3. Faryab: Rivers and Surface Waters

3.1 The Amu Darya (Oxus)

The Amu Darya (or Oxos / Oxus, as it was called by the ancient Greeks) is the main watercourse running through northern Afghanistan, and forming the border with Turkmenistan. It is a "trans-boundary" watercourse and its use has been the subject of considerable international controversy. Usage of water from the Amu Darya has also been controversial as it is one of the two large watercourses (the Syr Darya being the other), which feeds the inland Aral Sea. As has been widely reported, the volume of water entering the Aral Sea has dramatically reduced over recent decades, leading to a catastrophic shrinking of the area of the sea, and desertification of the adjacent area (Zavialov 2005).

One of the main abstractions of water from the Amu Darya is the quantity drawn off by the Lenin (now renamed the Niyazov) Karakum Canal near the town of Khatab, in Turkmenistan, close to the northern extremity of Jawzjan Province.

The Karakum Canal traverses the Turkmen desert north of Faryab, via the Mary (Merv) inland delta (where it connects with the Murghab) and Gökdepe (near Ashgabat) to Bereket (Gazandjyk) only some 130 km short of the Caspian Sea. It was constructed by the Soviet Union between 1954 and 1988, with the objective of irrigating the Karakum desert, primarily for cotton production, but also supplying the city of Ashgabat with water. The canal is 1375 km long, is partly navigable and conveys some 13 km^3/a of water (an average of 412 m^3/s). A large proportion of the water is reported to be lost via seepage to the ground. Soil and groundwater salinisation is reportedly promoted by canal leakage, causing rises in groundwater level and dissolution of salts from the unsaturated zone, and evaporative accumulation of salts in irrigation water (Kharin 2002; Esenov 2014; Zonn 2014; http://en.wikipedia.org/wiki/Karakum_Canal). The Zeid Reservoir at the head of the canal, in the Lebap region of the Turkmen desert, has a reported capacity of 3.5 km^3, and the maximum off-take from the Amu Darya to the Karakum Canal is reported by Glantz (1999) as 580 m^3/s.

The salinity of the Amu Darya at Kelif gauging station (Figure 3.13) is reported as c. 0.5 g/L (Gapparov et al. 2011), while the annual flow is reported as 55.3 km^3 (1752 m^3/s; INTAS 2006). At Kerki gauging station, a short distance downstream from the Karakum Canal offtake, the annual flow is reported as 1696 m^3/s (period 1932-1989).

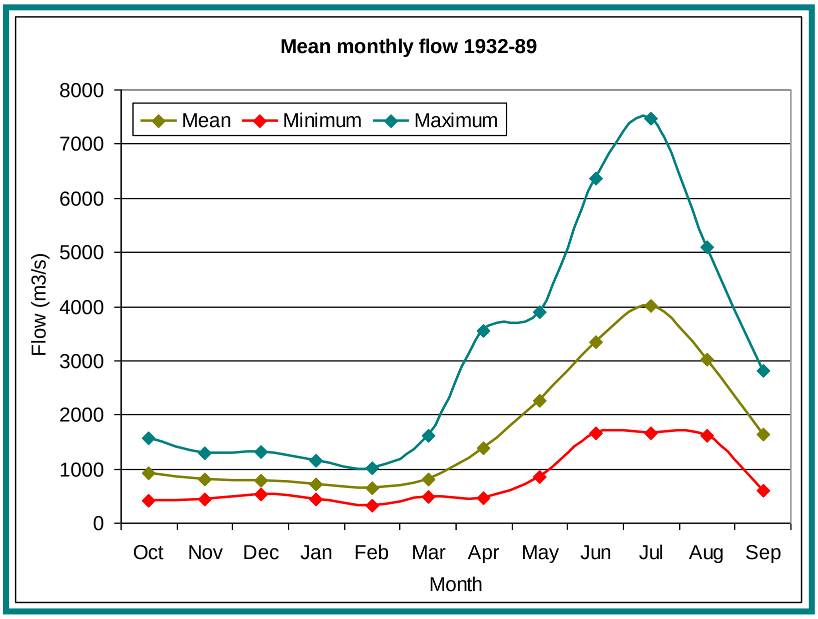

Figure 3.1. Mean monthly flows in the River Amu Darya at Kerki in Turkmenistan. *Source: UNH/GRDC from http://grdc.sr.unh.edu/html/Polygons/P2917110.html.*

Like the Balkh, Sar-e-Pol and Murghab Rivers, the Shirin Tagab system does not reach to the Amu Darya, but disperses within an inland delta system of distributary channels. There is no evidence that the Shirin Tagab ever discharged into the Amu Darya during historical or even recent geological (Holocene) times. The Amu Darya and Zeid depression does, however, form the base level towards which some of the groundwater in the aquifers of northern Faryab drains.

3.2 The Murghab

The Murghab River flows westward through Afghanistan between the Band-e-Turkestan range to the north and the Safed Koh mountains to the south. Leaving Faryab, it passes through Badghis Province (and the town of Bala Murghab. It then enters Turkmenistan, before running out in the distributary channels of the inland delta in the desert around the town of Mary (historic *Merv*).

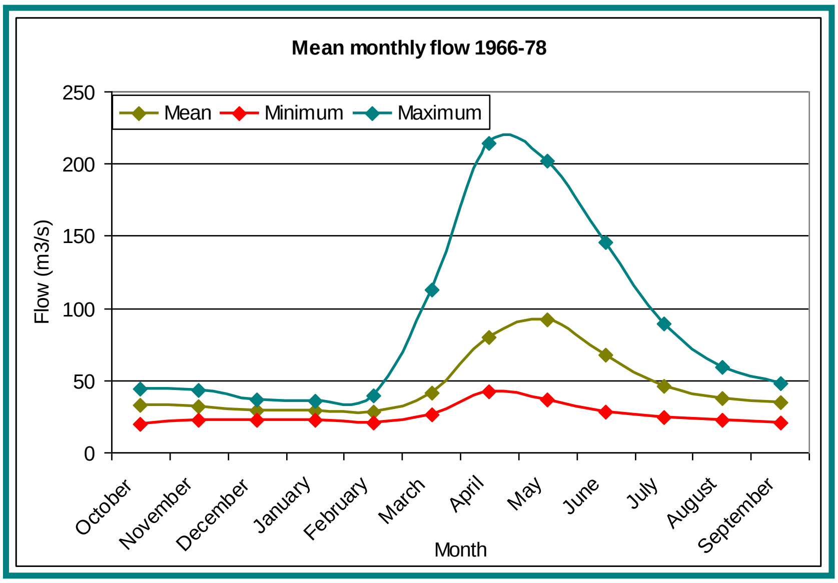

Figure 3.2. Mean monthly flows in the River Murghab at Qala-e-Niazkhan (station 40) in Badghis Province. *Source: USGS stream gage database. http://afghanistan.cr.usgs.gov/AfghanWater/tables/40_350200064010000.xls*

1966-1978 data from the USGS suggest that the flow is strongly seasonal, with the greatest flows (exceeding 50,000 L/s at Qala-e-Niazkhan) between March and June, and being related to snowmelt. The river baseflow is likely to be substantially supported by groundwater discharge, especially from the large areas of Palaeogene-Cretaceous limestone aquifer outcrop that it traverses.

The long-term annual average flow at Qala-e-Niazkhan is 46,800 L/s, for an upstream catchment area of 13,805 km². This equates to an average run-off of 3.4 L/s/km² or 107 mm/a.

3.3 The Chechaktu (or Western Qaysar or Ghormach) River

The Chechaktu River (also referred to as the Western Qaysar river, the Ghormach River or the Karawal Kana) rises in the Ban-e-Turkestan mountains and exits the mountains onto the alluvial outwash plain at Zyarat Gah. The river has small tributary channel that rises very close to Qaysar town, within "spitting distance" of the true Qaysar River.

As the Chechaktu leaves Faryab and enters Ghormach district, it is joined by other tributaries flowing down from the Bund-e-Turkestan (notably the Shakh and Ghormach rivers) and from the north (the Hodja Sepilan river). The Chechaktu joins the larger Murghab River just downstream of Bala Murghab (Figure 3.14).

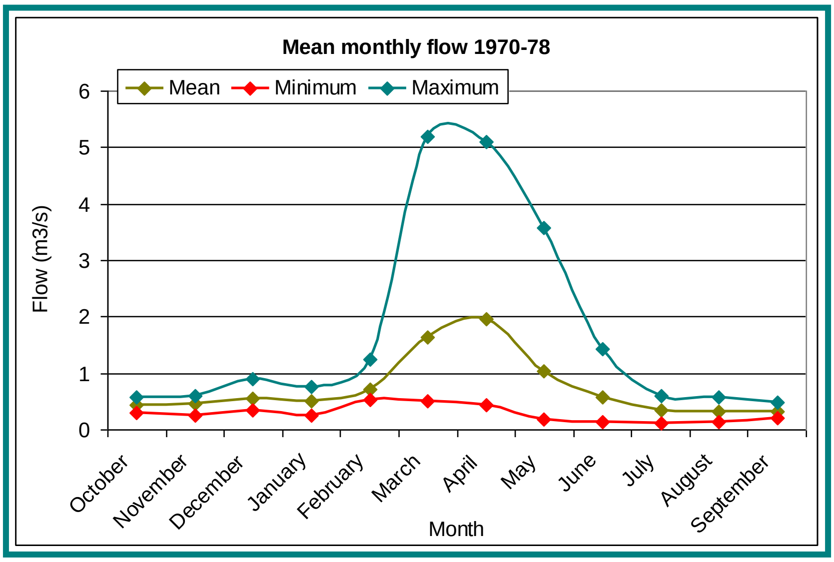

Figure 3.3. Mean monthly flows in the River Chechaktu at Chechaktu (station 44) in Qaysar District. *Source: USGS stream gage database.*

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1970-1978 data from the USGS suggest that the flow is strongly seasonal, with the greatest flows (exceeding 2,000 L/s at Chechaktu) between March and May, and being related to snowmelt.

The long-term annual average flow at Chechaktu is 760 L/s, for an upstream catchment area of 415 km^2. This equates to an average run-off of 1.8 L/s/km^2 or 58 mm/a.

3.4 The Shirin Tagab

According to Ahmad & Wasiq (2004) the Shirin Tagab has a total catchment area of 13,600 km^2. The annual run-off is estimated as between 100 and 132 Mm^3.

A major tributary joins the Shirin Tagab river near Pata Baba in Dowlatabad district. This is the Shor Darya, which carries the combined flow deriving from the Almar, Qaysar and Maimana Rivers. They are fed by snowmelt, rainfall and groundwater base-flow, especially baseflow from the productive Palaeogene-Cretaceous limestone aquifers up in the mountains.

All these rivers rise in the northern slopes of the Band-e-Turkestan mountains. It has been argued that the Qaysar / Shirin Tagab river system may be the River *Ochus* referred to by writers of antiquity (Rawlinson 1879, Olbrycht 2010).

The rivers flow north down on the Neogene molasse and Quaternary loess plains, where they deposit their eroded sediment load and often form poorly-defined braided river channels. They also change from a gaining (spring-fed) regime, to a losing regime, where flow temporarily or permanently infiltrates into the alluvial outwash sediments and starts to be lost to evaporation and irrigation take-off.

The Shirin Tagab is a so-called "blind" river system, which dissipates due to evaporation, irrigation off-take and infiltration to the ground, without ever reaching the Amu Darya. The River dissipates in an "inland delta" area, today comprising a network of irrigation channels around the city of Andkhoi.

The Shirin Tagab

The Shirin Tagab proper rises in the eastern part of Bilchiragh Province, although near Bilchiragh town, it is joined by the Chashma-i Khwab river, flowing out of a spectacular gorge. The Chashma-i Khwab is, in turn, is fed by the streams of five valleys flowing out

of Gurziwan: the Khwaja Ghar, the Shakh, the Zang, the Takhra and the Rabat (Favre & Kamal 2004)

There are three historic gauging stations on the course of the Shirin Tagab. In descending order these are (Figure 3.14):

1. At Khisht Pul, in Pashtun Kot district, shortly after the river has emerged from the pre-Neogene terrain onto the Neogene proluvial outwash deposits.
2. At Dowlatabad, prior to the confluence with the Shor Darya.
3. At Pata Baba, downstream of the confluence with the Shor Darya.

In the Shirin Tagab we can see that elevated flows are observed during the rainier months from October-November through to February. In March-May there is a strong snow-melt peak, and then the flow drops quickly to summer levels.

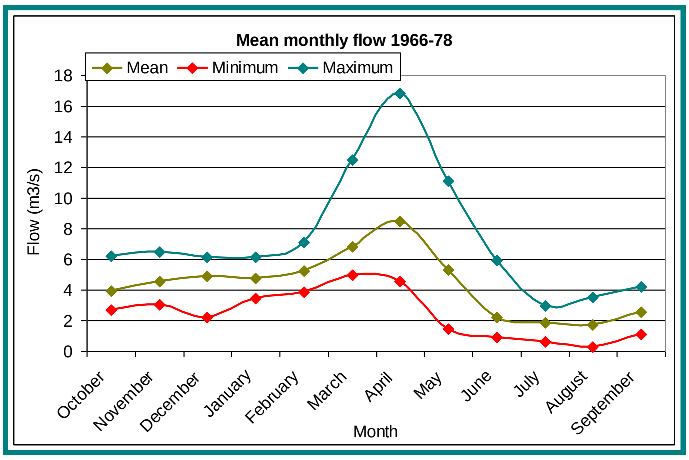

Figure 3.4. Mean monthly flows in the Shirin Tagab at Khisht Pul (station 48) in Pashtun Kot District. *Source: USGS stream gage database.*

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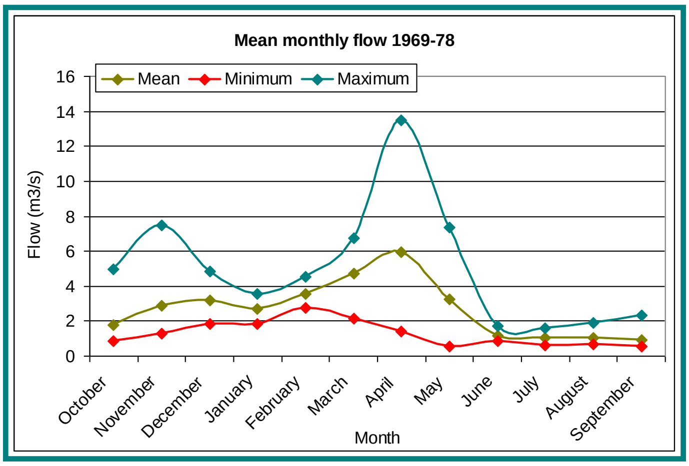

Figure 3.5. Mean monthly flows in the Shirin Tagab at Dowlatabad (station 47). *Source: USGS stream gage database.*

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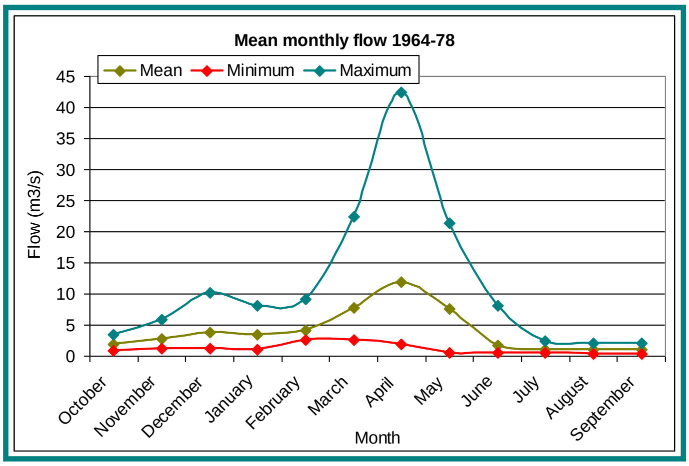

Figure 3.6. Mean monthly flows in the Shirin Tagab at Pata Baba (station 46,), Dowlatabad District. *Source: USGS stream gage database.*

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It is also important to note that the flows decrease downstream from Khisht Pul to Dowlatabad, by almost 50% on an annual average basis (Table 3.1). As yet it is not clear whether this can be ascribed to:

- infiltration losses to groundwater
- abstraction for irrigation (and thereafter loss to evapotranspiration or infiltration to groundwater)
- evapotranspirative losses

or (as would seem likely) a combination of all three. The total flow at Pata Baba is, on average 1640 L/s greater than at Dowlatabad, presumably due to the confluence with the Shor Darya (average 2440 L/s, see below), but the specific areally distributed run-off rate decreases consistently downstream.

Table 3.1. Change in discharge downstream along the Shirin Tagab river

Gauging station	Long term annual mean discharge	Upstream catchment area	Areally distributed long term run-off
Khisht Pul (station 48)	4,450 L/s	3,280 km²	1.4 L/s/km² 43 mm/a
Dowlatabad (station 47)	2,340 L/s	4,645 km²	0.50 L/s/km² 16 mm/a
Pata Baba (station 46)	3,980 L/s	11,775 km²	0.34 L/s/km² 11 mm/a

<u>The Astana River</u>

The Astana is an east-bank tributary of the Shirin Tagab. It is unique in not rising on the pre-Neogene terrain of the Band-e-Turkestan, but rather, within the Neogene molasse sediments of Shirin Tagab District. The River itself is known to be extremely salty, due to the highly saline nature of the groundwaters in the Neogene aquifer, which feed it. A sample from Chel Quduq, taken in October 2005, has an electrical conductivity of 45,000 µS/cm (Hassan Saffi 2010a).

The high salinity of the ground and surface waters in the Astana Valley may be ascribed to (i) the very high rates of evaporation in the area, leading to up-concentration of precipitation-derived salts in the soil and (ii) the suspected content of halite and gypsum in the Neogene soils.

To the north of the Astana River is a small inlier of Cretaceous and Palaeogene sedimentary rocks around Qara Qol. Somewhat fresher springs of groundwater drain from the southern flanks of this inlier (e.g. Moghaito springs, which have a reported discharge of up to 3 L/s and an electrical conductivity of 3400-4500 µS/cm), but these have largely been captured for public water supply purposes (Hassan Saffi 2010a).

3.5 The Qaysar / Maimana / Shor Darya Rivers

The Qaysar, Maimana and Almar Rivers all rise on the northern flank of the Band-e-Turkestan mountains.

<u>The Maimana River</u>

The Maimana is presumed to gain baseflow from groundwater discharge of the Cretaceous / Palaeozoic limestone aquifers of its upper reaches. Shortly before arriving at Maimana, it crosses onto Neogene molasse deposits.

<u>The Qaysar River</u>

The Qaysar River also traverses onto Neogene / Quaternary deposits shortly upstream of Qaysar town.

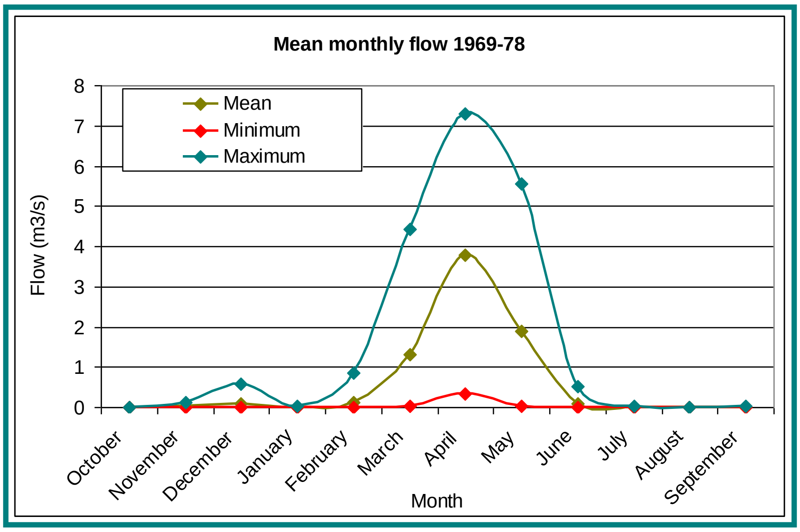


Figure 3.7. Mean monthly flows in the Qaysar River at Qaysar (station 49). *Source: USGS stream gage database.*

http://afghanistan.cr.usgs.gov/AfghanWater/tables/49_354200064180000.xls

1969-1978 data from the USGS suggest that the Qaysar River's flow is very strongly seasonal, with the greatest flows (typically up to 4,000 L/s at Qaysar town) between March and May, and being related to snowmelt. The river often effectively dries up at Qaysar between July and February, suggesting a lack of groundwater baseflow to the upper sections.

The long-term annual average flow of the Qaysar at Qaysar town is 540 L/s, for an upstream catchment area of 425 km^2. This equates to an average run-off of 1.3 L/s/km^2 or 40 mm/a (http://afghanistan.cr.usgs.gov/water).

The Almar and Aqsay Rivers

Several south bank tributaries join the Qaysar, of which the most important are the Almar River(s) and the Aqsay, all arising on the pre-Neogene rocks on the northern flanks of the Band-e-Turkestan mountains. In particular, the Almar River emerges from the pre-Neogene bedrock terrain through a canyon near Yaka Khana and immediately forms a wide alluvial fan and takes on a very diffuse, braided nature around Almar.

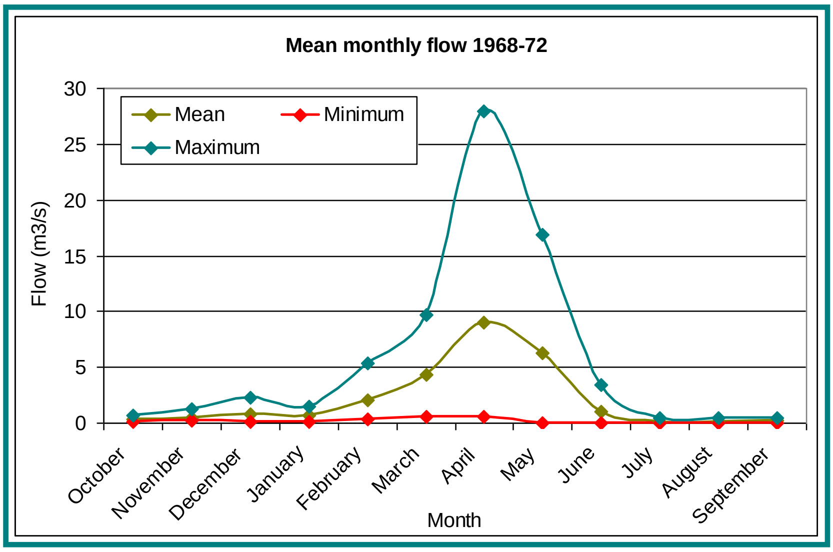


Figure 3.8. Mean monthly flows in the Shor Darya near Pata Baba (station 50), Dowlatabad District. *Source: USGS River gage database. http://afghanistan.cr.usgs.gov/AfghanWater/tables/50_363200064530000.xls*

The Shor Darya

The Shor Darya is the name given to the combined flow of the Qaysar and Maimana Rivers, downstream of their confluence near Ateh Khan Khwaja. The Shor Darya section is known to be saline. Afghan hydrogeologists with experience from the area state that,

although the Qaysar River's surface water is already relatively saline (c. 4000 µS/cm) at the confluence, its salinity creeps up downstream of the confluence to values of around 8000 µS/cm, due to seepages of saline groundwater into the bed of the Shor Darya (Hassan Saffi, *pers. comm.* Sept. 2013).

At Ateh Khan Khwaja, in the right bank of Shor Darya River where the Maimana River merges with the Qaysar River, there is a major spring (some 15-35 L/s reported by DACAAR, varying seasonally) discharging to the Shor Darya. It represents some of the freshest water in the area, with an electrical conductivity of 2660 µS/cm in May 2007 (Hassan Saffi 2010b).

In May 2007, the Shor Darya was sampled at Ateh Khan Khwaja, where the electrical conductivity was found to be 6000 µS/cm. It was also sampled at Chokazi, near Jalair, and the electrical conductivity was found to be 8730 µS/cm (Hassan Saffi 2010b).

1968-1972 data from the USGS suggest that the Shor Darya's flow is seasonal, with the greatest flows (typically up to 9,000 L/s near Pata Baba) between February and May. Flows are extremely low from July to November, suggesting a lack of groundwater baseflow. The long-term annual average flow of the Shor Darya, prior to its confluence with the Shirin Tagab at Pata Baba 2440 L/s, for an upstream catchment area of 6685 km^2. This equates to an average run-off of 0.36 $L/s/km^2$ or only 12 mm/a.

The total flow in the Shirin Tagab at Pata Baba is, on average, 1640 L/s greater than at Dowlatabad, presumably due to the confluence with the Shor Darya (but the specific areally distributed run-off rate decreases consistently downstream). From these figures and from the data in Figure 3.7 and Table 3.1 we can calculate the accretion of flow:

(a) on the Qaysar / Shor Darya, between Qaysar and Pata Baba, as

$(2440 - 540)$ L/s / $(6685-425)$ km^2 = 1900 / 6260 km^2 = 0.30 $L/s/km^2$ = 10 mm/a

(b) on the Shirin Tagab, between Khisht Pul and Dowlatabad, as

$(2340-4450)$ L/s / $(4645-3280)$ km^2 = -2110 / 1365 km^2 = -1.5 $L/s/km^2$ = -49 mm/a

(c) on the joint system, between Shor Darya / Dowlatabad and Pata Baba, as

$(3980-2440-2340)$ L/s / $(11775-6685-4645)$ km^2

= -800 / 445 km^2 = -1.8 $L/s/km^2$ = -57 mm/a

In other words, on the upstream reaches of the main rivers, we see (as we would expect) accretion of flow. Downstream, towards the north, the rate of accretion decreases and then becomes negative (rivers losing flow to evaporation, infiltration or irrigation offtake).

3.6 The 2013 Maimana River Survey

On 1st May 2013, a stretch of the Maimana River was surveyed between Koh-e Khana, on the northern outskirts of Maimana, and Badghisy, representing a linear distance of almost 19 km and a river distance of just over 25 km. Flow, electrical conductivity, pH and temperature were taken at 5 stations along this length (Figure 3.9), while chemical and isotopic samples, filtered at 0.45 µm, were taken at 3 stations and sent to the British Geological Survey, Keyworth, UK for analysis (see NORPLAN 2014 for methods).

The river temperature varied between 14.1 and 18.5°C (with one "high" reading of 21.4°C) over the course of the survey. The electrical conductivity increased from 545 to 690 µS/cm, while the field pH was relatively constant at 8.4.

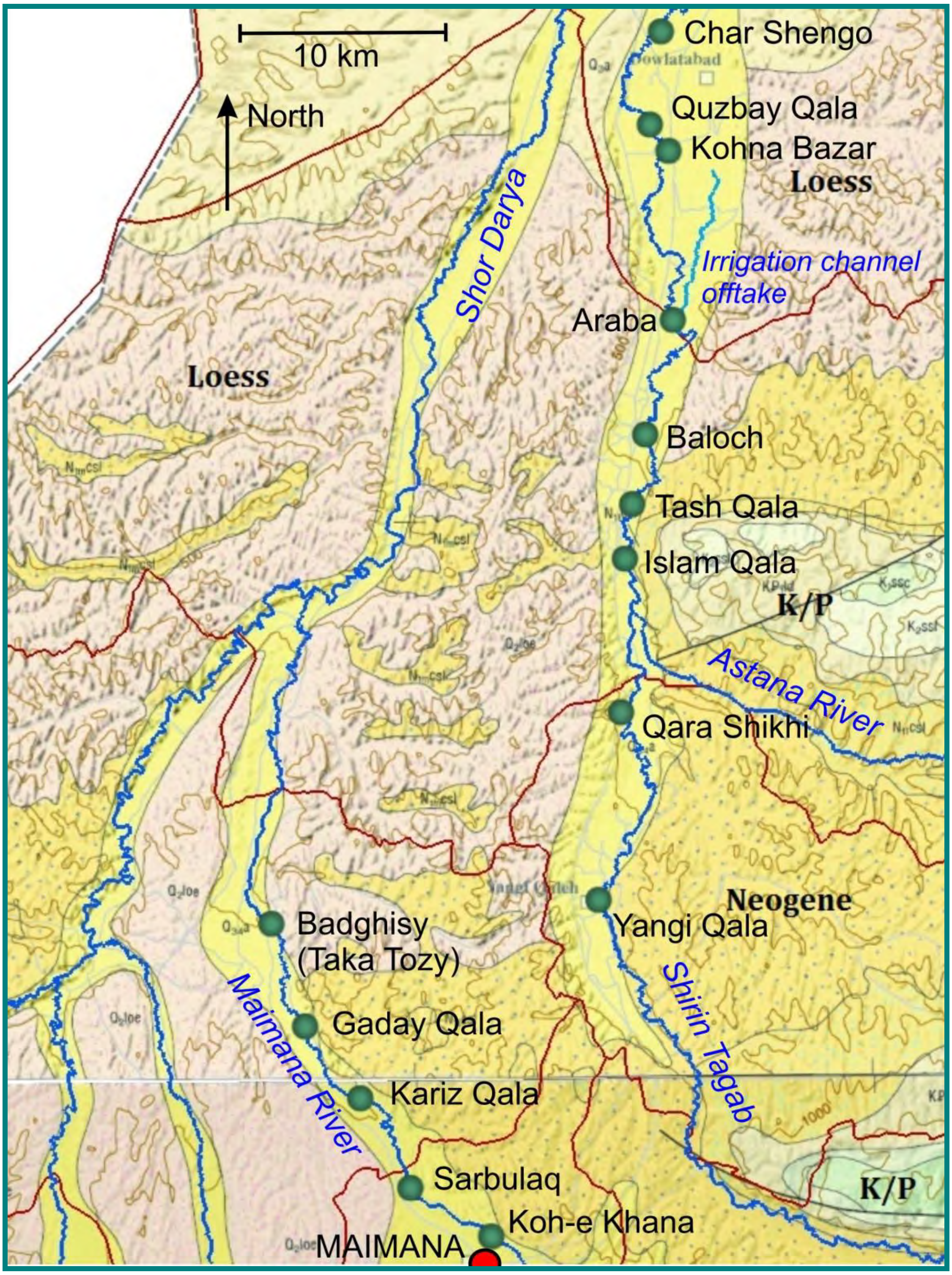


Figure 3.9. The locations for gauging and sampling during the 2013 survey of the Shirin Tagab and Maimana Rivers. The rivers are superimposed on the published 1:200,000 AGS/USGS geological maps (McKinney & Sawyer 2005; Wahl 2005), on which pink colours generally denote Quaternary loess, orange Neogene proluvial/molasse deposits, yellow Quaternary alluvium and green/brown Cretaceous / Palaeogene sedimentary rocks (K/P). These maps are believed to be public domain products.

At Koh-e Khana, the river contained around 8 mg/L nitrate (as NO_3^-) and <0.01 mg/L total phosphorus. The water chemistry was dominated by calcium and bicarbonate, with subsidiary sulphate.

Along the surveyed length, the flow rate (as estimated by impeller profile gauging) dropped from 2.1 m³/s to 1 m³/s, while the electrical conductivity rose by a factor of 1.27.

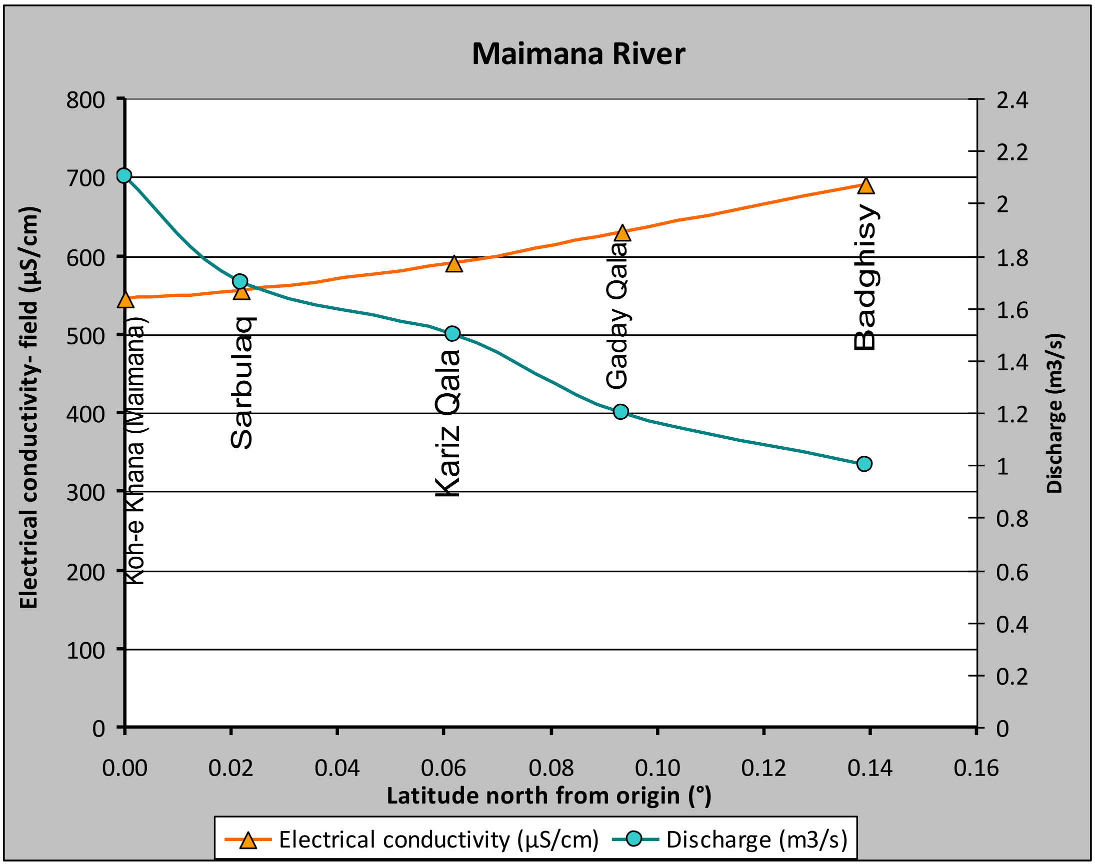


Figure 3.10a. Change in electrical conductivity and flow rate along the surveyed length of the Maimana River on 1st May 2013.

Different solutes were concentrated downstream at different rates, however, with calcium and bicarbonate accumulating relatively slowly, and solutes such as chloride, (followed by arsenic and potassium), which can be regarded as relatively conservative, accumulating by a factor of some 1.7.

The fact that the maximum solute up-concentration factor is only a little less than the flow loss factor (2.1) suggests that evaporation is a main driving force for loss of flow (abstraction and infiltration may also be factors in flow depletion).

If the channel is on average 6 m wide and 25 km long, the river stretch has a surface area of at least 150,000 m² (and probably more, given that narrow, straight sections were specifically chosen for gauging). The total flow loss over this section was 1.1 m³/s = 3960 m³/hr, implying the loss of 26 mm/hr from the open surface area.

From Chapter 2, we see that potential evapotranspiration in early May is around 140 mm per month (Figure 2.5); we could thus suppose that daytime evapotranspiration is approximately 0.4 mm/hr. Thus, we can conclude that direct evaporation from the river surface is unlikely to be adequate to account for the flow loss over the surveyed distance.

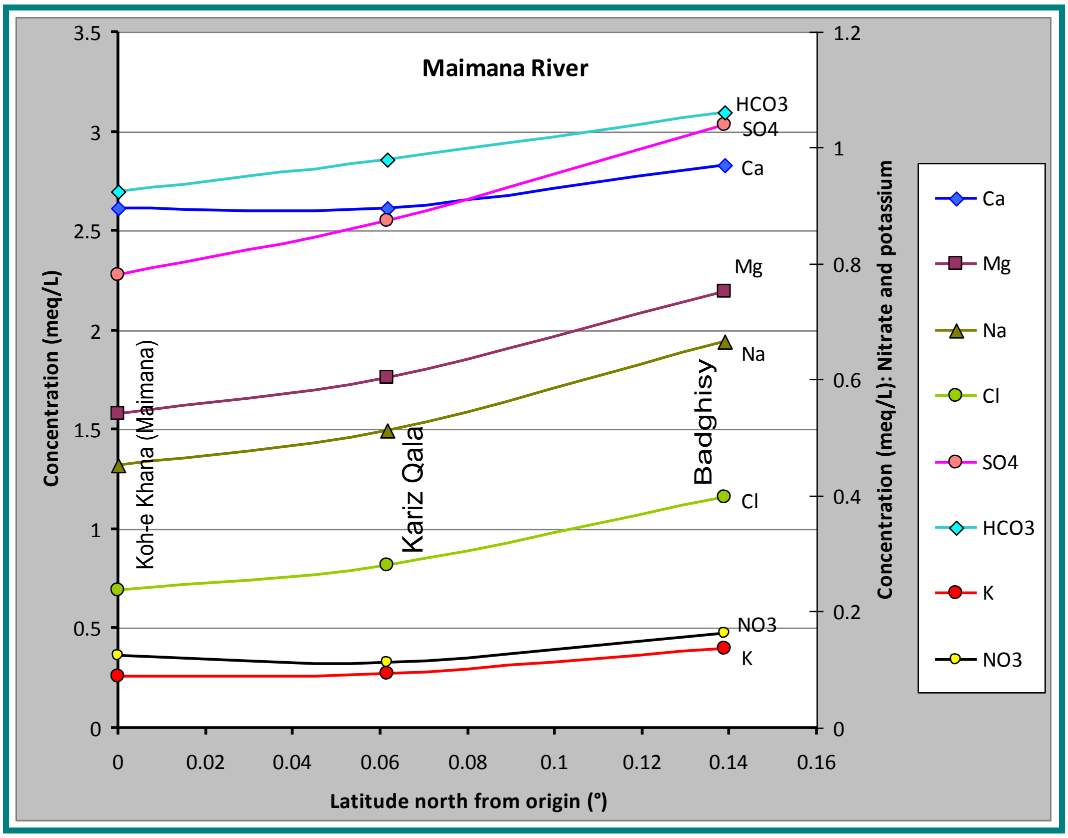


Figure 3.10b. Change in major ion concentrations (meq/L) along the surveyed length of the Maimana River on 1st May 2013. Samples analysed at British Geological Survey, Keyworth, UK.

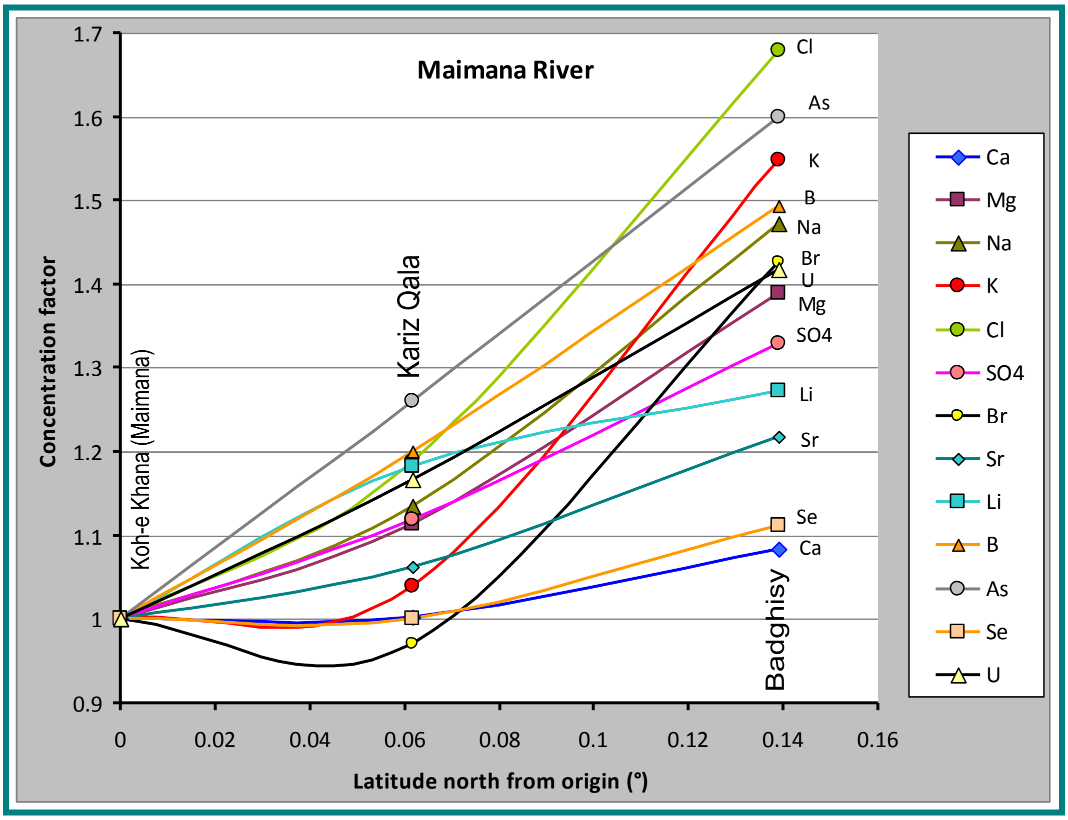


Figure 3.10c. Up-concentration of selected solutes (relative to Koh-e Khana) along the surveyed length of the Maimana River on 1st May 2013.

Stable isotopes of oxygen and hydrogen were also analysed at the NERC facility at the British Geological Survey and they show (Figure 3.10d) a steady enrichment in heavier isotopes downstream, indicative of evaporative fractionation. The isotopic values plot in the same area as rainfall in Figure 2.8 (see also Figure 11.2).

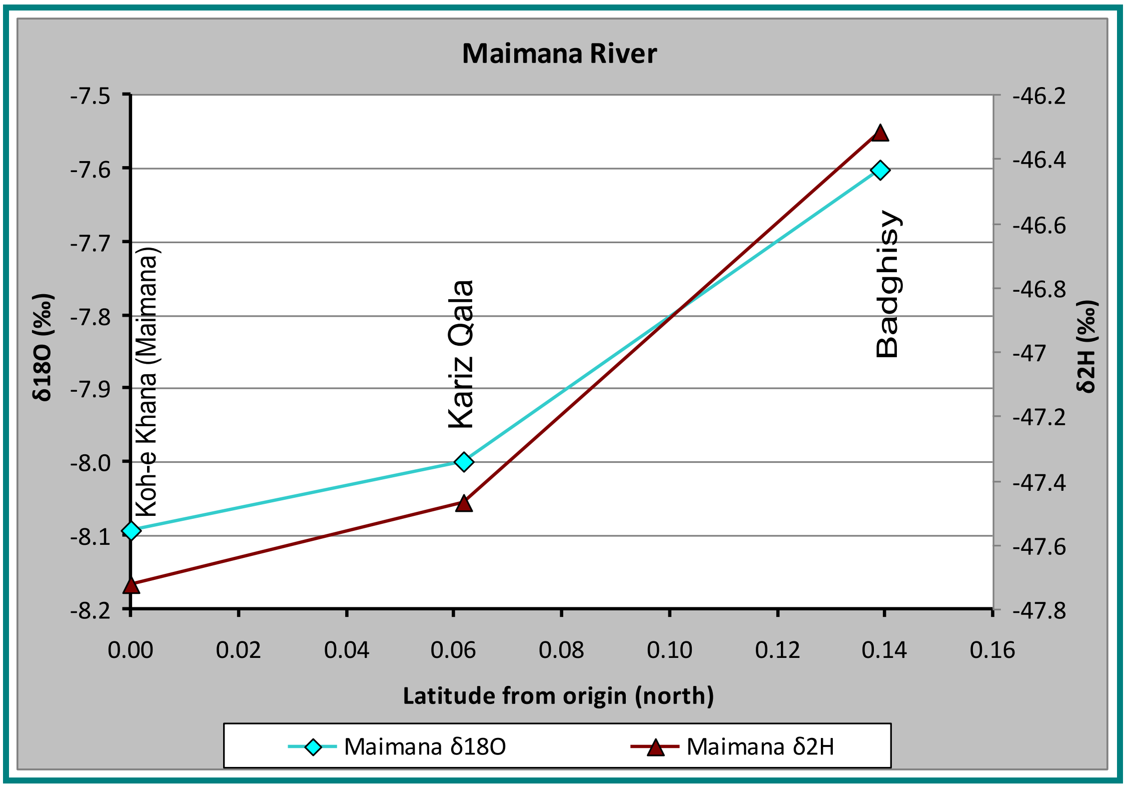


Figure 3.10d. Change in stable isotopic signature along the surveyed length of the Maimana River on 1st May 2013. Samples analysed at the NERC isotope facility at the British Geological Survey, Keyworth, UK.

3.7 The 2013 Shirin Tagab River Survey

On 11th-12th May 2013, a stretch of the Shirin Tagab River was surveyed between Yangi Qala and Char Shengo, representing a linear distance of c. 43 km and a river distance of c. 70 km. Flow, electrical conductivity, pH and temperature were taken at 9 stations along this length (Figure 3.9), while chemical and isotopic samples, filtered at 0.45 µm, were taken at 5 stations and sent to the British Geological Survey, Keyworth, UK for analysis (see NORPLAN 2014 for methods).

The river temperature varied between 16 and 18°C over the course of the survey, with 17°C being typical. The field pH was relatively constant at 8.4-8.5 upstream of Araba, and 8.1 to 8.2 downstream of Araba.

Along the surveyed stretch, the highly saline Astana River enters the Shirin Tagab just upstream of Islam Qala: it has no significant mitigating effect on the loss of flow in the Shirin Tagab, but *may* contribute to the step up in electrical conductivity at Islam Qala (Figure 3.11a).

Along the surveyed length, the flow rate (as estimated by impeller profile gauging) dropped from 1.9 L/s to 1 L/s between Yangi Qala and Baloch, while the electrical conductivity rose by a factor of 2.3 from 697 to 1605 µS/cm. The fact that the salinity increase exceeds the flow loss factor could be due to the saline input from the Astana valley area.

Just upstream of Araba, almost the entire flow of the Shirin Tagab is taken off into a major irrigation channel, leaving the natural channel of the Shirin Tagab effectively dry (Figures 1.2 and 1.3). The chemical and isotopic signature dips at Araba.

Downstream of Araba, the flow in the Shirin Tagab re-accretes: it is speculated that this is due to infiltration of irrigation water (i.e. the water taken off upstream of Araba) to the ground and thence discharging to the river. The flow rate does not reach its pre-Araba rate, however, with only 0.5 m^3/s being recorded at Kohna Bazar.

Salinity is re-acquired (irrigation water having been evapoconcentrated in the soil zone, and possibly also having picked up solutes from minerals in the unsaturated zone and aquifer), exceeding 2000 µS/cm in the lowermost stretches of the surveyed section.

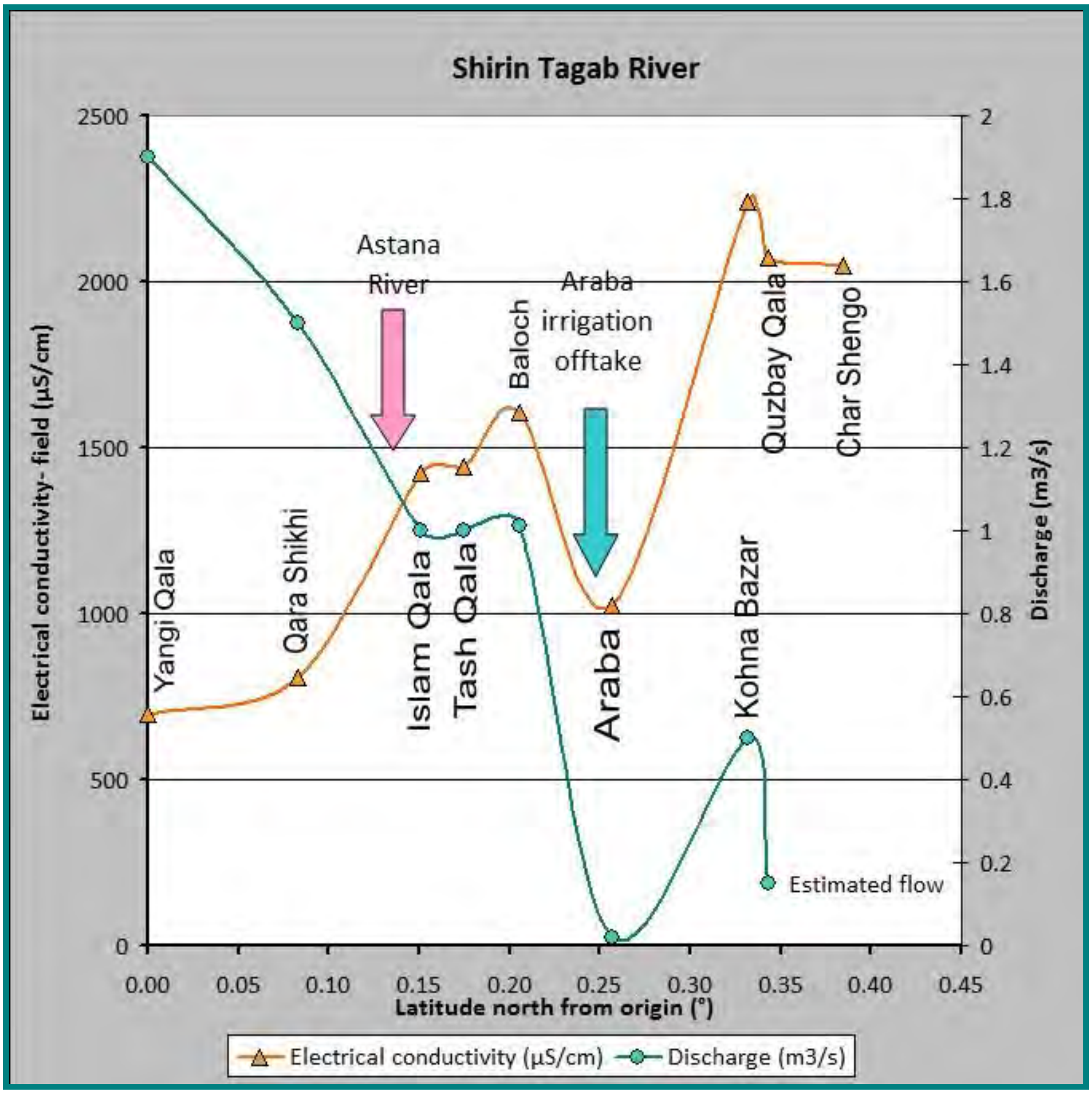


Figure 3.11a. Change in electrical conductivity and flow rate along the surveyed length of the Shirin Tagab River on 11th-12th May 2013.

At Yangi Khana, the river contained around 8.7 mg/L nitrate (as NO_3^-) which increases to c. 20 mg/L by Islam Qala and downstream. Total phosphorus is <0.01 mg/L along the entire surveyed length.

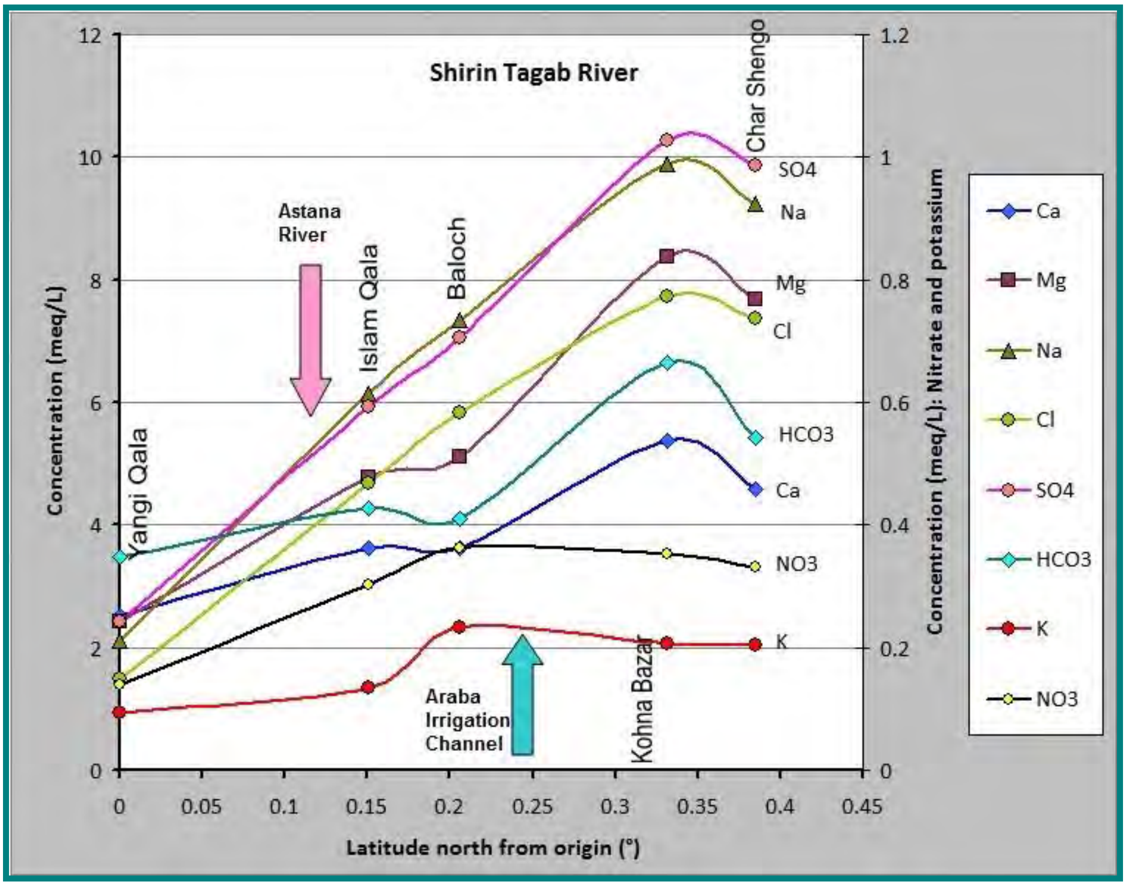


Figure 3.11b. Change in major ion concentrations (meq/L) along the surveyed length of the Shirin Tagab River on 11th-12th May 2013. Samples analysed at British Geological Survey, Keyworth, UK.

At Yangi Qala, the water chemistry is dominated by a Ca-(Na)-HCO_3^- composition. Downstream, concentrations of $SO_4^=$, Na, Mg and Cl^- increase rapidly and in parallel, whereas concentrations of Ca and HCO_3^- increase relatively slowly. Downstream, therefore, the water rapidly becomes dominated by Na and $SO_4^=$, with subsidiary Mg and Cl^-. It should be noted that this increase cannot be ascribed to simple dissolution of gypsum and halite, otherwise one would expect similar concentrations of Na and Cl. The approximately parallel increases in soluble ion concentrations bear the signature of evaporative concentration, with increases in calcium and bicarbonate possibly being suppressed by calcite saturation.

Different solutes were concentrated downstream at somewhat different rates, however, with calcium and bicarbonate accumulating relatively slowly, and solutes such as chloride, (followed by sodium, bromide and sulphate), which can be regarded as relatively conservative, accumulating by a factor of some 3-4 by Baloch and 4-5 by Kohna Bazar and Char Shengo (Figure 3.11c).

The fact that the maximum solute up-concentration factor is similar, though slightly greater than, the flow loss factor (1.9 to Baloch, c. 4 to Kohna Bazar) suggests that evaporation is a significant driving force for loss of flow (abstraction and infiltration may also be factors in flow depletion).

If the channel is on average 4 m wide and 34.1 km long between Yangi Qala and Baloch, the river stretch has a surface area of at least 136,400 m^2 (and probably more, given that narrow, straight sections were specifically chosen for gauging). The total flow loss over the Yangi Qala - Baloch section was 0.9 m^3/s = 3240 m^3/hr, implying the loss of 23.8 mm/hr from the open surface area.

From Chapter 2, we see that average potential evapotranspiration in early May is around 140-150 mm per month at Maimana and 180 mm in Andkhoi; we could thus suppose that daytime evapotranspiration is approximately 0.5 mm/hr in the Shirin Tagab area. Thus, we can conclude that direct evaporation from the river surface is unlikely to be adequate to account for the flow loss over the surveyed distance.

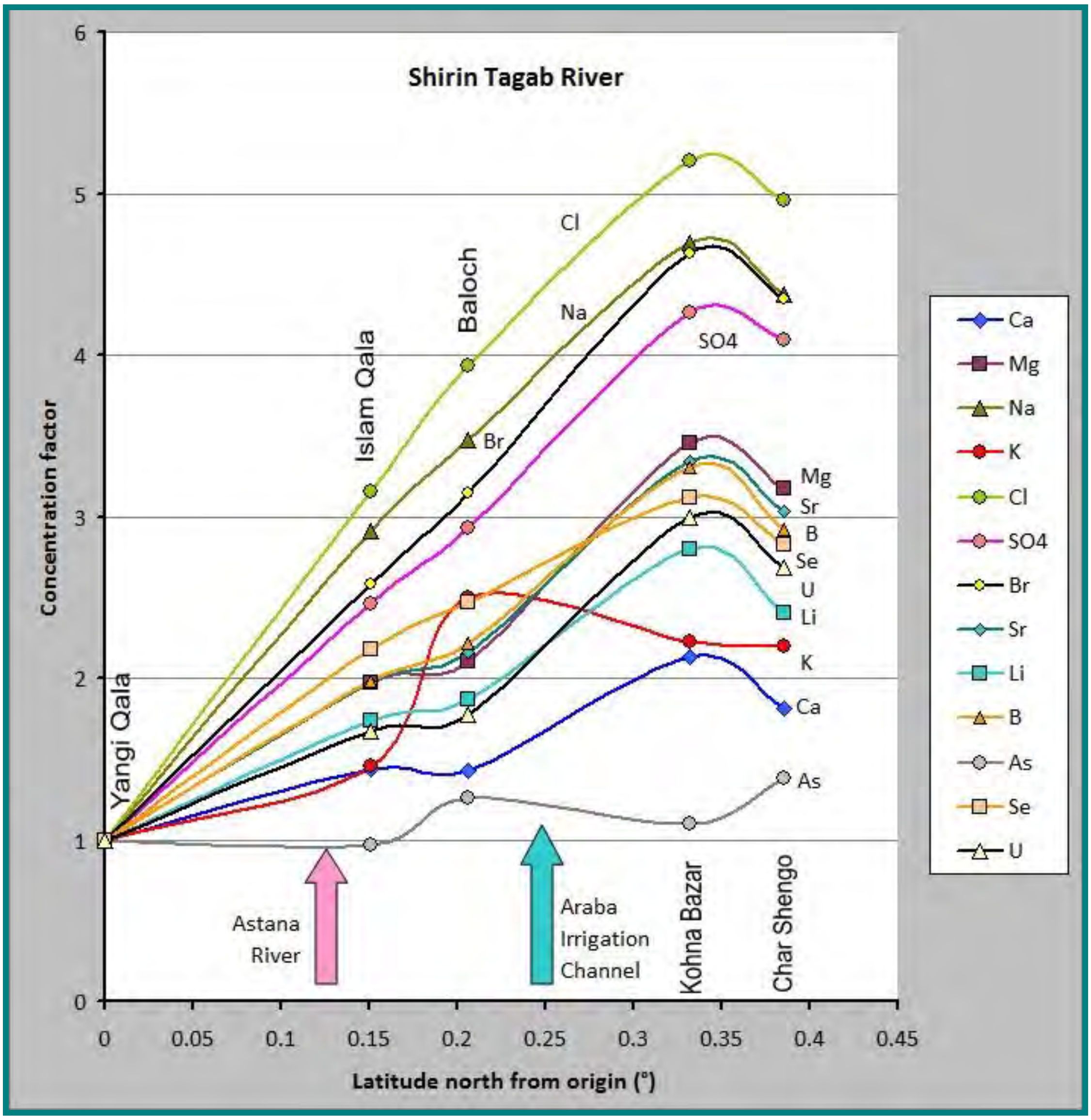


Figure 3.11c. Up-concentration of selected solutes (relative to Yangi Qala) along the surveyed length of the Shirin Tagab River on 11th-12th May 2013.

Stable isotopes of oxygen and hydrogen were also analysed at the NERC facility at the British Geological Survey. The isotopic values plot in the same area as rainfall in Figure 2.8 (see also Figure 11.2). The isotopic values show (Figure 3.11d) a steady enrichment in heavier isotopes downstream in the reaches of flow depletion, from Yangi Qala to Baloch and from Kohna Bazar to Char Shengo, indicative of evaporative fractionation. In the zone of flow accretion, however, from Araba to Kohna Bazar, the isotopic values fall: this is presumably due to the river being fed with groundwater baseflow with a lighter isotopic signature. The reason that such groundwater has a lighter signature may be that it was recharged to the ground in upstream reaches of the river, during times of snowmelt (lighter signature, see Figure 2.8).

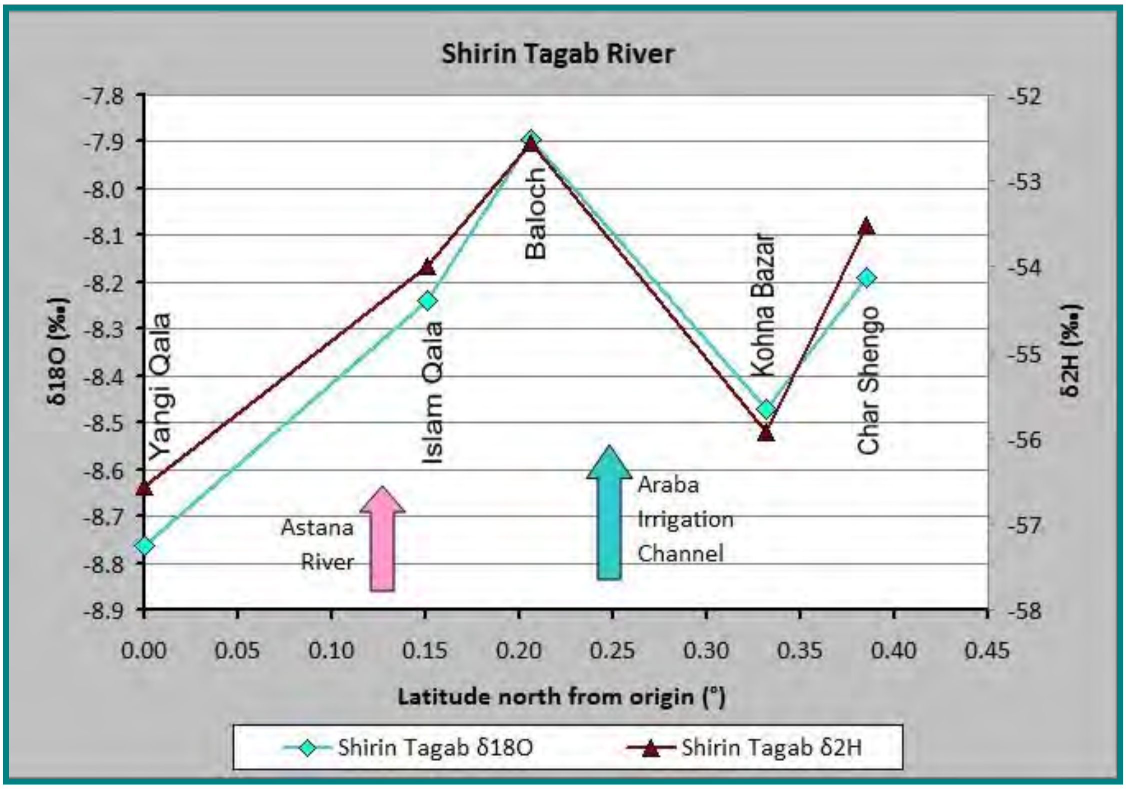


Figure 3.11d. Change in stable isotopic signature along the surveyed length of the Shirin Tagab River on 11th-12th May 2013. Samples analysed at the NERC isotope facility at the British Geological Survey, Keyworth, UK.

3.8 *Summary: 2103 River Survey*

The two River Surveys of 2013 reveal that, along the surveyed reaches, flows typically decrease downstream, with concentrations of solutes increasing. The fact that the solute up-concentration factors approximately mirror the flow loss factors strongly suggests that evapotranspiration is a major driving factor in this process. The steady enrichment of river waters in heavy stable isotopes is also strongly indicative of evaporative processes.

However, it would appear that direct evaporation from the river surface is inadequate to explain the flow loss. In fact, for both the Shirin Tagab and Maimana sections, around 50 times more surface area than appears to be available, would be required to result in the observed losses in flow due to open water evaporation. Even allowing for the fact that river widths measured at gauging stations may under-represent the average river width (as narrow, straight sections were preferentially chosen for gauging), we need to acknowledge that:

(i) abstraction and use for irrigation, and

(ii) river bed infiltration to groundwater

probably also contribute to loss in flow.

However, mechanism (i) could, in some circumstances, be regarded as an evapotranspirative up-concentration mechanism. Water abstracted from the river is used to irrigate riparian crops: plants and soils efficiently lose water via evapotranspiration, but most non-nutrient solutes remain in the residual water, which either infiltrates to the soil and shallow groundwater system, or discharges via drains. We will see in Chapter 6 that, along these river reaches, the alluvial sand and gravel aquifer beneath the river valleys is often effectively separated from the surface via a

layer of silty clay. Thus, infiltrating irrigation water may not reach the deeper sand and gravel aquifer, but may discharge as shallow groundwater or interflow, back to the rivers, via natural seepages, field drains or ditches. The net result is loss of river discharge (abstraction and evapotranspiration), proportionate up-concentration of solutes and an effectively increased area (additional areas of riparian irrigated land) for evaporative processes.

In the Shirin Tagab , just upstream of Araba, almost the entire flow of the Shirin Tagab is led off into an irrigation channel to water the land SE of Dowlatabad. We assume that the same evapo-concentrative processes occur in this irrigated land on a much larger scale. Eventually, the residual infiltrating water from the fields returns to the Shirin Tagab River and flow re-accretes (but never to pre-Araba levels) and with an increased load of solutes (see Chapter 6).

3.9 *The Kelif Uzboy and the ancient course of the Amu Darya*

The existence of enormous fresh groundwater resources in the Nubian sandstones below the Sahara Desert has drawn hydrogeologists' attention to the possibility that groundwater recharge could have taken place many thousands of years ago (during pluvial periods in the Pleistocene or early Holocene), bequeathing usable groundwater resources, even in terrains that are arid or brackish according to today's standards.

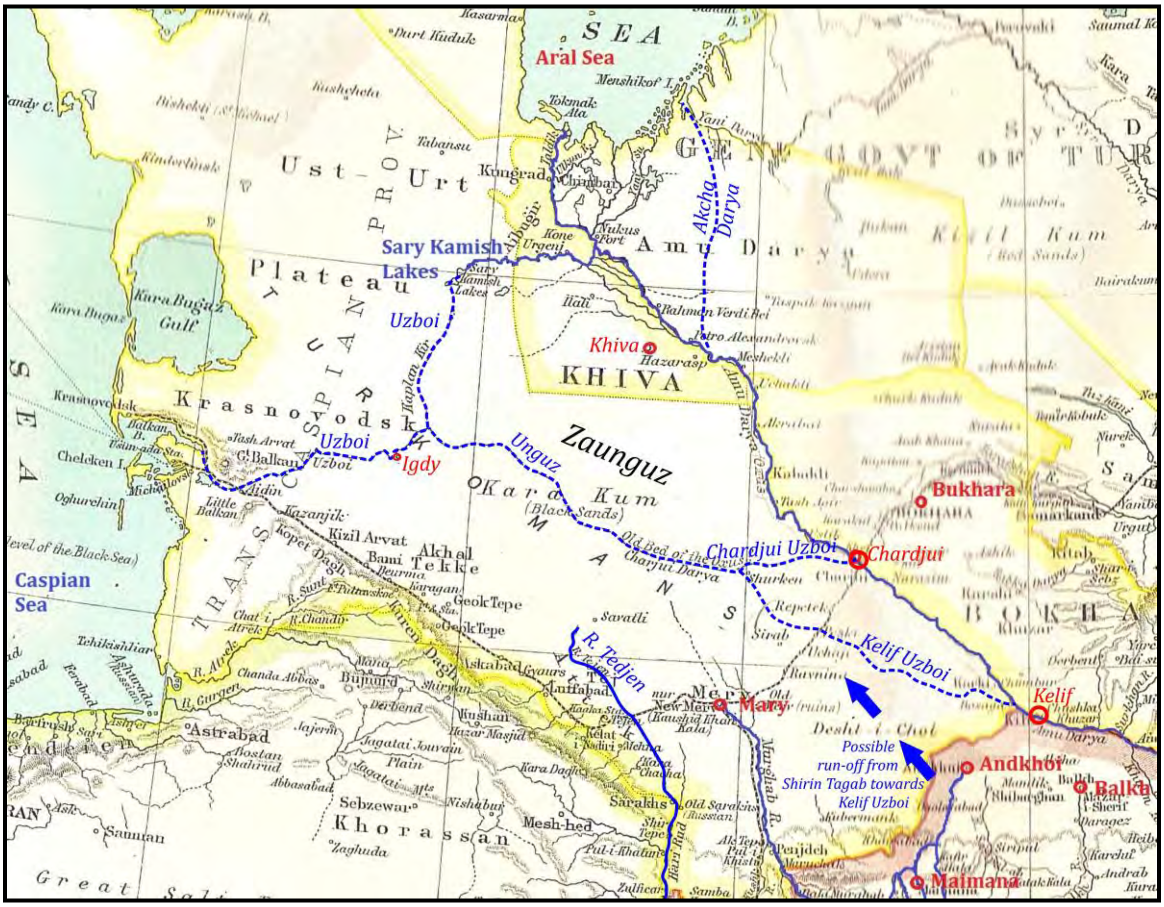


Figure 3.12. A map of Central Asia, showing the supposed former course of the Amu Darya (the Kelif Uzboi) and the borders of the Russian imperial territories of Khiva, Bokhara and Kokand around the time of 1902-1903. Source: http://en.wikipedia.org/wiki/Emirate_of_Bukhara. Believed to be public domain.

If we allow that, during such pluvial episodes, the river discharge in Faryab would have been greater and river water quality fresher, it seems reasonable that recharge of fresh

groundwater resources might also have been greater, either by direct recharge mechanisms or by increased infiltration of fresh river water in valleys, including river channels that are dry today.

The Aral Sea, the Sary Kamysh and the Unguz and the Uzbois

The Amu Darya, together with the Syr Darya, feeds the current inland Aral Sea. In large part, due to over-abstraction of the two rivers, the flows reaching the Aral Sea have decreased dramatically in recent decades, leading to a catastrophic desiccation of the Aral Sea (Zavialov 2005).

The palaeogeography of the Aral / Amu Darya system has long been a source of tremendous interest and controversy, because the system is associated with a number of apparent palaeochannels, which are largely inactive today. Amongst these are (Figure 3.12):

- The **Akcha Darya** channel: a minor palaeochannel system of the Amu Darya, by which water entered the Aral Sea somewhat to the east of the recent main course.
- The **Sary Kamysh lakes**. These are a string of saline lakes to the south-west of the Aral Sea that have historically been fed by waters from the Amu Darya in a number of episodes. Up to the 15th-16th centuries AD, some of the Amu Darya's flow continued to the Sary Kamysh saline lakes and, at times of high flow, overspilled into the Western Uzboi and thence towards the Caspian (Aladin et al. 2005, Pravilova 2008). Even after the 16th century, some of the channels between the Amu Darya and the Sary Kamysh lakes were maintained as irrigation channels. Breckle & Geldyeva (2012) note that the Sary Kamysh Lakes and the Aral Sea represent two terminal receptors for the Amu Darya flow and that, in historical times, the Amu Darya rather often changed its outflow between the two. The reasons for this alternation may have been natural, but many authors have suggested that irrigation / damming projects by the Central Asian civilizations may also have been important in determining flow distributions.
- The (**Western) Uzboi,** a (now largely dry) palaeochannel running from Sary Kamysh, through the desert town of Igdy, to the Caspian Sea (Aladin et al. 2005, Létolle et al. 2007, Zonn et al. 2010). This channel was historically regarded as a major, and partly navigable, watercourse, carrying excess water (ultimately from the Amu Darya) from the Sary Kamysh depression. It thus provided an outlet for the Amu Darya's waters to the Caspian Sea.
- The **Unguz** has the appearance of a palaeochannel crossing the Karakum towards the Caspian Sea, meeting the Western Uzboi just upstream of Igdy. It appears that it may have been linked to other apparent palaeochannels (the **Kelif Uzboi** or **Chardjui Uzboi**) further east. It has been widely speculated that these channels represent a former southern course of the Amu Darya, departing the current course near the towns of Kelif or Chardjui (respectively) and conveying the flow of the Amu Darya directly to the Caspian Sea.

The Unguz / Kelif Uzboi

Within various literature sources, it is widely (but, by no means, universally - see Boroffka 2010) claimed that the Amu Darya formerly left its current channel near Kelif (or possibly Chardjui), to cross the Karakum desert in a desiccated valley (supposed palaeochannel), referred to as the **Kelif Uzboi** (or Chardjui Uzboi) or **Unguz**, which joined the Western Uzboi upstream of Igdy and discharged to the Caspian Sea.

Fyedorovich (1979) states that the central and southern Karakum desert is composed of the alluvial deposits of the ancient Amu Darya and those of the deltas of the Murghab and Tedzhen. The **Unguz** *consists of a chain of hollows up to 15 km long and 1–4 km wide, with flat bottoms of solonchak or takyr (*Great Soviet Encyclopaedia 1979 - entry for Unguz), running along the northern margin of the central Karakum, at the foot of the scarp (40-80 m high) of the elevated Zaunguz Karakum plateau to the north. [Fyedorovich suggests that the northern Zaunguz plateau itself is composed of Miocene and Pliocene sedimentary rocks, laid down by an earlier palaeo-Amu Darya]. The Great Soviet Encyclopaedia (1979) believes that the Unguz is a palaeochannel of the former Amu Darya, and that some of its hollows are filled in sands from the river and later *deformed by tectonic movements and subjected to denudation.*

It is thus widely accepted that the palaeo-Amu Darya traversed the central Karakum in Neogene and Pleistocene times. However, the "myth" of the Kelif Uzboi as a more recent channel for the Amu Darya seems remarkably tenacious. The rumour of the Amu Darya discharging into the Caspian seems to have its root in some very hazy Greek geography by Herodotus, Strabo and Patrocles (Tarn 1901), which not only appears to confuse the Aral with the Caspian, but which also introduces the nebulous River *Ochus* (easily confused with the *Oxus* - Olbrycht 2010). This *Ochus* might plausibly be construed an alternative southern course of the Amu Darya to the Caspian (Rawlinson 1879). Such rumours persisted for many centuries. Indeed, on the wall of the Doge's Palace in Venice, there is a 17th Century map showing the Amu Darya discharging to the Caspian rather than the Aral Sea. The ideas were kept alive by Russian and English adventurers and geographers such as Baron Aleksander V. Kaulbars, Arthur Conolly, General Mikhail N. Annenkoff and Sir Henry Creswicke Rawlinson (1879).

In 1714, Peter the Great was taken with the idea of turning the Amu Darya away from the Aral, into its former (Sary Kamysh - Western Uzboi) course to the Caspian (thus creating a waterway from Moscow to India), and ordered an expedition to investigate this possibility. Eventually, the Russians convinced themselves that the Amu Darya had been deliberately diverted away from its old course via the Sary Kamysh lakes by the Turkmen nations (Zonn et al. 2010). In 1879, the Grand Duke Nikolaj Konstantinovich organized an expedition to survey the entire Amu Darya basin. By the summer of that year, a group had arrived at the (then Bokhara-controlled) fortress on the Amu Darya at Kelif (just north of Faryab). A Turkmen guide (one Geldygog) informed the party that, close by, near the Afghan village of Aladat, a former channel of the Amu Darya (termed the "Shor") branched off the left bank of the Amu Darya and continued across the desert towards the Caspian Sea. Thus grew the myth of the **Kelif Uzboi** or **Chardjui Uzboi** as a recent southern course of the Amu Darya - possibly with a basis in Pleistocene geological reality, but partly in wishful thinking on the part of Russian adventurers!

<u>The Recent Geological History of the Amu Darya / Aral Sea</u>

The complex early Quaternary history of the Aral Sea is documented by Breckle & Geldyeva (2012) and its later history by Boomer et al. (2009) and Boroffka (2010). Boomer et al. (2000) probably provide the best overall overview of the evolution of the system, upon which the following is largely based:

- the Aral / Sary Kamysh depression was formed in the late Neogene, some 3 million years ago (Boomer et al. 2000). The Aral Sea may first have become water-filled by overflow from the Caspian Sea some 2-3 million years ago.
- During the latest Neogene (Pliocene) and early Pleistocene, the Amu Darya probably traversed the area known as the **Zaunguz Karakum** (between its modern course and the Unguz) towards the Caspian Sea, laying down broad expanses of sandy / clayey sediments. It is these sediments which, today, underlie the Zaunguz plateau (see above, and Fyedorovich 1979).

- Somewhere in the middle of the early Pleistocene, the Amu Darya's course shifted south to the *Nizmenie (Lower) Karakum*, i.e. to the area occupied by the apparent Kelif Uzboi / Unguz palaeochannel. The Amu Darya thus flowed towards the Caspian Sea and laid down the geological sequence of sediments known to Russian geologists as the Karakumskaya Suite (sand, clay and carbonate muds). In this period, the Murghab and Tedzhen Rivers would have been left-bank tributaries of the Amu Darya.
- Sometime during the late Pleistocene, the course of the Amu Darya began to migrate northwards towards its current channel, possibly in response to a gradual uplift and doming of the Karakum (Lyberis & Mering 2000). It may also have been in response to an increase in the flow and erosive power of the River (related to changes in climate or uplift patterns in the Pamir). The Unguz may thus have been one of the most recent Pleistocene palaeochannels in the area.
- During large parts of the Pleistocene, the Aral would likely have been dry for protracted periods.
- At the end of the late Pleistocene, or early Holocene, the course of the Amu Darya turned north and began to fill the Sary Kamysh depression and the Aral Sea. Fyedorovich (1979) suggests that the Amu Darya left the Karakum depression (the Unguz) some 20-30,000 years BP. Other authors place the filling of the Aral Sea at a later date (17,000 to 9,000 years BP; Zavialov 2005). Boomer et al. (2000) place the final diversion of the Amu Darya away from the Caspian towards the Aral / Sary Kamysh / Khorezm Basin (the so-called "Great Aral Sea") at the onset of the Lavlakansky Pluvial period around 9000 years BP.
- During the warmer climate of 5000-7000 years BP, the Amu Darya's increased flow passed both into the Aral Sea (possibly via the Akcha Darya channel) and via the Sary Kamysh and Western Uzboi to the Caspian Sea. Fyedorovich (1979), Zavialov (2005) and Breckle & Geldyeva (2012) concur that the Amu Darya began to overflow from the Sary Kamysh lakes to the Caspian via the Western Uzboi in the early to mid Holocene (Fyedorovich suggests somewhere in the 5th-2nd millennia BC). Boroffka (2010) suggests that the Sary Kamysh / Western Uzboi route may have been active earlier than this, however.
- Up to the 15th-16th centuries AD, some of the Amu Darya flow continued to the Sary Kamysh lakes and, at times of high flow, overspilled into the Western Uzboi and thence towards the Caspian (Aladin et al. 2005, Pravilova 2008). During this period, the flow of the river was partially managed by the Khorezm civilization for irrigation. In 1558, an English merchant, Anthony Jenkins, observed that:

  > *`..the water that serveth all the country is drawn by ditches out of the river Oxus unto the great destruction of the said river, for which it falleth not into the Caspian Sea as it hath done in times past, and in short time all that land is like to be destroyed, and to become a wilderness for want of water, when the river Oxus shall fail."* (cited in Boomer et al. 2000).

- Even after, the 16th century some of the channels between the Amu Darya and the Sary Kamysh lakes were maintained as irrigation channels. In 1878, a major flood on the Amu Darya broke through to the Sary Kamysh, and re-filled the lakes.

So: What is the Kelif Uzboi / Unguz ?

Although many authors regard the Unguz as a former channel of the Amu Darya in the Pleistocene and even late Neogene (e.g. Lyberis & Mering 2000), there is not a complete consensus. Aladin et al. (2005) state that there is no trace of any flow of the Amu Darya

along the Kelif or Chardjui "Daryas" during the past five centuries. Furthermore, their assessment of the Unguz suggests that the "channel" shows no obvious traces of fluviatile activity and may be a wind-erosional feature.

According to Pravilova (2009) and Zonn (2014), the Kelif Uzboi was not (at least in the recent past) a southern channel for the Amu Darya, but rather an intermittent channel accepting discharge from the northern Afghan Rivers (such as the Balkh, Shirin Tagab and Sar-e-Pol) at times of excessive flow. Indeed, Berg (1950) records that, in 1907, water from the rivers of northern Afghanistan penetrated into the Kelif Uzboy.

Of Etymological Interest

The name ***Shirin Tagab*** means *sweet water*.

Murghab means *River of the Birds*. In Greek it is believed to have been *Margiana*.

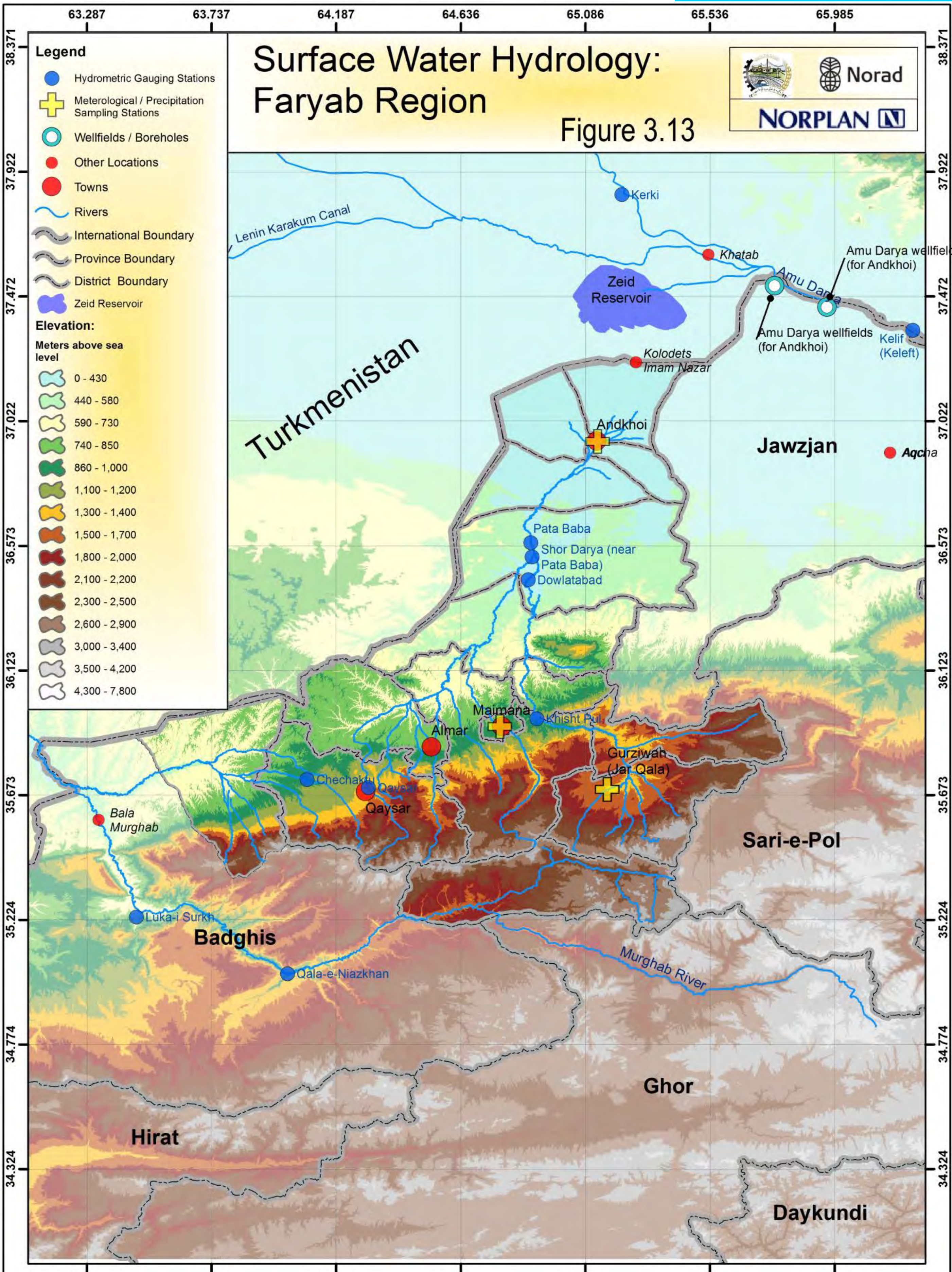
Amu Darya means the *River of Amul* (the city of Amul is the modern city of Türkmenabat, in Turkmenistan). In Greek the river was called the *Oxos* (Latin *Oxus*; Sanskrit *Vaksu*) and the plain between it and the mountains (including northern Faryab) was called *Oxiana*.

Shor Darya means *salty river* - a very apt description.

The Turkic name ***Unguz*** is believed to refer to an *old dry river bed* - see http://en.wikipedia.org/wiki/User:Yeniler/Hazar.

The ***Kelif Uzboi*** was believed to be the former channel of the River Amu Darya that diverged from the current channel near the town of Kelif and followed the initial line of the Lenin Canal, through Zeid and the Unguz towards the Caspian Sea. There is no evidence that the Amu Darya followed this course in historic times, and is based on a misunderstanding (see text).

Safed Koh means *White Mountains*, while ***Band-e-Turkestan*** refers to this range forming the *boundary wall to Turkestan*.



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Datum: WGS 1984
Units: Degree

Data Sources:
1. MRRD
2. DACAAR
3. USGS

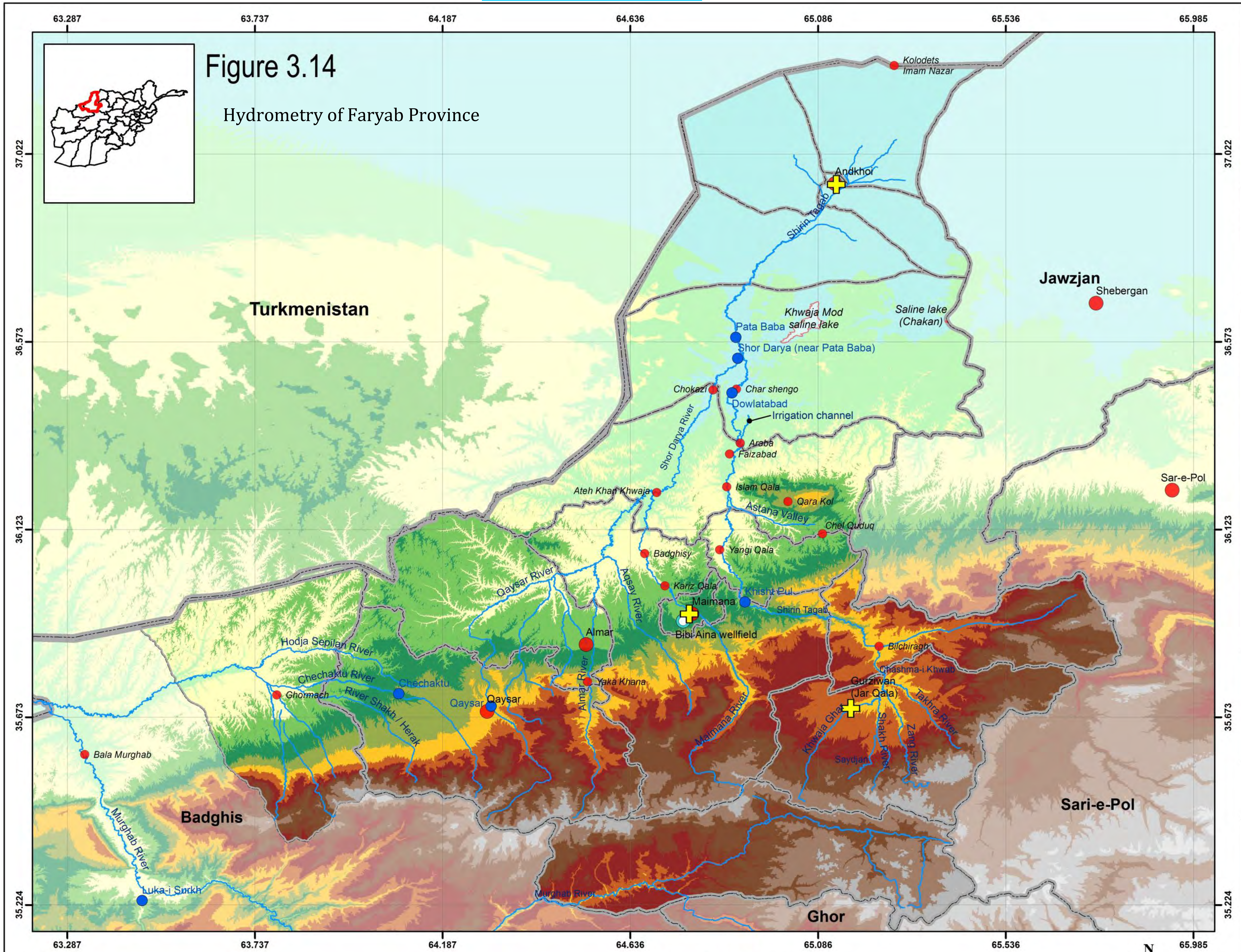

Figure 3.14

Hydrometry of Faryab Province

Legend

- Hydrometric Gauging Stations
- Meterological / Precipitation Sampling Stations
- Wellfields / Boreholes
- Other Locations
- Towns
- Rivers
- International Boundary
- Province Boundary
- District Boundary
- Khwaja Mod saline lake
- Chakan saline lake

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:

Surface Water Hydrology of Faryab Province

Drawn by: Shuaib Zarinkhail Date: Feb 2014
Checked by: David Banks Date:
Authorized by: Date:
Drawing No: 01
Version: 1.5

PROJECT:

Capacity Building and Institutional Cooperation in the field of Hydrogeology for Faryab Province, Afghanistan

CLIENT:

Norad

NORPLAN

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File Path: Y:\2 RuWATSIP\1_RGIS\01_Project_Files\03_Working\forAtlas\Figure 3.14 Surface water hydrology- Faryab Province v1.5.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 40 Kilometres

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