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Technique for Estimation of Streamflow Statistics in Mineral Areas of Interest in Afghanistan

Open-File Report 2011–1176

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph showing the Balkh River at Sari Puhl in northern Afghanistan.

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By Scott A. Olson and Thomas J. Mack

Open-File Report 2011–1176

U.S. Department of the Interior
U.S. Geological Survey

USGS Afghanistan Project Product Number 232

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia 2011

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Suggested citation:
Olson, S.A., and Mack, T.J., 2011, Technique for estimation of streamflow statistics in mineral areas of interest in Afghanistan: U.S. Geological Survey Open-File Report 2011–1176, 17 p., at http://pubs.usgs.gov/of/2011/1176/.

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Flow rate	
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Vertical and horizontal coordinate information is referenced to the World Geodetic System of 1984 (WGS 84). Elevation, as used in this report, refers to distance above the vertical datum.

Technique for Estimation of Streamflow Statistics in Mineral Areas of Interest in Afghanistan

By Scott A. Olson and Thomas J. Mack

Abstract

A technique for estimating streamflow statistics at ungaged stream sites in areas of mineral interest in Afghanistan using drainage-area-ratio relations of historical streamflow data was developed and is documented in this report. The technique can be used to estimate the following streamflow statistics at ungaged sites: (1) 7-day low flow with a 10-year recurrence interval, (2) 7-day low flow with a 2-year recurrence interval, (3) daily mean streamflow exceeded 90 percent of the time, (4) daily mean streamflow exceeded 80 percent of the time, (5) mean monthly streamflow for each month of the year, (6) mean annual streamflow, and (7) minimum monthly streamflow for each month of the year. Because they are based on limited historical data, the estimates of streamflow statistics at ungaged sites are considered preliminary.

Introduction

Afghanistan has many mineral areas of interest (fig. 1) that may be a source of economic opportunity for the country (Peters and others, 2007; 2011). Water is needed both for mining processes and to support the communities and related industries that may develop around a mining economy. Mining activities generally require large volumes of processing water, which may be obtained most economically from surface-water sources. Estimates of streamflow statistics are needed to assess whether sufficient water is likely to be available in local streams at various times of the year for both mining and community needs. Streamflow statistics, based on data collected from the mid-1940s to 1980, are available for 150 of 174 historical streamgaging sites in Afghanistan that were operated by the Afghanistan Ministry of Energy and Water (Olson and Williams-Sether, 2010; Williams-Sether, 2008; Vining, 2010). In some mineral areas of interest, however, no historical gages are present (fig. 1); therefore, methods for estimating streamflow characteristics in these areas are needed.

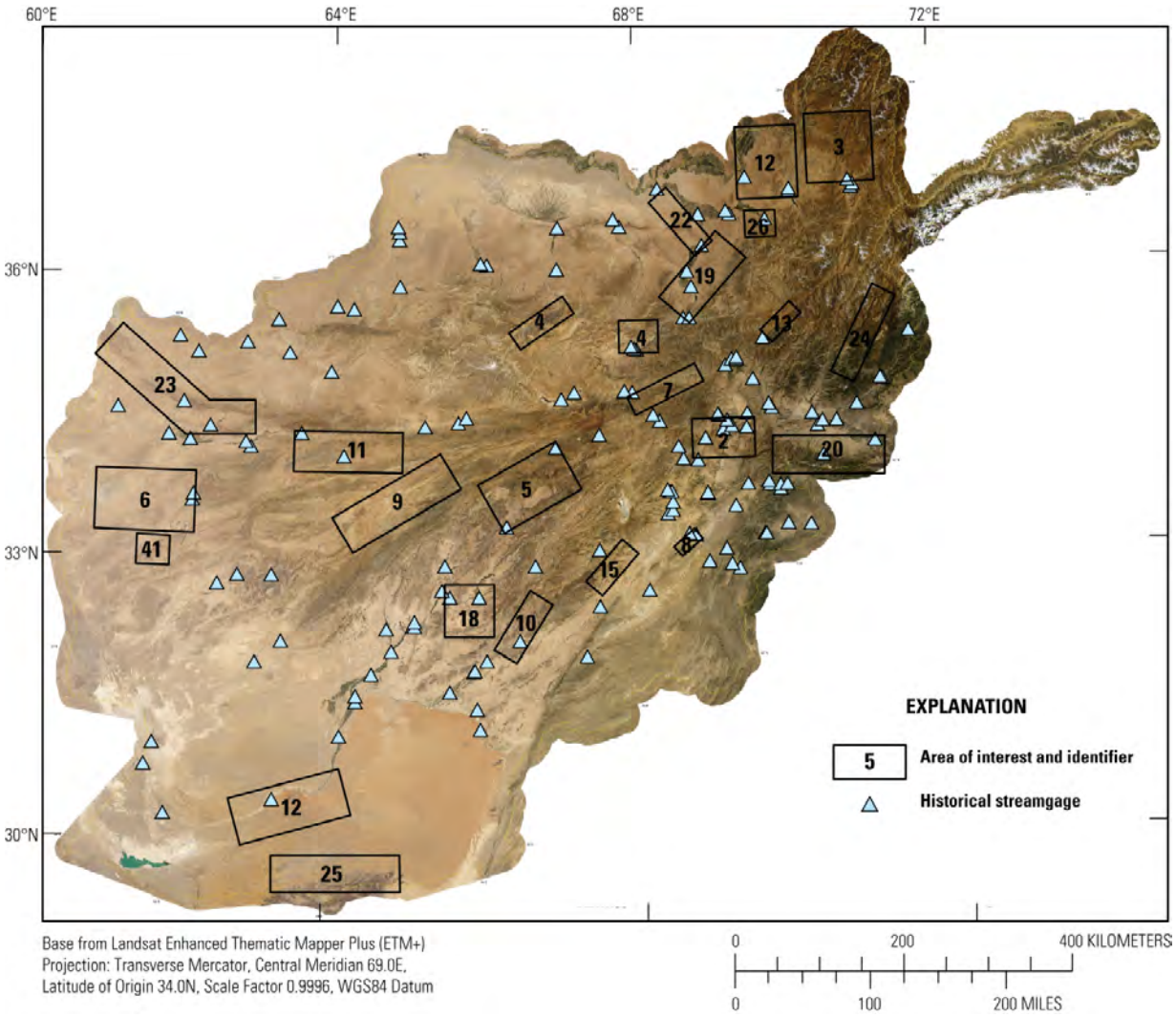

Figure 1. Historical streamgage locations and mineral areas of interest in Afghanistan.

Mineral areas of interest (fig. 1) identified by the U.S. Geological Survey (USGS) and the Afghanistan Geological Survey (AGS) (Peters and others, 2007) were the subject of additional study as part of a cooperative investigation of the USGS and the U.S. Task Force for Business and Stability Operations (TFBSO) from 2009 to 2011 (Peters and others, 2011). As part of this investigation, the USGS conducted field investigations and preliminary hydrologic site assessments, including estimation of surface- and groundwater resources at the mineral areas of interest. This report documents a technique for estimating streamflow statistics, primarily low to average flows, at ungaged sites in these areas. The technique, a drainage-area ratio equation with empirical factors derived by regression, was applied in a parallel investigation which provides estimates of streamflow statistics for selected mineral areas of interest in Afghanistan (Peters and others, 2011). Streamflow statistics generated with this technique, together with geologic data and other information, can be used by resource managers in Afghanistan to make economic decisions concerning the mineral areas of interest.

Streamgages Used for Estimation of Streamflow Statistics

Streamflow measurements in Afghanistan were first made at a few gaged locations in the mid-1940s. The number of streamgages increased over the years until the late 1970s, when Afghanistan had a network of approximately 160 sites. Streamflow measurements were discontinued soon after the Soviet invasion of Afghanistan in 1979. In 2005, three historical streamgages were re-established, and currently (2011) much of the historical network is in the process of being re-established by the Afghanistan Ministry of Energy and Water (MEW). No recent streamflow data were available for this study, however, and only data collected prior to 1980 were used in this analysis.

Of the 150 streamgages for which historical streamflow data were available, several criteria limited the number of eligible streamgages used in development of the technique for estimating streamflow statistics to 97. The first criterion required that streamflow at the gage be only minimally impacted by human activities. This criterion eliminated several streamgages that were located downstream from reservoirs, as well as many streamgages that were located within or downstream from areas of extensive irrigation. Because irrigation, which is common in Afghanistan, may complicate streamflow statistics, a criterion was established that basins in which greater than 10 percent of the area was classified as irrigated land (Afghanistan Information Management Service, 1997) were eliminated from the analyses. Additionally, streamgages whose basins are in the southwestern plains regions were eliminated from analysis because runoff characteristics in these basins are typically dominated by losses to groundwater and can be significantly different from the characteristics of streamflow in the mountainous basins that cover much of Afghanistan.

Another criterion was related to the minimum number of years of streamflow data available at a streamgage. For estimating flow-duration statistics, monthly and annual means, and monthly minimums, streamgages with as few as 4 complete water years of data collection were used in the analyses. The minimum number of years of available data used for streamflow estimation studies is typically 10, but the number of sites used in this analysis would have been severely limited had that criterion been used.

The number of streamgages used in the final analyses was further reduced because streamgages having streamflow values equal to zero for the selected flow characteristics were removed from the analyses. This criterion was necessary because of the strong relation that exists between basin characteristics and the logarithm of streamflow values, and the fact that the logarithm of zero does not exist. After all these criteria were met, the number of streamgages used in the analyses was (1) 89 streamgages for flow duration, (2) 93 streamgages for mean monthly streamflow and mean annual streamflow, and (3) 83 streamgages for minimum mean monthly streamflow. Of the 93 streamgages, 21 had more than 15 years of record, 32 had 10 to 15 years of record, and 40 had less than 10 years of record. The streamgages used in the analyses are listed in table 1.

The streamflow statistics that were used in this analysis can be found in Williams-Sether (2008), Olson and Williams-Sether (2010), and Vining (2010); the exception is 7-day low-flow annual series for each streamgage, which were computed from the daily mean streamflows available in the USGS National Water Information System database at http://waterdata.usgs.gov.

Table 1. Streamgages used for estimation of streamflow statistics in mineral areas of interest in Afghanistan.

[USGS, U.S. Geological Survey; x, used for estimation; --, no data]

USGS streamgage identification number	Streamgage name	Streamgage data used in the development of the equation for estimating:			
		Mean monthly and annual streamflow	Minimum monthly streamflow	Flow duration	Annual minimum 7-day streamflow statistics
315700066020000	Arghandab River above Arghandab Reservoir	x	x	x	x
321000066270000	Arghandab River at Mizan	x	x	x	--
323800065340000	Tirin River at Anarjuy	x	x	x	x
323800065560000	Tirin River at Tirin	x	x	x	x
324200065280000	Helmand River at Dehraut	x	x	x	x
325100062520000	Farah River near Petch Tangi	x	--	x	--
325100063180000	Malmand River near Shawalat	x	x	x	x
325500069150000	Urgun River at Pirkoti	x	--	x	--
325800065300000	Kaj River at Yakhdan	x	x	x	--
325800066390000	Tirin River at Urosgan	x	x	x	x
325800069090000	Dahane Legad River near Urgun	x	x	x	--
330000068520000	Park River near Park Dasht	x	x	x	--
330800067280000	Arghandab River at Sang-i-Masha	x	x	x	x
331700069360000	Spera River near Spera	x	x	x	x
332200070100000	Shumal River at Tora Tigha	x	x	x	x
332300066170000	Helmand River at Gizab	x	x	x	--
332300069530000	Matum River at Matum	x	x	x	x
333800062160000	Adraskan River at Adraskan	x	x	x	x
334200062170000	Rud-i-Gaz River near Adraskan	x	--	x	--
334300068520000	Charkh River at Kharwar Dam Inflow	x	x	x	--
334500069480000	Gaber River near Chamkani	x	--	x	--
334600068210000	Barikab River above Seraj Reservoir	x	--	x	--
334800069400000	Khurram River at Doda	x	x	x	--
334800069480000	Khurram River at Chamkani	x	x	x	x
334800069530000	Khurram River at Pul-i-Bangakh	x	--	x	--
334900069230000	Jilga River near Mechalghu	x	x	x	x
335000069390000	Khurram River at Ahmadkhel	x	x	x	--
340500068450000	Logar River at Shekhabad	x	x	x	x
340600068340000	Logar River above Band-i-Chak Wardhak	x	x	x	--
340800064120000	Kowgan River at Tangi Azu	x	x	x	x
341300063000000	Kowgan River at Langar	x	x	x	x
341400066550000	Punjab River at Waras	x	x	x	x
341400068300000	Logar River at Kajab	x	x	x	x
341400071020000	Kabul River at Dakah	x	x	x	x
341600062560000	Hari Rud River at Robat-i-Akhond	x	x	x	x

Table 1. Streamgages used for estimation of streamflow statistics in mineral areas of interest in Afghanistan.

[USGS, U.S. Geological Survey; x, used for estimation; --, no data]

USGS streamgage identification number	Streamgage name	Streamgage data used in the development of the equation for estimating:			
		Mean monthly and annual streamflow	Minimum monthly streamflow	Flow duration	Annual minimum 7-day streamflow statistics
342100063390000	Hari Rud at Tagaw Ghaza	x	x	x	x
342100067290000	Markhana River at Dahane Rishqa	x	x	x	x
342400069050000	Kabul River at Tangi Saidan	x	x	x	x
342500069230000	Chakari River at Band-i-Amir Ghazi	x	x	x	x
342500070180000	Surkhrud River near Sultanpur	x	--	--	--
342600062280000	Karukh River near Herat	x	x	x	--
342600069120000	Logar River at Sang-i-Naweshta	x	x	x	x
342800070220000	Kabul River near Daronta	x	x	x	--
342800070330000	Konar River at Pul-i-Kama	x	x	x	x
343000068160000	Helmand River at Gardandewal	x	x	x	x
343100065150000	Hari Rud River at Chekhcheran	x	x	x	x
343300065460000	Hari Rud River at Daulatyar	x	x	x	x
343300070140000	Laghman River at Pul-i-Qarghai	x	x	x	x
343400068110000	Syahang River near Gardandewal	x	x	x	x
343400069240000	Kabul River at Tang-i-Gharu	x	x	x	x
343700069430000	Kabul River at Naghlu	x	x	x	x
343800070490000	Konar River near Konari	x	x	x	x
344000069410000	Tagab River at Tagab	x	x	x	--
344500067000000	Balkh River near Nayak	x	x	x	x
345000067490000	Bamyan River at Bamyan	x	x	x	--
345300071100000	Konar River near Asmar	x	x	x	x
345400071080000	Pech River at Chaghasarai	x	x	x	x
350200064010000	Murghab River at Qala-i-niazkhan	x	x	x	x
350500069080000	Ghorband River at Pul-i-Ashawa	x	x	x	x
350900069130000	Salang River at Bagh-i-Lala	x	x	x	x
350900069170000	Shatul River at Gulbahar	x	x	x	x
351000069170000	Panjsher River at Gulbahar	x	x	x	x
351300062170000	Kushk River at Chil Dukhtaran	x	x	x	--
351400063280000	Bum River at Luka-i-Surkh	x	x	x	--
351600067590000	Bamyan River at Doab	x	x	x	x
351800067550000	Kunduz River at Dasht-i-Safed	x	x	x	--
352000062550000	Kashan River at Babulai	x	--	--	--
352200069380000	Panjsher River at Omarz	x	x	x	x
353500063190000	Murghab River at Bala Murghab	x	x	x	x
353600068360000	Kunduz River at Pul-i-Konda Sang	x	x	x	x

Table 1. Streamgages used for estimation of streamflow statistics in mineral areas of interest in Afghanistan.

[USGS, U.S. Geological Survey; x, used for estimation; --, no data]

USGS streamgage identification number	Streamgage name	Streamgage data used in the development of the equation for estimating:			
		Mean monthly and annual streamflow	Minimum monthly streamflow	Flow duration	Annual minimum 7-day streamflow statistics
353600068410000	Andarab River at Doshi	x	x	x	x
355600068430000	Kunduz River at Pul-i-Khumri	x	x	x	x
355700064540000	Shirin Tagab River at Khisht Pul	x	x	x	x
360600068400000	Kunduz River at Baghlan	x	x	x	x
360800066570000	Suf River near Kishandeh	x	--	--	--
361100066020000	Shorab River near Sare Pul	x	x	x	x
361200065570000	Sare Pul River at Asiabad	x	x	x	x
362200068520000	Kunduz River at Gerdab	x	x	x	x
362700064530000	Shirin Tagab River at Daulatabad	x	x	x	--
363200064530000	Maimana River near Pata Baba	x	--	--	--
363500064520000	Shirin Tagab River at Pata Baba	x	x	x	x
363500066580000	Balkh River at Rabat-i-Bala	x	x	x	x
363500067470000	Khulm River at Sayad	x	x	x	x
363800069430000	Farkhar River near Taloqan	x	x	x	x
364000067420000	Khulm River at Tangi Tashqurghan	x	x	x	x
364200069150000	Bangi River at Pul-i-Bangi	x	x	x	x
364400069120000	Taloqan River at Pul-i-Chugha	x	x	x	x
365500070030000	Keshem River near Keshem	x	x	x	x
365600070520000	Kokcha River near Jurm	x	x	x	x
365700070030000	Kokcha River near Keshem	x	x	x	x
365800070540000	Warduj near Baharak	x	x	x	x
370100070500000	Warduj River at Shashpul	x	x	x	x
370500069280000	Kokcha River at Khojaghar	x	x	x	x

Basin Characteristics for Gaged and Ungaged Locations

Drainage-basin boundaries for the streamgages were determined using a Geographic Information System (GIS) and a digital flow-direction grid derived from a 90-meter digital elevation model of Afghanistan (Chirico and Barrios, 2005). Additional dimensional basin characteristics were computed with ArcHydro software (Environmental Systems Research Institute, Inc., 2008), also using the digital elevation model. Gridded precipitation data published by the International Institute of Applied Systems Analyses (Leemans and Cramer, 1991) were used to determine the precipitation characteristics for each streamgage. The basin characteristics for the streamgages used in the study are shown in appendix 1 (at end of report) and may differ from characteristics reported by other studies.

Estimation of Streamflow Statistics at Ungaged Locations

Methods for estimating streamflow statistics at ungaged stream sites in mineral areas of interest were developed using a drainage-area-ratio technique, with empirical factors derived by using selected gages from the historical network, and individual historical gages. Although more detailed regression analyses that included regional, topographic, and estimated climatic variables were also examined during this study, the standard errors of regression and resulting flow statistics indicated that such an analysis could not be justified without additional, higher quality input data.

For an ungaged site, streamflow statistics can be generated using nearby historical gages where available or, if no gage is near the ungaged site, a historical gage in a similar setting. One or more historical gages are present upstream or downstream from several of the mineral areas of interest. In this case, logarithmic interpretations, based on ratios of gaged to ungaged drainage areas, can be used to estimate streamflow statistics at an ungaged site. Estimates of streamflow statistics generated using the methods discussed in this report, and data from various historical gages, were used in a parallel investigation assessing mineral areas of interest in Afghanistan (Peters and others, 2011). Because the generated streamflow statistics use historical data for basins that may differ in size and hydrologic setting from those of the ungaged site, no information is available with which to assign a confidence to the streamflow statistics at the ungaged site.

Equations for Estimation of Streamflow Statistics at Ungaged Locations

The drainage-area-ratio technique is a useful method for estimating streamflow statistics when one or more streamgages are present in the vicinity of, or in an area with characteristics similar to those of, the area containing the ungaged location of interest. Typically, the drainage area of the ungaged point of interest is limited to being within a certain percentage of the drainage area of the streamgage. Published limits for this technique vary, but the rule of thumb most commonly used is to limit the size of the drainage area of the ungaged point of interest to ±50 percent of the size of the drainage area of the streamgage.

The following equation is used:

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right), \tag{1}$$

where A_u and A_g are the drainage areas of the ungaged and gaged locations, respectively, and Q_u and Q_g are the streamflows at the ungaged and gaged locations, respectively. The technique relies on the relation commonly found between drainage area and streamflow. This relation is typically more linear when logarithmic units are used (fig. 2). The mean relation between drainage area and streamflow in logarithmic units is determined by regression for each streamflow statistic. These logarithmic relations are then used in the equation

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^x, \tag{2}$$

where x is the slope of the relation between drainage area and streamflow in logarithmic units determined by regression. The exponent, x, can be found in table 2 for each of the streamflow statistics.

Table 2. Suggested drainage-area-ratio exponents for estimation of streamflow statistics in mineral areas of interest in Afghanistan.

Streamflow (discharge) statistic	Drainage-area-ratio exponent
7-day low flow with 10-year recurrence interval, 7Q10	1.14
7-day low flow with 2-year recurrence interval, 7Q2	1.03
90-percent flow-duration discharge, D_{90}	1.25
80-percent flow-duration discharge, D_{80}	1.18
October mean monthly discharge, OCT_{mean}	1.10
November mean monthly discharge, NOV_{mean}	1.09
December mean monthly discharge, DEC_{mean}	1.08
January mean monthly discharge, JAN_{mean}	1.06
February mean monthly discharge, FEB_{mean}	1.00
March mean monthly discharge, MAR_{mean}	0.92
April mean monthly discharge, APR_{mean}	0.90
May mean monthly discharge, MAY_{mean}	1.05
June mean monthly discharge, JUN_{mean}	1.18
July mean monthly discharge, JUL_{mean}	1.08
August mean monthly discharge, AUG_{mean}	1.06
September mean monthly discharge, SEP_{mean}	1.09
Mean annual discharge, ANN_{mean}	1.04
October minimum monthly discharge, OCT_{min}	1.20
November minimum monthly discharge, NOV_{min}	1.19
December minimum monthly discharge, DEC_{min}	1.18
January minimum monthly discharge, JAN_{min}	1.21
February minimum monthly discharge, FEB_{min}	1.17
March minimum monthly discharge, MAR_{min}	1.04
April minimum monthly discharge, APR_{min}	1.03
May minimum monthly discharge, MAY_{min}	1.17
June minimum monthly discharge, JUN_{min}	1.30
July minimum monthly discharge, JUL_{min}	1.25
August minimum monthly discharge, AUG_{min}	1.29
September minimum monthly discharge, SEP_{min}	1.27

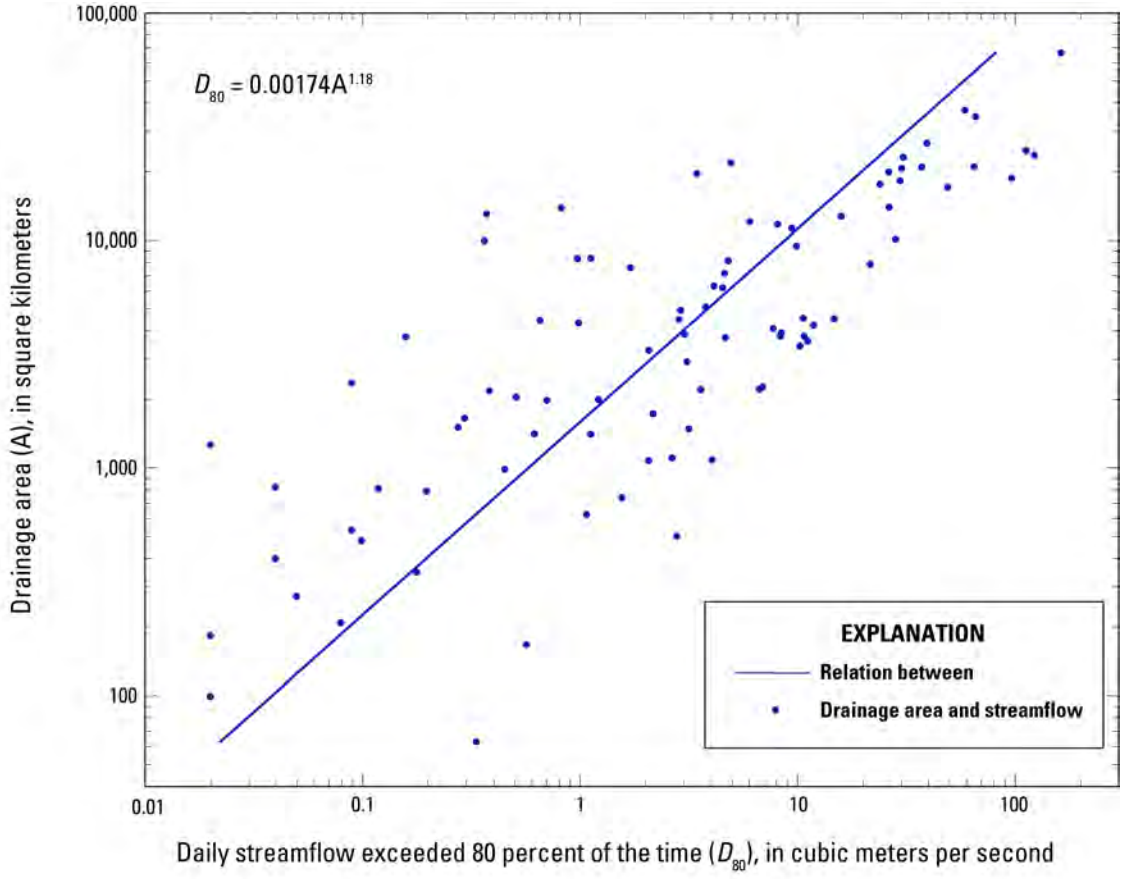

Figure 2. Drainage area verses daily streamflow exceeded 80 percent of the time (D80) for historical streamgages used in this investigation of mineral areas of interest in Afghanistan.

Application of Streamflow Statistics at Ungaged Locations

Streamflow statistics for an ungaged location can be estimated using equation 2 to provide some probable estimates of flow in a mineral area of interest. Ideally, the historical streamgage selected for use with equation 2 would be on the same stream as the ungaged location, with no intervening regulation. In practice, the streamgage used to calculate a streamflow statistic at an ungaged site may not be on the same stream and may not have the same size drainage area. The best choice for a gage would be a nearby gage with similar basin characteristics or, if there are no nearby gages, a gage in a similar region of the country (north, south, east, or west) with similar geohydrologic characteristics. For example, to estimate streamflow statistics at an ungaged stream in the mineral area of interest number 6 (fig. 1), the Dusar-Shaida copper and tin mineral area of interest (Peters and others, 2007), one of the two historical streamgages at the eastern boundary of the area of interest, the Adraskan River at Adraskan or the Rud-i-Gaz River near Adraskan (table 1, appendix 1), would likely be the most representative historical gage for use with this method because of its proximity to the estimation point. Using a historical mean annual streamflow of 6.53 m^3/s for the Adraskan River, a 1,950-km^2 drainage area, and an exponent of 1.04 for mean annual discharge (table 2) with equation 2, the mean annual flow for a stream with a 2,900-km^2 drainage area in the Dusar-Shaida area of interest is estimated to be about 9.9 m^3/s. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at http://afghanistan.cr.usgs.gov/water.php.

Limitations of Streamflow Statistics at Ungaged Locations

The analyses presented in this report were based on streamflow records that, for some streamgages, were shorter than those typically used in such analyses. It was necessary to include gages with short periods of record (less than 10 years) in the analyses in order to include characteristics of streamflow in all areas of the country. In addition, the periods of record of the gages used in the analyses were not necessarily concurrent. Moreover, most of the streamflow data that were used in this study were collected in the 1960s and 1970s; it is not known whether this time period is representative of the long-term hydrology of the region, nor how streamflow may have been affected by climatic variations over time. Any climatic changes that may have occurred since 1980 may further limit the accuracy of the estimated streamflow statistics. For these reasons, streamflow statistics calculated using the equations presented in this report are considered preliminary and should be used with an understanding that they may not accurately represent the streamflow in the basin of interest. Improved streamflow statistics can be developed when additional streamflow and climatic data become available.

This technique for estimating streamflow statistics is applicable only to basins that are hydrologically similar to those used in the development of the drainage-area-ratio relations. Therefore, the technique may not be suited for use with regulated streams in basins that consist of more than 10 percent irrigated land. Furthermore, the equations can only be reasonably used to estimate streamflow statistics for sites whose basins have characteristics that are within the range of basin characteristics used in the development of the equations. The ranges of basin characteristics used in the analysis are shown in appendix 1. If the characteristics of basins of ungaged sites are outside these ranges, the results are considered extrapolations.

Summary

This report documents a technique for estimating streamflow statistics at ungaged sites in mineral areas of interest in Afghanistan. The technique produces equations that can be used to estimate streamflow statistics at an ungaged site using a ratio of its drainage area to the drainage area of a hydrologically similar site with known streamflow statistics determined from streamflow data collected at gaged locations in Afghanistan through 1980. Equations incorporating the drainage-area ratio were developed for estimating the (1) 7-day low flow with a 10-year recurrence interval, (2) 7-day low flow with a 2-year recurrence interval, (3) daily mean streamflow exceeded 90 percent of the time, (4) daily mean streamflow exceeded 80 percent of the time, (5) mean monthly streamflow for each month of the year, (6) mean annual streamflow, and (7) minimum monthly streamflow for each month of the year. Improved streamflow statistics could be developed given longer streamflow records and additional climatic data that currently (2011) are unavailable.

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Appendix 1. Basin Characteristics for Streamgages Used for Estimation of Streamflow at Ungaged Locations in Mineral Areas of Interest in Afghanistan

Appendix 1. Basin characteristics for streamgages used for estimation of streamflow at ungaged locations in mineral areas of interest in Afghanistan.

[USGS, U.S. Geological Survey; km^2, square kilometers; m, meters; mm, millimeters]

USGS streamgage identification number	Streamgage name	Drainage area[1] (km^2)	Mean basin slope (percent)	Elevation of basin centroid (m)	Percentage of basin above 3,000 m	Basinwide mean of monthly precipitation[2] (mm)				Percentage of basin consisting of irrigated land
						October	November	December	January	
315700066020000	Arghandab River above Arghandab Reservoir	11,200	26.8	3,270	25.1	6.1	15.2	31.7	47.2	6.47
321000066270000	Arghandab River at Mizan	9,340	27.6	2,700	29.9	6.7	16.4	32.4	47.1	6.93
323800065340000	Tirin River at Anarjuy	8,060	24.3	1,860	10.9	5.1	12.5	28.4	44.2	7.72
323800065560000	Tirin River at Tirin	3,690	27.7	2,080	19.0	6.9	16.0	31.0	45.3	4.53
324200065280000	Helmand River at Dehraut	37,100	33.6	3,230	32.3	10.6	21.3	33.4	43.5	3.52
325100062520000	Farah River near Petch Tangi	19,400	26.1	1,840	4.75	8.0	15.1	32.2	41.0	1.59
325100063180000	Malmand River near Shawalat	1,480	27.4	1,430	4.62	3.8	10.3	24.9	34.8	0.19
325500069150000	Urgun River at Pirkoti	803	14.9	2,280	1.87	7.3	17.3	33.0	47.5	6.98
325800065300000	Kaj River at Yakhdan	11,600	31.0	2,180	9.98	9.1	15.0	29.6	39.6	3.14
325800066390000	Tirin River at Urosgan	1,060	30.9	2,860	36.6	9.3	22.1	35.9	48.4	4.71
325800069090000	Dahane Legad River near Urgun	177	17.2	2,410	3.99	7.0	17.1	33.0	47.5	0.97
330000068520000	Park River near Park Dasht	264	14.1	2,490	2.73	4.3	12.7	27.2	40.4	4.43
330800067280000	Arghandab River at Sang-i-Masha	2,170	30.6	3,210	67.0	10.7	26.5	41.5	54.6	6.50
331700069360000	Spera River near Spera	771	32.3	2,010	7.48	10.1	19.5	35.2	51.5	1.69
332200070100000	Shumal River at Tora Tigha	4,280	23.3	1,480	3.51	11.0	17.5	31.5	45.9	8.54
332300066170000	Helmand River at Gizab	20,700	34.5	2,810	50.6	12.4	27.0	37.3	46.8	3.83
332300069530000	Matun River at Matun	338	32.0	1,870	4.10	12.4	20.1	35.1	52.4	2.03
333800062160000	Adraskan River at Adraskan	1,950	26.1	2,390	7.56	7.3	16.3	32.8	42.8	4.46
334200062170000	Rud-i-Gaz River near Adraskan	2,140	19.4	2,420	0.71	7.1	16.6	32.0	42.7	1.57
334300068520000	Charkh River at Kharwar Dam Inflow	519	15.4	2,470	9.30	4.5	17.1	33.3	49.2	7.26

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334500069480000	Gaber River near Chamkani	465	36.6	2,620	22.4	13.6	23.0	39.0	58.6	2.93
334600068210000	Barikab River above Seraj Reservoir	95.9	24.1	2,770	31.4	9.2	27.1	44.6	58.2	8.51
334800069400000	Khurram River at Doda	1,050	33.5	2,750	31.6	14.5	27.4	44.6	65.5	6.94
334800069480000	Khurram River at Chamkani	1,380	35.6	2,160	27.9	14.6	27.1	44.1	65.1	5.72
334800069530000	Khurram River at Pul-i-Bangakh	1,960	35.4	1,910	25.1	14.5	25.8	42.5	63.3	5.26
334900069230000	Jilga River near Mechalghu	60.6	30.7	2,880	67.6	12.2	27.5	45.6	64.2	0.00
335000069390000	Khurram River at Ahmadkhel	723	33.3	2,250	34.4	14.9	27.5	44.6	65.9	6.49
340500068450000	Logar River at Shekhabad	4,860	22.8	2,990	55.7	11.4	33.9	51.5	63.9	4.22
340600068340000	Logar River above Band-i-Chak Wardhak	4,440	22.5	2,810	59.5	11.7	34.5	52.0	64.3	4.14
340800064120000	Kowgan River at Tangi Azu	2,010	16.3	2,520	7.19	12.1	18.3	37.7	43.8	3.51
341300063000000	Kowgan River at Langar	7,500	23.5	2,620	4.42	11.5	18.8	38.9	45.7	2.86
341400066550000	Punjab River at Waras	1,700	32.6	3,060	73.2	14.3	27.7	32.3	39.1	3.54
341400068300000	Logar River at Kajab	3,800	21.9	2,840	66.6	12.1	35.2	52.6	64.6	3.68
341400071020000	Kabul River at Dakah	66,400	40.5	2,550	43.2	17.3	35.3	51.5	65.1	5.71
341600062560000	Hari Rud River at Robat-i-Akhond	21,700	24.3	2,650	17.3	12.9	19.8	36.3	42.0	2.80
342100063390000	Hari Rud at Tagaw Ghaza	11,900	24.5	2,280	28.3	13.6	20.4	33.6	38.5	1.93
342100067290000	Markhana River at Dahane Rishqa	1,080	38.1	3,100	86.7	14.4	35.3	46.4	54.6	2.61
342400069050000	Kabul River at Tangi Saidan	1,620	33.7	2,810	36.2	10.8	35.5	55.8	70.1	9.66
342500069230000	Chakari River at Band-i-Amir Ghazi	388	24.1	2,340	21.4	12.7	33.0	51.0	70.7	2.99

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342500070180000	Surkhrud River near Sultanpur	2,610	31.2	2,970	29.2	18.3	27.7	42.7	68.5	9.50
342600062280000	Karukh River near Herat	1,380	19.1	1,520	1.32	10.4	19.6	37.2	46.4	4.64
342600069120000	Logar River at Sang-i-Naweshta	9,870	19.6	2,710	31.5	9.7	29.2	46.7	61.5	7.15
342800070220000	Kabul River near Daronta	34,700	33.0	1,730	35.6	14.4	37.8	58.1	73.7	7.30
342800070330000	Konar River at Pul-i-Kama	24,600	56.1	2,720	62.6	21.2	36.0	47.6	55.8	1.26
343000068160000	Helmand River at Gardandewal	607	35.2	3,610	99.8	13.4	42.5	64.0	76.5	0.41
343100065150000	Hari Rud River at Chekhcheran	6,110	25.2	2,740	48.9	14.0	21.7	28.7	33.6	2.19
343300065460000	Hari Rud River at Daulatyar	2,880	28.8	2,720	58.2	14.9	23.9	28.2	32.7	2.12
343300070140000	Laghman River at Pul-i-Qarghai	6,230	49.6	2,000	44.6	20.4	41.2	61.5	78.1	3.10
343400068110000	Syahang River near Gardandewal	162	31.6	3,350	100	14.7	43.8	63.4	74.0	8.40
343400069240000	Kabul River at Tang-i-Gharu	12,900	21.3	2,140	29.8	9.9	30.2	48.0	63.1	8.67
343700069430000	Kabul River at Naghlu	26,500	30.0	2,310	36.1	12.9	38.4	59.3	73.9	8.63
343800070490000	Konar River near Konari	23,400	57.1	2,120	65.5	21.5	37.3	49.0	56.2	0.99
344000069410000	Tagab River at Tagab	793	38.4	1,970	19.0	14.9	36.0	54.4	73.4	7.26
344500067000000	Balkh River near Nayak	1,450	24.0	3,020	90.5	15.9	37.1	45.5	51.2	1.18
345000067490000	Bamyan River at Bamyan	964	23.0	3,120	83.8	15.7	40.7	54.4	61.3	3.03
345300071100000	Konar River near Asmar	18,600	58.6	3,080	71.0	21.3	37.5	48.0	52.6	0.34
345400071080000	Pech River at Chaghasarai	3,870	55.4	3,070	56.0	23.8	42.6	60.8	76.7	1.72
350200064010000	Murghab River at Qala-i-niazkhan	13,800	28.7	2,770	18.1	14.0	20.0	37.9	42.0	0.71

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350500069080000	Ghorband River at Pul-i-Ashawa	4,040	42.2	2,170	53.0	13.4	44.4	68.0	80.7	4.64
350900069130000	Salang River at Bagh-i-Lala	488	48.3	2,900	46.0	15.1	49.3	80.2	93.6	4.19
350900069170000	Shatul River at Gulbahar	202	48.5	3,250	63.9	16.8	52.6	85.5	99.4	0.72
351000069170000	Panjsher River at Gulbahar	3,550	49.7	3,750	77.9	23.3	64.1	97.7	108.8	2.07
351300062170000	Kushk Riverat Chil Dukhtaran	2,320	15.9	1,320	0.03	10.0	20.8	34.2	45.6	2.44
351400063280000	Bum River at Luka-i-Surkh	1,240	16.3	1,410	0.16	17.2	20.5	45.0	47.8	0.67
351600067590000	Bamyan River at Doab	5,030	32.8	4,060	61.9	14.7	41.4	57.1	64.9	3.11
351800067550000	Kunduz River at Dasht-i-Safed	3,740	30.2	3,240	73.5	15.0	36.6	45.8	50.8	0.84
352000062550000	Kashan River at Babulai	5,290	15.9	987	0.08	12.2	20.1	40.9	48.5	3.08
352200069380000	Panjsher River at Omarz	2,230	48.7	2,850	87.3	25.5	67.9	100.6	109.8	1.34
353500063190000	Murghab River at Bala Murghab	20,500	26.6	2,260	12.3	14.9	20.2	39.9	43.8	0.88
353600068360000	Kunduz River at Pul-i-Konda Sang	12,600	35.4	2,420	59.7	14.3	40.9	56.6	64.0	2.01
353600068410000	Andarab River at Doshi	3,740	43.7	2,410	38.7	16.0	51.3	81.7	93.0	3.93
355600068430000	Kunduz River at Pul-i-Khumri	17,500	36.8	2,010	51.4	14.3	42.6	61.4	69.7	2.47
355700064540000	Shirin Tagab River at Khisht Pul	3,240	24.2	1,360	2.05	11.5	19.9	36.1	42.9	2.82
360600068400000	Kunduz River at Baghlan	19,800	35.3	1,330	46.3	13.8	41.5	59.5	67.7	3.16
360800066570000	Suf River near Kishandeh	3,080	28.1	1,700	21.6	12.0	32.0	42.4	48.0	1.42
361100066020000	Shorab River near Sare Pul	3,710	20.6	1,400	10.1	11.7	22.6	33.7	39.4	4.91
361200065570000	Sare Pul River at Asiabad	7,100	22.7	1,920	14.3	12.4	22.9	35.1	40.5	3.84
362200068520000	Kunduz River at Gerdab	23,000	33.2	1,210	40.2	13.3	39.9	56.9	65.0	4.27

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362700064530000	Shirin Tagab River at Daulatabad	4,390	22.4	1,320	1.51	10.9	20.6	35.4	43.6	4.48
363200064530000	Maimana River near Pata Baba	8,600	16.6	628	0.48	9.9	19.8	36.9	46.8	5.41
363500064520000	Shirin Tagab River at Pata Baba	13,700	18.3	778	0.78	10.2	20.2	36.2	45.6	5.14
363500066580000	Balkh River at Rabat-i-Bala	18,100	29.1	1,900	34.3	12.6	28.0	36.4	41.2	1.71
363500067470000	Khulm River at Sayad	8,230	20.5	2,350	10.4	9.6	31.1	43.5	49.1	2.21
363800069430000	Farkhar River near Taloqan	4,170	52.5	3,920	61.8	25.9	64.7	87.8	91.3	1.96
364000067420000	Khulm River at Tangi Tashqurghan	8,280	20.7	2,370	10.3	9.5	31.0	43.3	48.9	2.23
364200069150000	Bangi River at Pul-i-Bangi	4,480	42.2	1,780	29.3	16.7	46.8	69.7	78.1	5.40
364400069120000	Taloqan River at Pul-i-Chugha	10,000	43.8	4,210	40.2	21.0	54.4	76.3	82.1	5.61
365500070030000	Keshem River near Keshem	2,180	47.2	2,140	41.8	25.1	56.1	73.1	75.6	3.71
365600070520000	Kokcha River near Jurm	7,770	55.9	2,830	80.4	32.5	73.4	91.5	90.6	1.25
365700070030000	Kokcha River near Keshem	16,900	48.7	2,060	61.4	28.7	61.8	76.2	75.2	1.88
365800070540000	Warduj near Baharak	3,380	50.3	4,700	85.8	29.5	61.9	73.8	70.9	1.64
370100070500000	Warduj River at Shashpul	4,460	50.2	4,020	81.1	29.5	61.7	72.9	69.1	2.62
370500069280000	Kokcha River at Khojaghar	20,900	46.7	3,470	54.2	27.2	58.6	72.8	72.9	1.94

[1] Drainage area calculated by this study may differ from that reported by other studies.

[2] Precipitation estimates from Leemans and Cramer (1991).

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