Chapter 12B. Geohydrologic Summary of the North Takhar Gold Placer Area of Interest

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12B.1 Introduction

This chapter describes the geohydrology of the North Takhar gold-placer area of interest (AOI) in Afghanistan identified by Peters and others (2007) (fig. 12B–1*a*,*b*). The AOI is located in northeastern Afghanistan in the Darqad, Chah Ab, Shahri, Buzurg, Yanqi Qalla, Rustag, Fayzabad, Kisham, Kalafgan, and Khwaja Ghar Districts in the Takhar and Badakhshan Provinces (fig. 12B–1*a*,*b*). The AOI encompasses an area of 6,128 km^2 (square kilometers) (the areas in Tajikistan are not considered).

Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information on the seasonal availability of, and seasonal demands for, water. The geohydrology of the AOI is described through the use of maps of streams and irrigated areas, generalized geohydrology and topography, and well locations. Where these data are available, the depth to water and height of static water in wells are documented. The results of lineament analyses are presented to identify areas where the rock may be more fractured than in other areas, which may be an indicator of high relative water yield and storage in bedrock aquifers.

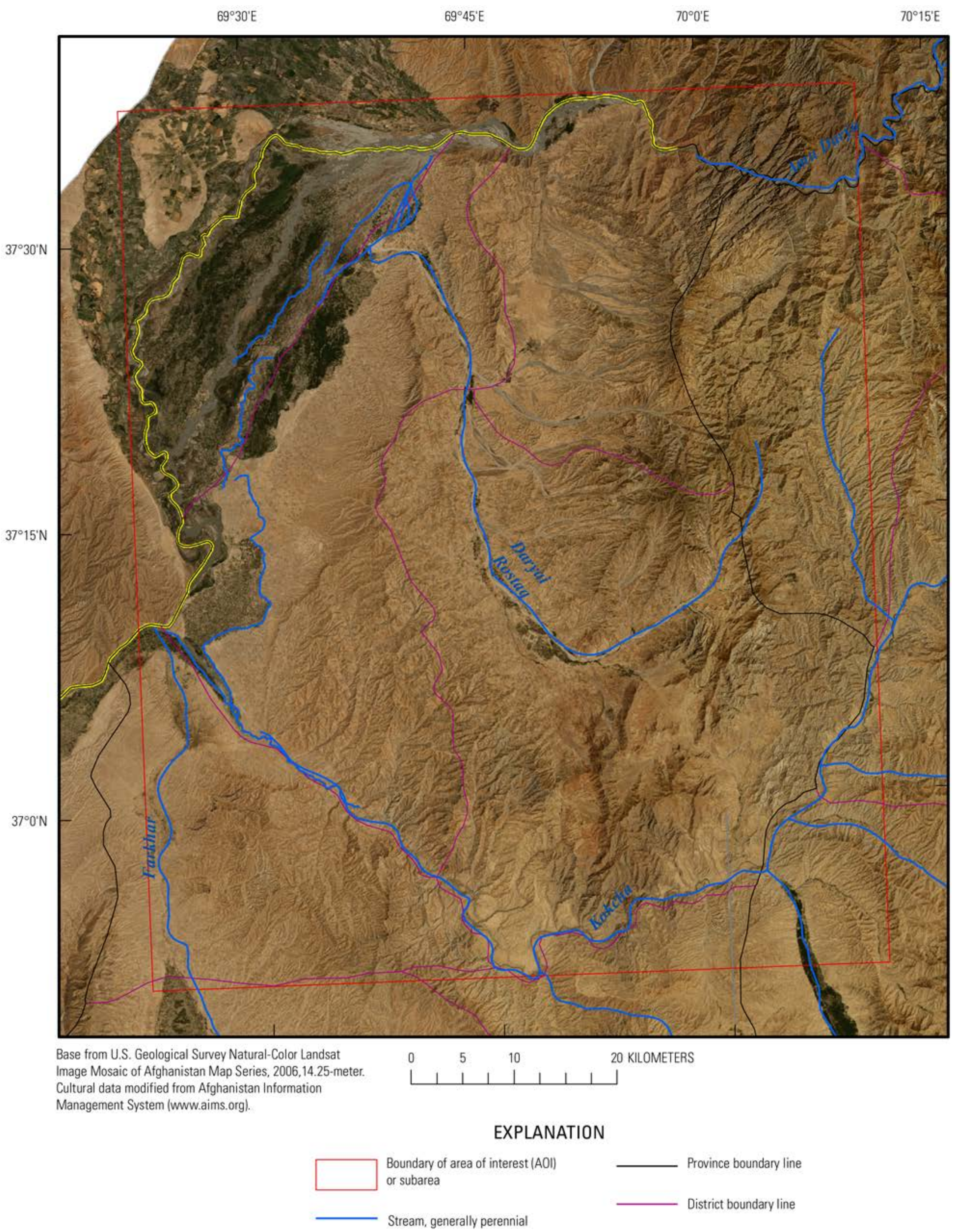
Afghanistan's recent turbulent history has left many of the traditional archival institutions in ruins, and most water-resource and meteorological data-collection activities had stopped by 1980. Recently (2011), nongovernmental organizations (NGOs), foreign government agencies, and the Afghan government have begun water-resource investigations; however, these activities and the amount of data collected are limited. This report summarizes the satellite imagery and climatic, topographic, geologic, surface-water, and groundwater data available. Geohydrologic inferences are made on the basis of an integrated analysis of these data and an understanding of conditions in other areas of Afghanistan.

12B.1.1 Climate and Vegetation

Climate information for the North Takhar gold placer AOI is based on data generated for the Afghanistan agricultural-meteorological (Agromet) project. Agromet was initiated by the U.S. Agency for International Development and the United Nations Food and Agriculture Organization in 2003 to establish data-collection stations and develop country-wide agrometeorological services. Scientists with the Agromet project are assisting the Afghan Government to collect and analyze agricultural and meteorological data as they relate to crop production, irrigation, water supply, energy, and aviation. The U.S. Geological Survey (USGS) assumed responsibility for the operation of the project in 2005; by the end of August 2010, 87 Agromet stations were recording precipitation data and other parameters. Additionally, the Agromet project receives data from 18 Afghanistan Meteorological Authority (AMA) weather stations. The Agromet project has developed a database that includes data collected at the Agromet stations over the past 6 years (2005–2011), data collected at the AMA weather stations, and historical data collected at weather stations from 1942 to 1993. Data collected as part of the Agromet project are compiled annually by water year (September through August) and are reported in the Afghanistan Agrometeorological Seasonal Bulletin (Seasonal Bulletin) published by the Ministry of

Agriculture, Irrigation, and Livestock. Unless otherwise specified, the Agromet data cited in this report are from the agricultural season that extends from 1 September, 2009, to 31 August, 2010.

The average precipitation for the 2009–2010 water year for the region of Afghanistan that includes the AOI, as published in the Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 2), ranged from 255 to 300 mm (millimeters). The AOI received 61 to 100 mm of precipitation in February 2010, the month with the greatest precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 3). The AOI received 24 to 58 mm of precipitation in October 2009, the month with the least precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 4). The amount of precipitation increases from west to east across the AOI.



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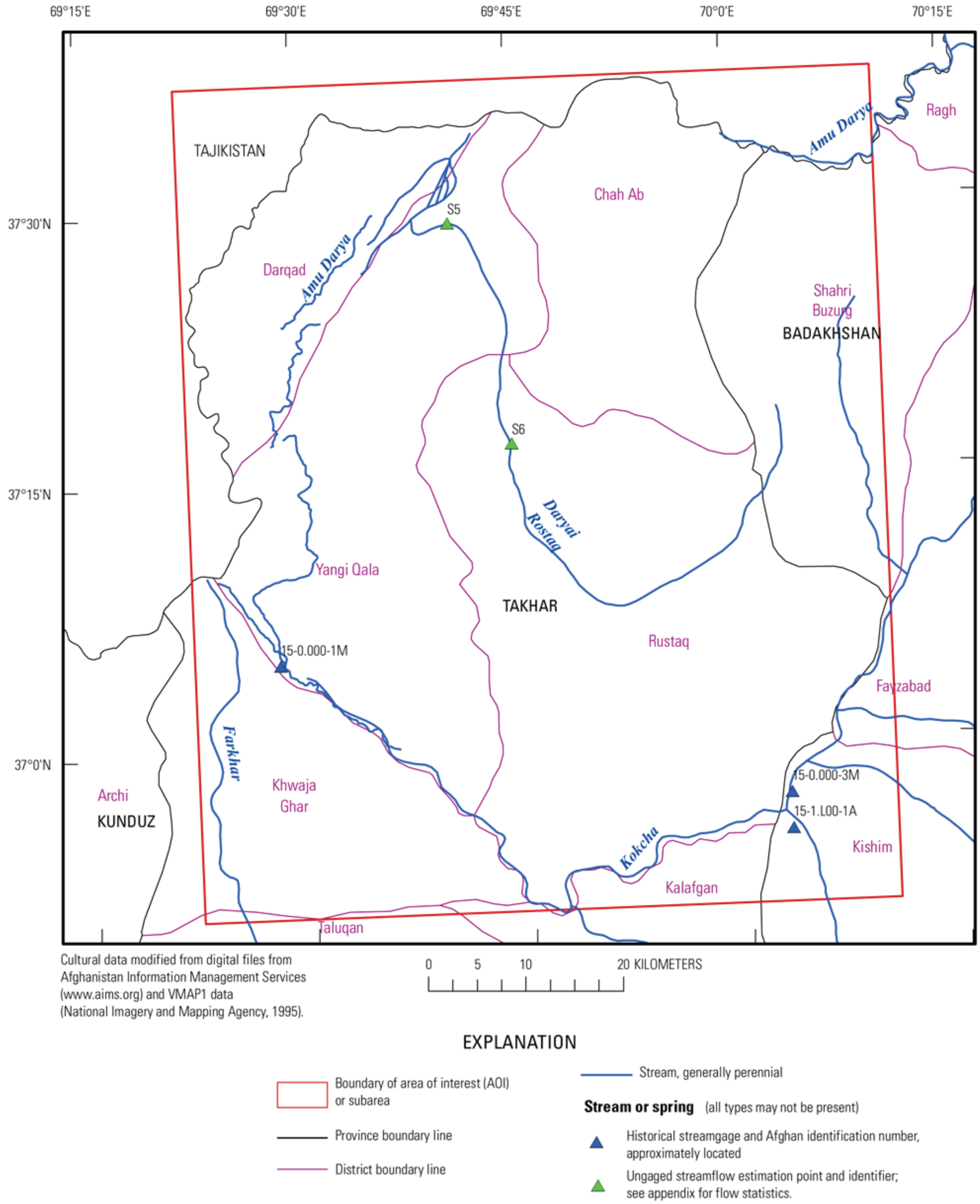


Figure 12B–1. (*a*) Landsat image showing the location of, and (*b*) place names, stream names, and streamgage station numbers in, the North Takhar gold placer area of interest in Afghanistan.

There are no Agromet stations located within the AOI, but there are two stations within 70 km of the center of the AOI. The Taluqan (Taloqan) Agromet station is located in Takhar Province approximately 55 km south-southwest of the center of the AOI. This is the closest Agromet station to the AOI for which 2009–2010 water year and long-term average (LTA) precipitation data are available. Precipitation data for the Taluqan Agromet station (Ministry of Agriculture, Irrigation, and Livestock,

2010) are shown in table 12B–1. The Agromet maps discussed above show the integration of data from several stations; therefore, precipitation values differ from those in table 12B–1. The total snowfall reported for the 2009–2010 water year at the Taluqan station was 74 cm (centimeters). For comparison, snowfall during the 2008–2009 water year was 127 cm.

Table 12B–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Taluqan and Faizabad Agrometeorological (Agromet) stations within 70 km of the North Takhar gold placer area of interest, Afghanistan.

[AOI, area of interest; km, kilometers; m, meters; mm, millimeters; °C, degrees Celsius; nr, not reported]

Agromet station	Distance from AOI center (km)	Elevation (m)	Precipitation				Temperature		
			2009–2010 annual (mm)	Long-term average[1]			Long-term average[1]		
				Annual (mm)	Monthly minimum (mm) and month	Monthly maximum (mm) and month	Minimum (°C) and month	Monthly mean (°C)	Maximum (°C) and month
Taluqan	55	820	518.5	563	0.1 June 0.3 August	131.1 March	nr	nr	nr
Faizabad	63	1,200	594.3	492.6	1.1 August	99.2 April	–0.6 January	11.3	26.9 July

[1]Long-term averages are based on data from 1942 to 1993 and 2005 to 2010 as reported in the Afghanistan Agrometeorological Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010).

The Faizabad Agromet station is approximately 63 km east of the center of the AOI. Available data for this station include 2009–2010 water year and LTA precipitation and temperature data.Precipitation and temperature data for the Faizabad Agromet station (Ministry of Agriculture, Irrigation, and Livestock, 2010) are shown in table 12B–1. The Faizabad Agromet station received a total of 45 cm of snow during the 2009–2010 water year. Snow fell at this Agromet station on 7 days during the 2009–2010 agricultural season: 1 in January, 5 in February, and 1 in March. The snow-depth map for 17 January, 2010 (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 6), indicates that snow depth ranged from less than 2 cm in the northwest corner of the AOI to 30 cm in the eastern part of the AOI.

The “Potential Natural Vegetation” described in Breckle (2007) is the vegetation cover that would be present if it had not been modified by human activity. Today, as a result of continued exploitation such as grazing, farming, and deforestation, much of the original natural vegetation is found only in a few remote areas of Afghanistan. The destruction of the natural vegetation has resulted in the degradation and erosion of the soil cover in some areas. Many areas exhibit signs of long-lasting desertification caused by human activity.

The vegetation is azonal riverine along the Amu Darya River in the northern part of the AOI (Breckle, 2007). The vegetation transitions to *Pistacia vera*-Woodlands to the east and to higher elevations in the AOI. Farther east and at still higher elevations, the vegetation is *Amygdalus*-Woodlands as classified by Breckle (2007). Much of the upland surface of the AOI is bedrock outcrop with thin alluvial cover and sparse vegetation. Azonal riverine vegetation likely was present in the stream valleys, but the trees have been harvested for fuel and building materials. Most land suitable for farming has been plowed and planted, especially along major stream valleys and some of the ephemeral tributary stream valleys. Large irrigated areas are present in the northwest corner of the AOI (fig. 12B–2).

12B.1.2 Demographics

The population in the North Takhar gold placer AOI is concentrated in the northwest corner of the AOI and in some of the major stream valleys as mapped by LandScan (Oak Ridge National Laboratory, 2010) (fig. 12B–3). The population density is related to the availability of water for domestic supply and irrigation. In a few areas, population density exceeds 5,000/km^2. Population density in most of the high-population areas ranges from 51 to 2,500/km^2; except in these areas, the AOI is sparsely populated. Some of the higher elevation areas are uninhabited, as indicated by the gray shading in figure 12B–3. Population densities in other areas range from 1 to 50/km^2. The population density shown in figure 12B–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

12B.1.3 Topography

The topography of the North Takhar gold placer AOI transitions from the low-elevation plains along the Amu Darya River to the mountains in the east (Davis, 2006) (fig. 12B–4). Elevations along the Amu Darya River range from 420 to 550 m (meters) above sea leval (asl). The elevations of some highest peaks in the eastern part of the AOI exceed 2,000 m asl, and one peak is mapped at 2,814 m asl (Bohannon, 2005). The wide valley formed by the Amu Darya River at the border between the AOI and Tajikistan is the dominant geographic feature in the northwest corner of the AOI (fig. 12B–1*b*).

12B.2 Geohydrology

The geohydrology of Afghanistan has been described in general terms by Abdullah and Chmyriov (1977, book 2). As defined in their "Geology and mineral resources of Afghanistan," the North Takhar gold placer AOI is in the North Afghanistan Artesian Region. The North Afghanistan Artesian Region is located in the north of the country and is part of the drainage area of the Amu Darya River. The outcrops and near-surface rocks in the AOI can be grouped according to their physical and hydraulic properties. The generalized geohydrology of the AOI is shown in figure 12B–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figures 12B–5*a* and *b* show the generalized geohydrology without topography for a clearer depiction of the geohydrologic units. Wells present in the map area (discussed in the Groundwater section) are shown in figures 12B–5*a* and *b*. Generalized geohydrologic groups were created from a country-wide geologic coverage (Doebrich and Wahl, 2006) by combining sediments and rocks into major sediment- or rock-type groups of similar hydrologic characteristics. The geohydrologic groups in the AOI, ranked from high to low relative hydraulic conductivity (Freeze and Cherry, 1979, table 2.3), are "river channel; sands, undifferentiated; loess and fine sediments; tills; conglomerate sediments and rocks; sedimentary rocks; and intrusive rocks and lavas" (figs. 12B–4, 12B–5*a*). Doebrich and Wahl (2006) used geologic maps at a scale of 1:250,000, modified from Russian and Afghan Geological Survey (AGS) mapping, to generate the country-wide geologic coverage. The 1:250,000-scale geologic map that covers this AOI is provided by Fridrich and others (2005).

River-channel sediments and sands are present in the Amu Darya River valley and other river valleys in the AOI. The thicknesses of these deposits are unknown, but in the Amu Darya River valley they could be tens to hundreds of meters thick. Where these units are in the Amu Darya River valley, they could compose an alluvial aquifer with considerable groundwater resources. Sands mapped on topographic highs (fig. 12B–4) may compose unconsolidated aquifers of limited thickness and extent overlying bedrock units. The conglomerate sediments and rocks, which in many areas of Afghanistan are semi-consolidated, are deposited on topographic high areas overlying bedrock units. The conglomerate sediments and rocks occupy the largest areal extent of all rock types in the AOI. If these deposits are thick and laterally extensive, this unit could also be a source of considerable groundwater in the AOI. There is a small outcrop of sedimentary rocks near the southeast corner of the AOI. It appears that this outcrop has been exposed by either nondeposition or erosion of the overlying conglomerate sediments and rocks group. Field investigations, including geologic mapping, geophysical surveys, and borehole drilling and testing, are needed to determine whether the sands and conglomerate sediments and rocks groups represent areas of groundwater resources in the AOI. If sedimentary rocks are present beneath the conglomerate sediments, those rocks also could be a potential source of groundwater in the AOI. Additional investigation also would be needed to determine the groundwater potential of this unit.

12B.2.1 Surface Water

A network of major, mostly perennial streams in the North Takhar gold placer AOI, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and

Mapping Agency, 1995), is shown in figure 12B–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 12B–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI also are shown in figure 12B–1b.

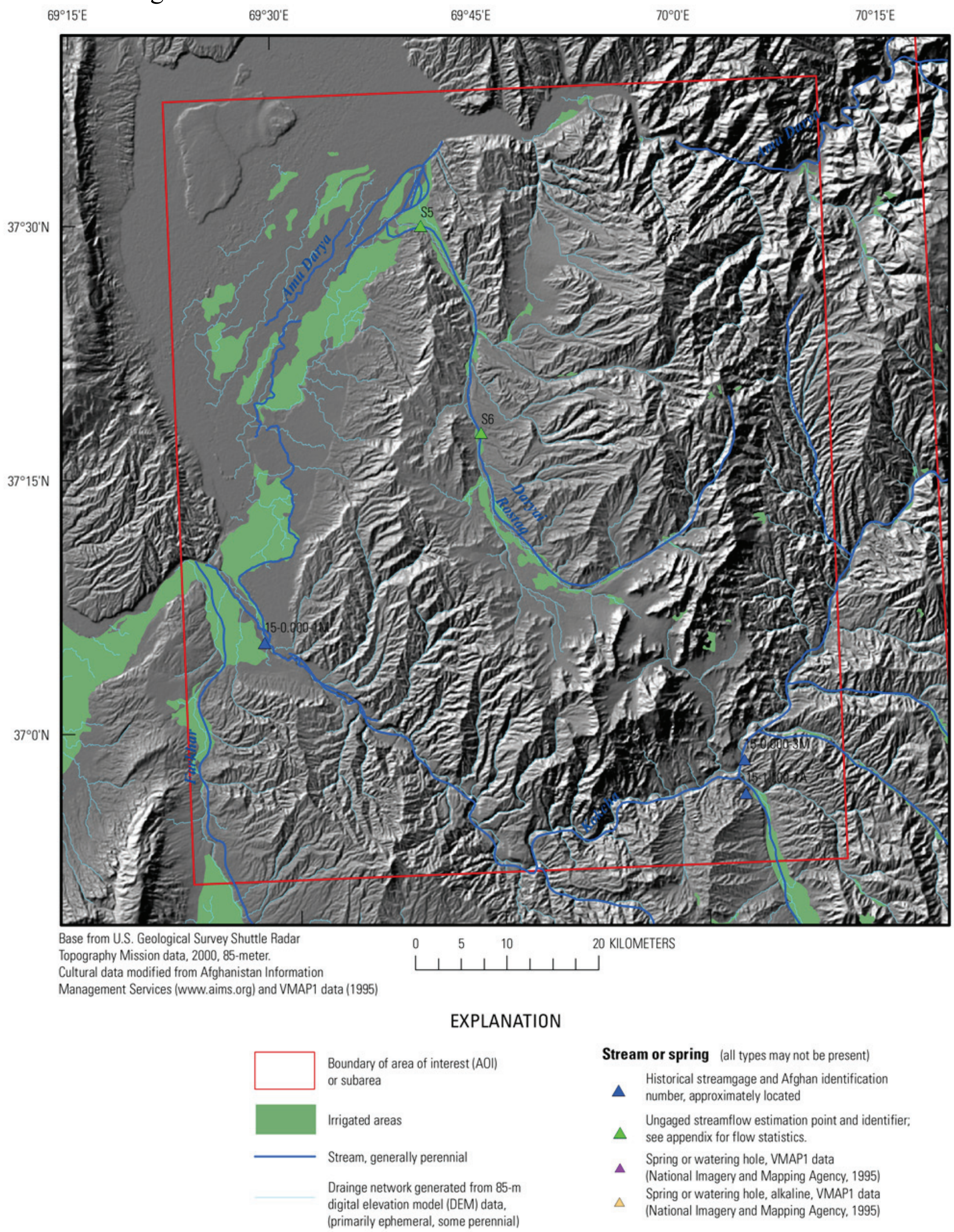


Figure 12B–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the North Takhar gold placer area of interest in Afghanistan.

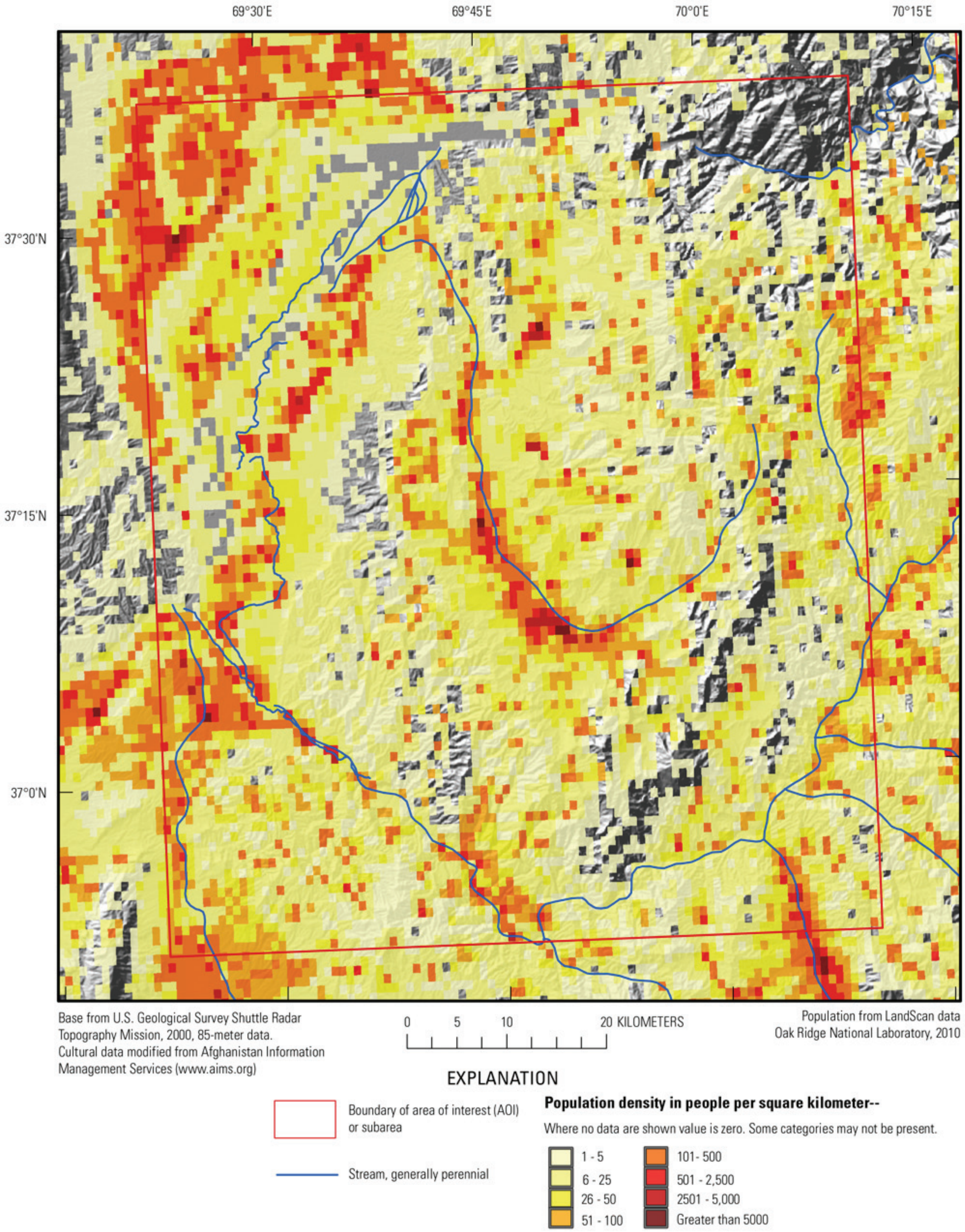


Figure 12B–3. Population density of the North Takhar gold placer area of interest in Afghanistan.

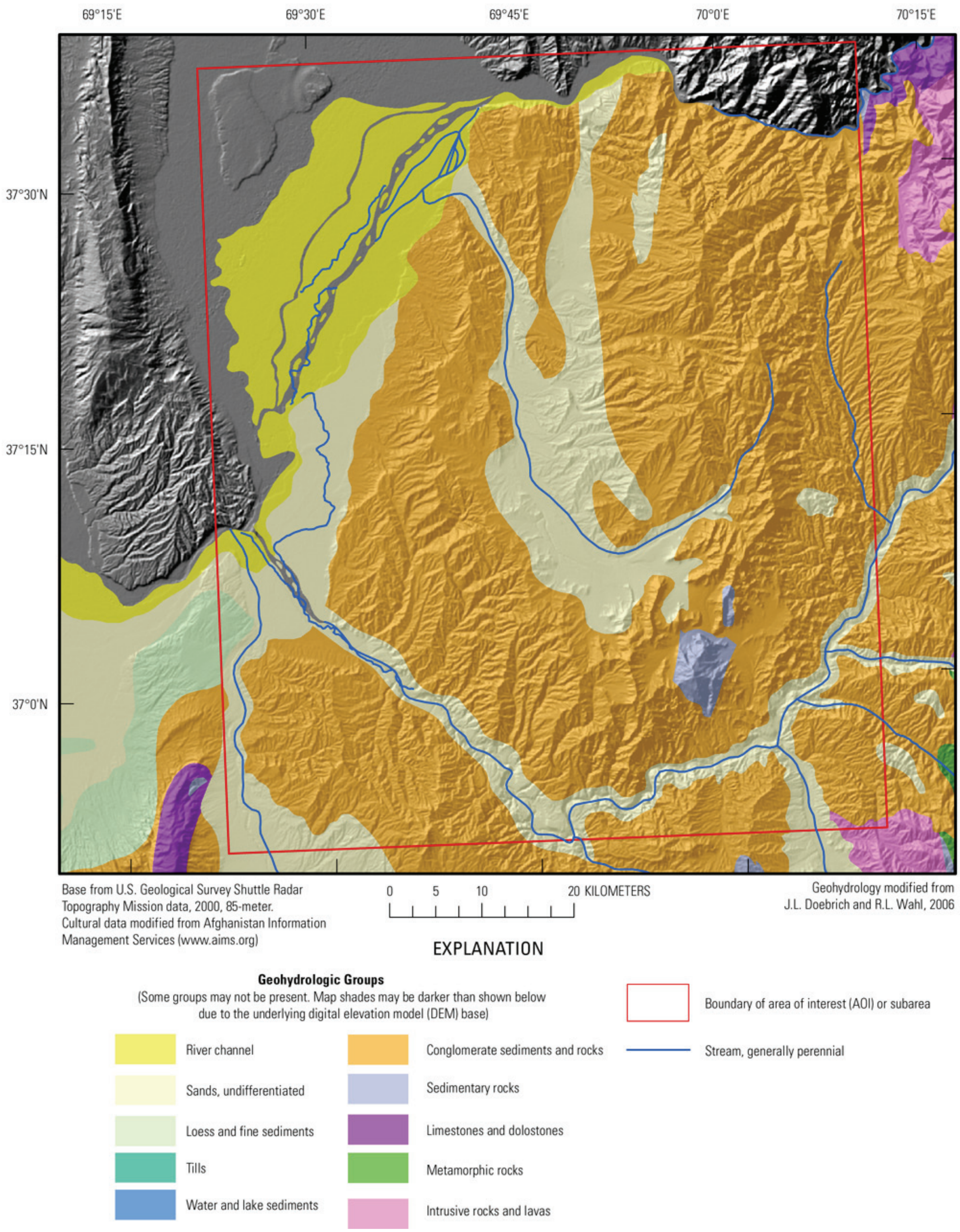


Figure 12B–4. Topography and generalized geohydrology of the North Takhar gold placer area of interest in Afghanistan.

There are three streamgage stations in the AOI. Two are located on the Kokcha River and one is on a tributary to the Kokcha River. The Kokcha River at Khojaghar streamgage station

(Afghan identification number 15-0.000-1M) is located near the western border of the AOI (figs. 12B–1*b*, 12B–2). This station is at an elevation of 446 m asl and has a drainage area of 20,645 km^2 and a period of record that extends from 26 April, 1964, to 30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0096 $m^3/s/km^2$ (cubic meters per second per square kilometer). The seasonal timing of maximum and minimum monthly streamflow is high flows in the early to mid summer and low flows in the late fall and winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 12B–2. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php*.

The Kokcha River near Keshem streamgage station (Afghan identification number 15-0.000-3M) is located in the southeast corner of the AOI (figs. 12B–1*b*, 12B–2). This station is at an elevation of 805 m asl and has a drainage area of 16,765 km2 and a period of record that extends from 1 October, 1969, to 30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0095 m3/s/km2. The seasonal timing of maximum and minimum monthly streamflow is high flows in the early to mid summer and low flows in the winter through early spring. A statistical summary of monthly and annual mean streamflows for this station is presented in table 12B–3.

The Keshem River near Keshem streamgage station (Afghan identification number 15-1.L00-1A) is located in the southeast corner of the AOI (figs. 12B–1*b*, 12B–2). This station is at an elevation of 822 m asl and has a drainage area of 2,145 km^2 and a period of record that extends from 8 October, 1969, to 30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0096 $m^3/s/km^2$. The seasonal timing of maximum and minimum monthly streamflow is high flows in the early to mid summer and low flows in the winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 12B–4.

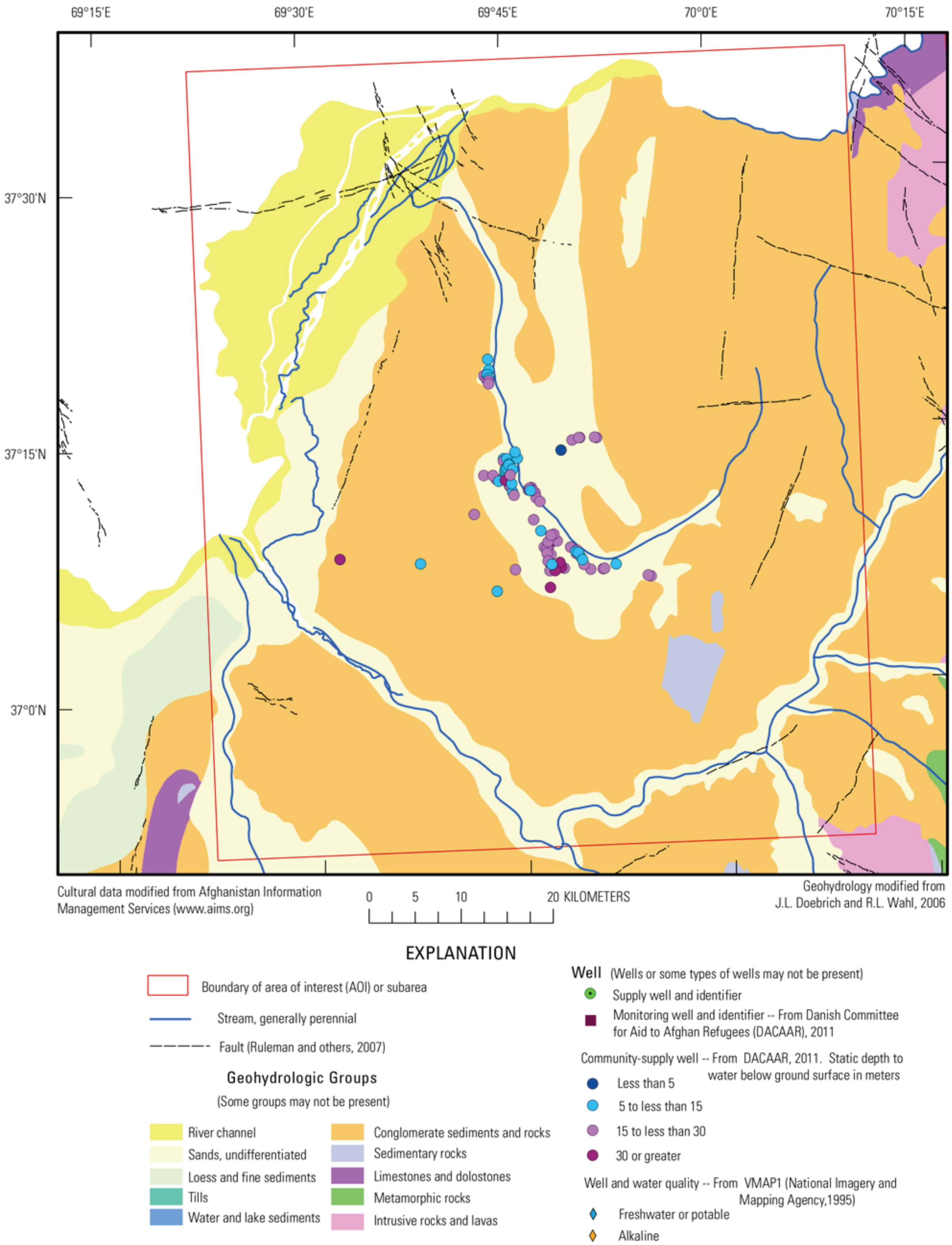
Streamflow statistics were estimated for selected ungaged streams that may be prominent in the AOI or subareas to provide some probable estimates of flow for these locations. Streamflow statistics, presented in appendix 2, were calculated for points S5 and S6 (figs. 12B–1*b* and 12B–2) using a drainage-area-ratio method (Olson and Mack, 2011) based on historical flows at the Keshem River near Keshem streamgage station (Afghan identification number 15-1.L00-1A) (Olson and Williams-Sether, 2010). The estimated mean annual streamflow for point S5 (app. 2), with a drainage area of 1,246 km^2, is about 11.5 m^3/s (cubic meters per second). By applying the same method, the estimated mean annual streamflow at point S6 is 6.37 m^3/s. The seasonal timing of maximum and minimum monthly streamflow, with high flows in the summer and low flows in winter (app. 2), probably is similar to that at the Keshem River near Keshem station. Appendix 2 also shows streamflow estimates based on historical flows at the Farkhar River near Taloqan streamgage station. The drainage area of the Farkhar River near Taloqan streamgage station is twice that of the Keshem River near Keshem station, and the streamflow per unit area is greater (0.01 $m^3/s/km^2$); therefore, flows estimated by using data from the Farkhar River near Taloqan station are greater than those estimated by using data from the Keshem River near Keshem station. The Keshem River station was used in the analysis above because it is the most representative historical gage, and using data from this station results in more conservative streamflow estimates than using data from the Farkhar River station.

The Amu Darya and Kokcha Rivers are considerable surface-water resources within the AOI and may provide sufficient water for mining-related activities. The dense population and irrigation along these rivers indicate that these water sources are highly utilized. Streamflow monitoring and additional investigations are needed to assess the potential effects of additional withdrawals from these rivers on local and downstream water users.

12B.2.2 Groundwater

Approximately 240 shallow community groundwater-supply wells have been installed in the North Takhar gold placer AOI by NGOs. Information about these wells can be found in a database maintained by DACAAR (Danish Committee for Aid to Afghan Refugees, 2011). Well-depth and static-water-level information is available for 90 of the wells in this database (figs. 12B–5*a*,*b*). About

78 percent of the supply wells are more than 30 m deep and the deepest well is 54 m deep. The median well depth is moderately deep at 39 m. The depth to water in 33 percent of the supply wells in the AOI is less than 15 m (fig.12B–5*a*). The median depth to water is 18 m.



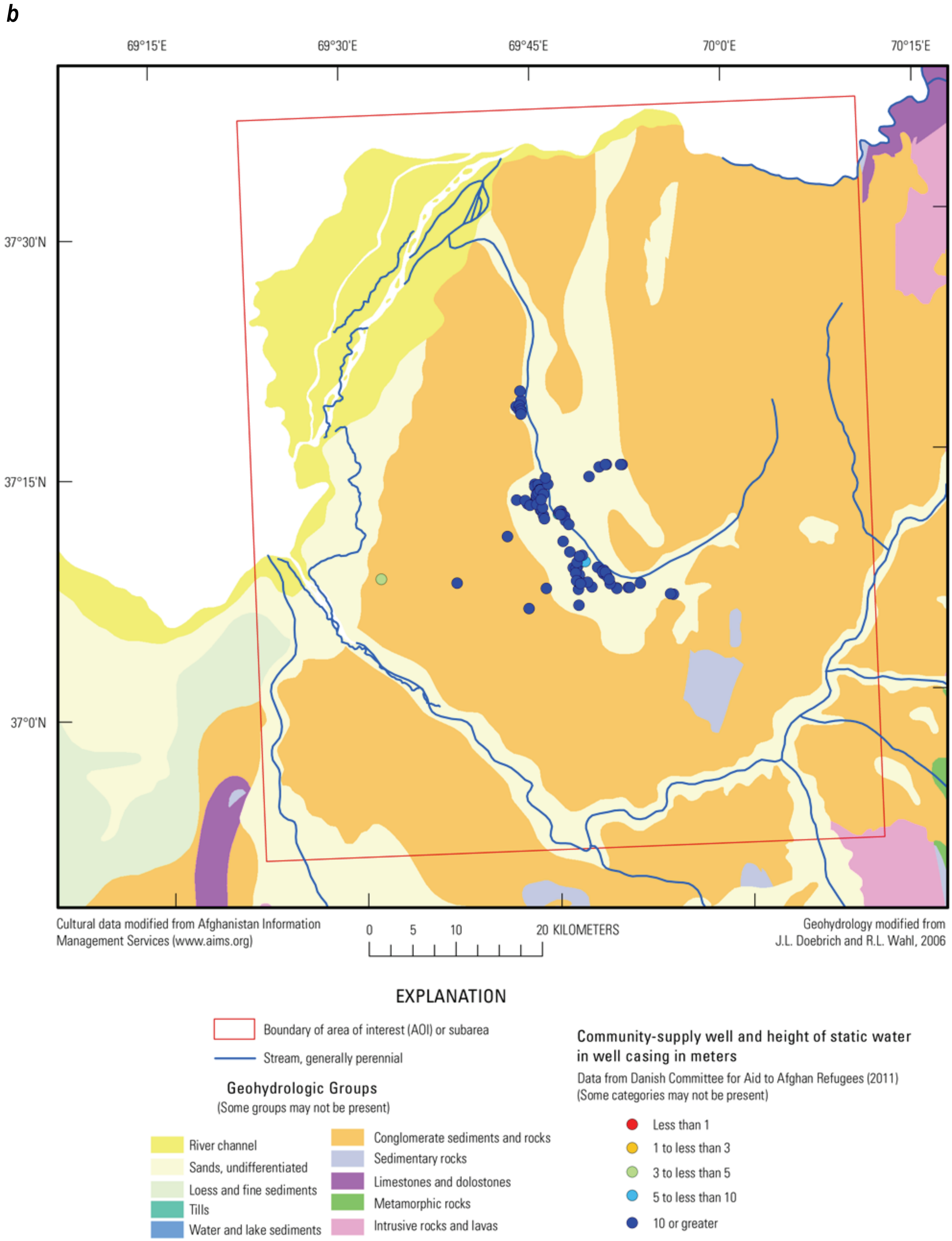


Figure 12B–5. (*a*) Generalized geohydrology, mapped faults, well locations, and depth to water, and (*b*) geohydrology and height of static water in well casings in community supply wells in the North Takhar gold placer area of interest in Afghanistan.

Table 12B–2. Statistical summary of monthly and annual mean streamflows for the Kokcha River at Khojaghar streamgage station (Olson and Williams-Sether 2010).
[m^3/s, cubic meters per second]

15-0.000-1M KOKCHA RIVER AT KHOJAGHAR

Month	Maximum		Minimum		Mean			
	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	142	1968	82.2	1972	110	19.9	0.18	4.67
November	111	1970	64.8	1978	85.9	16.3	0.19	3.65
December	99.8	1970	53.1	1973	72.3	13.8	0.19	3.08
January	92.7	1970	42.5	1973	62.6	15.2	0.24	2.66
February	84.3	1970	46.5	1971	63.3	14.1	0.22	2.69
March	153	1969	42.7	1977	80.4	24.2	0.30	3.42
April	201	1978	60.7	1977	133	47.4	0.36	5.67
May	368	1969	128	1974	225	70.7	0.31	9.57
June	748	1978	291	1974	484	137	0.28	20.6
July	703	1969	313	1970	511	133	0.26	21.7
August	472	1967	205	1972	338	76.5	0.23	14.4
September	240	1967	130	1972	186	30.9	0.17	7.90
Annual	**262**	**1969**	**144**	**1972**	**198**	**37.4**	**0.19**	**100**

Table 12B–3. Statistical summary of monthly and annual mean streamflows for the Kokcha River near Keshem streamgage station (Olson and Williams-Sether 2010).
[m^3/s, cubic meters per second]

15-0.000-3M KOKCHA RIVER NEAR KESHEM

Month	Maximum		Minimum		Mean			
	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	116	1970	69.5	1978	92.9	15.6	0.17	4.86
November	105	1970	47.7	1978	71.1	16.7	0.23	3.72
December	80.7	1970	41.0	1978	56.1	11.3	0.20	2.93
January	73.0	1970	35.9	1978	48.4	11.4	0.24	2.53
February	67.4	1970	39.0	1977	48.1	9.37	0.19	2.51
March	67.5	1973	39.6	1977	57.0	8.59	0.15	2.98
April	153	1975	49.3	1977	102	38.0	0.37	5.34
May	271	1978	105	1977	196	61.8	0.31	10.3
June	666	1978	262	1974	402	146	0.36	21.0
July	579	1978	285	1970	414	111	0.27	21.6
August	374	1978	171	1972	274	56.2	0.21	14.3
September	180	1978	104	1972	151	25.9	0.17	7.89
Annual	**210**	**1978**	**122**	**1972**	**160**	**29.3**	**0.18**	**100**

Table 12B–4. Statistical summary of monthly and annual mean streamflows for the Keshem River near Keshem streamgage station (Olson and Williams-Sether 2010).
[m^3/s, cubic meters per second]

15-1.L00-1A KESHEM RIVER NEAR KESHEM

Month	Maximum		Minimum		Mean			
	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	12.2	1973	9.39	1972	11.4	0.99	0.09	4.78
November	10.6	1973	7.67	1974	8.93	1.05	0.12	3.75
December	10.1	1978	5.56	1970	7.60	1.54	0.20	3.19
January	8.25	1978	5.20	1970	6.45	1.11	0.17	2.71
February	8.01	1978	3.83	1972	5.84	1.48	0.25	2.46
March	11.7	1973	4.59	1974	7.09	2.11	0.30	2.98
April	24.4	1978	4.90	1974	14.5	6.65	0.46	6.1
May	48.3	1978	8.62	1974	28.6	11.1	0.39	12.0
June	74.7	1978	28.8	1974	50.7	16.6	0.33	21.3
July	83.8	1976	27.5	1970	50.1	19.8	0.40	21.00
August	41.3	1973	20.8	1974	29.5	6.12	0.21	12.4
September	23.4	1973	13.0	1971	17.2	3.84	0.22	7.25
Annual	**26.2**	**1978**	**12.7**	**1974**	**20.5**	**4.85**	**0.24**	**100**

Available well-construction information is limited; however, most wells are "tube" wells (driven wells with polyvinyl chloride (PVC) casing) or dug wells with concrete-ring casing. Wells are generally installed in unconsolidated sediments, completed a few meters below the depth at which water is first encountered, and equipped with a hand pump. The wells near perennial streams are likely to be completed in river-channel sediments; however, the limited areal extent and thickness of these deposits precluded showing them on the 1:250,000-scale geologic maps. Figure 12B–5*b* shows the height of static water in the casings of the water-supply wells (well depth minus static depth to water). The median height of static water in well casings is 19.5 m. In all but three wells in the AOI for which information is available, more than 10 m of static water is present. No groundwater-monitoring wells are in or near the AOI; however, wells with more than 10 m of static water are not likely to be subject to drying due to seasonal water-level fluctuations. The shallow and moderately thick alluvial aquifers in the valley bottoms of the AOI may be a groundwater resource with the potential to supply water for mining activities; however, the quality and sustainability of the water in these aquifers is not known, and the effects of any additional withdrawals on existing wells would need to be closely monitored to avoid adverse effects on existing water uses. The characteristics of groundwater in deeper, conglomeritic aquifers also are not known.

12B.2.3 Lineament Analyses

Lineaments are photolinear features that could be the result of underlying zones of high-angle bedrock fractures, fracture zones, faults, or bedding-plane weaknesses. Lineament analyses of the North Takhar gold placer AOI were conducted using DEM and natural-color satellite imagery (fig. 12B–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 12B–7*a*,*b*). Lineament identification and analysis have long been used as a reconnaissance tool for identifying areas in carbonate bedrock environments where groundwater resources are likely to be found (Lattman and Parizek, 1964; Siddiqui and Parizek, 1971). Lineament analysis is increasingly used to identify areas of high relative well yields in other bedrock settings, including crystalline bedrock

(Mabee, 1999; Moore and others, 2002). The lineaments shown in figure 12B–6 were delineated visually, whereas those in figure 12B–7 were delineated using an automated process and on the basis of the multispectral characteristics of the land surface (B.E. Hubbard, T.J. Mack, and A.L. Thompson, U.S. Geological Survey August 24, 2011, written commun.).

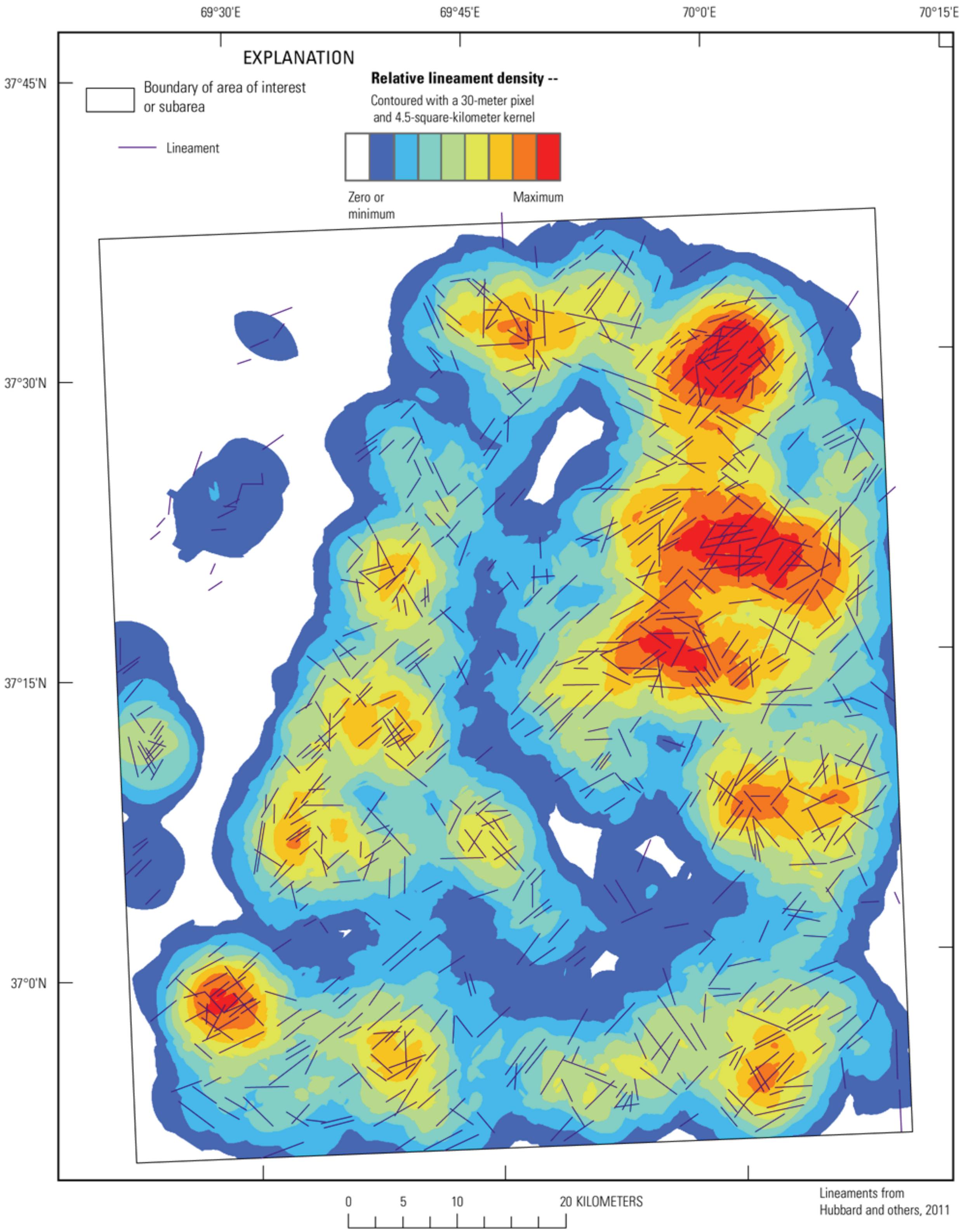


Figure 12B–6. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the North Takhar gold placer area of interest in Afghanistan.

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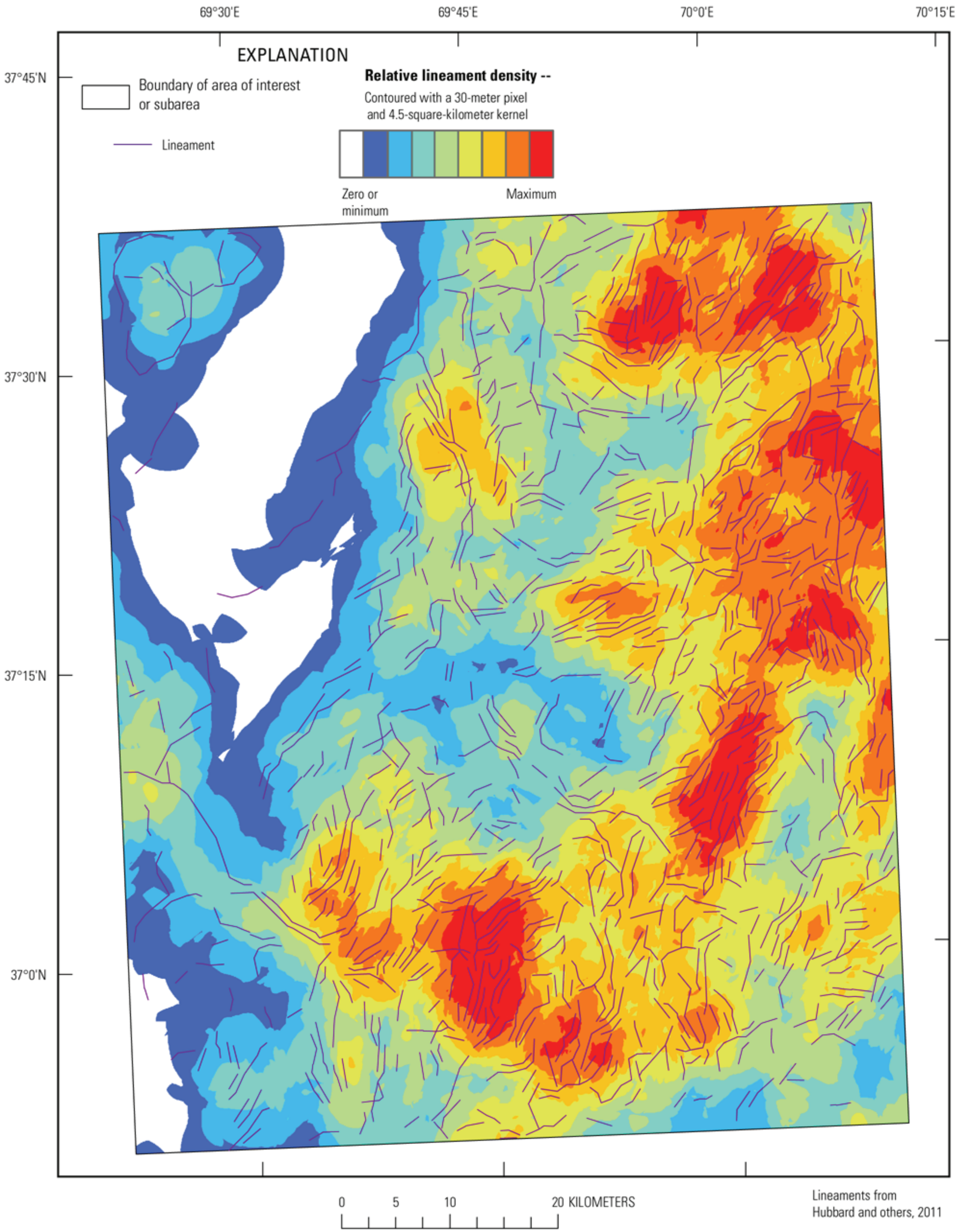
69°30'E
69°45'E
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37°15'N
37°0'N
EXPLANATION
Boundary of area of interest or subarea
Lineament
Relative lineament density --
Contoured with a 30-meter pixel and 4.5-square-kilometer kernel
Zero or minimum
Maximum
0
5
10
20 KILOMETERS
Lineaments from Hubbard and others, 2011

b

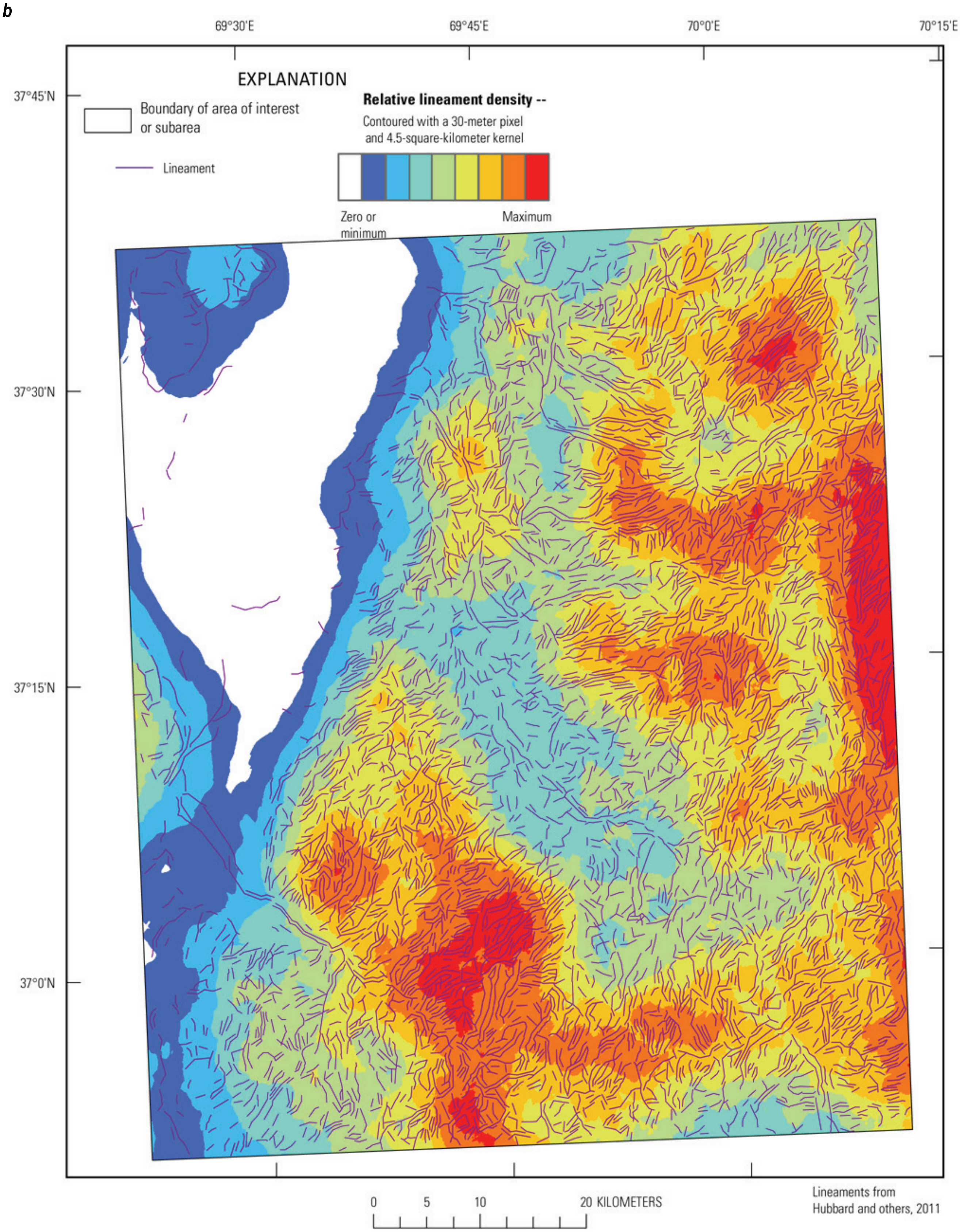

Figure 12B–7. (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery, and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery, in the North Takhar gold placer area of interest in Afghanistan.

Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. There are many northeast-trending lineaments in the AOI that may be caused by fracturing related to regional structure or bedding-plane weaknesses. Areas where lineament density is high, such as the northeast areas of the AOI (figs. 12B–6, 12B–7*a*, 12B–7*b*), potentially are areas where bedrock fractures are more prevalent than in other areas of the AOI. Lineaments provide an indication of areas that warrant further investigation for optimal bedrock water-well placement. Lineaments may also indicate areas of preferential flow and storage of groundwater, and areas with a high density of lineaments may indicate high secondary porosity. Any lineament analyses, including those presented in this investigation, need to be corroborated by field investigations and additional data to confirm the nature of the lineaments and their relation to water-filled bedrock fracture zones.

12B.3 Summary and Conclusions

Water resources are more likely to be available in the North Takhar gold placer AOI than in other areas of Afghanistan as determined from the relatively high streamflows, indicating high recharge rates, and the presence of potential aquifer units in the AOI. The presence of considerable groundwater resources is particularly likely in the Amu Darya River valley and along other perennial streams in the AOI. Surface-water resources in the AOI also are likely to be considerable on the basis of historical information. Shallow to moderately deep alluvial aquifers in valley bottoms and streams are a highly utilized resource in the AOI. The diversion of water from rivers to support mining activities would need to be closely monitored, particularly during low-flow periods, if the quantity and quality of the water resource are to be preserved so that surface-water flow remains sufficient to supply water for irrigation and to provide recharge to the aquifers that supply groundwater to the shallow wells for domestic consumption.

No information is available about deep groundwater in the AOI or adjacent areas. Some areas of the AOI, as indicated by generalized geohydrologic maps and lineament analyses, are likely areas for further exploration for groundwater resources. The quality and sustainability of water resources in the AOI remain to be determined, however. Close monitoring and careful management of potential new surface-water or groundwater withdrawals would help to protect the quantity and quality of the existing supply for current local water uses. Field investigations, including geologic mapping, geophysical surveys, and hydraulic well testing, are needed to adequately characterize the extent and availability of groundwater resources in the AOI.

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