5. Faryab: Hydrogeology

5.1 Previous hydrogeological maps

A hydrogeological map of Afghanistan was produced in 1977 by Abdullah & Chmyriov (1977a) at a scale of 1:2,000,000. This was accompanied by a map of mineral waters at a scale of 1:2,000,000 (Abdullah & Chmyriov 1977b), and a map of mineral and fresh water springs at a scale of 1:4,000,000 (Abdullah & Chmyriov 1977c).

Prior to this, however, Mishkin (1968) prepared a hydrogeological map of the Quaternary deposits of Northern Afghanistan (Faryab), which was subsequently reproduced in monochrome in Marinova's (1974) "*Hydrogeology of Asia*".

The hydrogeology of areas of Turkmenistan adjacent to Faryab province is discussed and shown in Krizhanovskii (1972).

Most recently, the Chinese Geological Survey (2012) includes the Faryab area in their set of hydrogeological and groundwater resources maps of Asia, broadly compiled according to the Standard International Association of Hydrogeologists' guidelines (Struckmeier & Margat 1995). The Chinese maps are at too coarse a scale to indicate much interesting detail regarding Faryab, however.

5.2 Overview

During the course of 2012-2014 an attempt has been made by the NORPLAN project team to register as many as possible groundwater features in Faryab. This has been performed largely by collating all available existing information - the majority being held by DACAAR. This information was supplemented by rapid field surveys carried out in

- Kohistan
- Bilchiragh
- Gurziwan
- Qaysar
- the area around Maimana Airport
- the four northern districts of Andkhoi, Qurgan, Qaramqol and Khani Chahar Bagh.

<u>Springs</u>

Figure 5.1 shows the distribution of registered springs in Faryab. It will be seen that these are especially abundant in the mountainous districts of Kohistan (Figure 5.3) and Gurziwan, where they are largely derived from the late Cretaceous-Palaeogene limestone aquifer. In the mountain areas of southern Faryab, these springs form the backbone of potable water supply and also provide a valuable baseflow contribution to rivers.

Additionally, a number of small springs can be seen in the Qaysar / Ghormach areas, feeding the headwaters of the various tributaries of the Chechaktu River system.

A limited number of large springs (Figure 5.5) also emerge in the alluvial valleys of the main rivers (Shirin Tagab and Maimana). These coincide with locations where the water table approaches the surface and may be related to constrictions in the subsurface topography of the valley systems. This will be discussed in more detail in Chapter 6.

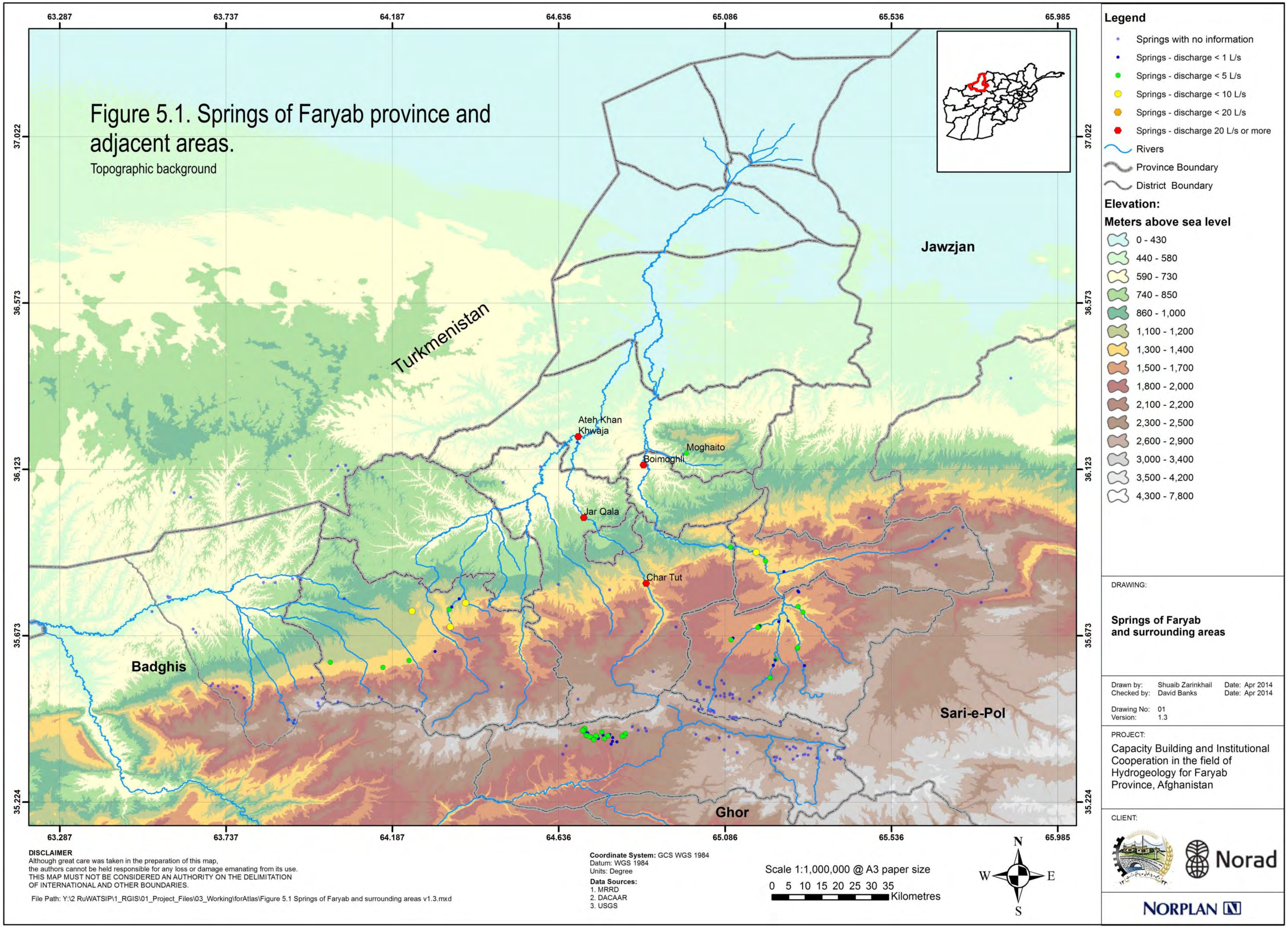


Figure 5.1. Springs of Faryab province and adjacent areas.
Topographic background
Turkmenistan
Jawzjan
Badghis
Sari-e-Pol
Ghor
Ateh Khan Khwaja
Moghaito
Boimoghli
Jar Qala
Char Tut
63.287
63.737
64.187
64.636
65.086
65.536
65.985
37.022
36.573
36.123
35.673
35.224
Legend
Springs with no information
Springs - discharge < 1 L/s
Springs - discharge < 5 L/s
Springs - discharge < 10 L/s
Springs - discharge < 20 L/s
Springs - discharge 20 L/s or more
Rivers
Province Boundary
District Boundary
Elevation:
Meters above sea level
0 - 430
440 - 580
590 - 730
740 - 850
860 - 1,000
1,100 - 1,200
1,300 - 1,400
1,500 - 1,700
1,800 - 2,000
2,100 - 2,200
2,300 - 2,500
2,600 - 2,900
3,000 - 3,400
3,500 - 4,200
4,300 - 7,800
DRAWING:
Springs of Faryab and surrounding areas
Drawn by: Shuaib Zarinkhail Date: Apr 2014
Checked by: David Banks Date: Apr 2014
Drawing No: 01
Version: 1.3
PROJECT:
Capacity Building and Institutional Cooperation in the field of Hydrogeology for Faryab Province, Afghanistan
CLIENT:
Norad
NORPLAN
DISCLAIMER
Although great care was taken in the preparation of this map, the authors cannot be held responsible for any loss or damage emanating from its use.
THIS MAP MUST NOT BE CONSIDERED AN AUTHORITY ON THE DELIMITATION OF INTERNATIONAL AND OTHER BOUNDARIES.
File Path: Y:\2 RuWATSIP\1_RGIS\01_Project_Files\03_Working\forAtlas\Figure 5.1 Springs of Faryab and surrounding areas v1.3.mxd
Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree
Data Sources:
1. MRRD
2. DACAAR
3. USGS
Scale 1:1,000,000 @ A3 paper size
0 5 10 15 20 25 30 35
Kilometres
N
W
E
S

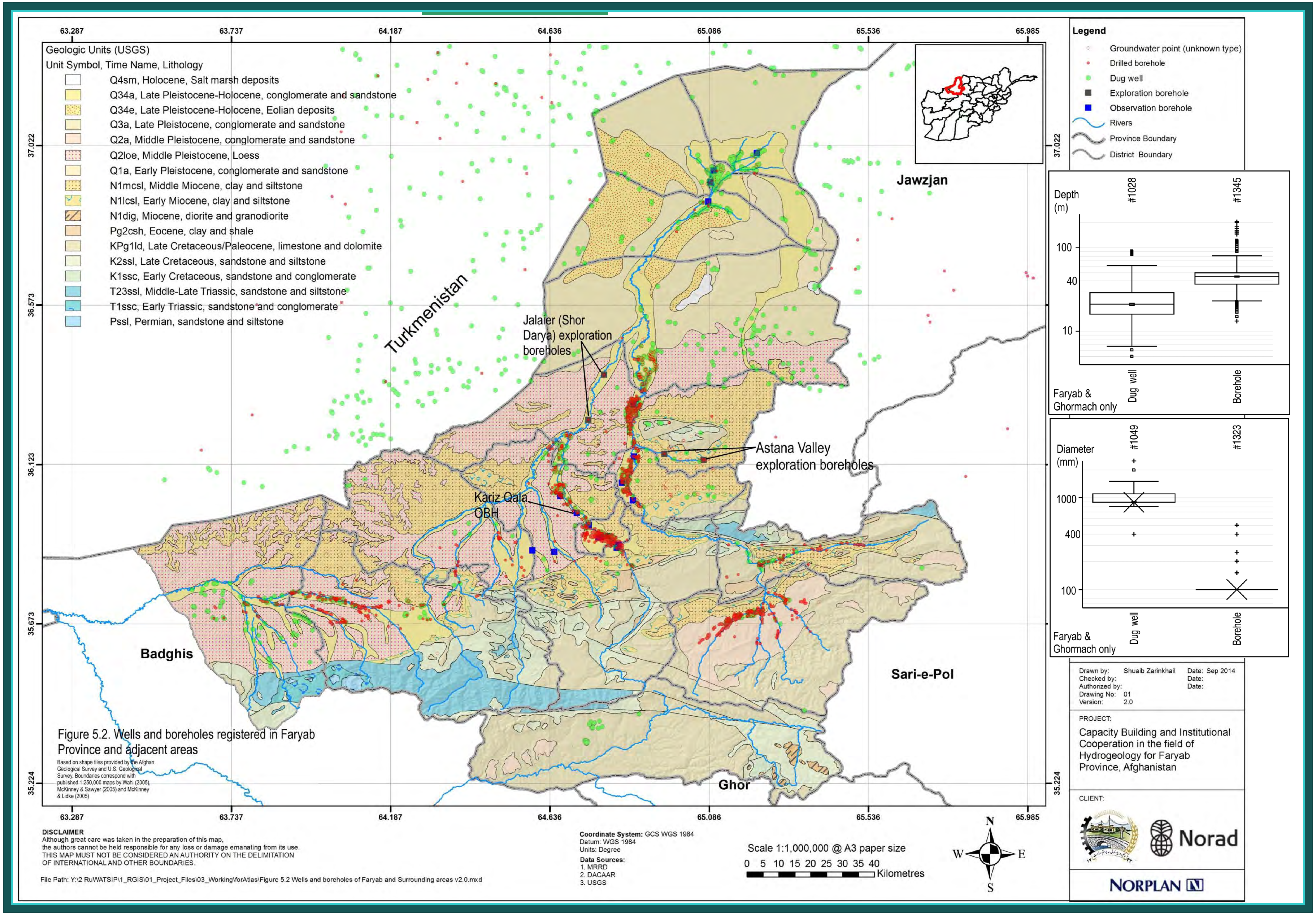


Figure 5.2. Wells and boreholes registered in Faryab Province and adjacent areas

Figure 5.3. A mountain spring in Kohistan emerging from a sedimentary rock sequence. Taken 23rd May 2013 by DACAAR.

Figure 5.4. A spring in a ravine, Qaysar district. Photo by DACAAR, 6th March 2013.

Figure 5.5. Kariz Qala spring emerging from the alluvial plain of the Maimana River in Pashtun Kot district around 10 km NW of Maimana city. Taken 5th May 2013 by DACAAR. The discharge is around 2 L/s of water with an electrical conductivity of 1350 µS/cm.

Boreholes and Dug Wells

Figure 5.2 shows the distribution of registered drilled boreholes and dug wells in Faryab and Ghormach (and some from surrounding areas). The map only shows registered features and can thus be assumed to be incomplete. There appears, however, to be a predominance of drilled boreholes in the alluvial valleys of the Shirin Tagab and Maimana Rivers, in Shirin Tagab, Khwaja Sabz Posh, Pashtun Kot and Maimana districts. Drilled boreholes are also found along the valleys of the tributaries of the Chechaktu and along the river valleys in Gurziwan district.

Dug wells are much more common in the northern districts, where the water table is typically within c. 30 m of the surface and water yields are modest. Large numbers of dug wells are also recorded in Turkmenistan. Dug wells into the shallow limestone and sandstone aquifers of Kohistan are also registered.

Of the 1328 registered dug wells, as of June 2014, in Faryab and Ghormach (excluding adjacent territories), 1028 have information on depth, which ranges from 5 to 91 m. The deepest dug wells, in the range 55-91 m, are exclusively from Qaysar district. The interquartile range is 16 to 29 m, with a median depth of 21 m (see boxplot insets in Figure 5.2). 1049 wells have information on diameter, which ranges from 400 mm to 2500 mm. The interquartile range is 889 to 1100 mm, with a median of 889 mm. A large number of wells are of diameter 889 mm (35”).

Of the 1389 registered drilled boreholes in Faryab and Ghormach (as of June 2014), 1345 have information on depth, which ranges from 13 to 204 m. The interquartile range is 36.5 to 50 m, with a median depth of 45 m. 1323 boreholes have information on completed diameter: almost all have a completed diameter of 100 mm (4”), which reflects an NGO policy of installing 100 mm PVC casing to hinder the unrestricted use of boreholes for motorised pumping. The maximum diameter was 500 mm.

Figure 5.6. A dug well in Kohistan district. Photo by DACAAR, 25th May 2013.

Figure 5.7. A dug well in Qaysar district. Photo by DACAAR, 5th March 2013.

Figure 5.8. A dug well in the northern plains area around Andkhoi. Photo by DACAAR, 4th April 2013.

Figure 5.9. Drilling a test borehole in the Astana Valley. Photo by Engineer Hassan Saffi, DACAAR, 8th April 2008.

Karezes

It is reported that karezes were formerly used to provide groundwater for irrigation in Faryab (see Chapter 1.3). During the 2012-14 NORPLAN survey, not a single karez was registered in Faryab.

5.3 Aquifers and aquitards of Faryab

Figure 5.12, at the end of this Chapter, shows the hydrogeological map that has been produced as a result of this project, broadly according to the standardised hydrogeological legend of Struckmeier & Margat (1995).

The following succession considers the allocation of each stratigraphic units (based on the digitised 1:250,000 USGS maps of McKinney & Sawyer (2005), McKinney & Lidke (2005) and Wahl (2005).

For many stratigraphical units, the real quantified hydrogeological data are extremely sparse and classification has been allocated on the basis of

- anecdotal evidence from Afghan hydrogeologists.
- hydrogeological evaluation of lithological descriptions.
- information provided in literature, especially from the section of Abdullah & Chmyriov (2008b) dealing with the hydrogeology of Northern Afghanistan, which information is used to supplement the descriptions that follow.

Map legend

The standardised hydrogeological legend of Struckmeier & Margat (1995) is broadly followed, in which:

- aquitards / non-aquifers are portrayed in an orange-brown colour
- granular (clastic) aquifers are portrayed in a blue colour
- fractured or karstic aquifers are portrayed in a green colour.

For the aquifers, the colours become more intense as the productivity of the aquifer increases. Additionally, in the context of this project:

- cover material, overlying other aquifer strata, but which may not be fully saturated themselves, are coloured grey.

It is very important to realise that **the Hydrogeological Map in Figure 5.12 only provides information about likely aquifer nature and groundwater productivity and not about water quality or salinity**. I.e. a “good” aquifer can produce saline water!

Pre-Cimmeride basement

Carboniferous-Triassic rocks are exposed largely in the Band-e Turkestan and almost no quantified information exists on their aquifer properties.

- **C_2ls** Late Carboniferous limestones, with subordinate clastic sedimentary and volcanic rocks. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.
- **Pssl** Permian sandstones and siltstones, with subordinate conglomerates and mudstones. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.
- **T_1ssc** Early Triassic sandstone and conglomerate, with subordinate volcanics. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.

- **T_{23}ssl** Middle-Late Triassic sedimentary complex. Fractured, complex aquifer system containing many lithologies, dominated by sandstone and siltstone, with subordinate shale, mudstone, limestone, conglomerate, volcanics. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.

  Abdullah & Chmyriov (2008b) state that groundwater in the Triassic of the upland areas is limited to sandstones and limestones and that springs seldom exceed 1 L/s in discharge. Water is fresh and usually of Ca^{++}-HCO_3^- type (occasionally HCO_3^--$SO_4^=$ or Na^+-$SO_4^=$) Groundwater in the older Palaeozoic strata is broadly of a similar nature.

Post-Cimmeride / pre-Himalayan strata

- Jurassic strata are not exposed in outcrop in Faryab and thus are not designated a shading on the hydrogeological map. They do occur at depth beneath the northern portion of Faryab, however, and permeable sandstones and limestones within the sequence can yield substantial thermal water quantities from deep boreholes.

  For example, Abdullah & Chmyriov (2008b) note that "*Jurassic carbonate rocks with confined waters have been drilled through by deep wells on the Bayangor and Koh-i-Alburs structures* [both of these are anticlinal structures, east of Faryab, associated with the Sheram and Shadian arch structures - see Figure 4.3]*, with the flowing well yields of 0.09 L/s and 350 L/s, respectively. The water is of the chloride-sodium type; its dissolved-solids content ranges from 66 to 78 g/l.*"

- **K_1ssc** Early Cretaceous sandstone / conglomerate complex. Fractured aquifer capable of supporting moderate spring-flow (may not be perennial). Also occurs at depth below northern part of Faryab province and may provide thermal saline groundwater. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.

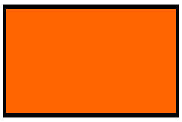
- **K_2ssl** Late Cretaceous sandstone / siltstone complex. Fractured aquifer capable of supporting moderate spring-flow (may not be perennial). Also occurs at depth below northern part of Faryab province and may provide thermal saline groundwater. Presumed to represent a fractured aquifer of weak to moderate productivity. Colour coding - pale green.

  Abdullah & Chmyriov (2008b) confirm that sandstone, conglomerate, limestone and marl strata within the K_1ssc and K_2ssl sequence can function as aquifers, with natural spring discharges in upland areas ranging from several hundredths to 1 L/s and water typically being of calcium-bicarbonate type. As the strata plunge northward beneath later cover, salinity and temperature increases. In the Mazar-e Sharif basin, boreholes can yield substantial quantities of thermal saline water.

- **KP_1ld** Upper Cretaceous and Palaeocene limestone, dolomite and marl complex. Karst aquifer capable of supporting large perennial springs, providing significant baseflow to river headwaters. Karstic aquifer of strong productivity. Colour coding - medium green.

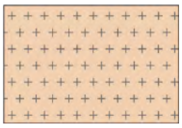
Abdullah & Chmyriov (2008b) confirm that the Upper Cretaceous-Palaeogene limestone forms a good, freshwater karstified aquifer. Springs from this aquifer often yield 0.1 to 7 L/s, with the possibility of considerably higher yields under favourable conditions. Waters in the upland areas are typically of HCO_3^-, $SO_4^=$-HCO_3^--Ca^{++} and Ca^{++}-Na^+ types, with mineralisations of 0.3 to 0.5 g/L. Abdullah & Chmyriov (2008b) caution, however, that in mountain regions, the highly dissected topography can drain the majority of the aquifer thickness, with springs only occurring at the very base of the aquifer against the boundary with underlying lower permeability rocks. In other words, the saturated aquifer thickness in such regions can be low. They state, "*For instance, in the upper reaches of the Maymana, Balkh and Samangan rivers, the limestone forms steep 300-400m high slopes without a single water manifestation, and it is only at the base that springs can be found discharging as much as 3-5 L/s.*"

Abdullah & Chmyriov (2008b) suggest that the Upper Cretaceous-Palaeogene limestone can retain its aquifer character as it dips northward below the later cover, with substantial yields being recorded from deep wells. The water becomes increasingly saline however (several g/L) and reducing (H_2S).

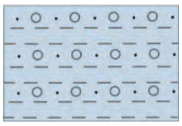


- **P_2csh** Eocene clays, shales and siltstones. Presumed to behave predominantly as an aquitard. Local groundwater resources may be associated with minor sandstone / conglomerate / limestone horizons. Colour coding - orange.

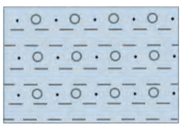
Post Orogenic Molasse, Alluvium and Igneous Rocks



- **N_1dig** Miocene diorites, granodiorites and associated igneous rocks. Presumed to contain local occurrences of groundwater associated with fractures zones. Igneous bodies with local productivity only. Colour coding - pale orange.

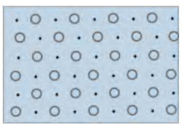


- **N_{1l}csl** Neogene (early Miocene) molasse-type deposits. Red clay and siltstone more abundant than sandstone, conglomerate, limestone. Well yields typically <1-3 L/s. Contains lenses of halite / gypsum and groundwater is often saline. Higher yields and fresher water can sometimes be obtained in valley areas. Designated a granular aquifer of weak productivity. Colour coding pale blue.



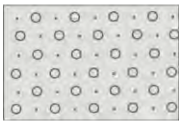
- **N_{1m}csl** Neogene (Mid Miocene) molasse-type deposits. Brown clay and siltstone more abundant than sandstone, conglomerate, limestone. Well yields typically <1-3 L/s. Contains lenses of halite / gypsum and groundwater is often saline. Higher yields and fresher water can sometimes be obtained in valley areas. Designated a granular aquifer of weak productivity. Colour coding pale blue.

Abdullah & Chmyriov (2008b) appear to confirm that well yields from the Neogene tend to be lower than from recent Quaternary alluvium. They suggest that salinity increases as Neogene aquifers dip northward below the Quaternary cover.

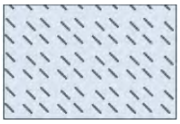


- **Q_1a** Early Pleistocene alluvium. Gravels and sands (sometimes lithified) dominate over silt and clay. Presumed to be less

productive than Q_{34}a. Contains predominantly saline water in north of region. Designated a granular aquifer of weak productivity. Colour coding pale blue.

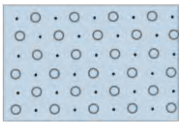


- **Q_2a (?)** Gravels and sands (sometimes lithified) dominate over silt and clay. Occurs at high elevations in south of area as a cover deposit overlying Cretaceous / Palaeogene and Neogene aquifers. It is not known whether it contains saturated portions and if it constitutes an aquifer in its own right. Either **Q_2a** mid-Pleistocene alluvium or **Q_{34}t** late-Peistocene-recent glacial till. Designated a granular cover material. Colour coding - pale grey.

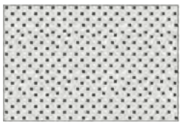


- **Q_2loe** Pleistocene loess. Poor aquifer, silty and often yielding saline water. Where saturated, can support small yields from dug wells and is used by nomads in the Shor Darya area. Designated a granular aquifer of very weak productivity. Colour coding very pale blue.

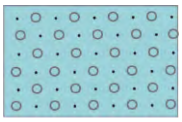
  Of the loess aquifer, Abdullah & Chmyriov (2008b) state that yields of dug wells can be 0.1 to 0.4 L/s, while "*In the Qaysar and Maymana valleys, many ascension springs are observed at the foots of coniform hills built up of loess. Their discharges vary between 0.01 and 6.6 L/s.*" The salinity of loess waters is often very high, however, typically 5-10 g/L, with a range from 0.8 to 20.3 g/L and a sulphate-chloride-sodium-calcium type.



- **Q_3a** Late Pleistocene alluvium. Gravels and sands (sometimes lithified) dominate over silt and clay. Presumed to be less productive than Q_{34}a. Contains predominantly saline water in north of region. Designated a granular aquifer of weak productivity. Colour coding pale blue.

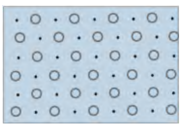


- **Q_{34}e** Late Pleistocene-recent aeolian sands. Occurs as cover deposits over alluvial plains in north of region. Not known if aeolian deposits contain saturated portions. Designated a granular cover material. Colour coding - pale grey.



- **Q_{34}a** Late Pleistocene-recent Quaternary alluvium south of Pata Baba. Gravels and sands (sometimes lithified) dominate over silt and clay. Reported to be coarser grained and more productive south of confluence with Shor Darya. Individual boreholes can sometimes produce 10 L/s or more. Here, designated a granular aquifer of moderate productivity. Colour coding medium blue.

  Of this aquifer, Abdullah & Chmyriov (2008b) say, "*The ground water of the Maymana Valley occurs in sand and coarse gravel found at a depth from 3.5 to 67 m. The depth to water table varies between 16.6 and 21.0 m. The specific yield of the wells ranges from 3.5 to 4.0 l/s.*". The water is of a HCO_3^--$SO_4^=$-Na^+-Ca^{++} chemical type, mineralisation 0.7 - 0.9 g/L and temperature 16 - 17°C.



- **Q_{34}a** Late Pleistocene-recent Quaternary alluvium north of Pata Baba. Reportedly less productive, finer grained and containing saline groundwater towards the north. Here, designated a granular aquifer of weak productivity. Colour coding pale blue.

  Of this aquifer, Abdullah & Chmyriov (2008b) imply that in the northern areas of Shirin Tagab, Darreh-i Siyah and Balkh deltas,

groundwater can be found in sand layers within thick clayey-sandy sequences. They state that *"the specific yields* [without quite explaining what a "specific yield" is] *of the wells range from 1.2 to 3.7 L/s; the yield of the dug wells are from 0.1 to 0.7 L/s."* The water is reported as saline, with mineralisations 3-10 g/L and usually of sodium-sulphate character. Abdullah & Chmyriov (2008b) specifically state that "*Small lenses of sulphate and bicarbonate-sulphate-magnesium-calcium waters having the dissolved solids content from 1 to 3 g/L were tapped near irrigation canals and river channels*".

- **Q_4sm** Recent Quaternary salt marsh deposits. Coloured white.

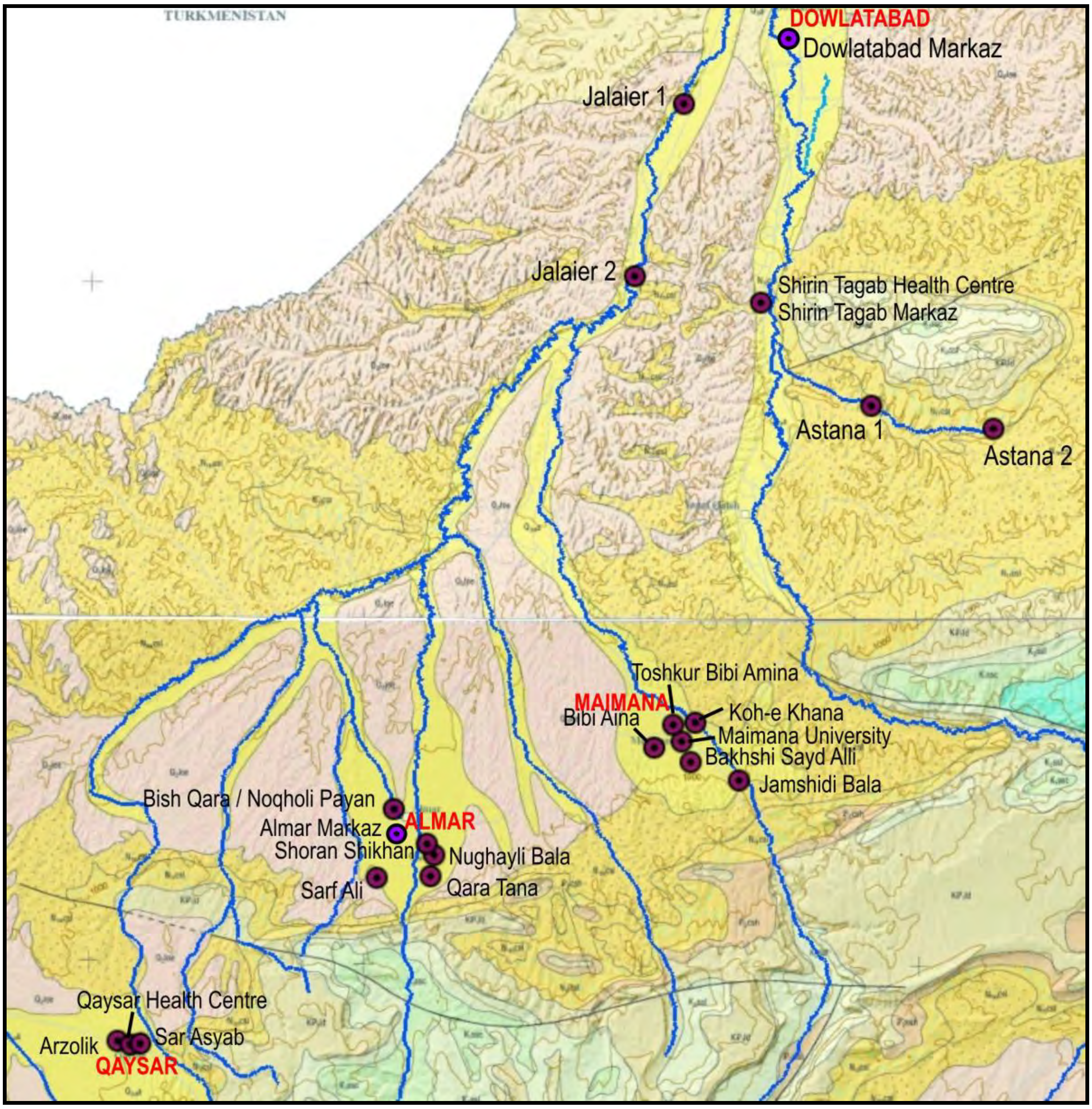


Figure 5.10. Geological map of Faryab, showing the locations of test-pumped boreholes. Background is formed by AGS/USGS 1:250,000 maps **by** McKinney & Sawyer (2005) and Wahl (2005).

5.4 Aquifer Properties in Faryab

Very few wells or boreholes have any yield data associated with them in Faryab. Even fewer have any form of test pumping data. Of the few test-pumped boreholes, in no case is the test pumping data of adequate quality to permit any form of reliable interpretation using, for example Theis or Cooper-Jacob analysis.

In several cases, a yield (Q) figure is associated with a drawdown (s) and a pumping test duration. These boreholes are shown on Figure 5.10. This permits us to apply the Logan Approximation to estimate aquifer transmissivity (T). The Logan Approximation can be stated (Misstear et al. 2006) as:

$T = (Q/s) * 1.22$ for hydraulically ideal wells

$T = (Q/s) * 2$ for real "inefficient" wells

where T is an "apparent transmissivity" in m^2/d, Q is in m^3/d and s is in m.

The results of these calculations are shown in Table 5.1, as "high" and "low" estimates of transmissivity, calculated from the above expressions. It should be recognised that, in no case does the transmissivity value calculated represent the transmissivity of the entire aquifer sequence, nor even the transmissivity of the Quaternary / Neogene sequence. It merely represents the transmissivity of the aquifer strata hydraulically accessible to the well.

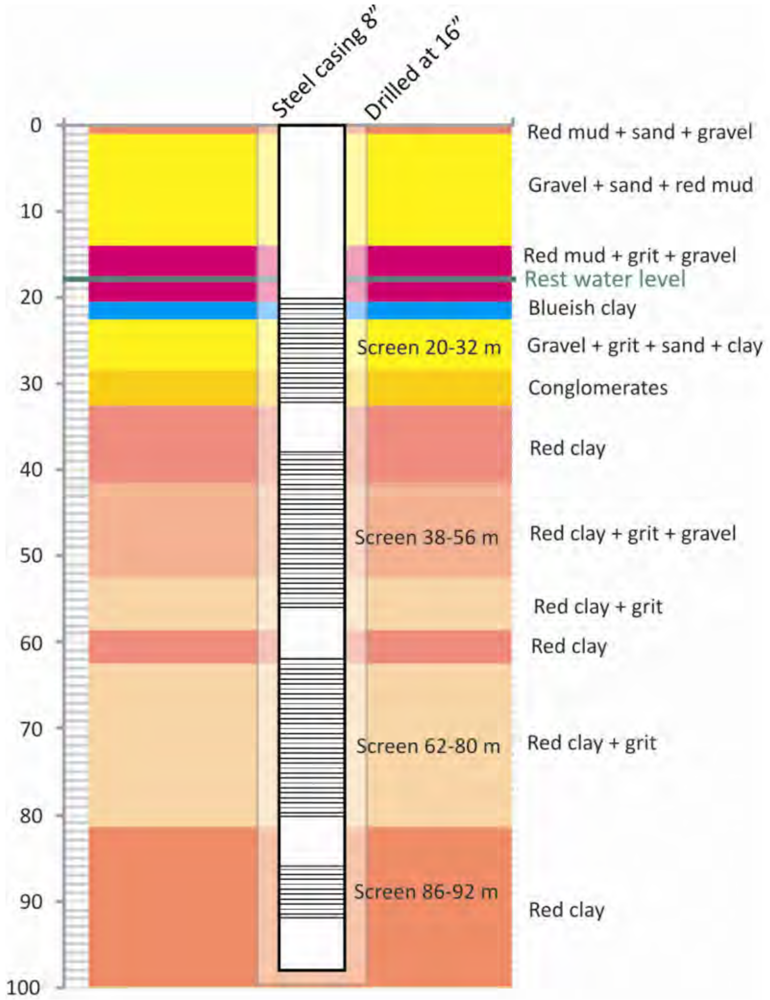


Figure 5.11. Borehole construction log for Koh-e Khana test well, District 1, Maimana city. (It is not clear if the reddish, clayey strata represent Neogene beneath Quaternary cover).

Table 5.1. Boreholes in Faryab with pumping / drawdown data. Transmissivity range estimated by Logan approximation. * = transmissivity very low (pump dry); $ = approximate grid reference only. SWL = static water level. The Koh-e Khana well may also contain Neogene (Figure 5.11).

Borehole	Aquifer	Depth	Diameter	Date	SWL	Yield *Q*	Yield *Q*	Drawdown *s*	Duration	*T* (high)	*T* (low)
		m	mm		m bwt	L/s	m3/d	m	hr	m²/d	m²/d
Qaysar area											
Arzolik borehole		145	152	05/03/2008	91.4	4	346	13.6	8	51	31
Qaysar Health Centre$		104	254	31/03/1979	78.72		86	3.5	8	49	30
Sar Asyab borehole		150	152	04/03/2008	27.5	5	432	15.2	4	57	35
Almar area											
Sarf Ali borehole		160	152	01/06/2010	134.2	2.77	239	Pump dry	0.22	*	*
Qara Tana borehole		150	152	01/06/2010	87.1	2.9	251	Pump dry	0.27	*	*
Nughayli Bala borehole		150	152	06/03/2008	101	3	259	19	6	27	17
Shoran Shikhan borehole		150	152	03/06/2010	105	1.85	160	25	5	13	8
Almar Markaz (Centre)$	Quaternary	66	152	Aug-75	52	0.7	60	6		20	12
Bish Qara / Noqholi Payan borehole		122	152	29/05/2010	83.7	3.5	302	15.3	15	40	24
Maimana area											
Jamshidy Bala borehole	Neogene	92	203	18/03/2012	26.8	3.5	302	34.3	6	18	11
Bakhshi Sayd Alli borehole	Neogene	118	203	16/07/2012	61.8	2.5	216	47.32	7	9	6
Maimana University borehole	Quaternary	90	203	30/11/2011	41	0.7	60	1.5	6	81	49
NCA Maimana (Koh-e Khana) test borehole	Quaternary	98	203	16/10/2011	20.3		864	6.7	24	258	157
Bibi Aina borehole	Quaternary (some Neogene)	204	254	30/06/2008	65	8	691	6	5	230	141
Toshkur Bibi Amina (Maimana District)$		74	254	24/06/1979	50		216	0.7	13	617	376
Further north											
Shirin Tagab Health Centre$		42	203	21/06/1978	21.5	1.6	138	3.8	20	73	44
Shirin Tagab Markaz (Centre)$	Quaternary	41	203	Feb-75	22.9	5	432	1.32	5	655	399
Astana 1 deep bore (Mahad)	Neogene	200	152	08/09/2009	10	2	173	13	7	27	16
Astana 2 deep bore (Gul Qudoq)	Neogene	200	152	09/11/2009	9	1.5	130	121	0.73	2.1	1.3
Jalaier 1 deep bore (Chokazie village)	Neogene	200	152	24/12/2009	23	4	346	11.1	8.5	62	38
Jalaier 2 deep bore (Atomchi village)	Neogene	200	152	07/02/2010	16.7	0.75	65	129.1	6	1.0	0.6
Dowlatabad Markaz (Centre), borehole 2$	Quaternary	42	152	1976	13	5	432	6	19	144	88

For most of the boreholes in Table 5.1, it is reasonable to assume that the borehole has been installed with well-screen in the most transmissive portions of the aquifer (see a diagram of the Maimana Koh-e Khana borehole construction in Figure 5.11) and thus that the calculated transmissivity represents the transmissivity of the saturated section of strata penetrated by the well.

The transmissivities of the Quaternary aquifer system range from several hundred m²/d in northern Maimana (Bibi Aina, Toshkur Bibi Amina, Koh-e Khana) and the Shirin Tagab valley, down to a few tens of m²/d around Qaysar and Almar. In an international perspective these transmissivities would probably be regarded as low to moderate.

In the desert of Turkmenistan, the 82.7 m deep Soviet borehole 182 (see Table 4.1 & Figure 8.1; Krizhanovskii, 1972) yielded 0.91 L/s for a drawdown of 1.61 m from Quaternary strata (static water level 26.9 m bgl). This indicates a transmissivity of 60-98 m²/d (estimated hydraulic conductivity 1.1 to 1.8 m/d).

For the Neogene, the transmissivities are even lower, ranging from around 1 m²/d to 40-60 m²/d.

In Table 5.2, the estimated transmissivity values have been divided by saturated depth to result in a very approximate estimate of depth-averaged hydraulic conductivity (permeability).

	Aquifer	T (high)	T (low)	Saturated depth	K (high)	K (low)
		m²/d	m²/d	m	m/d	m/d
Qaysar area						
Arzolik borehole		51	31	53.6	0.9	0.6
Qaysar Health Centre		49	30	25.28	2.0	1.2
Sar Asyab borehole		57	35	122.5	0.5	0.3
Almar area						
Sarf Ali borehole		*	*	25.8	*	*
Qara Tana borehole		*	*	62.9	*	*
Nughayli Bala borehole		27	17	49	0.6	0.3
Shoran Shikhan borehole		13	8	45	0.3	0.17
Almar Markaz (Centre)	Quaternary	20	12	14	1.4	0.9
Bish Qara and Noqholi Payan borehole		40	24	38.3	1.0	0.6
Maimana area						
Jamshidi Bala borehole	Neogene	18	11	65.2	0.3	0.16
Bakhshi Sayd Alli borehole	Neogene	9	6	56.2	0.16	0.10
Maimana University borehole	Quaternary	81	49	49	1.6	1.0
NCA Maimana (Koh-e Khana) test borehole	Quaternary	258	157	77.7	3.3	2.0
Bibi Aina borehole	Quaternary (some Neogene)	230	141	139	1.7	1.0
Toshkur Bibi Amina		617	376	24	25.7	15.7
Further north						
Shirin Tagab Health Centre		73	44	20.5	3.5	2.2
Shirin Tagab Markaz (Centre)	Quaternary	655	399	18.1	36.2	22.1
Astana 1 deep bore (Mahad)	Neogene	27	16	190	0.14	0.09
Astana 2 deep bore (Gul Qudoq)	Neogene	2.1	1.3	191	0.01	0.01
Jalaier 1 deep bore (Chokazie village)	Neogene	62	38	177	0.4	0.21
Jalaier 2 deep bore (Atomchi village)	Neogene	1.0	0.6	183.3	0.005	0.003
Dowlatabad Markaz (Centre), bore 2	Quaternary	144	88	29	5.0	3.0

Table 5.2. Boreholes in Faryab with pumping / drawdown data. Transmissivity range estimated by Logan approximation. * = transmissivity very low (pump dry).

It is important to remember that the saturated portion of the geological section will contain a range of strata of different permeabilities, aquitards and aquifers. Thus, this arithmetic average hydraulic conductivity will grossly underestimate the hydraulic conductivity of the most permeable horizons. In shallower boreholes, the saturated section is more likely to dominated by a specific sand/gravel aquifer, resulting in a high average hydraulic conductivity

Estimates of average hydraulic conductivity of the sequences fall in the range 1-3 m/d for northern Maimana, and in the shallower strata of the Toshkur Bibi Amina borehole it is in the range 15-26 m/d.

In the Quaternary strata of the Shirin Tagab valley, estimates of average hydraulic conductivity of the sequences are also >2.2 m/d, and in the shallower strata of the Shirin Tagab Markaz borehole it is in the range 22-36 m/d.

The aquifers in Qaysar and Almar appear to have typical average conductivities of a few tenths of a m/d to <2 m/d, while the Neogene aquifers return typical average conductivities of <0.3 m/d.

Of Etymological Interest

Aquifer: From the Latin *aqua* (water) and *ferre* (to carry). This term denotes a geological body or stratum with sufficient transmissivity(or hydraulic conductivity) and storage to permit the economic abstraction of groundwater. Note that (1) in arid areas, groundwater is scarcer and has higher “value”, thus the threshold for designating a stratum an aquifer may be lower; (2) the definition says nothing about the use of the water or the water quality.

Aquitard: From the Latin *aqua* (water) and *tardus* (slow). The opposite of an aquifer. This term denotes a geological body or stratum with **insufficient** transmissivity and storage to permit the economic abstraction of groundwater. This designation does not imply that the stratum is impermeable, however.

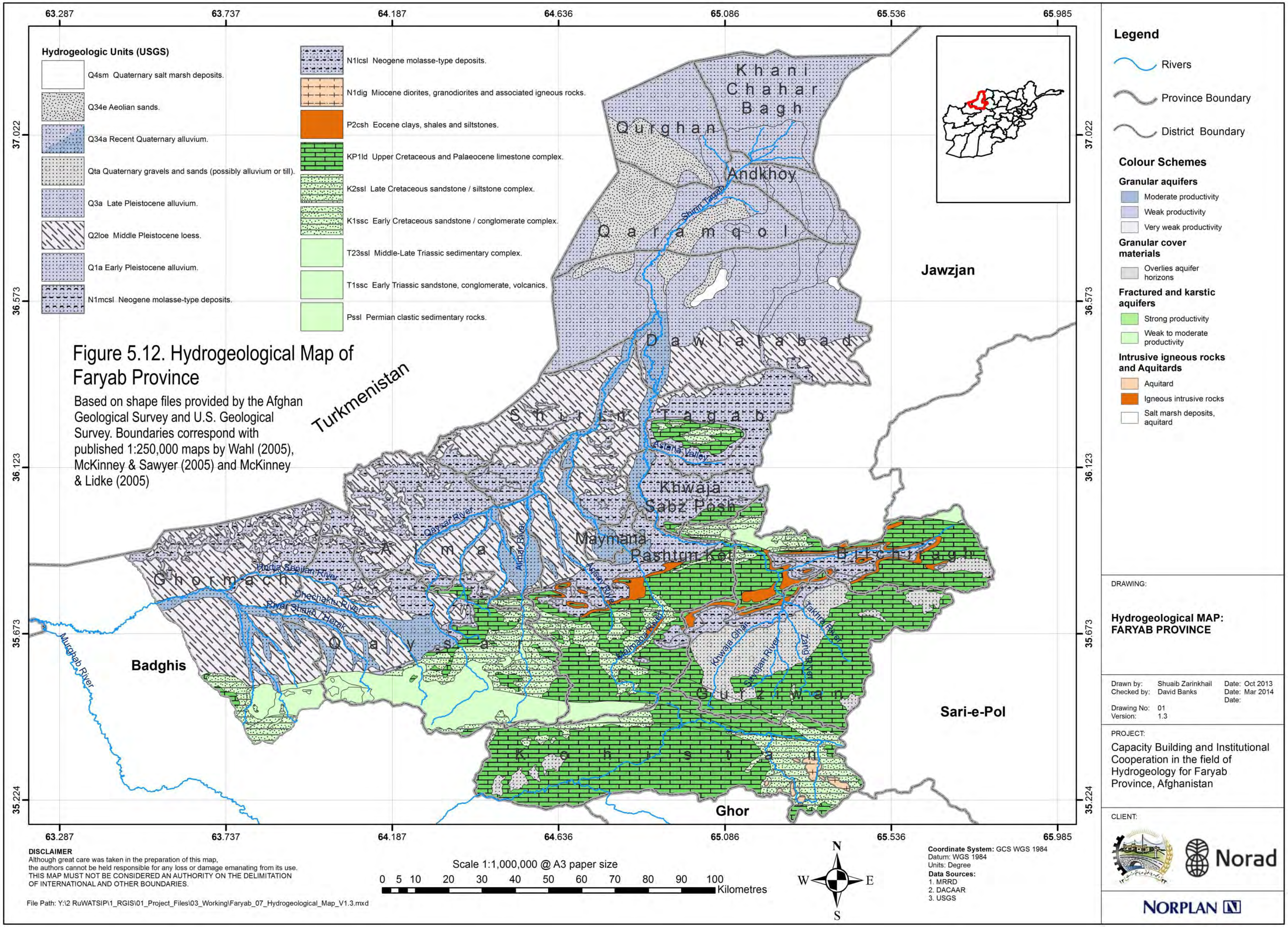


Figure 5.12. Hydrogeological Map of Faryab Province