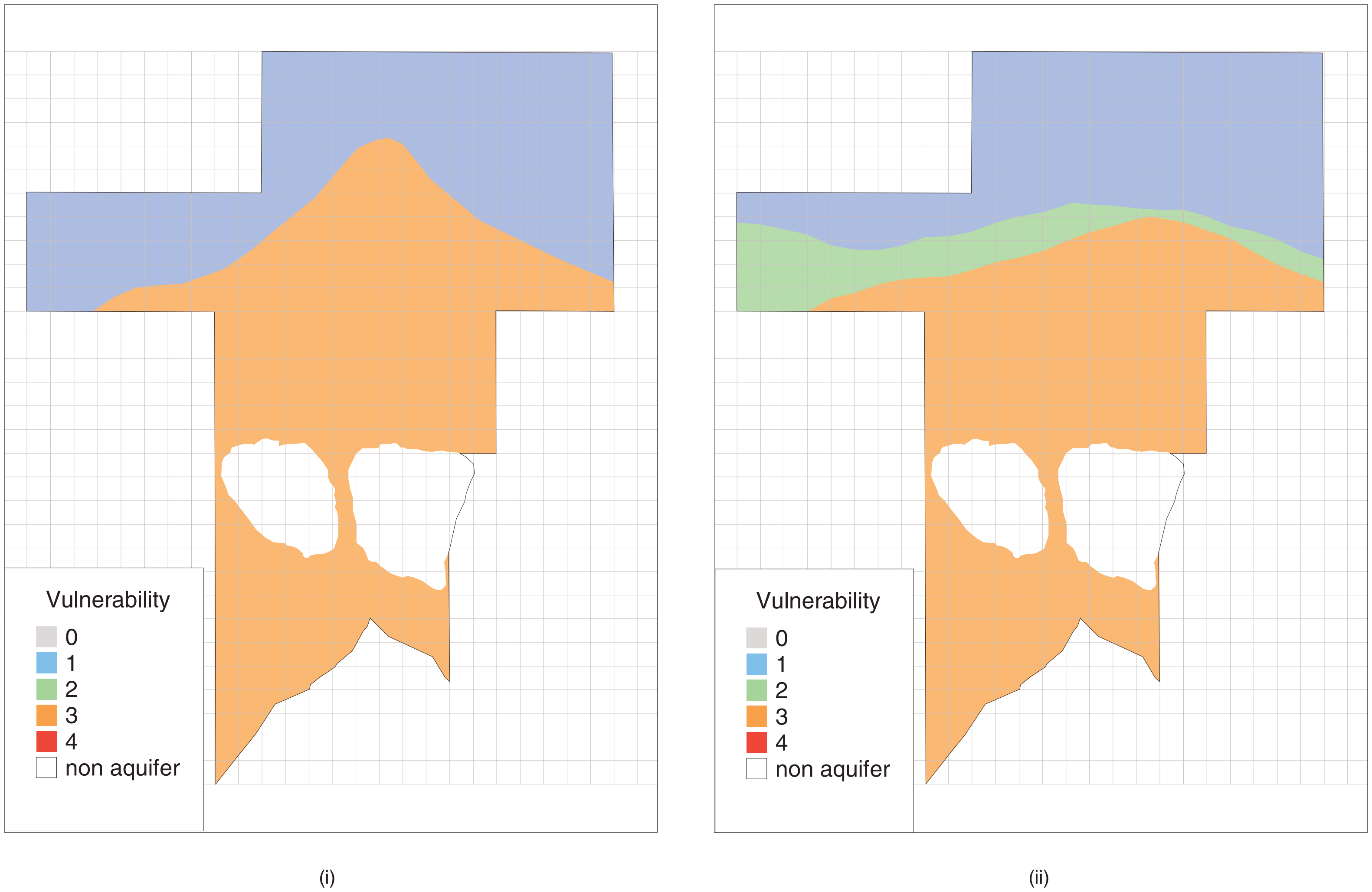
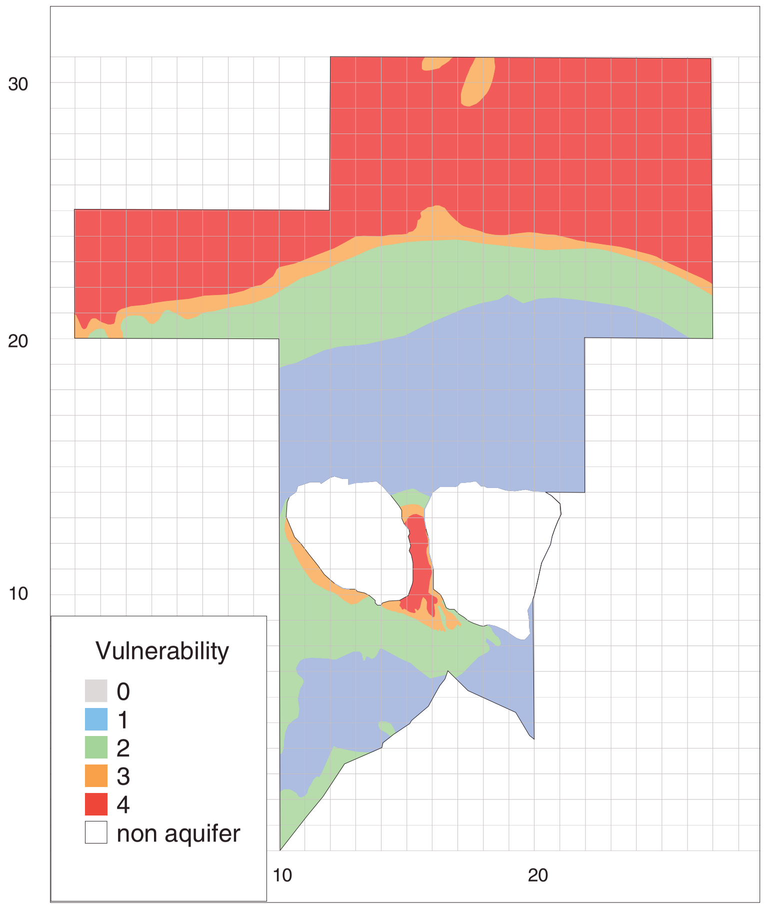
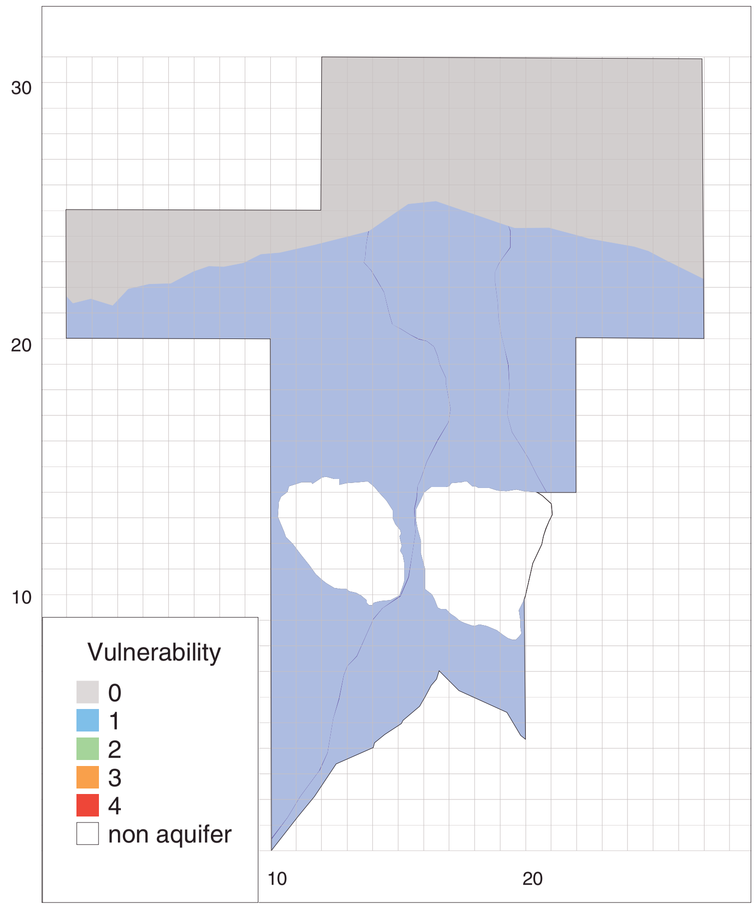


Figure 4.5a **Input themes for Bishkek groundwater vulnerability map, showing relative vulnerability scores: (i) low permeability surface layer and (ii) geological units.**



(iii)



(iv)

Figure 4.5b **Input themes for Bishkek groundwater vulnerability map, showing relative vulnerability scores: (iii) depth to groundwater level and (iv) surface hydraulic conditions.**

This MapInfo map not available in format suitable for import to Word document

Figure 4.6 **Interim stage of vulnerability map production showing the results of overlaying the four component layers and resultant vulnerability scores**

4.2.8 Results of GVM exercise

The final stage of GVM production involves the aggregation of point scores into groupings of low, moderate, high and extreme vulnerability. This helps simplify the map for policy use without losing the underlying cumulative hazard principle. The results, shown in Figure 4.7, divide the city and its suburbs into five principal areas:

(i) The northern half of the city (north of a line approximating to Prospekt Chuy/Prospekt Zhibek Zholy) overlies aquifer of low vulnerability. This is due to the presence of a thick low permeability surface layer, the frequency and thickness of aquitard layers and the low downward vertical head gradients. All of these features protect the producing horizons from penetration of contaminants that may be present in urban recharge.

(ii) Further south, the presence of a high water table across central parts of the city makes the system sensitive to change. As the low permeability layer thins and the aquitards become subordinate, the vulnerability rapidly changes to moderate and then high in an east west belt either side of the main railway. This central area appears complex because the edges of constituent polygons in several component maps interact to give zones with slightly different cumulative point-score.

(iii) Once the ground surface starts to rise more steeply from the old airport across the piedmont plains, the water table becomes much deeper and the vulnerability reduces to moderate as far south as the inliers of Tertiary alluvium. There are however linear high vulnerability features in the form of the channels of the Ala Archa and Ala Medin rivers, whose highly permeable beds are conducive to river leakage

(iv) Further south the valley of the Ala Archa River narrows into the highly productive alluvial fill tapped by the Orto Alysh well field. As the water table rises, the vulnerability class increases in these exposed highly permeable deposits to High and locally to Extreme along the axis of the river channel (where pumping-induced influent conditions almost certainly occur). This area without doubt constitutes the most vulnerable part of the Bishkek aquifer system, and it also coincides with the city's most important wellfield resource.

(v) Further south as the ground continues to rise, the water table becomes deeper and vulnerability rating lessens, although it should be noted that this area remains sensitive because it lies within the composite capture zones of the production boreholes comprising the Orto Alysh well field.

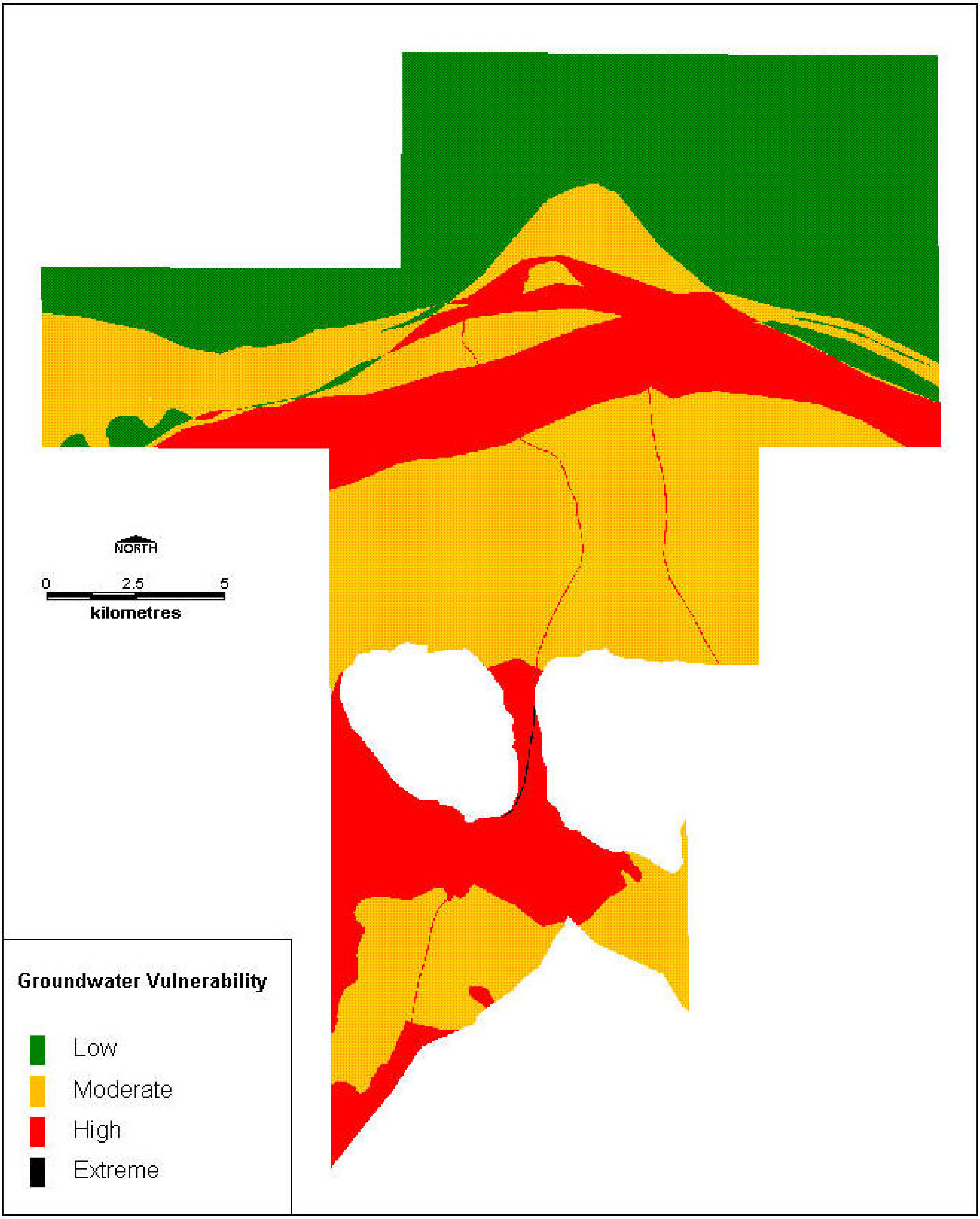


Figure 4.7 **Groundwater vulnerability map (GVM) for upper part of aquifer system in Bishkek**

4.3 Methodology for Investigating the Potential Groundwater Contaminant Load in Bishkek

There are two major sources of potential urban groundwater contaminant load in Bishkek: pollutants from industrial activities and the products of on-site sanitation of low rise private housing. More minor sources include sewer leakage and highway runoff, although the latter is likely to be less important than would appear, as despite severe winters, road de-icing with salt in Bishkek is minimal. The other common urban source, leachate from municipal waste disposal sites, is not relevant for Bishkek because the municipality is reported to collect and transport all solid waste to landfill sites located outside the city limits to the north.

Reliable information in this topic area is scanty. This is the more so because the decline in industries operated under the former Soviet command economy system has changed large former industrial plants dedicated to the mass production of a rather specific item or range. These state or quasi-state agencies have declined in size since independence and so rent out offices/factory space as an important source of income. The plants have therefore become industrial/commercial complexes, subdivided into numerous smaller enterprises, not necessarily related to each other or to the former site use. A comprehensive survey to meet the exact needs of a contaminant load inventory was not feasible with the resources available to this project, which needed to rely primarily on available data with only minor field investigation.

4.3.1 Producing a potentially hazardous industrial activity map (PHAM)

Collating existing data

An important resource identified for this part of the project is a database produced by a Bishkek company, Areopag, as part of the German Federal Republic's programme of technical assistance to small business development, financed by the German development bank KfW. The database is provided commercially with associated visualisation software on a CD-ROM called Kyrghyzstan 98 (K98) and is intended to serve as an introduction to the Kyrghyz economy for potential foreign investors and business ventures from outside. The database lists a large number (1886) of commercial organisations in Bishkek with details of their business activity, location and size. Many of these businesses were screened out at an early stage as being neutral or of low hazard in terms of their contamination potential to underlying groundwater, either because

(i) they comprise service industries (such as national and regional government, banking/finance, insurance, commerce, most retail and distributive enterprises and tourism) generating no industrial effluent load, or

(ii) the industrial unit is small in size, and therefore likely effluent/load generating capacity is small.

Screening out of service industry organisations was achieved by querying the database to identify and select enterprises undertaking one or more of the activity classes listed in Table 2.1 that could potentially pollute groundwater. Over 500 organisations of all sizes and types were identified in this first-pass listing. The organisations were plotted in MapInfo as a separate theme to allow comparison first with data on the locations of production wells (particularly for public water supply and potable quality industrial supply), and later with data on vulnerable areas.

Additional information on industrial activities was obtained from a list of 25 businesses recognised as potential sources of groundwater pollution in Bishkek (Appendix 6. Source: KHS report). The data are based on tests carried out during the early and mid-1990s. Many of these businesses overlap with entries in the K98 database.

Checking existing data and adding value

Verification of the data in the list of potentially polluting organisations extracted from the K98 database was combined with enquiries to establish industrial unit size and confirm the industrial activity. This is because many enterprise names are ambiguous and do not indicate whether manufacturing is actually occurring at the site or merely import and distribution. This task was undertaken by a combination of telephone survey and field observation visits. Industrial activity was defined by the classifications listed in Table 1.1. Where possible, organisations were classified into one of three size codes:

(i) large (over 100 employees),

(ii) medium (10 to 100 employees) or

(iii) small (less than 10 employees).

Many of the entries in the K98 database do not give any information on the number of employees, and individual organisations were often unwilling to give this information when questioned.

The initial plan was to check all of the businesses on the list, starting with those located close to groundwater supply wells. At the start of the activity two pilot areas near the sites of public water supply and potable industrial supply wells were chosen to test the techniques. For a description of the procedure for checking the data, see Appendix 5.

The most efficient method for checking the business information was found to be a telephone survey covering as many businesses as possible, followed up by field visits by car to locate and verify those businesses which could not be contacted by telephone. Searching for individual businesses in the field was time-consuming, and minimising the need for this part of the procedure was preferable.

As described above, many firms, especially smaller, newer businesses, rent space in a building belonging to a larger organisation. Other small (generally non-industrial) firms are based in private flats within large apartment blocks. However, many of the larger, established industries are concentrated within relatively limited areas of the city, particularly along the railway line. Much of the rest of the urban zone is residential in nature. Shops and offices also tend to be concentrated along particular streets in the central area of the city.

The experiences of testing the techniques in the two pilot areas demonstrated that simply working through each firm in each selected area was not the most efficient method. It was decided to prioritise the first-pass listing of 500+ businesses in order to target those likely to generate the highest pollution hazard, and the following list was drawn up, in order of priority:

- All firms defined in the K98 database as employing more than 100 people
- All firms on the list of potential sources of groundwater pollution from KHS
- All firms defined in the K98 database as dealing in chemicals or oil products, and all fuel filling stations
- All firms for which the K98 database gives no information on the number of employees.

The last category was designed to ensure that no large institution with significant pollution potential was overlooked.

On-site sanitation

In the past, low rise private houses in Bishkek were not served by mains water or sanitation services. Although this is changing, KSRII-GML estimates that 50 percent of private houses still have on-site sanitation. Each house generally has a small plot of land that is cultivated for vegetables and fruit, with irrigation from the piped urban water supply (either as mains to the house or from street standpipes). The on-site sanitation comprises a dug latrine in the garden plot, septic tanks not apparently being widely employed. In areas of shallow groundwater levels (less than 3 mbgl) the cesspits are dug on average to less than 0.5 m above the water table. They are used for about one year, then filled in and the latrine moved. The former latrine site is then cultivated and irrigated along with the rest of the garden plot.

The effect of on-site sanitation alone may be significant, but will also be modified by the intensive irrigation regime typical of the garden plots. This practice would have two contrasting effects; on the one hand, enhanced downwards infiltration from irrigation water applied in excess of crop requirements would reduce the travel time of entrained pollutants towards the saturated aquifer. On the other hand, irrigation with high quality piped water of potable standard would decrease solute and suspended matter concentrations in recharge water, although the total mass transported would be the same in the long term. Based on observations in other urban environments (Morris *et al* 1994, Foster *et al* 1994), the practice would be likely to have an adverse effect on the quality of shallow groundwaters.

4.3.2 Construction of the potentially hazardous activity map

The inputs to the map therefore comprise the following information:

industrial activities; location and activity codes for :

(i) medium to large industrial firms (those with >100 employees)

(ii) firms on the KHS environmental control list

(iii) chemicals and oils handling/processing enterprises

(iv) fuel filling stations

On-site sanitation; digitised distribution maps of :

(i) areas of dominantly low-rise private housing where horticultural/garden watering are enhancing local recharge rates

The results are shown in Figure 4.8. Fuel filling stations are common in central districts and the southern suburbs but more restricted in the northern suburbs. Two stations are located very close to the Orto Alysh wellfield The major potentially contaminating industries are sited principally in a broad east-west corridor either side of the of the Kara Balta-Tokmak highway and the international railway.

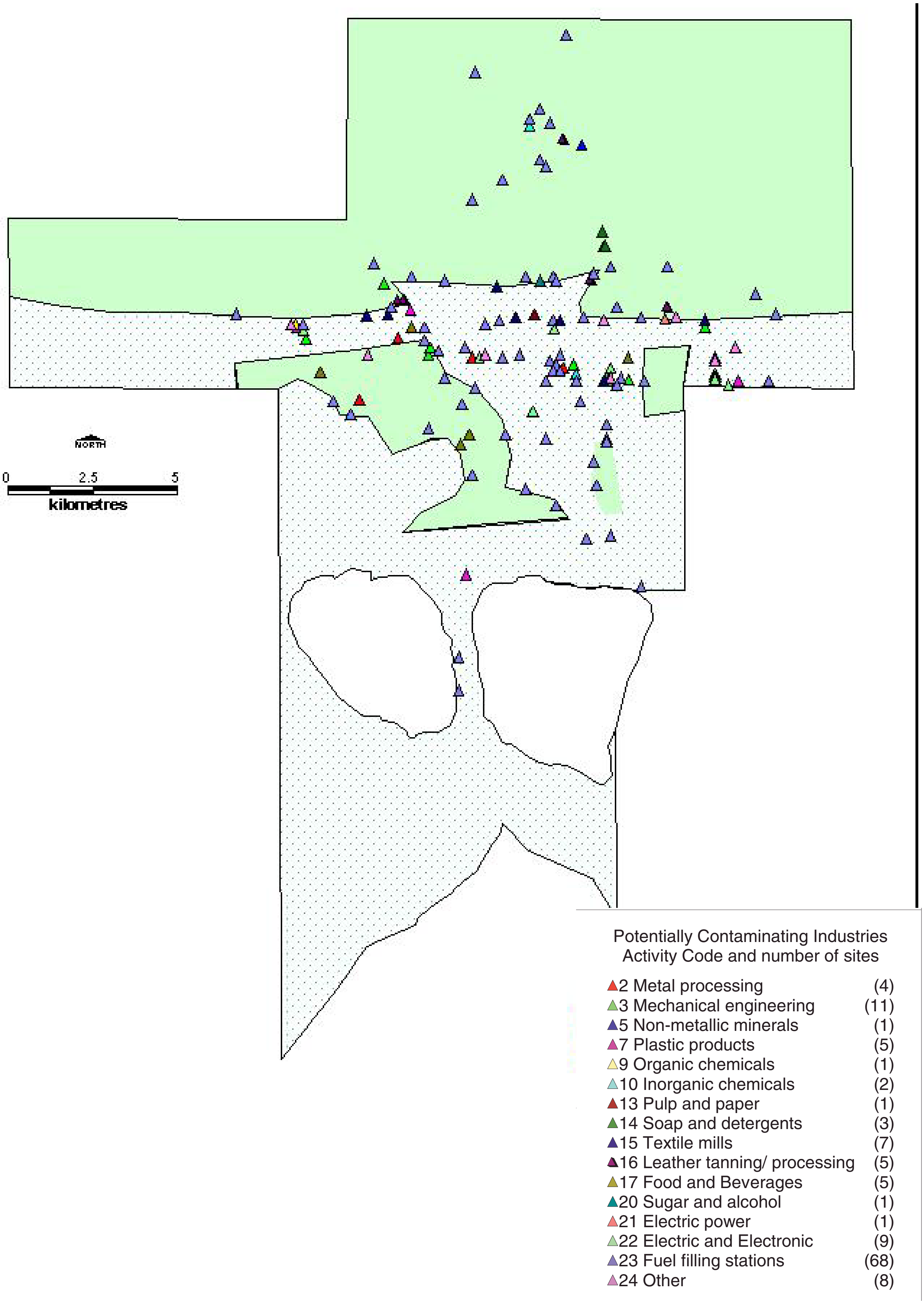


Figure 4.8 Potentially hazardous activities map (PHAM)

5. RESULTS OF THE RISK ASSESSMENT MAPPING IN BISHKEK

5.1 Interfacing the Groundwater Vulnerability and Potentially Hazardous Activities Maps

The final part of the thematic map production stage is shown in Figure 5.1, where the groundwater vulnerability map (GVM) is overlain by the potentially hazardous activities map (PHAM). The result is a precursor of the groundwater resource planning map (GVM + PHAM→GRPM, see Figure 2.2) which will be used for policy development which is the second stage of the case-study.

Key features include:

(i) Approximately 135 point-source locations were identified, over 90% of which are located on moderate or high vulnerability aquifer

(ii) Several fuel filling stations, chemical plants and other potentially contaminating industries are located upon highly vulnerable aquifer

(iii) the principal areas are in a band parallel with the main railway line and the east-west national highway in the centre of the city

(iv) most other potentially contaminating activities are located on areas of moderate groundwater vulnerability, with very little industry presently located on low vulnerability terrain

(v) In several places in the southern half of the city fuel filling stations are located close to losing reaches of watercourses or in areas of intensive irrigation. Both would tend to increase the likelihood of mobilisation of fuel contamination from spillages, leaking tanks or pipework down into the upper aquifer. This is most notably the case in the particularly sensitive Orto-Alysh area, where two fuel filling stations are located alongside the extremely vulnerable losing reach of the Ala Archa river, just north of the main wellfield zone.

(vi) Much of the immediate catchment of the very important Orto-Alysh wellfield is underlain by highly vulnerable aquifer. Protection of this zone is consequently a high priority.

(vii) While much of the intensively irrigated land is found in northern districts of Bishkek, where groundwater vulnerability is generally low to moderate, some areas in the central district and the southern suburbs overlie the high vulnerability category, including alongside losing reaches of the Ala Archa and Ala Medin rivers.

5.2 Groundwater resource protection and policy development

The next report in this case-study will employ the groundwater vulnerability and the potentially contaminating activities maps provided in this report as tools to assist in the development, with stakeholders, of resource protection and planning policies.

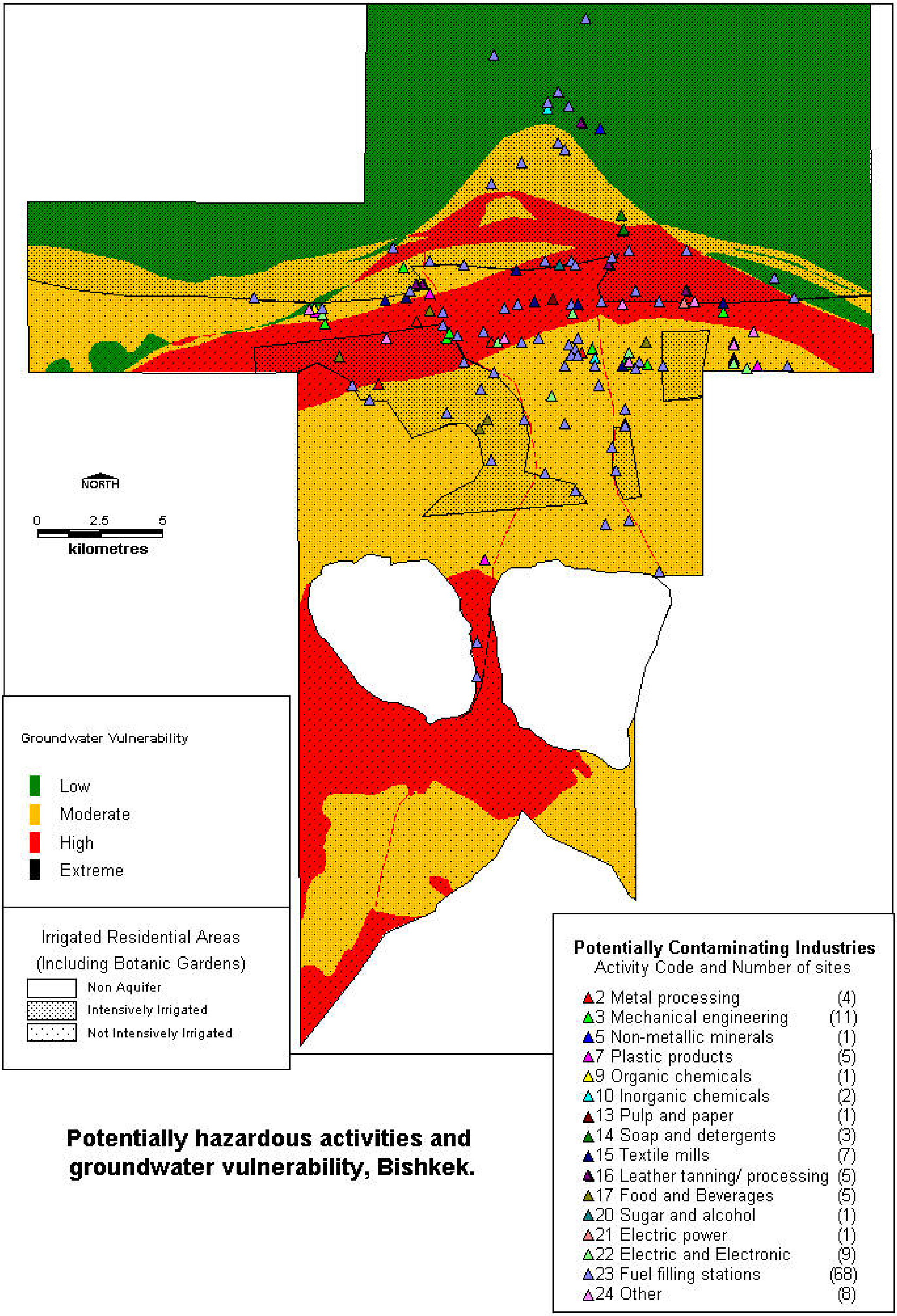


Figure 5.1 **'Hot-Spot' Map, Bishkek**

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APPENDIX 1:THE LOGICAL FRAMEWORK

Narrative summary	Measurable indicators	Means of verification	Important assumptions
Goal: Increase sustainability of groundwater used for public water supply in cities.	Groundwater continues to be safely used for public supply in vulnerable urban/ periurban settings	National statistical reviews	*(Goal to supergoal)* Aquifer system sustainability not also threatened by factors unrelated to surface land use e.g. macroeconomic factors
Purpose: Improved protection of aquifers from urban/ industrial activities	Groundwater pollution risk assessment becomes a regularly employed tool for resource planning and management	Number and quality of assessments gleaned from technical reviews, funding agency applications and response to articles	*(Purpose to goal)* Municipal/state decision-makers & legislators willing to listen to /act on recommendations from planners/collaborating agencies & to implement protection measures
Outputs: 1.Aquifer vulnerability and contaminant load assessments completed for each case study city 2.Collaborators successfully trained in techniques of groundwater protection assessment 3. Guidelines for sustainable management of urban aquifers developed for case study cities and generalised for wider use	1. Maps and reports for each city issued by Dec. 2000. 2. Adequate visits and 2-way interchange with UK staff during project fieldwork phase to ensure training of counterparts in necessary techniques 3. Workshop completed by March 2002 4. Summary report issued by end-March 2002	Draft reports by Oct. 2000 Project records Project records, workshop publicity material. Draft report byMarch. 2002	*(Output to purpose)* 1.City planners willing, able to use pollution risk assessments proactively as tool to direct city development 2. Identified agencies capable of conducting fieldwork and subsequent interpretation to required standard 3. City settings not so diverse as to frustrate identification of common themes 4. Stakeholder groups proactive in developing policy guidelines in each city
Activities: 1.1 lit.survey; collect data to assess aquifer vulnerability; produce map 1.2.Collect data on contaminant loads, priorities, produce map 1.3.Supplement any missing data with field surveys 1.4. Assess pollution hazard for each case study area by identifying areas where groundwater most at risk		1.1.Vulnerability map for each area 1.2.Contaminant load map and prioritisation for each area 1.3.Progress reports and B- to-O reports 1.4.Risk assessment section in city final report	*(Activity to output)* 1 - Sufficient basic data on geology and hydrogeology available to make task practicable, accurate base maps already available - Ability of collaborators to conduct the necessary field surveys not compromised by local circumstance - Basic commercial/ industrial census data publicly available - Standard techniques of aquifer vulnerability and pollution load assessment applicable 2 - Suitable agencies found and government permission to operate granted - International cooperation OK throughout fieldwork and report production/ publication stages - Counterpart funding in kind for collaborators can be secured from government concerned for duration of project 3 - Links with municipality strong enough to permit practicable policies to be identified for implementation - Stakeholder groups can be identified and willing to participate in policy development
2.1 Establish links with collaborating agencies, identify counterpart staff 2.2 Supply technical documentation and initiate training in field areas 2.3 Provide any required supplementary training by training visits and workshop(s)		2.1 Progress reports 2.2 Project records and progress reports 2.3 Workshops completed, progress reports, project records	
3.1Collaboratively develop management strategy for each study area comprising policies appropriate for municipal circumstances 3.2 Identify common messages and produce management guidelines 4.1 Project management		3.1 Draft versions of city final reports 3.2 Draft versions of summary report	

APPENDIX 2

URBAN GROUNDWATER QUESTIONNAIRE

COVER SHEET

Name of City	Bishkek
Country	Kyrghyz Republic
Currency	som
Exchange Rate (and date)	1$=30,2018som 21.01.1999 1$=17,6955som 20.01.1998
Inflation rate (and date)	6% per month in 1998 year

Contact Person	Litvak R. G.
Position/Title	Head of Ground Water Laboratory of KNIIIR
Organisation	Ground Water Laboratory, KNIIIR
Address	Kyrghyz Republic. Bishkek Dushanbinsky 4a 720000
Telephone and Fax	Tel: (996-312) 212934
E-mail (if available)	LIT1 @ IMFIKO. BISHKEK. SU
Date:	
Who was questionnaire completed by? (state name and position)	Litvak R. G. Head of Ground Water Laboratory of KNIIIR

A. SOCIO-ECONOMIC CONTEXT

A1	DEMOGRAPHIC CHARACTERISTICS			
1.1	**Population figures and estimates**			
		City proper	Metropolitan areas	Urban agglomeration
		Population (thousand)		
	Year 1994	591.300	601.000	
	Year 1995	583.900	593.600	
	Year 1996	585.800	595.700	
	Year 1997	589.400	599.300	
	1998	592.600	602.500	
	Year…			
	Year…			
1.2	**Population density and growth rate**			
	Land areas (km^2) and population density (1997)	157,25 km^2 3748 men.per km ^{2}		
	Annual growth rate (%/year)	2,72		
	Additional comments/description: • Metropolitan areas is equal to the city proper plus population of Chon-Aryk and Orto-Sai. • Average annual growth rate from 1993 to 1997.			

A2	INCOME AND ECONOMIC STRUCTURE		
2.1	**Income**		
	Regional domestic product per capita per year	$/cap/year	161 (1997 year)
	Urban poverty line?	$/cap/year	504 (1997 year)
	Population below poverty line	%	62% families, 51% persons (1996 year)
2.2	**Economic activities**		
	• Agro-industry/processing (✓) • Transport hub/port (✓) • Manufacturing (inc. light and heavy engineering; petrochemical and refining) (✓) • Mining • Finance/insurance (✓) • Commerce/retailing (✓) • Tourism	Please tick (✓) most important economic activities in your city, then rank in order of importance: 1. Manufacturing 2. Transport hub/port 3. Commerce/retailing 4. Finance/insurance 5. Agro-industry/ processing 6. Tourism	
	Additional comments/description: Population below poverty calculated like minimum food product for person, data for Kyrghyz Republic, !996 year. (information from Kyrgyz representative of World Bank)		

A3	MUNICIPAL SERVICES			
3.1	**Services provided by municipal government**			
		Yes - all (✓)	Yes - some (✓)	None (✓)
	Water supply		✓	
	Sewerage	✓		

	Wastewater treatment	✓		
	Drainage		✓	
	Solid waste collection and disposal	✓		
	Additional comments/description:	• Central sewerage is under responsibility of municipal government. Substantial part of individual houses no combine with central sewerage and use individual pour hole. • Solid waste collection disposals to north of the city border.		

Main sources of information:

1. Bishkek city in values 1997 year. Short statistical collection. Bishkek 1998year, 100p.
2. Data from the documents of World Bank.

HELP NOTES - SECTION A

A1.1	Please provide population estimates over at least a 15 year period. Demographic data can be obtained from census returns, often quoted in government and donor reports on urban issues
A1.2	The annual growth rate can be calculated as the average annual rate of population growth in the preceding five year period.
A2.1	Provide city-level data if available. If unavailable, please provide state or national statistic Urban poverty line: "those having less income than that needed to buy the minimum requirement of calories and protein, shelter, clothing and other necessities". This information may only be available in research studies on income inequalities undertaken by the national or city economic planning agency, or academic institutions engaged in economic research. If a national or city-level figure is not available, use the World Bank's World Development Report (1997) estimate of XX$/capita/year.
A2.2	This is intended to provide a 'rough and ready' (and subjective) economic profile of the city. More detailed information on urban employment and economic activities is requested in Section D.
A3.1	In some cities, municipal government may provide most of the services listed. In others, the private sector may be important. More detailed information on groundwater supply and waste disposal arrangements is requested in Sections C and D.
Additional material	Obtain a map showing the physical location of the city and its boundaries.

Your comments

Please provide comments on this section (including the help sheet), suggesting improvements if possible.

B. HYDROGEOLOGICAL SETTING

B1	AQUIFER SYSTEM

see file bb. jpg

B2	GEOLOGY

see file bb. jpg

B3	SHALLOW UNCONFINED AQUIFER		
	If your city is underlain by a shallow unconfined aquifer please answer the following questions otherwise tick the box below questions not applicable ☐		
3.1	Is there significant leakage from the unconfined aquifer to deeper confined aquifer(s) under?:		

		Yes (✓)	No (✓)	Don't know (✓)
	natural conditions?	. ✓		.
	pumping induced conditions?	. ✓		

3.2	What is the regional groundwater gradient in the unconfined aquifer?
	From 0,005 to 0,03
3.3	What is the depth to the water-table from the ground surface in metres?

	(metres)
3.3.1(for south part) maximum minimum	 **80,0** **5,0**
3.3.1(for north part) maximum minimum	 **5,0** **0,0**
average	

B4	AQUIFER PARAMETERS
4.1	Estimate the average transmissivity for each aquifer unit and tick the range within which the value falls.

		Transmissivity (m^2/d)				
		<10	10-100	100-500	500-1000	>1000
	for south part					**6000**
	for north part				**900**	

Give details of the source of the information on which you based the estimate of aquifer parameters given above:

1)

4.2	Estimate the average storativity and porosity for each aquifer unit and tick the range within which the values fall

		Storativity (-)					Porosity (%)		
		$<10^{-4}$	10^{-4}-10^{-3}	10^{-3}-10^{-2}	10^{-2}-10^{-1}	$>10^{-1}$	<1	1-10	>10
	Aquifer					✓			✓

Give details of the source of the information on which you based the estimate of aquifer parameters given above:

1)

B5	AQUIFER RECHARGE
5.1	What is the mean annual rainfall for your city in mm/ per year?
	400
5.2	Tick the appropriate range for mean annual natural aquifer recharge to the aquifer system beneath your city.

		<50	50-100	100-200	>200

	Aquifer recharge (mm/year)		✓		
	Give details of the source of the information on which you based the estimate of aquifer recharge given above: **This table includesonly natural rainfall** **2) and 3)**				

B6	**MAPS**			
	It would be helpful if you could provide copies of maps that add detail to the information provided in this section. Please send any other maps that you think are relevant in describing the physical setting of your city: Tick boxes for maps included.			
	Map of city showing topography and surface water features	✓	Transmissivity	✓ ☐
	Geology	✓	Storativity	✓ ☐
	Depth to water-table	✓	Porosity	☐
	Height of the water-table	☐	Aquifer recharge	☐
	Other **Map of Geological.and genetical complexes**☐		………………………………..	☐
	………………………………..	☐	………………………………..	☐

1) Krivchenko O.S.and ather. Regulation of the regime observation wells for ground water Balance exploration for Chu Valley Kyrghyz State Geological Service, Frunze.1980

2) Litvak R. G. (Head of the Project), Substantiation of drainage measures on the housing estate Bakay-Ata. Scientific report, KNIIIR,Bishkek, 1996, 30 pp

3) Kaplinsky M.I., 1977. Prediction of changing of the drainage runoff under the influence of' the water economical measures. Frunze. "Ilim".

C. GROUNDWATER USE

Complete this section by providing the most up to date and verifiable information you can obtain. If you cannot provide quantitative data, please provide a qualitative response, referring to the Help Sheet for guidance. Provide all volumes in Megalitres/day (= 000 m^3d).

C1	URBAN WATER RESOURCES		
	Source	**Abstraction (Ml/d)**	**%**
1.1	Surface water		
	River Lake Reservoir Inter-basin transfer Other Total	73,74 73,74	 12,85
1.2	Groundwater		
	City centre City Metropolitan area Total	? 250 250 500	 87,15
1.3	Other		
	TOTAL	573,74	100%
	Additional comments/description:		

C2	GROUNDWATER SUPPLY AND USE												
2.1	**Supply sources, uses and volumes (D = Domestic; I = Industrial; M = Municipal; O = Other)**												
		Piped supply (state agency; utility) (Gross Ml/d, before distribution losses)				Licensed, legally sanctioned private supply (Ml/d)				Unlicensed, unregulated private supply (Ml/d)			
	Aquifer Unit	D	I	M	O	D	I	M	O	D	I	M	O
	1												
	2												
	3												
	4												
	All Units												
	TOTAL ABST.	500											
2.2	Groundwater use, net of distribution (unaccounted for) losses												
	TOTAL USE	500											
	Additional comments/description: The information about lossees is absent												

C3	GROUNDWATER DELIVERY
3.1	**Technology type (BH = Borehole; SW = Shallow well; S = Spring)**

		Piped supply (public; utility company) (Gross Ml/d)			Licensed, legally sanctioned private supply (Ml/d)			Unlicensed, unregulated private supply (Ml/d)		
	Aquifer Unit	BH	SW	S	BH	SW	S	BH	SW	S
	A1									
	A2									
	A3									
	A4									
	All Units	500	0	0		0	0		0	0
3.2	**Typical yield range (m^3/d) ???????**									
	A1									
	A2									
	A3									
	A4									
	All Units									
	Additional comments/description:									

C4	**TRENDS IN GROUNDWATER USE**							
4.1	**Total abstraction from aquifer for any purpose (Ml/d) and % of total urban supply**							
		Past trend					**Future projection**	
	Aquifer Unit	Year……	Year……	Year……	Year……	Year… 1998…	Year… 2010…	Year……
	A1							
	A2							
	A3							
	A4							
	TOTAL					500	1296	
	Additional comments/description							

C5	WATER QUALITY CONSTRAINTS						
5.1	**Groundwater contamination and treatment**						
	Aquifer Unit	Within WHO drinking water norms? (Y/N)	Problem parameters*	Water treated before use? (Y/N)			Widespread/ local problem? (W/L)
				Piped supply	Licensed supply	Unlicensed supply	
	A1						
	A2						
	A3						
	A4						
		Y	N	Y	?	N	L

Note *water quality problems:

F = faecal pathogens; S = salinity; H = heavy metals; N = nutrient compounds (principally nitrogen); T = taste/odour/stain (manganese, iron); O = micro-organics inc. petroleum products (LNAPLs), solvents (DNAPLs) and/ororganic load (dissolved organic carbon, BOD)

Additional comments/information:

E. GROUNDWATER MANAGEMENT

Tick (✓) the box that best describes water resources policy

E1	POLICY FRAMEWORK				
1.1	**National water policy**				
	Sustainable management and conservation of water resources (including groundwater) is an integral part of national development policy	Fully ✓	Partially	A little	Not at all
1.2	**Urban groundwater policy**				
	An urban groundwater management and development policy exists and is effectively implemented	Yes - policy exists and is implemented	Exists, but not effectively implemented ✓	Exists, but ineffective	No policy; no implementation
	Goals for urban groundwater management and development are clearly defined, responsibilities allocated, and resources committed	Yes - goals exist, with full provision to implement	Goals exist, but only partial provision to implement ✓	Goals exist, but no provision to implement	No goals or provision to implement
1.3	**Strategies and action plans**				
	A specific strategy and action plan (S&AP) for urban groundwater development and management is laid out, responsibilities allocated, and resources committed	S&AP exists; full provision to implement	S&AP exists; partial provision to implement ✓	S&AP exists; no provision to implement	No S&AP or provision to implement
	Additional comments/description:				

Tick (✓) the box that best describes the institutional framework for groundwater management

E2	INSTITUTIONAL FRAMEWORK/ARRANGEMENTS				
2.1	**Coordination**				
	Formal arrangements exist to ensure cooperation between water-related agencies, and are implemented on an ongoing basis	Formal arrangements are fully effective ✓	Formal arrangements are partially effective	There is informal coordination	There is active competition between agencies
	Formal arrangements enable participation of groundwater users, NGOs and other non-government stakeholders in groundwater planning and management	Yes			No ✓
2.2	**Regulation**				
	Legally binding procedures exist, with machinery to implement them, to allocate groundwater and resolve conflicts between competing users and uses	Procedures exist; full provision to implement ✓	Procedures exist; partial provision to implement	Procedures exist; no provision to implement	There are no procedures
	There is a functional separation, but legal link between, groundwater regulation and groundwater development.	Yes ✓			No
2.3	**Capacity**				
	Institutions dealing with groundwater management have the technical, financial and management skills and resources to fulfil designated tasks and functions	Fully	Partially	A little ✓	Not at all
	Regulatory body has the capacity and authority to monitor compliance with groundwater-related legislation, and to enforce controls	Regulations strictly monitored and enforced	Partial monitoring and enforcement ✓	Some monitoring but little enforcement	Inadequate monitoring and enforcement of controls
	Additional comments/description: For 2.3 There are low financial resources to fulfill designated tasks and functions.				

Please tick (✓) the appropriate box

E3	POLICY INSTRUMENTS FOR GROUNDWATER MANAGEMENT				
		Measure exists and is fully implemented	Measure exists but is only partially implemented	Measure exists but is not implemented	Measure does not exist
3.1	**Pollution control - regulation**				
	Ambient groundwater quality standards (listing permissible concentrations)	✓			
	Effluent standards (quality; quantity) -for specific industries -for specific pollutants -in vulnerable recharge areas	✓			
	Industrial process standards	✓			
	Mandatory pretreatment/treatment	✓			
	Discharge permit system -for specific industries -for specific pollutants -for specific areas	✓			
	Technical standards	✓			
	Land use and building controls	✓			
3.2	**Pollution control - economic incentives**				
	Effluent charges/taxes	✓			
?	Marketable discharge permits ???				
	Subsidies for clean technologies		✓		
3.3	**Pollution control - other**				
	Self monitoring and reporting				✓
3.4	**Abstraction controls - regulations**				
	Abstraction licenses/permits	✓			
	Abstraction quotas	✓			
	Technical standards/controls	✓			
	Process standards	✓			
	Land use and building controls - zoning	✓			
3.5	**Abstraction controls - economic incentives**				
	Groundwater tariffs -mains piped -private industrial/household	✓			
	Enforcement incentives	✓			
?	Administration charges ???				
?	Marketable quotas/licenses ????				
	Subsidies for water efficient technologies		✓		
3.6	**Abstraction controls - other**				
	Metering		✓		
	Additional comments/description: For 3.3 The self-acting monitoring for pollution is absent				

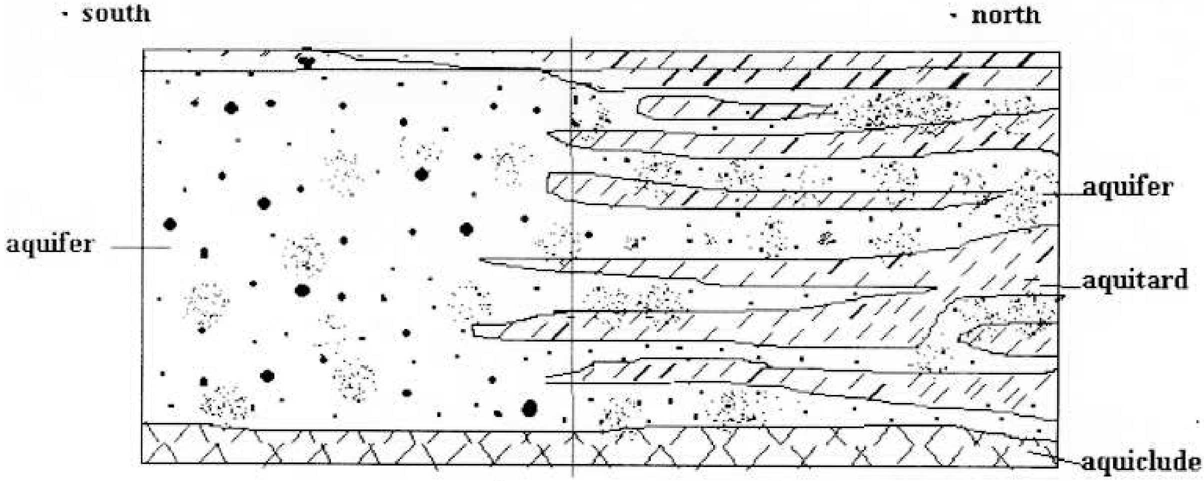
E4	INSTITUTIONAL INVENTORY
4.1	**Classification** Status: G = Government; SG = Semi -government agency; P = Private; NGO = Non-government Organisation; A = Academic; O = Other (please specify)

	Jurisdiction: C = City/municipality; R = Region; B = Basin; N = National			
	Function	**Name of institution(s)**	**Status**	**Jurisdiction**
1	Groundwater resource assessment and research	Kyrghyz Hydrogeology Expedition Kyrghyz Institute of Irrigation	G G	N N
2	Groundwater resource policy formulation	Municipal Power Kyrghyz Hydrogeology Expedition Department of water economy Kyrghyz Institute of Irrigation	G G G G	C N N N
3	Coordination of water-related activities	Government of Kyrghyz Republic	G	N
4	Groundwater resource planning	Bishkekvodokanal Department of water economy Municipal Power	G G G	C N C
5	Regulation and enforcement of controls and standards	Sanitary and Epidemiological Station	G	C
6	Operations management	Bishkekvodokanal	G	C
	Additional comments/description:			

Please tick (✓) the appropriate box

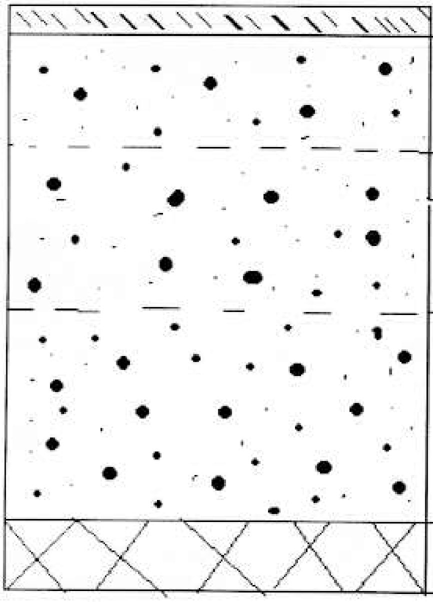
E5	**INFORMATION, PLANNING AND PUBLIC AWARENESS**				
5.1	**Information availability**				
	Information on groundwater conditions and rates of change is sufficient for planning, development and management of the resource	Fully sufficient	Adequate	Insufficient ✓	No information available
5.2	**Information use**				
	Information on groundwater conditions and rates of change is routinely used in urban planning and groundwater management	Yes - full use	Partial use ✓	Little use	Not use at all
5.3	**Administration and support**				
	Information collection, processing and dissemination is handled by a specialist support unit, independent of other line agencies, and serves all government agencies and the private sector	Yes - specialist unit provides comprehensive, prompt service	Specialist unit provides limited support	No specialist unit; data holdings fragmented ✓	No specialist unit or data holdings
5.4	**Public knowledge**				
	Information about water resources are available to the public to aid their participation in planning and decision-making	Extensive information readily available	Limited official information supplements news media	Limited information is available by via news media ✓	No information is available through any medium
5.5	**Consensus**				
	There is broad consensus on the causes and consequences of degradation among groundwater users/polluters, city residents generally, and professional planning/regulatory agencies	Yes	Problem/facts not disputed; action is ✓	Facts, interpretation, and action disputed	No debate therefore nothing to dispute
	Additional comments/description:				

B1



B2

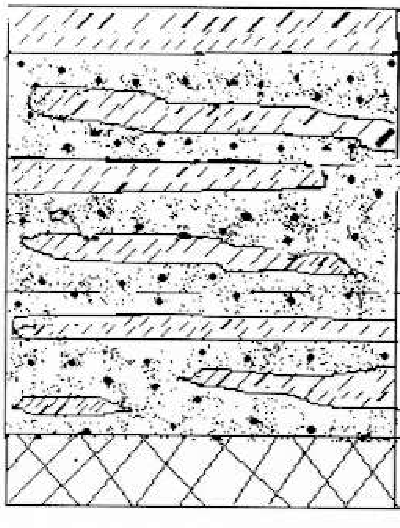
for south part



5 m		loam
20 m	paQ_{III}^{2}	coarseboulder - coarse-gravel + sandy, gravel
90 m	paQ_{III}^{1}	
350 m	paQ_{II}	Transmissivity -4000-6000 m2/d gradient - 0,003-0,009
	N	conglomerate+clay

B2

for north part

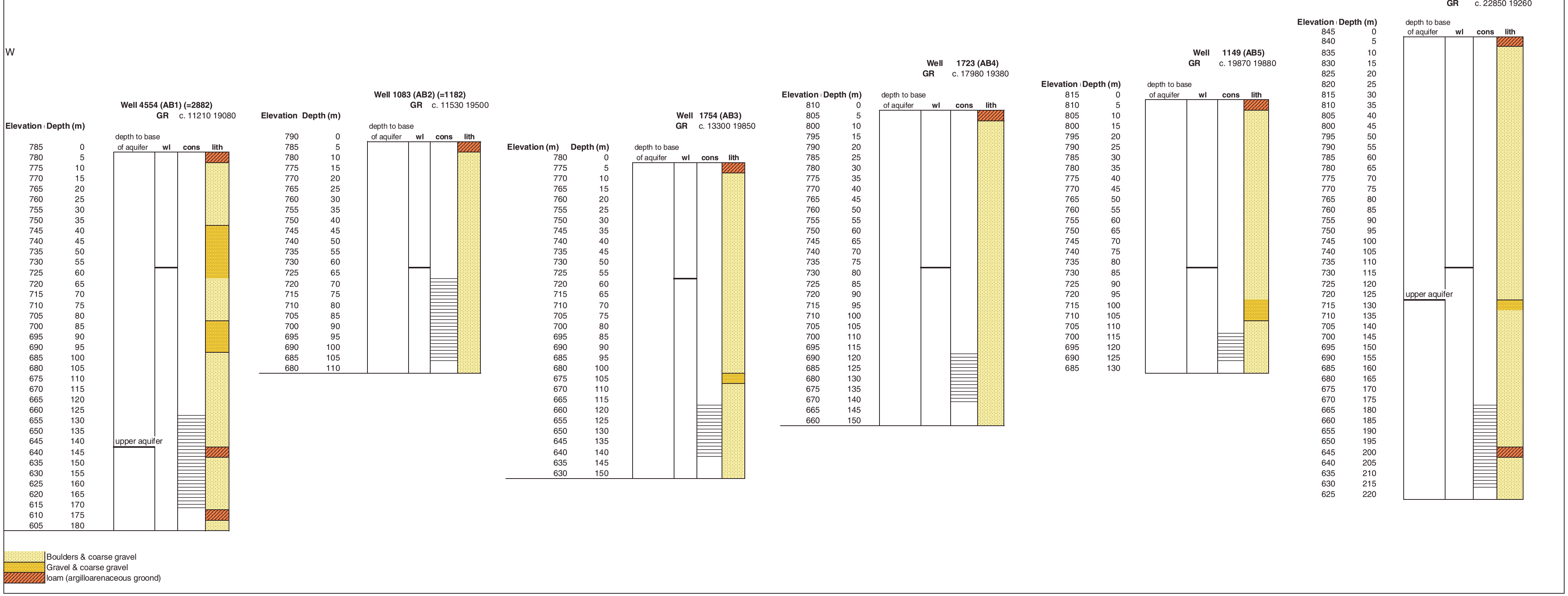


10 m		loamy
40 m	apQ_{III}^{2}	gravel+sand+loam+ clay
120 m	apQ_{III}^{1}	
350 m	apQ_{II}	Transmissivity - 900 m2/d gradient -0,005-0,01
	N	conglomerate+clay

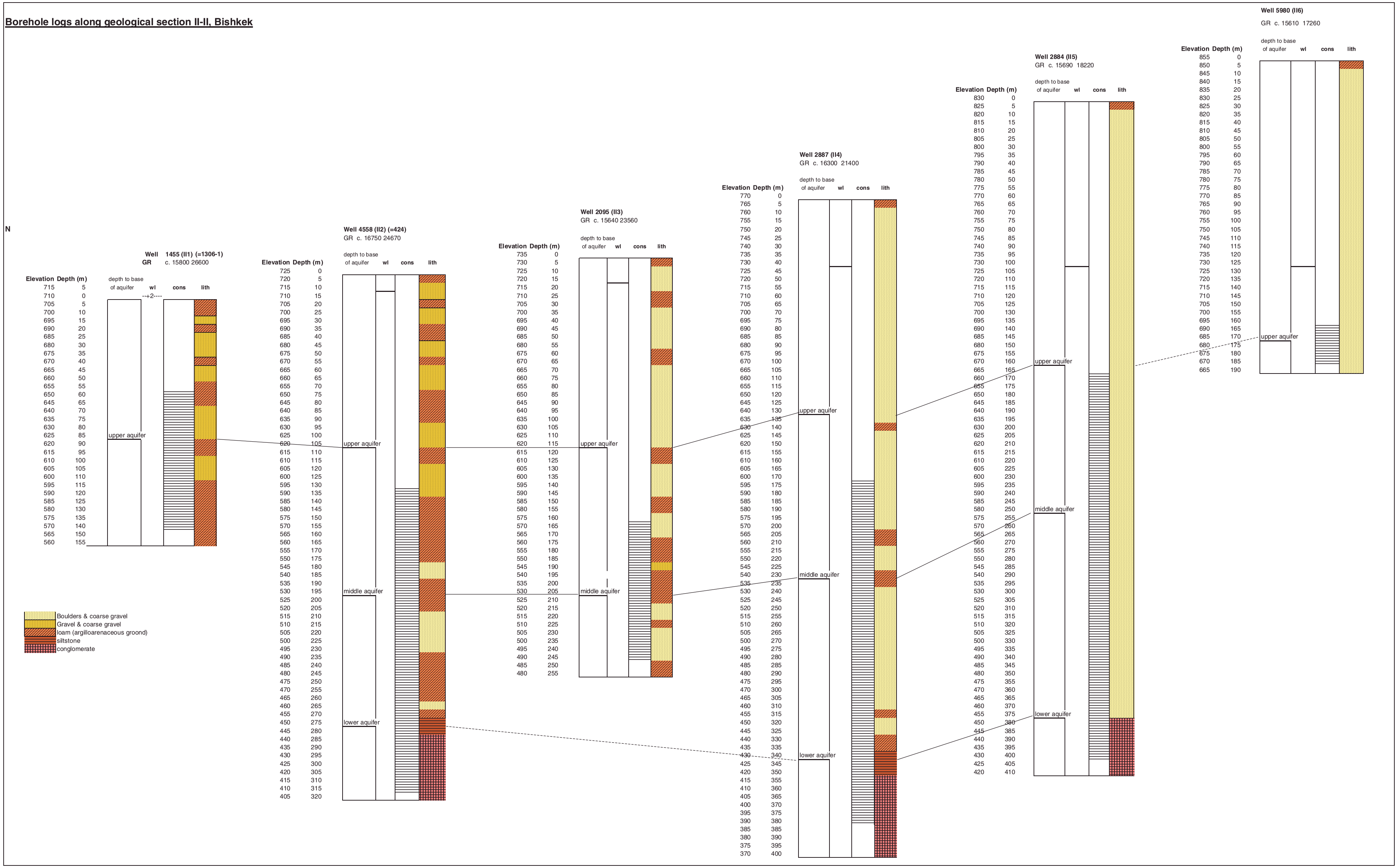
APPENDIX 3-

Well Number	Alternat. No.	Cross Section & No.	Easting	Northing	OD (m)	Depth to Base of Upper Aquifer (m)	Base of Upper Aquifer (m OD)	Base of Middle Aquifer	Base of Lower Aquifer
4554	2882	AB1	11210	19080	785	140	645		
1083	1182	AB2	11530	19500	790				
1754		AB3	13300	19850	780				
1723		AB4	17980	19380	810				
1149		AB5	19870	19880	815				
5968		AB6	22850	19260	845	125	720		
1455		II1	15800	26600	710	85	625		
4558	424	II2	16750	24670	725	105	620	530	450
2095		II3	15640	23560	735	115	620	530	
2887		II4	16300	21400	770	130	640	540	430
2884		II5	15690	18220	830	160	*670*	*580*	455
5980		II6	15610	17260	855	170	*685*		
1490	3015	III1	20750	27880	680	45	635	585	
1395	1331	III2	21670	24180	710	90	620	560	445
2538		III3	20250	22040	760	125	635	510	430
4278	2170	III4	18740	20150	810	140	670		
6316	1748	III5	18480	18180	860	160	*700*		
2883		VG1	10560	20480	745	120	625	535	425
6319		VG2	12700	21290	740				
949		VG3	13770	21425	745	125	620		
2485		VG4	14320	21450	750	130	620	530	420
7253		VG5	17890	21305	750				
1753		VG6	19170	21315	750				
2538		VG7	20250	22040	760	125	635	510	430
2397		VG8	22810	21188	750	115	635		

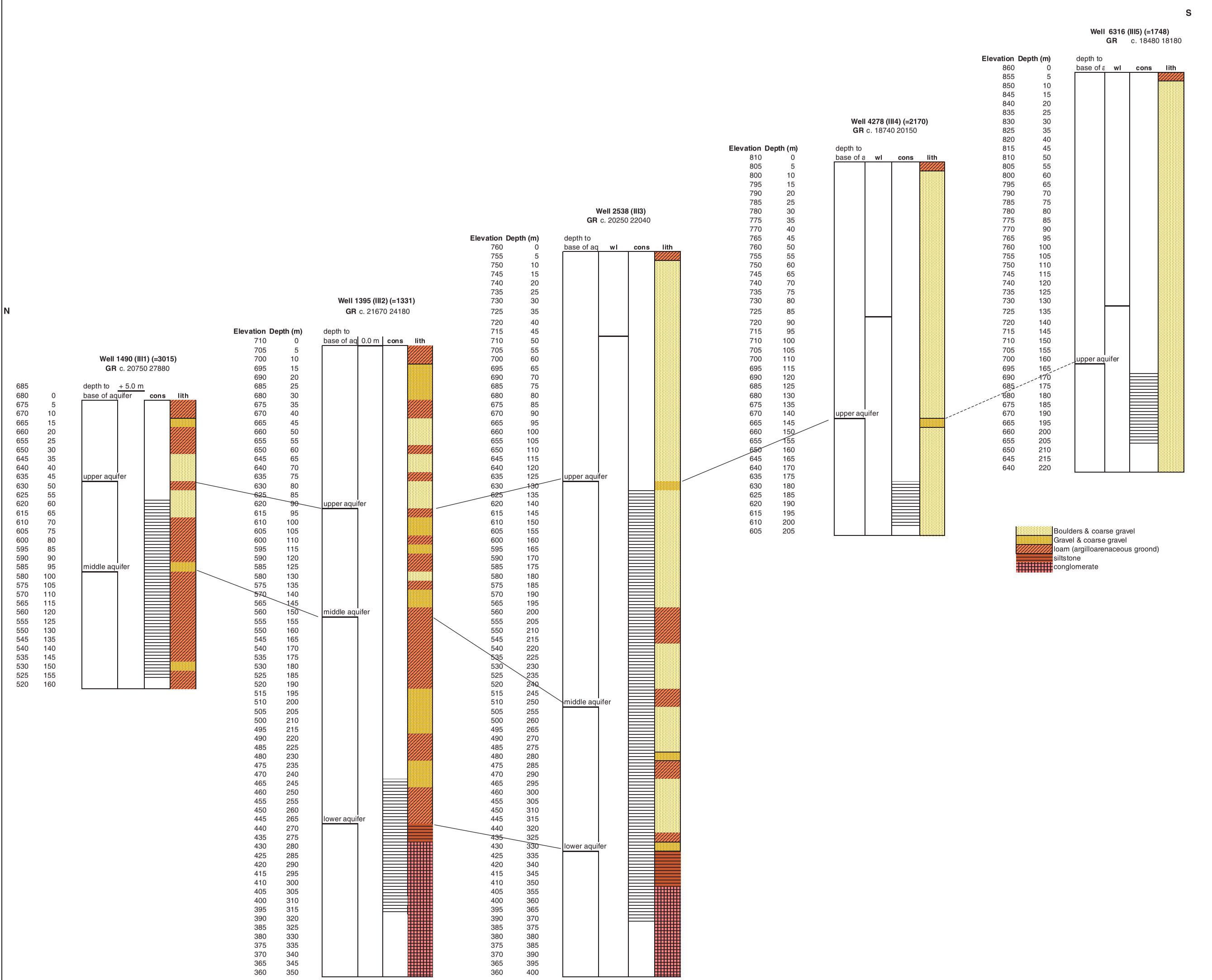
Borehole logs along geological section A-B, Bishkek



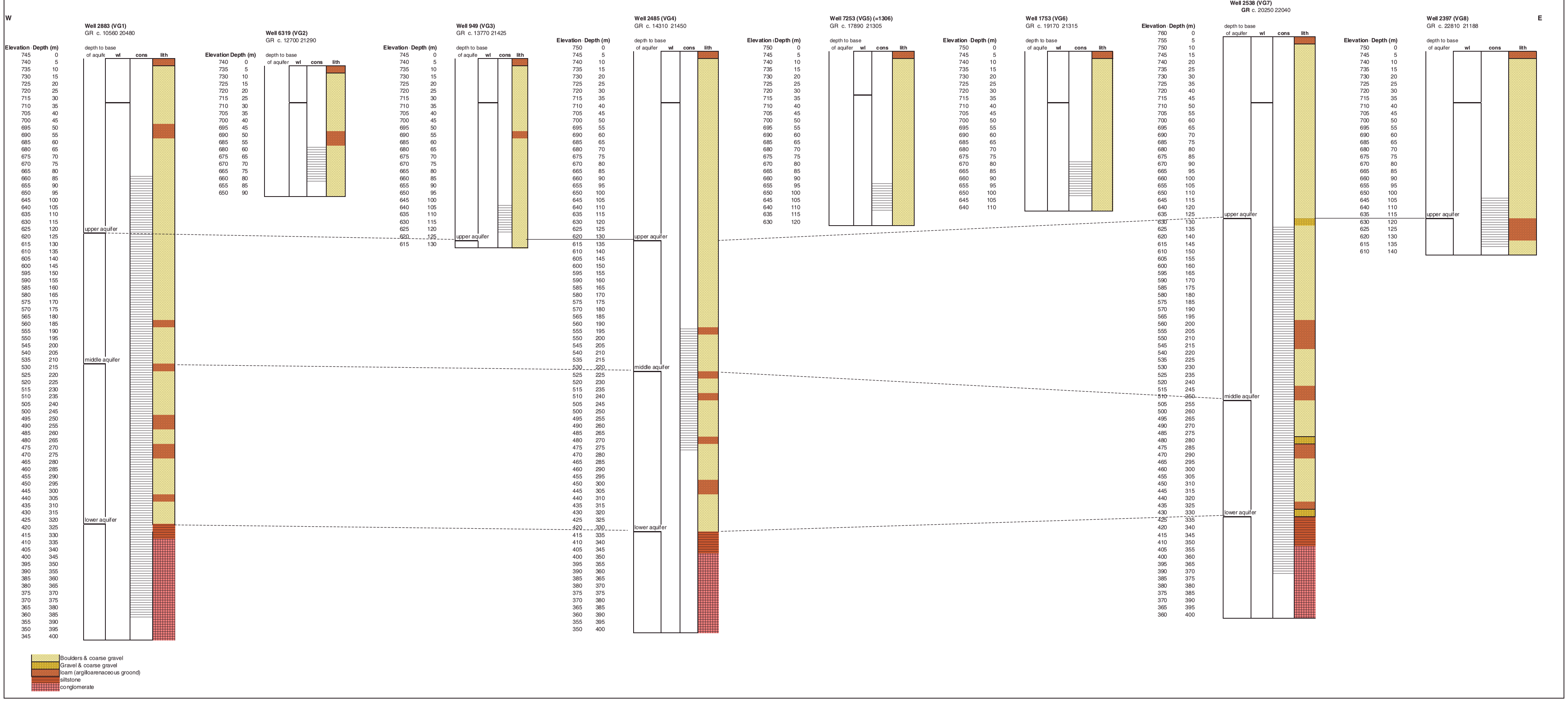
Borehole logs along geological section II-II, Bishkek



Borehole logs along geological section III-III, Bishkek



Borehole logs along geological section V-G, Bishkek



APPENDIX 4

<u>Details of MapInfo and Vertical Mapper techniques for producing map layers</u>

<u>Producing the base map</u>

A number of paper maps of Bishkek and the area to the south of the city were scanned and imported as raster images to MapInfo, then registered to conform to the project co-ordinate system. From these, the main physical features of the city were digitised, using the drawing facilities within MapInfo, as separate line or polygon themes: the project boundary, railway, roads, rivers and canals; areas of high relief; the approximate boundaries of the urbanised area in the 1970s and 1980s, and the municipal boundary of the city in the 1980s.

<u>Producing map layers showing vulnerability zones of each criteria</u>

Information on the spatial distribution of relative groundwater vulnerability for each individual theme was obtained from paper maps. These were digitised as scanned images and imported to MapInfo as raster base-maps, registered to the project co-ordinates. Using these, polygons representing each zone were digitised within MapInfo. Attribute tables were created to store information about each zone. At a minimum, this information included an ID number, description of zone classification, and a weighting representing the relative groundwater vulnerability.

Add sample table & poss, sample map showing polygons etc.

<u>Producing a composite groundwater vulnerability map</u>

Each map theme was converted to a grid using Vertical Mapper's Region to Grid utility. This technique converts existing MapInfo polygons (termed 'regions') to a grid by first overlaying a grid on the polygon file at a user-defined cell size and then assigning a value to each grid cell from the polygon in which it falls. Each grid cell holds a single value, which in this case is the value of the vulnerability weighting of each of the polygons in the MapInfo input layers (Fig. X).

Fig. X : diagram to illustrate overlay of grid on polygons

Grid cell size is set by the user, and for the GVM input maps was set at 25 m (length of cell size): this produces a grid of X 000 cells. This relatively fine resolution was required to represent the river buffer zones within the Surface Hydraulics input map, which are represented by linear polygons only bounding the rivers. The river beds are typically less than 20 m wide along the urban reaches, and the buffer zones are only 30 m wide on each bank. Experimentation with grid cell sizes showed 25 m to be the coarsest resolution which fully represented the river buffer zones.

The individual grid layers were then superimposed by adding the weighting values for each grid, creating a composite map illustrating the point score of relative groundwater vulnerability for each cell.

A technical glitch within Vertical Mapper means that VM cannot perform calculations on grids which have different X and Y dimensions: i.e., the outer boundaries of each grid in the calculation must be identical. To allow the input grids to be added together, each of the MapInfo polygon input layers must be set with the same minimum and maximum X and Y values. When the grids are created from these input layers they maintain the same outer dimensions.

Because the composite map is formed from the superimposition of the irregular polygons which make up the input MapInfo layers, it has a relatively complex appearance. The composite grid was reclassed as a character (non-numeric) grid, regrouping the composite vulnerability data into a simpler classification system to represent areas of low, medium and high vulnerability.

APPENDIX 5

<u>Procedure for verifying data on industries from K98 database:</u>

- If a phone number is given for the business, telephone to verify:
- (1) whether it still exists by the same name; (2) whether what it produces is the same as the details in the K98 database; and (3) the size of the firm
- If there is no phone number, or the phone number given is wrong, get accurate phone number from directory enquiries.
- Use the information obtained to classify each business into one of the activity codes described in table X, with comments describing their status (still in existence or length of time since they stopped existing; size: small (<10)/medium (10 – 100)/large (>100)).
- If the business cannot be reached by phone, visit the site by car to verify if it still exists.
- For field visits, to assist with locating individual firms, a large scale map of the area to be checked can be produced in MapInfo. This has the locations of the businesses and the streets marked. A map of the streets was warped to the project co-ordinate system and is not completely accurate, particularly towards the outer boundaries of the project area. The businesses should be labelled, both by name and by ID number. Where more than one business lies at the same location, with the same ID number, MapInfo does not label their names separately, so it is usually more useful to label by ID number. The businesses to be verified by field visit should be highlighted.

Note: The number of employees quoted for each business in K98, and the number businesses will admit to during verification, may be less than the actual number of employees.

<u>MapInfo techniques for potentially contaminating activities survey</u>

<u>Procedure for selecting businesses for verification:</u>

- In MapInfo, select all businesses in the pilot area using the Region Select tool
- Export the details of the selected businesses, e.g. to Access or as a .dbf file to be opened in Excel.
- Sort businesses by ID number
- Where there is more than one business at the same location (and for some reason, sometimes even where there is only one), MapInfo does not distinguish all details and gives the message “Several businesses in object”. To get the data for these, EITHER go through printed list manually & find each one by ID number, OR search for all ID numbers in the Access database and remove the duplicates manually.

APPENDIX 6

List of potential sources of groundwater pollution (Source: KHS report & KSRII research)

ID in K98	Name of Institution	Nature of outflow	Where disposed
	Bishkek Equipment Factory	industrial & domestic-type waste water	public sewers
21011	Usta – Bishkek Agrospetsremmash Repair Plant		public sewers
21410	Bulgaary Leather Factory	Waste water	to a collector system & treated, then probably to public sewers
21149	Ak-Maral	Solid and liquid waste	Solid waste collected in a container and taken to town rubbish dump. Waste water to public sewers
	Alamedinskaya fur factory	Waste water	to collector system then mixed with surface & groundwater and put into canals & Alamedin R.
	Ilbirs knitting mill	Waste water	mainly reused for (factory) heating
	Kubat truck depot		public sewers
21160	Suusar fur factory	Waste water	Probably to public sewers
	Bishkek Kenaf/ Ambary (rope?) factory	Domestic & industrial waste water	Domestic type waste water to public sewers. Industrial waste water to collector system and transported by container lorry to treatment
21019	Ainur (company "Ala Too")	Some domestic, mainly industrial waste water	(? To public sewers)
1656	Dastan	Some domestic, mainly industrial waste water	Domestic type waste water to public sewer. Industrial waste first treated onsite then to public sewer. Solid waste collected in a container and taken to factory rubbish dump
21155	Janar electronics factory		Public sewer
	Frunze Tannery		to treatment plant (probably onsite) and then to Alamedin river
	Experimental (or Experienced) leather tanning and leather haberdashery		treatment plant (on site?) then ? (probably to Alamedin river, as above)
	Dostuk truck depot		Public sewer
21052	Bishkek Drill Production Plant	Mainly domestic-type waste water, small amount of industrial	domestic-type waste water to public sewers; industrial water used twice for technical purposes then probably to public sewers
21566	Edelweiss Joint Stock Hosiery Firm	industrial and domestic -type waste water	to same collector system as for Bulgaary
60326	Frunze Agricultural Machinery Plant	2/3 industrial waste water and 1/3 domestic-type	Public sewer
21015	Tyashelectromash (Oremi)		Public sewer
	Bishkek Vodokanal Sewage Treatment Plant	Treat all waste water from public sewers. Dry residue sometimes sold for use as fertiliser in big farms	-
	"8 March" Weaving factory	2/3 industrial and 1/3 domestic type waste water.	waste water held in system onsite to separate solid waste then to public sewers. Solid waste to town rubbish dump
ID in K98	**Name of Institution**	**Nature of outflow**	**Where disposed**
21110	Kyrghyz Car	90% industrial and 10%	Public sewer

	Assembly Plant	domestic-type waste water	
	Mechanical Repair Factory (leased enterprise)		stored in concrete containers on site then removed by container - where??
	Bishkek Dairy Garage		Treated on site, then?
	Railway station unloading zone	No waste water.	Toilets to septic tank then removed by container lorry
	Kyrgyzavtomach plant	No information	No information
	Usta Repair & Engineering Works	No information	No information
	Alamedin Railway Station	No information	No information
	Ala-Too production	No information	No information