Chapter 2C. Geohydrologic Summary of the Aynak Copper, Cobalt, and Chromium Area of Interest

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2C.1 Introduction

This chapter describes the geohydrology of the Aynak copper, cobalt, and chromium area of interest (AOI) in Afghanistan identified by Peters and others (2007). The AOI is located in southern Kabul, northern Logar, and eastern Wardak Provinces (fig. 2C–1*a*,*b*) and is part of the Kabul Basin. The Logar Valley subarea, at 1,013 km^2 (square kilometers), is the largest subarea in the 3,439-km^2 AOI.

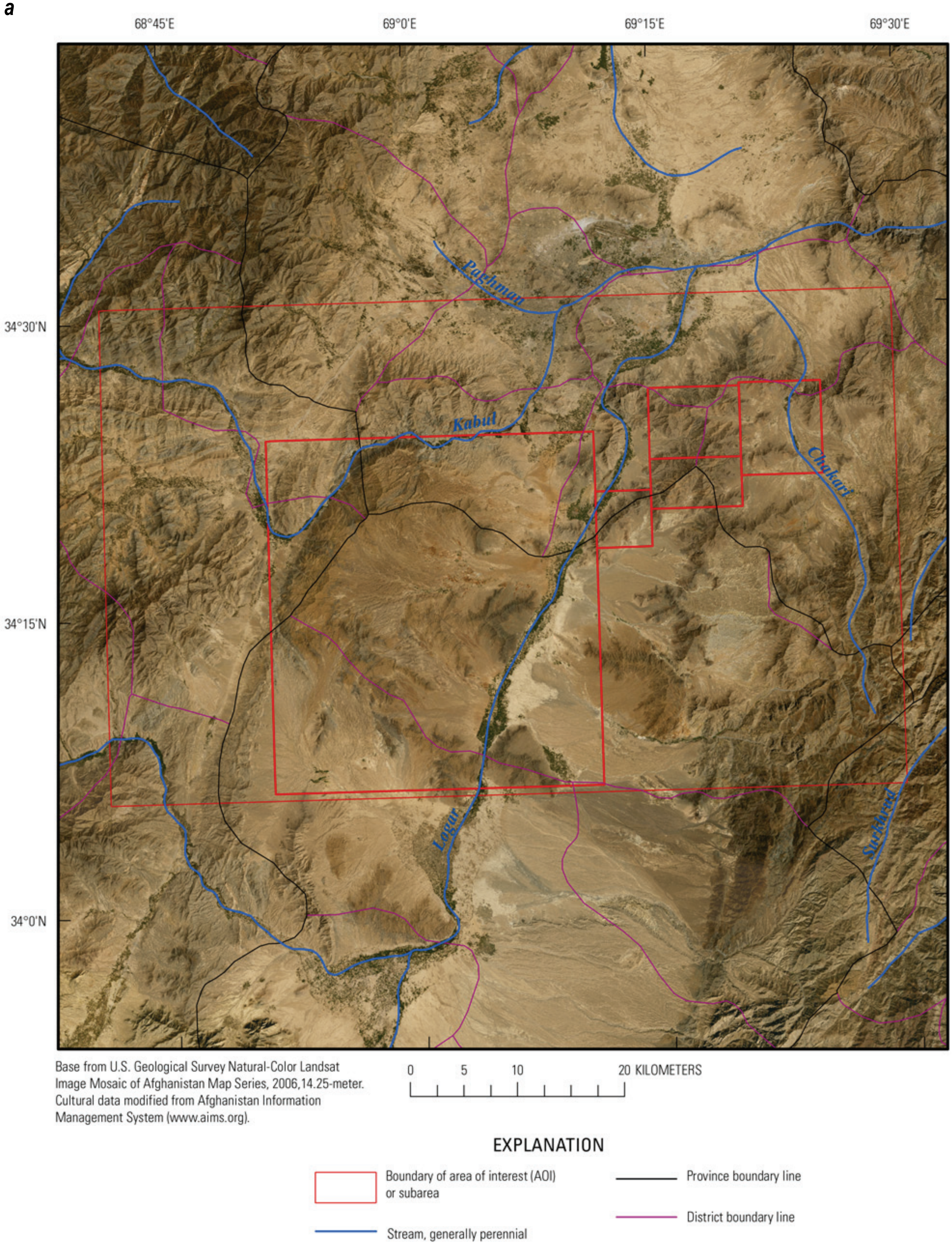
Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information 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.

2C.1.1 Climate and Vegetation

Climate information for the Aynak copper, cobalt, and chromium 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.

a



Base from U.S. Geological Survey Natural-Color Landsat Image Mosaic of Afghanistan Map Series, 2006, 14.25-meter. Cultural data modified from Afghanistan Information Management System (www.aims.org).

b

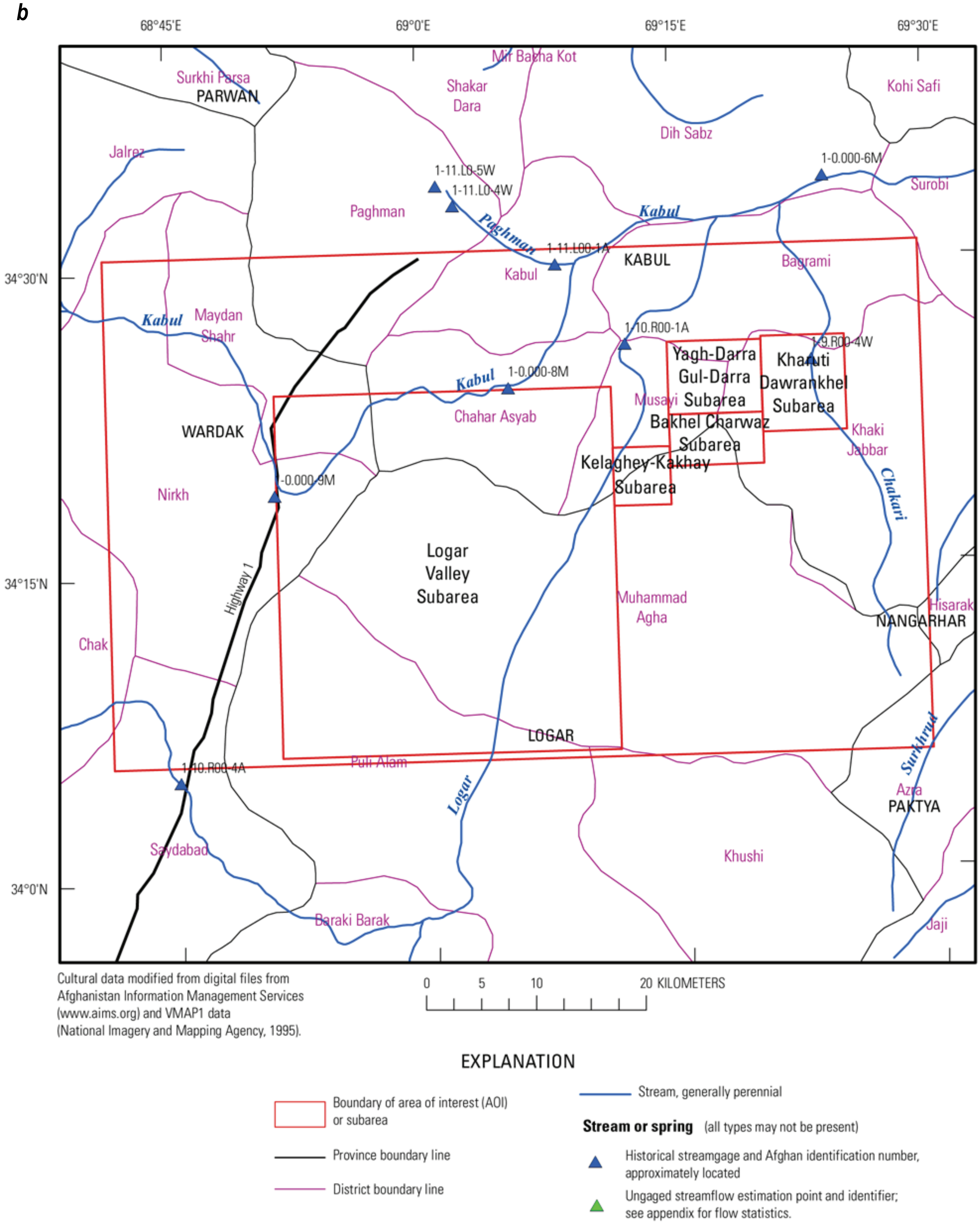


Figure 2C–1. (*a*) Landsat image showing the location of, and (*b*) place names, stream names, and streamgage station numbers in, the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

The AOI is located in the Capital region of the Agromet network and includes several precipitation stations (Ministry of Agriculture, Irrigation, and Livestock, 2010). The yearly observed total precipitation for the AOI in the 2009–2010 water year as reported in the Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 2) ranged from 221 to 300 mm (millimeters). Available data for the Kabul Agromet station, just inside the northern border of the AOI in Kabul, include 2009–2010 water year and long-term average (LTA) precipitation and temperature data. A statistical summary of precipitation and temperature data for the Kabul Agromet station is shown in table 2C–1.

An Agromet station located in the southeast corner of the Logar Valley subarea had a total of 7 snow days during the 2009–2010 water year, distributed as follows: November and December 2009, 1 snow day each; January 2010, 2 snow days; and February 2010, 3 snow days. During the 2009–2010 water year, this station received a total of 48 cm (centimeters) of snow, compared to the LTA of 137 cm. The Afghanistan snow-depth map in the 2009–2010 Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010) showed that the AOI had 2 to 10 cm of snow cover on 17 January, 2010, but this snow cover was estimated prior to the 3 days of snow in February 2010.

The “Potential Natural Vegetation” described in Breckle (2007) is the vegetation cover that would be present if not 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.

Although the natural vegetation in Afghanistan has been severely degraded, there are some areas where native vegetation is still dominant, such as high and remote mountain regions and extreme desert environments. The “Map of potential natural vegetation” in Breckle (2007, fig. 2) shows two vegetation zones within the AOI. The vegetation zones are controlled by elevation, climate, and amount of soil development. Much of the surface of the AOI above the basin bottoms is bedrock outcrop and has very sparse vegetation. The lower elevations are classified as *Pistacia atlantica* woodlands, which give way to *Amygdalus* woodlands (Breckle, 2007); however, there is very little actual woodland. Irrigated fields and pastures are present in the valleys in the AOI wherever water can be accessed, and small orchards may be present (fig. 2C–3).

Table 2C–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Kabul Agrometeorological (Agromet) station in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

[AOI, area of interest; km, kilometers; m, meters; mm, millimeters; °C, degrees Celsius]

			Precipitation				Temperature		
				Long-term average[1]			Long-term average[1]		
Agromet station	Distance from AOI center (km)	Elevation (m)	2009-2010 annual (mm)	Annual (mm)	Monthly minimum and month (mm)	Monthly maximum and month (mm)	Minimum and month (°C)	Monthly mean (°C)	Maximum and month (°C)
Kabul	24	1,810	304.3	317.5	1.2 June and August	83.2 April	–2.6 January	9.8	24.8 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).

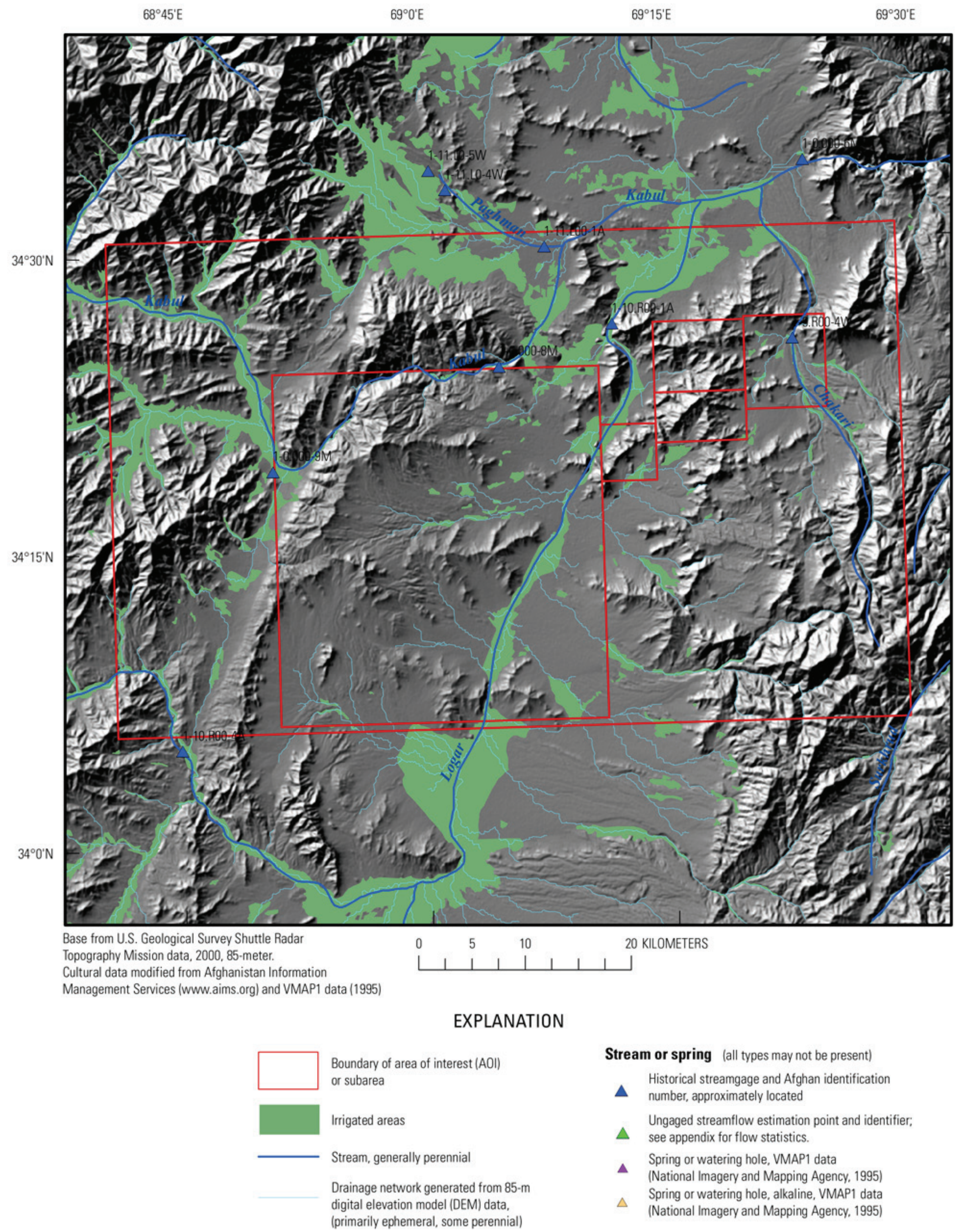


Figure 2C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

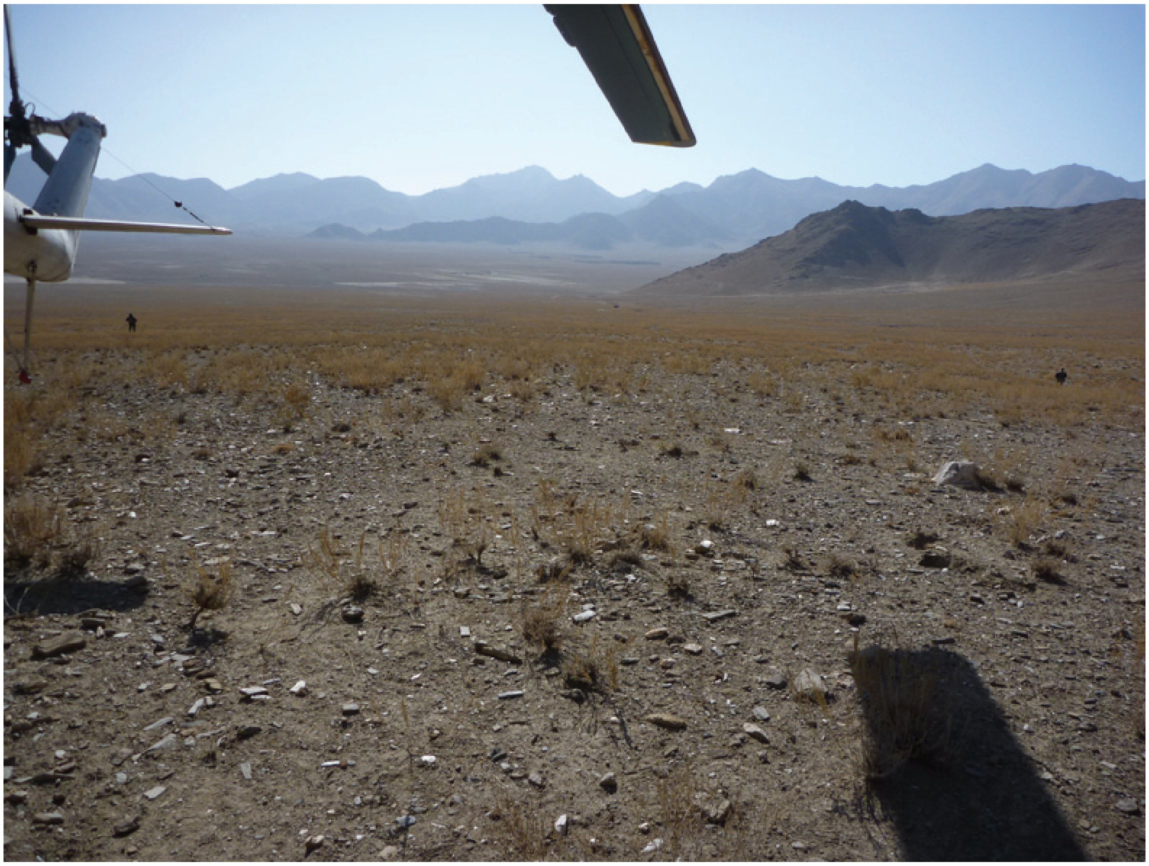


Figure 2C–3. Photograph showing the Chakari River basin looking south from the Kharuti Dawrankhel subarea, Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

2C.1.2 Demographics

Population density in Kabul ranges from greater than 5,000/km^2 within the metropolitan area to 2,501 to 5,000/km^2 in the surrounding urban areas of the Aynak copper, cobalt, and chromium AOI as mapped by LandScan (Oak Ridge National Laboratory, 2010). Kabul, the capital of Afghanistan, is located at the northern boundary of the AOI (fig. 2C–1*b*). Some small areas in the northern part of the AOI near the junction of the Kabul and Paghman Rivers have densities greater than 20,000/km^2. Dense populations in the AOI are concentrated along the Kabul and Logar Rivers; these populated areas coincide with irrigated areas (fig. 2C–2). The city of Kabul has a population greater than 4 million and the greatest population density in Afghanistan. The population density shown in figure 2C–4 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

Elsewhere in the AOI are many small settlements with population densities in the range of 101 to 500/km^2 (fig. 2C–4). The population density away from the rivers, in the basins without perennial streams, and in the upland areas ranges from 0 to 50/km^2. For example, the areas of the Chakari River basin south of the Bakhel Charwaz and Kharuti Dawrankhel subareas are largely uninhabited (fig. 2C–3). Much of the smaller subareas in the AOI, particularly the Yagh-Darr Gull Darra and Bakhel Charwaz (fig. 2C–1*b*), are generally populated only where springs flow from upland areas. The high, rugged mountains in the AOI are uninhabited (fig. 2C–3). Afghanistan Highway 1 is a primary road in the western part of the AOI, and Afghanistan Highway 76 (not shown) follows the Logar River through the AOI (fig. 2C–1*b*). With the exception of Highways 1 and 76, and the roads and streets within the capital city of Kabul, all roads in the AOI are mapped as “tracks” on the district maps for this area (Afghanistan Information Management Service, 2004).

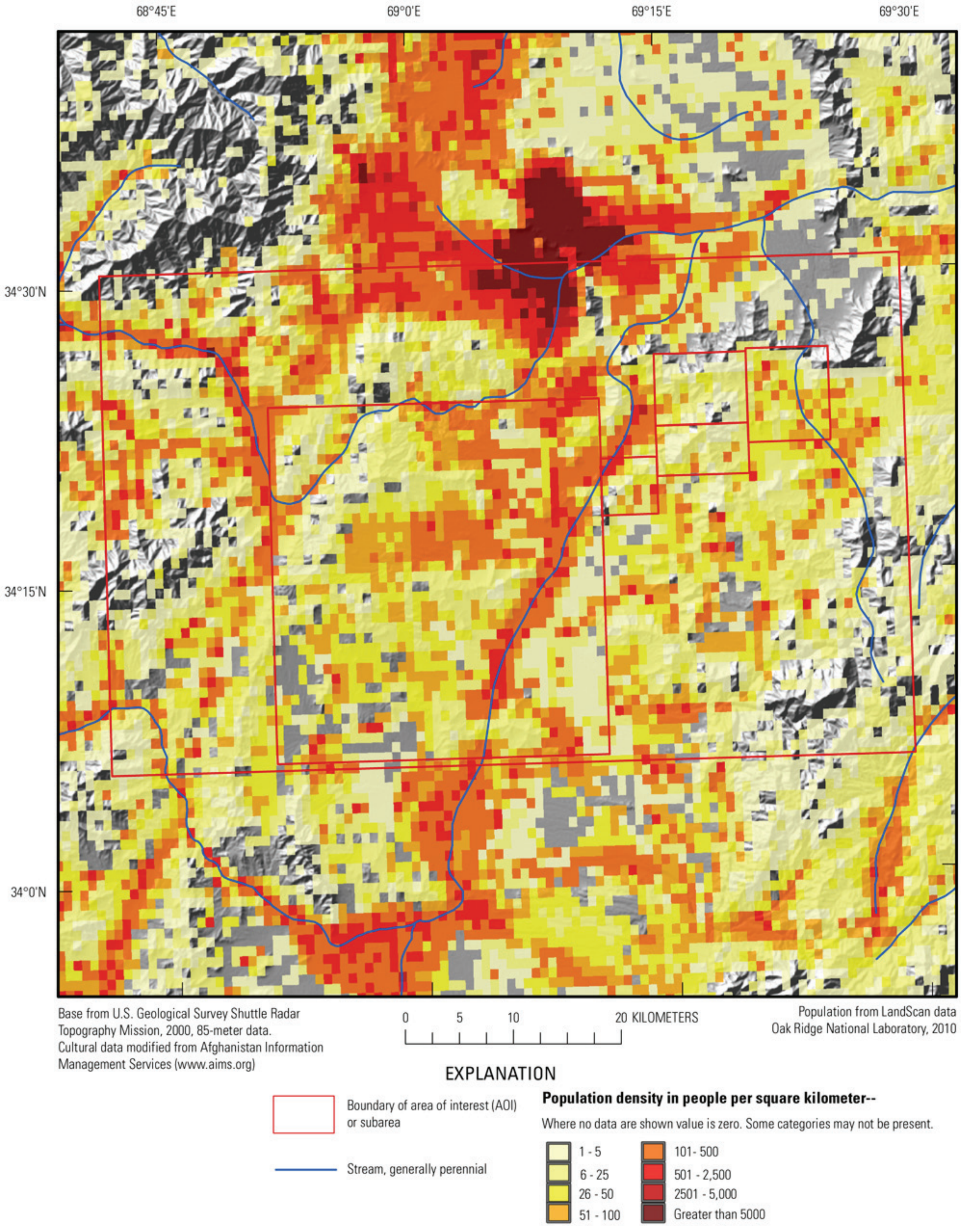


Figure 2C–4. Population density of the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

2C.1.3 Topography and Geomorphology

The topography of the Aynak copper, cobalt, and chromium AOI is dominated by the river valleys formed by the Kabul, Logar, and Chakari Rivers (fig. 2C–1*a*,*b*). The middle of the AOI is a wide valley formed by the drainage network of the Logar River. The elevation of the valley ranges from 1,800 m (meters) above sea level (asl) along the Logar River to 2,000 m asl. The valley is flanked on the east and west by high mountains that generally trend north-northeast. The mountains in the western half of the AOI have many peaks whose elevations exceed 4,000 m asl. In the lower reaches of many of the smaller streams, the relief between the stream bottoms and flanking ridge tops is 1,000 m. The mountains in the eastern part of the AOI also have some peaks whose elevations exceed 4,000 m asl; most high peaks have elevations of about 3,500 m asl. In these mountains, relief between valley bottoms and ridge tops commonly exceeds 1,000 m (Bohannon, 2005). A prominent topographic feature in the western part of the AOI is a long, north-northeast-trending fault-controlled valley (fig. 2C–5) (Bohannon and Turner, 2005; Davis, 2006).

The geomorphology of the AOI is dominated by the Kabul, Logan, and Chakari Rivers, and the northeast-trending structural fabric (fig. 2C–5) (Bohannon and Turner, 2005). The mountainous areas on the western and eastern borders of the AOI are dissected by streams that form dendritic drainage patterns, although structure appears to control some of the drainage patterns (fig. 2C–2).

2C.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 Aynak copper, cobalt, and chromium AOI is in the “Central Afghanistan Hydrogeological Folded Region that occupies the central part of the country with a predominantly mountain climate.” 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 2C–5 with the underlying topography to allow examination of the geohydrology in the context of relief. Figure 2C–6*a* shows 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 2C–6*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 and near 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; conglomerate sediments and rocks; limestones and dolostones; sedimentary rocks; metamorphic rocks; and intrusive rocks and lavas” (figs. 2C–5, 2C–6*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 cover this AOI is provided by Bohannon and Turner (2005).

The conglomerate sediments and rocks geohydrologic group is mapped primarily as scattered outcrops in upland basins (fig. 2C–5); however, this group underlies most surficial sediment in the basin bottoms and has been described as semi-consolidated (Böckh, 1971; Mack and others, 2010). The surface area of some of these outcrops is large (as much as 60 km^2). The measured thickness of basin deposits in the AOI is at least 600 m in some places (Japan International Cooperation Agency, 2007), and their estimated thickness is as much as 1,000 m in some areas of the AOI (Homilius, 1969).

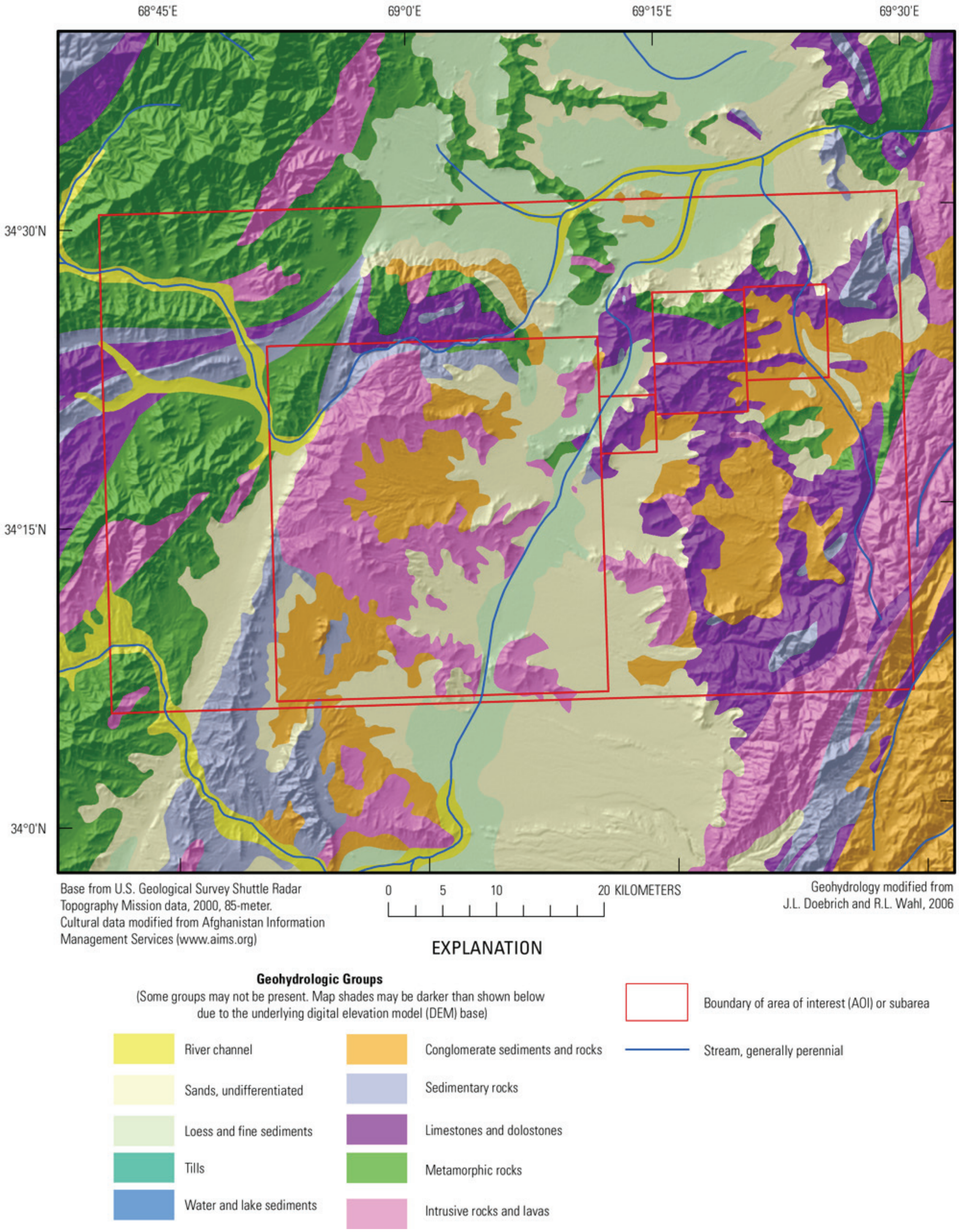
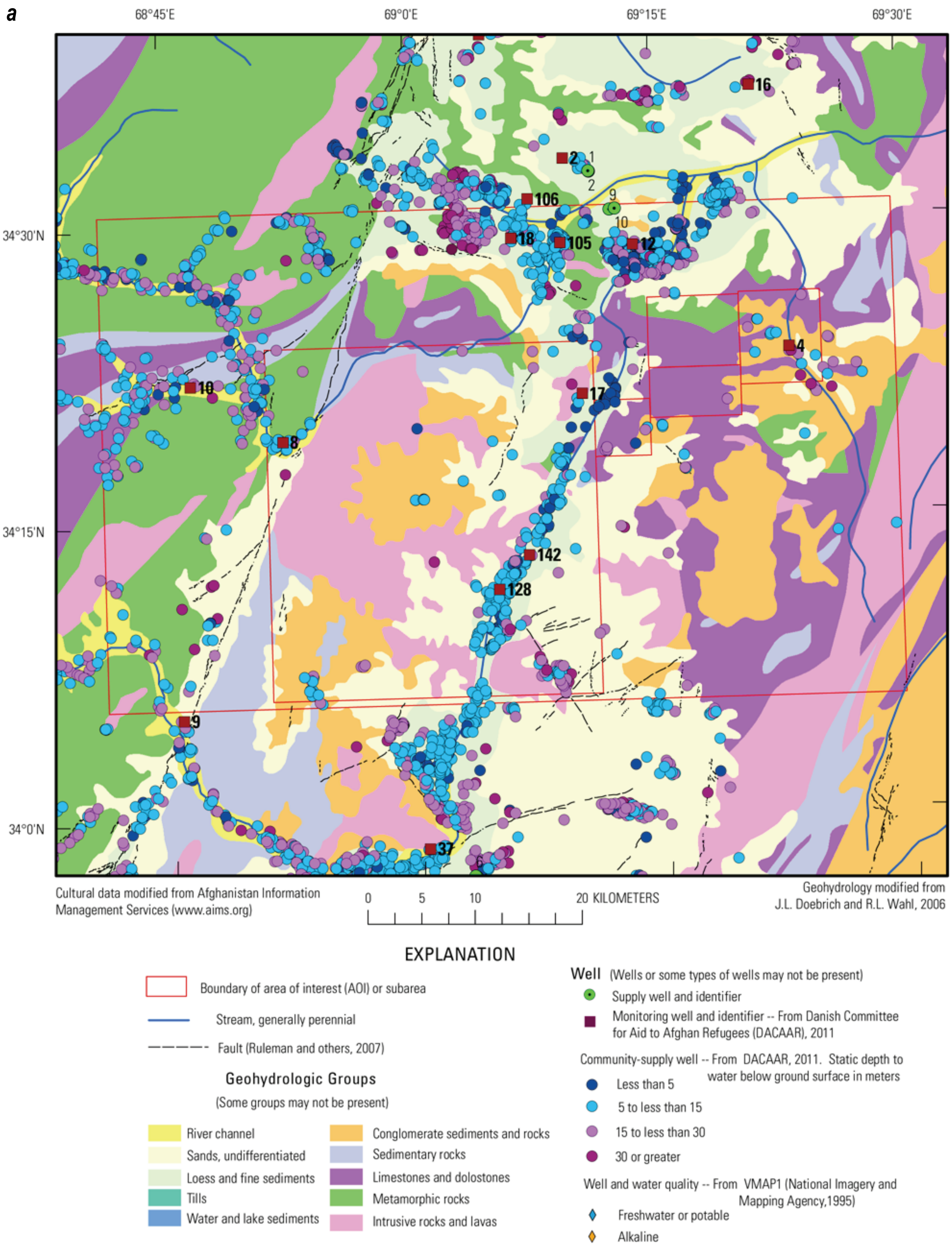


Figure 2C–5. Topography and generalized geohydrology in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.


a
68°45'E
69°0'E
69°15'E
69°30'E
34°30'N
34°15'N
34°0'N
16
2
1
2
9
10
106
18
105
12
4
10
17
8
142
128
9
37
6
Cultural data modified from Afghanistan Information Management Services (www.aims.org)
0
5
10
20 KILOMETERS
Geohydrology modified from J.L. Doebrich and R.L. Wahl, 2006
EXPLANATION
Boundary of area of interest (AOI) or subarea
Stream, generally perennial
Fault (Ruleman and others, 2007)
Geohydrologic Groups
(Some groups may not be present)
River channel
Sands, undifferentiated
Loess and fine sediments
Tills
Water and lake sediments
Conglomerate sediments and rocks
Sedimentary rocks
Limestones and dolostones
Metamorphic rocks
Intrusive rocks and lavas
Well (Wells or some types of wells may not be present)
Supply well and identifier
Monitoring well and identifier -- From Danish Committee for Aid to Afghan Refugees (DACAAR), 2011
Community-supply well -- From DACAAR, 2011. Static depth to water below ground surface in meters
Less than 5
5 to less than 15
15 to less than 30
30 or greater
Well and water quality -- From VMAP1 (National Imagery and Mapping Agency,1995)
Freshwater or potable
Alkaline

b

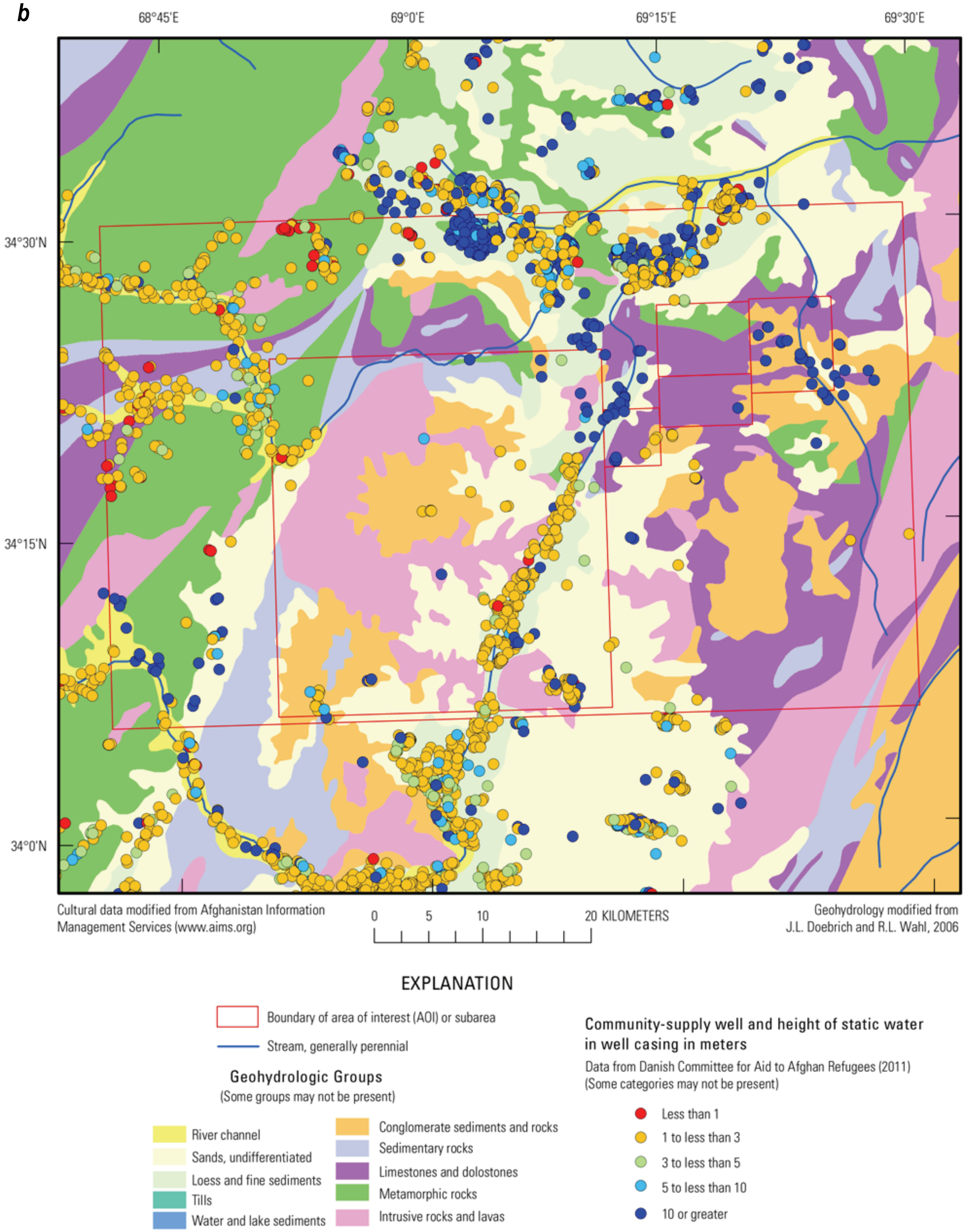


Figure 2C–6. (*a*) Generalized geohydrology, mapped faults, well locations, and depth to water, and (*b*) geohydrology and height of static water in well casings in community supply wells in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

The consolidated rocks in the AOI are grouped by rock type (including chemistry and genesis) and include sedimentary rocks; limestones and dolostones; metamorphic rocks; and intrusive rocks and lavas. This grouping also reflects the type and amount of porosity in these geohydrologic groups. The sedimentary rocks group (detrital sedimentary rocks such as sandstone and siltstone) and the limestones and dolostones group both have interstitial porosity. Both these groups can also have secondary fracture porosity, and in limestone the presence of solution cavities can greatly increase the secondary porosity. Outcrops of these two geohydrologic groups are limited in the AOI, but the limestones and dolostones group is present in the eastern part. The Yagh-Darra Gul-Darra subarea and the Bakhel Charwaz subarea (fig. 2C–1*b*) have extensive outcrops of the limestones and dolostones geohydrologic group (fig. 2C–5). Very few, if any, wells are shown in this geohydrologic group (figs. 2C–6*a* and *b*). The absence of wells in this geohydrologic unit is likely the result of the lack of hard-rock drilling equipment and the prohibitive expense of such drilling.

Rocks in the intrusive rocks and lavas group generally have minimal matrix (interstitial) porosity. The porosity in this group is a result of secondary fracturing from either cooling or tectonic activity. In the absence of seismo-tectonic fractures, the porosity of intrusive rocks such as granites is low to near zero. The presence of faults, fault zones, and fracture zones can increase the porosity of intrusive rocks and lavas. The metamorphic rocks have low matrix porosity but, depending on the degree of metamorphism, interstitial voids could remain in the rock. The movement of fluids through connected pore space in metamorphic rocks could be preferentially oriented parallel to bedding. The fracture porosity in metamorphic rocks can result from compaction foliation and be preferentially oriented along bedding. Secondary fracture porosity in metamorphic rocks can also be the result of tectonic activity. The porosity of this unit could be enhanced near faults, fault zones, and fracture zones. The intrusive rocks are present in the Logar Valley subarea and the southeast corner of the AOI. Very few wells are installed in this geohydrologic unit (fig. 2C–6*a*), mostly likely because of the prohibitive expense of drilling. The headwaters of the Chakari River are located at the contact between the limestones and dolostones group and the intrusive rocks and lavas group in the southeast corner of the AOI (figs. 2C–5).

2C.2.1 Surface Water

A network of major streams, mostly perennial streams, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), in the Aynak copper, cobalt, and chromium AOI is shown in figure 2C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 2C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 2C–1*b*. The Kabul and Logar Rivers transect the AOI and the Chakari River originates within the AOI (fig. 2C–1*b*). The headwaters of the Kabul and Logar Rivers are located in mountainous regions southwest of Kabul. Most precipitation falls as snow, and seasonal melting and runoff account for the peak streamflows in the AOI in April (Mack and others, 2010). Historical streamflow data are available for the Kabul, Logar, and Chakari Rivers (Olson and Williams-Sether, 2010; Vining, 2010). A few small dams and reservoirs are present on some of the tributary streams in the AOI. The dams appear to be used to store water for irrigation, but may also be used for flood control.

The Kabul River enters the AOI at its northwest corner and flows about 70 km to the city of Kabul, where it exits the AOI. Where the river crosses mountain ranges, the stream valley is incised and has steep sides. In other areas, the valley bottom is wide enough to accommodate irrigated agricultural fields (fig. 2C–2). Two historical streamgage stations are located on the Kabul River in the AOI (fig. 2C–1*b*). The streamgage station farthest upstream, Kabul River at Maidan (Afghan identification number 1-0.000-9M), is located where the Kabul River enters the Logar Valley subarea at its western border (Vining, 2010). This station is at an elevation of 2,130 m asl and has a drainage area of 1,305 km^2 and a period of record that extends from 1 October, 1961, to 30 September, 1980 (Vining, 2010). The annual mean streamflow for the period of record is 5.09 m^3/s (cubic meters per second), with a standard deviation of 2.31 m^3/s. The mean annual streamflow per unit area for this station is 0.004 $m^3/s/km^2$. The month with the highest annual mean streamflow is April, with 20.7 m^3/s, and the month with the lowest annual mean streamflow is September, with 0.92 m^3/s. The highest maximum monthly mean streamflow was 50.3 m^3/s for April 1980. The lowest minimum monthly mean streamflow was 0.206 m^3/s for July1980. A statistical summary of monthly and annual mean streamflows for this station is presented in table 2C–2 (Vining, 2010). Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php*.

The other streamgage station on the Kabul River in the AOI is the Kabul River at Tangi Saidan (Afghan identification number 1-0.000-8M). This station is located just outside the northern border of the Logar Valley subarea (fig. 2C–1*b*). This station is at an elevation of 1,875 m asl, has a drainage area of 1,625 km^2, and has a period of record that extends from 1 October, 1961, to 30 September, 1980 (Vining, 2010). The annual mean streamflow for the period of record is 4.05 m^3/s, with a standard deviation of 2.09 m^3/s. The mean annual streamflow per unit area for this station is 0.002 $m^3/s/km^2$. The month with the highest annual mean streamflow was April, with 17.2 m^3/s, and the month with the lowest annual mean streamflow was September, with 0.31 m^3/s. The highest maximum monthly mean streamflow was 43.9 m^3/s for April 1980. The lowest minimum monthly mean streamflow was 0.070 m^3/s for June, 1971. A statistical summary of monthly and annual mean streamflows for this station is presented in table 2C–3 (Vining, 2010).

The Logar River flows from south to north for about 56 km through the AOI and drains into the Kabul River just north of the AOI (fig. 2C–1*b*). The streamgage station on the Logar River at Sang-i-Naweshta (Afghan identification number 1-10.R00-1A) is located between the Logar Valley subarea and the Yagh-Darra Gul-Darra subarea (fig. 2C–1*b*). This station is at an elevation of 1,805 m asl, has a drainage area of 9,735 km^2, and has a period of record that extends from 1 October, 1961, to 30 September, 1980 (Vining, 2010). The annual mean streamflow for the period of record is 9.63 m^3/s, with a standard deviation of 2.81 m^3/s. The mean annual streamflow per unit area for this station is 0.00098 $m^3/s/km^2$. The month with the highest annual mean streamflow was April, with 22.9 m^3/s, and the month with the lowest annual mean streamflow was September, with 0.75 m^3/s. The highest maximum monthly mean streamflow was 45.9 m^3/s for April 1965. The lowest minimum monthly mean streamflow was 0.006 m^3/s for June 1971. A statistical summary of monthly and annual mean streamflows for this station is presented in table 2C–4 (Vining, 2010).

Table 2C–2. Statistical summary of monthly and annual mean streamflow for the Kabul River at Maidan streamgage station.

[m^3/s, cubic meters per second]

1-0.000-9M KABUL RIVER AT MAIDAN

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	2.46	1966	0.434	1980	1.08	0.55	0.51	1.77
November	3.40	1966	0.460	1972	1.63	0.91	0.56	2.67
December	3.78	1966	0.391	1972	2.12	1.00	0.47	3.46
January	4.16	1968	0.799	1972	2.50	0.96	0.38	4.10
February	4.25	1968	1.45	1972	2.65	0.77	0.29	4.33
March	12.4	1973	2.60	1963	6.65	3.27	0.49	10.9
April	50.3	1980	6.17	1970	20.7	12.8	0.62	33.8
May	31.8	1965	1.74	1971	14.4	9.73	0.68	23.5
June	20.6	1965	0.742	1971	5.71	5.42	0.95	9.34
July	6.99	1965	0.206	1980	1.72	1.49	0.87	2.81
August	2.75	1965	0.236	1980	1.09	0.53	0.49	1.79
September	1.81	1965	0.338	1980	0.92	0.35	0.38	1.50
Annual	9.10	1965	1.72	1971	5.09	2.31	0.45	100

Table 2C–3. Statistical summary of monthly and annual mean streamflow for the Kabul River at Tangi Saidan streamgage station.

[m^3/s, cubic meters per second]

1- 0.000-8M KABUL RIVER AT TANGI SAIDAN								
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	1.20	1966	0.128	1980	0.44	0.30	0.68	0.90
November	2.57	1966	0.219	1972	1.05	0.79	0.74	2.16
December	3.52	1966	0.417	1972	1.61	0.96	0.60	3.30
January	4.15	1962	0.961	1971	2.48	0.97	0.39	5.09
February	4.57	1968	1.31	1971	2.67	0.92	0.34	5.47
March	12.5	1968	1.56	1963	6.15	3.01	0.49	12.6
April	43.9	1980	3.48	1970	17.2	10.5	0.61	35.3
May	26.8	1965	0.406	1970	11.1	8.21	0.74	22.7
June	18.1	1965	0.070	1971	4.38	5.13	1.17	8.98
July	6.83	1965	0.079	1971	1.00	1.55	1.55	2.04
August	1.31	1965	0.076	1980	0.40	0.29	0.72	0.81
September	0.572	1962	0.097	1971	0.31	0.15	0.50	0.63
Annual	**7.96**	**1965**	**1.13**	**1971**	**4.05**	**2.09**	**0.51**	**100**

Table 2C–4. Statistical summary of monthly and annual mean streamflow for the Logar River at Sang-i-Naweshta streamgage station.

[m^3/s, cubic meters per second]

1- 10.R00-1A Logar River at Sang-i-Naweshta								
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	11.2	1966	0.212	1975	3.82	3.43	0.90	3.29
November	20.3	1966	3.14	1972	10.9	4.65	0.43	9.38
December	20.3	1966	7.99	1972	14.4	3.18	0.22	12.4
January	20.1	1962, 1966	10.5	1972	15.8	2.85	0.18	13.6
February	20.1	1969	10.2	1972	15.8	2.77	0.18	13.6
March	27.1	1968	11.1	1979	17.4	3.97	0.23	15.0
April	45.9	1965	7.07	1963	22.9	12.6	0.55	19.7
May	39.0	1965	0.235	1971	10.3	11.1	1.08	8.87
June	9.44	1965	0.084	1970	1.58	2.36	1.49	1.37
July	9.16	1978	0.006	1971	1.55	2.57	1.66	1.34
August	3.87	1978	0.017	1971	0.80	1.12	1.40	0.69
September	3.68	1965	0.030	1975	0.75	0.95	1.27	0.64
Annual	15.8	1965	5.48	1971	9.63	2.81	0.29	100

The headwaters of the Chakari River are in the mountains in the southeast corner of the AOI, in an area mapped as the contact between the limestones and dolostones geohydrologic group and the intrusive rocks and lavas geohydrologic group (fig. 2C–5). The Chakari River flows north for about 50 km and drains into the Kabul River north of the AOI (fig. 2C–1*b*). The streamgage station on the Chakari River at Band-i-Amir Ghazi (Afghan identification number 1-9.R00-4W) is located in the Kharuti Dawrankhel subarea (fig. 2C–1*b*). This station is at an elevation of 2,050 m asl, has a drainage area of 395 km^2 that includes approximately 3 km^2 of irrigated area, and has a period of record that extends from 26 May, 1965, to 30 September, 1980 (Olson and Williams-Sether, 2010). The annual mean streamflow for the period of record is 0.31 m^3/s, with a standard deviation of 0.12 m^3/s. The mean annual streamflow per unit area for this station is 0.0008 $m^3/s/km^2$. The month with the highest annual mean streamflow was May, with 0.55 m^3/s, and the month with the lowest annual mean streamflow was January, with 0.05 m^3/s. The highest maximum monthly mean streamflow was 1.71 m^3/s for April 1980. The lowest minimum monthly mean streamflow was 0.01m^3/s for January 1997, February 1977, and March 1978. The Chakari River was observed to be dry during a field reconnaissance visit on

21 November, 2009. A statistical summary of monthly and annual mean streamflows for this station is presented in table 2C–5 (Olson and Williams-Sether, 2010).

There are no mapped springs in the VMAP database (National Imagery and Mapping Agency, 1995); however, springs and karezes are present in the region, and the quality of water in at least two of these features in the AOI has been measured (Mack and others, 2010). During a field reconnaissance visit on 21 November, 2009, a spring was observed originating from highly fractured gneiss on the north flank of the Yagh-Darra Gul-Darra subarea. The spring, which had a volumetrically measured flow of approximately 0.1 L/s (liters per second) near its source, was managed by villagers for irrigation. Where it was measured, at an elevation of about 2,100 m asl, the spring was less than 1 km from the topographic peak (2,600 m asl) in the Yagh-Darra Gul-Darra subarea. An ephemeral spring was identified on the flank of a south-facing gully in the Kelaghy-Kakhay subarea. The spring, at an elevation of about 2,400 m, was about 0.7 km below a 2,700-m-high peak consisting of fractured carbonate rocks. The spring was not flowing when it was identified during the August 2010 reconnaissance trip; however, there were small orchards at its origin and a settlement downgradient along the spring channel. Both factors indicate a likely dependence on increased accessibility of groundwater resources, such as a shallow depth to groundwater, in the area of the spring. The springs identified in the Yagh-Darra Gul-Darra and Kelaghy-Kakhay subareas coincide with lineaments identified as part of this project (discussed in the Lineament Analyses section).

Table 2C–5. Statistical summary of monthly and annual mean streamflows for the Chakari River at Band-i-Amir Ghazi streamgage station.

[m^3/s, cubic meters per second]

1-9.R00-4W CHAKARI RIVER AT BAND-I-AMIR GHAZI

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	0.68	1968	0.05	1972	0.33	0.17	0.53	8.80
November	1.06	1968	0.10	1971	0.34	0.24	0.73	9.06
December	0.94	1968	0.02	1978	0.15	0.22	1.53	3.95
January	0.25	1967	0.01	1978	0.05	0.06	1.33	1.22
February	0.38	1967	0.01	1978	0.10	0.11	1.17	2.57
March	0.62	1980	0.01	1977	0.18	0.21	1.20	4.80
April	1.71	1980	0.03	1975	0.44	0.40	0.89	12.0
May	0.96	1967	0.05	1975	0.55	0.26	0.47	14.9
June	0.93	1974	0.04	1971	0.52	0.29	0.56	14.0
July	0.97	1980	0.03	1971	0.39	0.23	0.58	10.7
August	0.94	1980	0.05	1971	0.34	0.22	0.65	9.14
September	0.86	1979	0.06	1971	0.33	0.20	0.59	8.99
Annual	**0.58**	**1980**	**0.11**	**1971**	**0.31**	**0.12**	**0.39**	**100**

2C.2.2 Groundwater

Information about groundwater resources in the Aynak copper, cobalt, and chromium AOI is limited at this time to shallow-well data. Approximately 2,500 shallow community groundwater-supply wells installed by NGOs in the AOI are in a database maintained by the Danish Committee for Aid to Afghan Refugees (DACAAR, 2011). Well-depth and static-water-level information is available for most wells in this database (figs. 2C–6*a*,*b*). About 80 percent of the supply wells are less than 30 m deep and all are less than 100 m deep. The depth to water in the supply wells in the AOI is generally less than 15 m (fig. 2C–6*a*). The median depth to water is 11 m and about half of the wells are 5 to less than 15 m deep. The depth to water generally increases with distance from streams or with proximity to the basin walls (fig. 2C–6*a*). Depth to water in many wells in highly populated areas, such as Kabul (fig. 2C–4), is 30 m or more as a result of groundwater withdrawals.

Little well-construction information is available; however, most wells are "tube" wells, driven wells with polyvinyl chloride (PVC) casing, or dug wells constructed with concrete ring casing. Wells are generally installed in unconsolidated sediments, and completed a few meters below the first water depth encountered, and equipped with a hand pump. Figure 2C–6*b* shows height of static water in the water-supply well casings (well depth minus static depth to water). The median height of static water in well casings is 4 m. Spatially, most wells contain less than 3 m of static water. Many of the wells with 3 m of static water or less were drilled in the early 2000s or pre-2000, and some may currently be inoperable. Wells with little static water were found to be vulnerable to seasonal water-level fluctuations and becoming dry for extended periods of time, or even permanently, in areas of the Kabul Basin where groundwater withdrawals are increasing (Mack and others, 2010).

The water-supply wells are concentrated along the Kabul and Logar Rivers, with some concentrations of wells in other alluvial valleys (fig. 2C–6*a*). The recharge to the alluvial aquifer(s) in the river valleys is probably derived from the infiltration of streamflow and leakage from irrigated areas. There could also be a small component of recharge from local precipitation, particularly as snowmelt runoff from the mountainous areas. Some shallow wells are located in areas mapped as the conglomerate sediments and rocks geohydrologic unit (fig. 2C–6*a*). Most of these areas are upland areas with no perennial streams. The groundwater recharge in these areas would most likely be from local precipitation; however, Mack and others (2010) measured a component of recharge consisting of groundwater inflows, through sediment and rock, from the mountain range east of the AOI in a similar basin about 10 km north of the AOI.

Eight groundwater-monitoring wells (GWMs 4, 8, 10, 12, 17, 105, 128, and 142) in the AOI are monitored by DACAAR for groundwater levels and specific conductance. Five of the wells are in the AOI subareas (fig. 2C–6*a*). Hydrographs provided by DACAAR for wells in the AOI are presented in appendix 3. The hydrographs show the date in week number and year, groundwater specific conductance in microsiemens per centimeter at 25° Celsius (µS/cm), and depth to water in meters below ground surface (bgs). Of the wells in the subareas, four are located immediately adjacent to stream channels and the fifth (GWM 17) appears to be on an alluvium-covered upland basin or side slope about 2 km west of the Logar River. All of the monitoring wells are likely constructed entirely in alluvial material.

GWM 8 is located in the Kabul River valley in the "river channel" geohydrologic unit in the northwest corner of the Logar Valley subarea (fig. 2C–6*a*). River-channel sediments in the Kabul River Basin have been found to have a hydraulic conductivity of several hundred meters per day (Böckh, 1971). The well depth of GWM 8 is reported to be 10 m bgs. The water-level hydrograph for this is fairly flat at slightly less than 10 m bgs across the period of record, with three sharp peaks that occur in late April and early May during 2007, 2008, and 2009. The first and last peaks show about the same water-level rise to 7.5 m bgs and the second peak shows a water-level rise to 9 m bgs. Specific conductance increases along with the water-level peaks. GWM 8 is located about 1 km from the Kabul River at Maidan streamgage station. There are no streamflow records for this station that coincide with the water-level period of record in GWM 8, but the LTA for the Kabul River at Maidan streamgage station indicates that the maximum streamflow occurs during April and May. It appears that recharge from the Kabul River is supplying water to the shallow alluvial aquifer in the Kabul River valley.

GWM 10 is located in the valley of an ephemeral stream (in the "river channel" geohydrologic group) that is a tributary to the Kabul River (fig. 2C–6*a*). The total depth of the well is 42 m bgs. The period of record for the hydrograph is from week 19, 2005, through week 3, 2011. The water-level hydrograph shows distinct peaks (high water levels) that probably represent times when water was flowing in the ephemeral stream and valleys. Low water levels likely represent times of no flow in the ephemeral stream. The peaks are generally in the late spring and early to mid-summer; the lows are in early winter. The maximum water level during the period of record was about 16 m bgs during week 25, 2007. This area and much of Afghanistan experienced a drought that lasted from about 1999 to the mid-2000s (____ and others, 2007; Mack and others, 2010); however, the minimum water level (24 m bgs) appears to be the last measurement made during the period of record (late 2010). Maximum and minimum water levels in this well generally declined during the period of record. The specific-conductance hydrograph for the period of record fluctuates, but generally mirrors the water-level hydrograph–that is, high specific conductance is correlated with high water levels.

Three GWMs—17, 128, and 142—are located in the Logar River valley (fig. 2C–6*a*), in the "loess and fine sediments" geohydrologic unit. GWMs 128 and 142 are adjacent to the active stream channel, whereas GWM 17 is 2 km from the valley bottom and is located on an alluvial deposit that is adjacent to outcrops of the intrusive rocks and lavas geohydrologic group (fig. 2C–6*a*). GWM 128 is 13.5 m bgs. The period of record extends from week 18, 2007, until week 37, 2010. The water-level hydrograph exhibits distinct highs and lows. The highs generally occur in the spring and summer months, and the lows occur in late summer through winter. The water level in this well probably reflects the flow in the Logar River. The specific conductance in this well appears to fluctuate inversely with the water level; as the water level increases, specific conductance decreases. This relation could indicate that the water in the Logar River that is recharging this area is less saline during times of high flow than during low flow. The high water levels during the period of record generally appear to decline, from a maximum of 5.6 m bgs to 6.4 m bgs. The minimum water levels remained fairly constant at about 7.6 m bgs.

GWM 142 is 53 m bgs with a period of record that extends from week 24, 2007, until week 36, 2010. The water-level hydrograph for this well is flat (at 12.6 m bgs) from the start of the period of record until week 12, 2008, when it rises sharply (to 12.3 m bgs) and then declines. The water level then gradually increases to about 12.4 m bgs at about week 52, 2008. The remainder of the period of record displays the typical seasonal highs and lows associated with streamflow. The specific-conductance record for this well begins at about week 12, 2009, but shows a distinct peak in specific conductance during the winter months of 2009–2010. The water levels in this well are probably related to the flow in the Logar River.

The other GWM in the Logar River valley in the AOI is GWM 17 (fig. 2C–6*a*). The water-level hydrograph for this well shows fairly regular water-level maximums that are probably related to seasonal recharge in the spring and early summer. The water-level minimums occur most frequently in the winter. The maximum and minimum water levels during the period of record are fairly consistent. The maximums are about 11 m bgs and the minimums are about 14 m bgs. Because this well is about 2 km west of and 10 m higher than the Logar River, the closest surface-water source, the highs and lows could correspond to snowmelt runoff from the hills to the west, which reach elevations of 2,000 m asl. The specific-conductance hydrograph generally declines over the period of record.

GWM 4, in the Kharuti Dawrankhel subarea, is in the Chakari River valley about 250 m from the active river channel. This well is located in the conglomerate sediments and rocks geohydrologic group, and the bedrock outcrops that form the hills to the west are composed of the limestones and dolostones geohydrologic group (fig. 2C–6*a*). The conglomerate sediments and rocks are semi-consolidated deposits with an estimated hydraulic conductivity of about 1 to 10 m/d (meters per day) (Böckh, 1971; Mack and others, 2010). The well is 52 m bgs and has a period of record that extends from week 1, 2005, until week 35, 2010. The water-level hydrograph for this well shows an overall rise in the water level during the period of record. The early part of the period of record—from week 1, 2005, until about week 13, 2006—shows fairly regular water-level maximums that are probably related to seasonal recharge (highs in spring and early summer, lows in fall and winter). The later part of the record consists of a number of water-level highs and lows that do not correspond to the expected wet and dry times of the year in Afghanistan. It is not known whether the water levels were measured during static or pumping conditions; however, this well most likely is a hand-pumped well, and the water-level measurements probably represent reasonably static conditions. The variability in the water-level hydrograph from week 13, 2006, until the end of the period of record could be caused by interference from another nearby well that is outfitted with an electric pump. The specific-conductance hydrograph for this well follows the pattern of the water-level hydrograph.

A 90-m-deep supply well, located in the northeast corner of the Logar Valley subarea, for which well-completion and -development information was limited, was assessed by the Omran Consulting, Construction and Engineering Company (written commun., 2008). The well has a submersible pump that is reportedly set at 76 m bgs and the static water level was 31 m bgs. The water discharge rate for the well was 8.6 L/s, with a dynamic water level of 53.7 m bgs (drawdown of 22.7 m). This well is located in an ephemeral-stream valley in an area categorized as the "loess and fine sediments" geohydrologic unit; however, the well likely is set in the conglomerate sediments and rock geohydrologic group, which underlie the surficial sediments. The well log indicates that the 90-m-deep well is about 40 m from an existing water-supply well that is reported to be 50 m deep and therefore may be subject to well interference. Two other water-supply wells at the northern boundary of the AOI (wells 9 and 10, fig. 2C–6*a*), also likely in the conglomerate sediments and rocks group, had reported yields of about 8 L/s; additional information indicates, however, that actual yields were much less than 1 L/s.

Available information about groundwater in the AOI is very limited and almost entirely restricted to information about the occurrence of shallow groundwater. The shallow wells in the AOI are constructed mostly in the unconsolidated sediments of the river channel; sands, undifferentiated; and loess and fine sediments geohydrologic groups. Some wells are constructed in the conglomerate sediments and rocks geohydrologic group. This geohydrologic group is a potential source of groundwater in the Logar Valley subarea and the Kharuti Dawrankhel subarea (fig. 2C–6*a*); however, isotopic analyses of groundwater in the Kabul Basin indicate that water in this aquifer may be thousands of years old with limited recharge (Mack and others, 2010). Hydrologic investigations, including source-water analyses, would be needed to adequately characterize this resource. No lithostratigraphic information is available for the one reported deep well in the AOI, but this well probably is constructed in semi-consolidated conglomerates. No well information is available for consolidated-rock geohydrologic units. The consolidated-rock outcrops cover about 65 percent of the surface of the AOI (fig. 2C–6*a*). The sedimentary rocks and limestones and dolostones geohydrologic groups are potential areas for hydrologic investigations including detailed mapping and borehole construction and hydraulic testing. The metamorphic rocks and intrusive rocks and lavas geohydrologic groups could also be areas for groundwater exploration, although the amount of water contained in these rocks likely is limited and highly dependent on local fracturing. It is unlikely that the shallow alluvial aquifers could provide large withdrawals without disrupting existing domestic supply and irrigation. Additional hydrologic investigations are needed to determine whether large groundwater withdrawals from deep, semi-consolidated aquifers are sustainable. Close monitoring and careful management would be needed to avoid adverse effects on existing uses of local water resources and to ensure their sustainability.

2C.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 were conducted in the Aynak copper, cobalt, and chromium AOI using DEM and natural-color satellite imagery (fig. 2C–7) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 2C–8*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 2C–7 were delineated visually, whereas those in figure 2C–8 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.). Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. 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.

Lineament-density maps (figs. 2C–7 and 2C–8) indicate areas of potentially increased bedrock fracturing (figs. 2C–5 and 2C–6). Several areas on the west and east flanks of the Kabul Basin have high lineament densities. Some lineaments, particularly the 15-m lineament dataset (fig. 2C–8*b*), follow mapped faults such as the Chaman fault on the west side of the Kabul Basin (fig. 2C–5*b*), which could represent areas of high-permeability, highly fractured rock. The Yagh-Darra Gul-Darra and Bakhel Charwaz subareas, which are areas with little sediment cover, have areas of dense lineaments that may represent rock fracturing. Springs in the areas of mapped lineaments, described earlier in this chapter, indicate the potential for limited groundwater storage in fractured rock. A spring was found to originate in highly fractured metamorphic rock with little upland area on the north flank of the Yagh-Darra Gul-Darra subarea during a period with no recent precipitation. Evidence also was found of a spring originating in fractures in sedimentary rock in another area described earlier in this chapter, during the same period with no recent precipitation. Figure 2C–9 shows a gully and two linear cuts in a bedrock hillside that were identified in the 30-m DEM and natural-color image analysis (fig. 2C–7). Wet ground was observed where the lineament intersected the gully, and a small settlement was located downgradient along the gully or spring channel in an otherwise sparsely populated area. This finding indicates that groundwater resources are present in the fractured bedrock in the area; however, this resource may provide only enough water for small-scale uses, and close monitoring would be necessary to ensure that any new withdrawals did not adversely affect existing springs and water uses. In mineralized areas, water quality and potential changes in quality with use, such as changes in oxidation resulting from drawdown, would need to be assessed.

2C.2.4 Water Quality

Two previous USGS and AGS water-resource studies of the Kabul Basin included a northern portion of the Aynak copper, cobalt, and chromium AOI (Broshears and others, 2005; Mack and others, 2010); the water-quality findings from these two studies are representative of the AOI and are summarized here. The major-ion chemistry of groundwater in the Kabul Basin was generally of the calcium-magnesium-bicarbonate type. Concentrations of some water-quality constituents in the Logar area, as in the central Kabul Basin, were higher than those in other areas of the Kabul Basin. Differences in water chemistry in the region indicate possible influences of anthropogenic or industrial contamination, poor well construction, possible dissolution of rocks containing gypsum, or increased concentrations of ions caused by evapotranspiration processes as suggested by Broshears and others (2005). Groundwater in the Deh Sabz basin, about 10 km north of the AOI, which is in a hydrogeologic setting similar to that of the Chakari River basin in the eastern area of the AOI, appears to have evolved from the calcium-magnesium-bicarbonate type to a sulfate-chloride or sodium type (Mack and others, 2010).

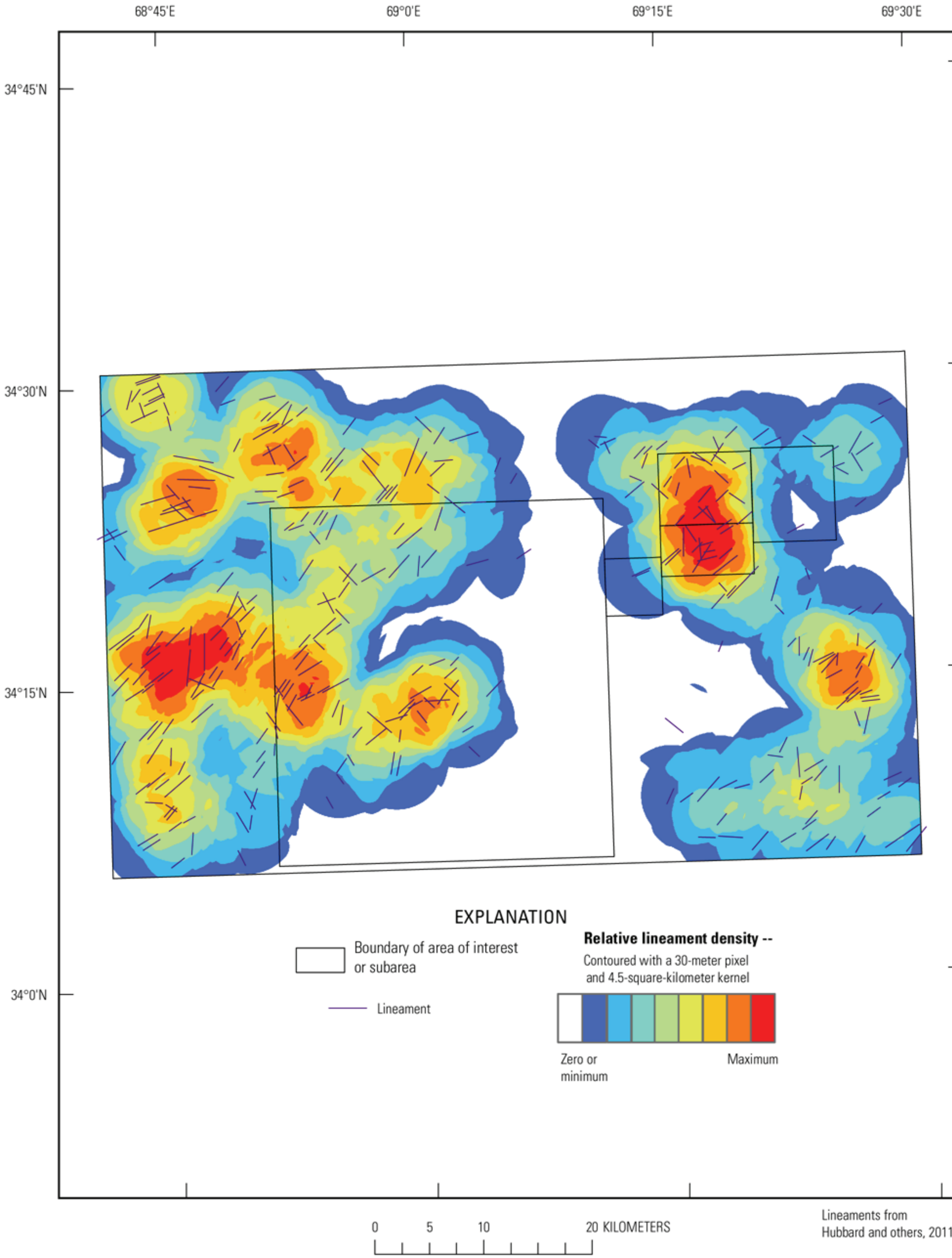
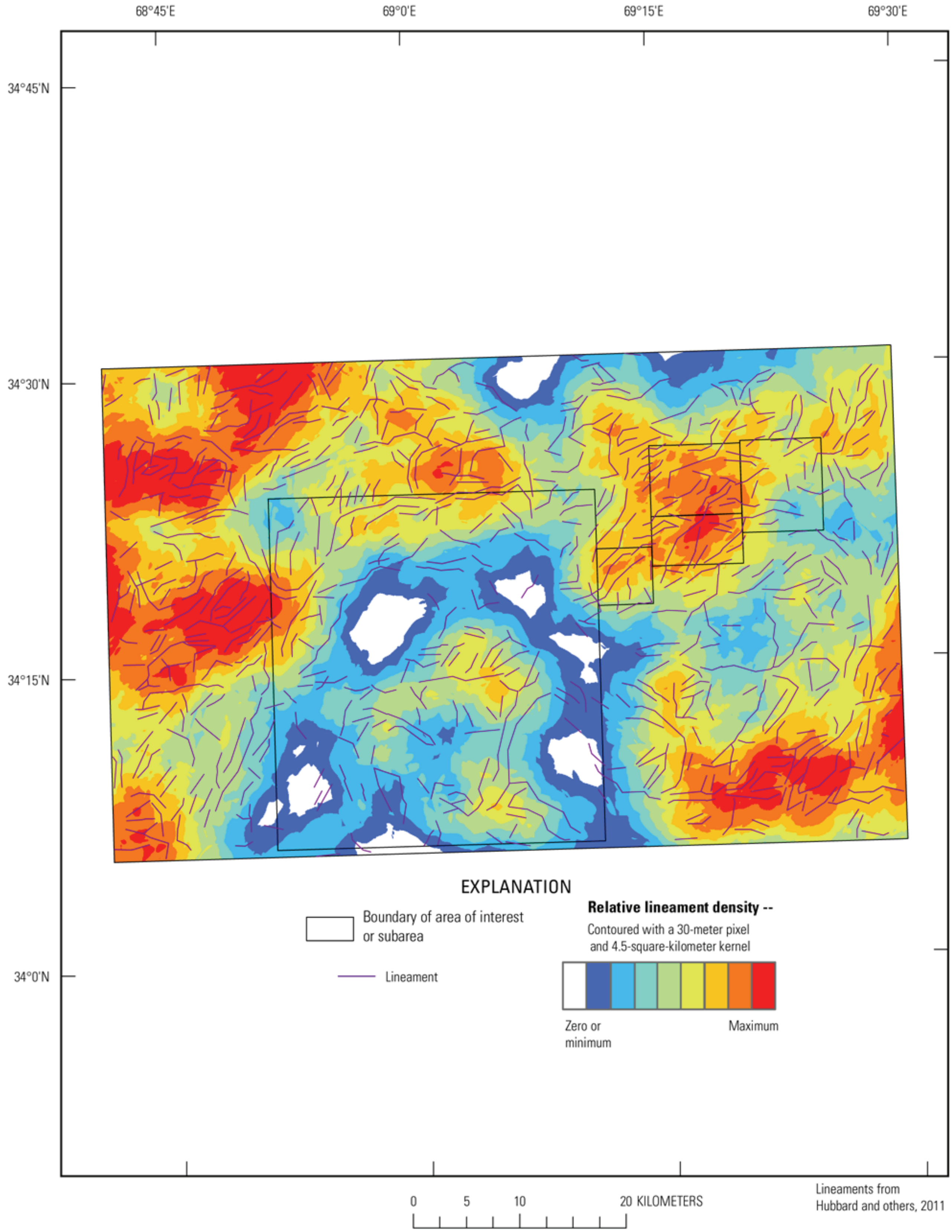


Figure 2C–7. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

a


68°45'E
69°0'E
69°15'E
69°30'E
34°45'N
34°30'N
34°15'N
34°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

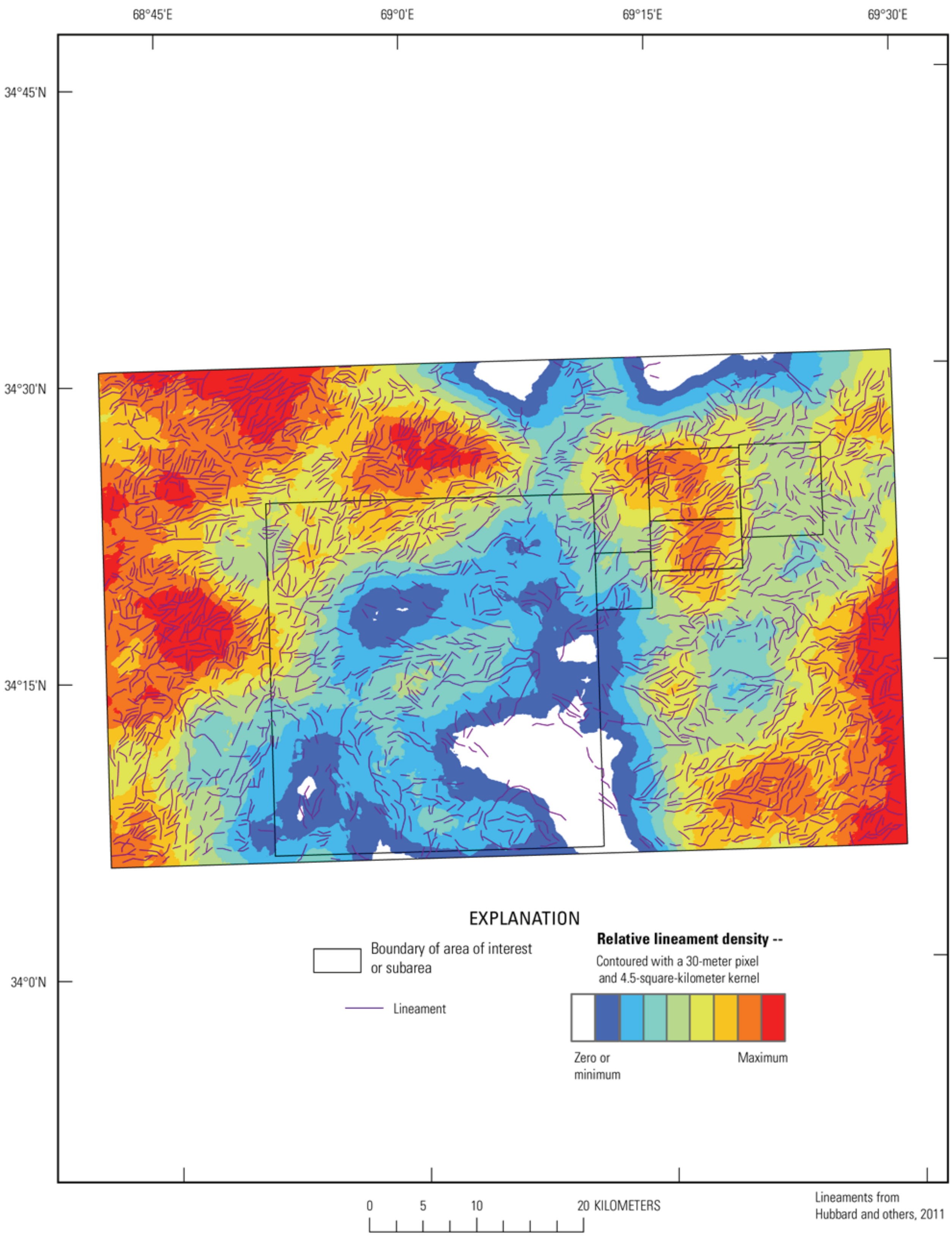


Figure 2C–8. (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery in the Aynak copper, cobalt, and chromium area of interest, and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Aynak copper, cobalt, and chromium area of interest in southeastern Afghanistan.

Figure 2C–9. Photograph showing small orchard at the intersection of linear features (lineaments) cutting a hillside and a small ravine at Zakhel.

The median values of several groundwater parameters, including specific conductance, hardness measured as alkalinity, and concentrations of nitrate plus nitrite, bromide, magnesium, sodium, potassium, chloride, arsenic, boron, nickel, and zinc, were elevated in densely populated areas. Uranium concentrations were higher than 5 µg/L (micrograms per liter) in much of the Kabul Basin; however, no World Health Organization (2006) standards for metals, such as arsenic, cobalt, copper, lead, or uranium, were exceeded in surface water or groundwater in the Logar River basin (Mack and others, 2010). Median specific conductance of groundwater ranged from 51 (near the mountains on the west side of the basin) to 1,177 µS/cm (in central Kabul). Specific conductance in the Kabul Basin generally was higher in densely populated than in sparsely populated areas. Overall, conditions in the aquifer were slightly oxic, with dissolved-oxygen concentrations in the subbasins ranging from 0.1 to 1.9 mg/L (milligrams per liter) as O_2 with a median value of 0.1 mg/L. Median concentrations of nitrate as N (nitrogen) ranged from 1.2 mg/L at the eastern side of the basin near the mountains to 6.7 mg/L in central Kabul. The median concentration of nitrate as N for the entire Kabul Basin was 3.3 mg/L.

Total coliform bacteria were detected in nearly all of the groundwater samples from the Kabul Basin. In some wells counts exceeded 2,420 colonies per 100 mL (milliliters). More than 100 colonies per 100 mL were detected in samples in all areas of the Kabul Basin except at the eastern side of the basin near the mountains (4 colonies per 100 mL). *E. coli* was detected in 66 of 68 samples collected in the Kabul Basin. Water from a well located in the Deh Sabz basin, which contained more than 2,420 colonies per 100 mL total coliform, had the highest reported concentration of colonies of *E. coli* present (461 colonies per 100 mL). Detections of *E. coli* appeared to be randomly distributed throughout the region. The prevalence of bacteria in groundwater samples likely indicates the existence of inadequate sanitation facilities for waste disposal and poor well construction throughout the region. These conditions allow sewage effluent to contaminate the wells.

2C.3 Summary and Conclusions

The availability of water resources for mining and other uses is likely to be more limited in the Aynak copper, cobalt, and chromium AOI than in other areas of Afghanistan because recharge rates are low and surface-water flow is limited. Water resources in the AOI and the surrounding area consist mainly of streams, and groundwater in deep aquifers. The Logar River, which flows through the center of the AOI, is the primary surface-water resource in the area. The river is used heavily for irrigation and local domestic supply, which limits the availability of this resource for additional uses. Close monitoring of withdrawals from the river would be needed to ensure the continued availability of this resource for existing uses. Some water potentially could be withdrawn from the Chakari River during high flows; however, during some periods of the year this river becomes dry. Because the Chakari River originates in carbonate rocks in the AOI, its existence indicates the potential for that geohydrologic group to store and yield water. In these rivers, spring to early summer is a time of high flow. Surface-water flow in these rivers is an important source of recharge for the shallow alluvial aquifers in the river valleys. As in many areas of Afghanistan, any additional diversion and use of water from the rivers would need to be carefully managed to prevent overuse or degradation of this resource.

There are more than 2,500 nongovernmental organization- (NGO) installed shallow drinking-water wells in the AOI. Most of these wells are probably polyvinyl chloride- (PVC) cased tube wells with hand pumps that are used to supply water for domestic consumption. Shallow wells completed in unconsolidated sediments are concentrated in the Kabul and Logar River valleys. The shallow groundwater in the AOI likely is recharged primarily by seasonal leakage from the Logar River and irrigated areas. Little information is available about groundwater in deep aquifers in the AOI. Deep groundwater resources in the conglomerates likely include a component of recharge from upland areas at the sides of the basin; however, this water is likely thousands of years old and of unknown quality and sustainability.

The major-ion chemistry of groundwater in the region is generally the calcium-magnesium-bicarbonate type; however, water quality is a concern in some areas of the AOI, particularly the more densely populated areas, where nitrate concentrations are likely to be high and bacterial contamination may be present. The amount of water available in the shallow alluvial aquifers in the river valleys probably is limited, and additional withdrawals of water for mining activities would likely adversely affect the continued availability of local water supplies. Although considerable groundwater may be present in the deep aquifers in the AOI, investigations are needed to characterize the quantity and quality of this resource, and careful planning would be needed to balance any new groundwater withdrawals with existing uses.

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