**US Army Corps
of Engineers
Afghanistan Engineer District**

AED Design Requirements: Hydrology Studies (Provisional)

Various Locations,
Afghanistan

SEPTEMBER 2009, Version 1.5

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AED DESIGN REQUIREMENTS
FOR
HYDROLOGY STUDY
VARIOUS LOCATIONS, AFGHANISTAN

1. General

The purpose of this document is to illustrate the technical requirements contractors shall show in design analyses for projects requiring hydrology analysis of storm drainage components that are part of USACE-AED projects. The guidance is provisional – meaning it serves for the time being only until permanently replaced. The development of hydrologic statistics in Afghanistan is an ongoing process and as new data and analyses become available they will be incorporated into this design guide. A companion design guide discusses technical requirements for the design of culverts and road causeways - two hydraulic structures that require hydrologic analysis as the basis of the design.

2. Hydrology

Hydrology studies include a careful appraisal of factors affecting storm runoff to insure the development of a drainage system or road crossing culverts are capable of providing the required flow conveyance at the specified annual flood frequency of protection in the contract technical requirements. If the design flood frequency is not specified, the engineer shall base the selection of design storm magnitudes not only on the protection sought but also on the type of construction contemplated and the consequences of storms of greater magnitude than the design storm as specified in References 1 and 9.

Hydrologic studies for USACE-AED projects are generally concerned with the estimate of peak flow rates for use in the hydraulic design of channels, culverts, and erosion control and energy dissipation structures. In limited situations where ponding capacity is required, such as detention or infiltration facilities, runoff volume estimation is required. General USACE design information is provided in Reference 1.

Two hydrologic methods are preferred for use on USACE-AED projects: the Rational Method and the unit hydrograph method. The Rational Method shall be used when the catchment area draining to the structure or other point of concentration is less than one (1) square kilometer (247 acres). The Rational Method is generally limited to the calculation of the peak flow rate. The unit hydrograph method is required for drainage areas greater than one square kilometer. The theory and assumptions involved with these methods are well documented in design manuals and hydrologic engineering texts; two references which can be obtained from U.S. Government internet sources are included in References 2 and 3. The intent of this guide is to provide standardized data and assumptions in the use of these methods to simplify design and review of projects.

3. Design Conditions

Ground conditions affecting runoff must be selected to be consistent with existing and anticipated development and also with the characteristics and seasonal time of occurrence of the design rainfall.

Design conditions for the Rational Method consist of the runoff coefficient (C), the rainfall intensity-duration-frequency relationship, and the time of concentration. The runoff coefficient is a single parameter that considers soil type, land use cover (bare, vegetation, or pavement) and slope. There are several sources for C values that are acceptable provided they are accompanied by a complete reference in the design analysis. Generally the more information that is used in the C-value evaluation, the more accurate the flow estimation will be. A suggested chart is included in the next section that has compiled C values from several references.

In the majority of areas such as military, industrial, and cantonment areas, the design storm will normally be based on rainfall of 10-year frequency. This is equivalent to an annual probability of being equaled or exceeded equal to ten percent each year (Probability=1/10= 0.1, or 10 percent expresses as a percent). Potential damage or operational requirements may warrant a more severe criterion which shall usually be stated in the contract technical requirements. A lesser criterion may also be employed in regions where storms of an appreciable magnitude are infrequent and either damages or operational capabilities are such that large expenditures for drainage are not justified. The design of roadway culverts will normally be based on 10-year rainfall. Examples of conditions where greater than 10-year rainfall may be used are areas of steep slope in which overflows would cause severe erosion damage; high road fills that impound large quantities of water; and primary diversion structures, important bridges, and critical facilities where uninterrupted operation is imperative.

4. Runoff Computation Methods

The design procedures for drainage facilities involve computations to convert the rainfall intensities expected from the design storm into runoff rates which can be used to size the various elements of the storm drainage system. As previously stated, there are two basic approaches: direct estimates of the proportion of the average rainfall intensity which will appear as the peak rate of runoff (Rational Method) and unit hydrograph methods which account for losses such as infiltration and for the effects of flow over the surface to the point of design. The Rational Method approach can be used successfully by experienced designers for drainage areas up to 100 hectares in size and is discussed first. **For watershed sizes greater than one square kilometer a second approach shall be used to compute peak runoff that includes techniques to generate hydrographs, or calculation of a continuous flow rate over time, for surface runoff where studies of large drainage areas or complex conditions of storage require hydrographs are required.**

4.1. Rational Method

To compute peak runoff using the Rational Method the following equation is used.

$$Q=kCIA$$

Where

- Q=peak flow (m^3/sec.)
- k=0.278 (dimensionless)
- C=runoff coefficient (dimensionless)
- I=rainfall intensity (mm/hr)
- A=drainage area (km^2)

The k value in the above equation is a conversion factor to convert the peak flow into units of m^3/second.

a) Runoff Coefficient. The runoff coefficient (C) is a variable of the Rational Method that requires significant judgment and understanding on the part of the designer. The coefficient must account for all the factors affecting the relation of peak flow to average rainfall intensity other than area and response time. A range of C-values is typically offered to account for slope, condition of cover, soil moisture condition prior to the storm, and other factors that may influence runoff quantities. Good engineering judgment must be used when selecting a C-value for design and peak flow values because a typical coefficient represents the integrated effects of many drainage basin parameters. When available, design and peak flows should be checked against observed flood data. The following discussion considers only the effects of soil groups, land use, and average land slope.

As the slope of the drainage basin increases, the selected C-value should also increase. This is because as the slope of the drainage area increases, the velocity of overland and channel flow will increase, allowing less opportunity for water to infiltrate the ground surface. Thus, more of the rainfall will become runoff from the drainage area. The lowest range of C-values should be used for flat areas where the majority of grades and slopes are less than 2 percent. The average range of C-values should be used for intermediate areas where the majority of grades and slopes range from 2 to 5 percent. The highest range of C-values should be used for steep areas (grades greater than 5 percent), for impervious areas, and for development in clay soil areas.

It is often desirable to develop a composite runoff coefficient based on the percentage of different surface types in the drainage area. The composite procedure can be applied to an entire drainage area or to typical "sample" blocks as a guide to selection of reasonable values of the coefficient for an entire area. Impervious areas such as roadways, need to be accounted for in actual design. An example table of runoff coefficient values is provided Table 1.

Table 1. Runoff Coefficient Values (10-year storm frequency)

Rational Method Runoff C Coefficients

Type of Cover	Soil Type	Flat	Rolling 2% to 10%	Mountains over 10%
Buildings and roofs		0.90	0.90	0.90
Concrete pavedsurfaces		0.80	0.90	0.95
Asphalt pavedsurfaces		0.70	0.80	0.90
Earth embankments	bare & compacted	0.60	0.60	0.60
Gravel road shoulders		0.50	0.55	0.60
Sidewalks		0.80	0.82	0.85
Grassed areas	sandy	0.10	0.15	0.20
Grassed areas	clay	0.15	0.20	0.30
Farmed land	sand & gravel	0.25	0.30	0.35
Farmed land	clay & loam	0.50	0.55	0.60
steppe forest	sandy	0.10	0.15	0.20
semi desert land	bare & loose	0.10	0.20	0.30

Source: References 7 and 8

Other values that might be more appropriate for specific projects may be used provided they are completely referenced in the design analysis.

b) Rainfall Intensity. The rainfall intensity in millimeters/hour is generally determined from **I**ntensity-**D**uration-**F**requency (IDF) curves, if available. IDF curves are developed for regional areas as opposed to using one value for the entire sections of the country due to the wide fluctuations in rainfall over a large area. Sufficient information is available from sources in Afghanistan that merit the use of local data rather than attempts to derive IDF relationships from other countries. Data obtained from The Ministry of Energy and Water (MEW). The data was developed into IDF curves shown in Appendix B. The curves were developed as follows:

- Maximum annual 24-hour rainfall total depth measurements were compiled and fit to the Log Pearson Type III probability distribution using the Corps of Engineers computer program FFA (Reference 4); 10-, 20- , and 50- year 24-hour peak rainfall intensities were calculated
- The peak 24-hour intensities for each frequency were multiplied by ratios to obtain hour, one-hour, 30-minute, and 15 minute rainfall intensities for each time duration. The ratios were based on regional rainfall intensity durations curves obtained from MEW.
- The calculated rainfall intensity data were plotted on charts using log-log abscissa and ordinate scales

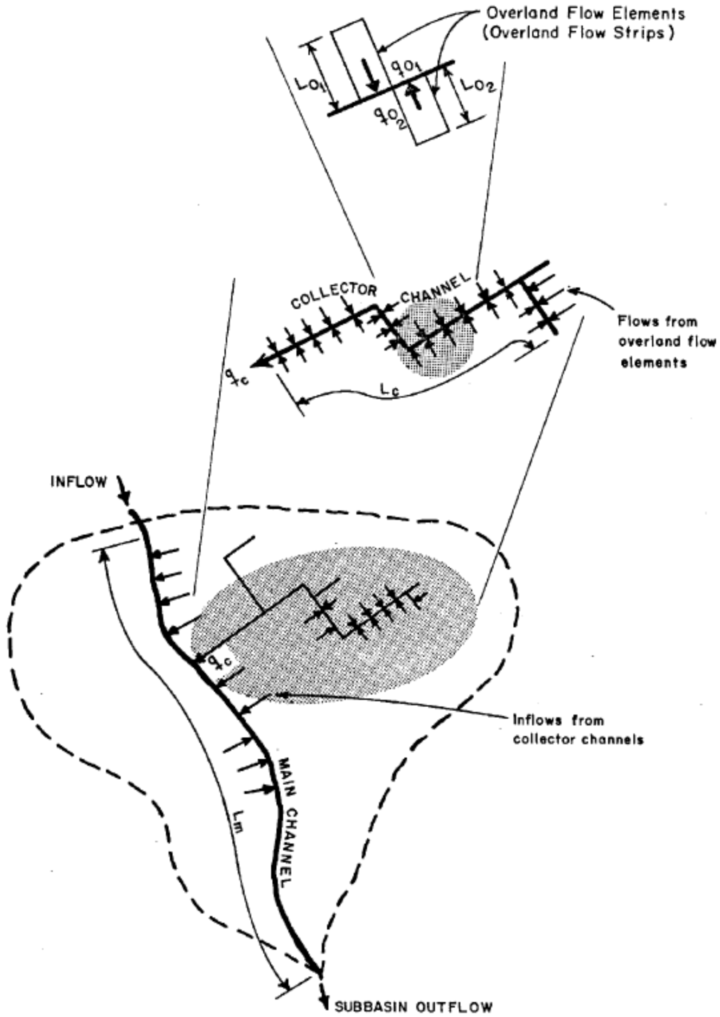
In regions where no I-D-F curve is available, the rainfall intensity may be calculated by the following formula:

$I=(R/24)*(24/T_c)^K$

Where

I=rainfall intensity (mm/hr)
R=maximum daily rainfall for design frequency (mm)
T_c=time of concentration (hr)
K = a regional coefficient whose approximate value is 0.722 for Afghanistan for 10-year storm

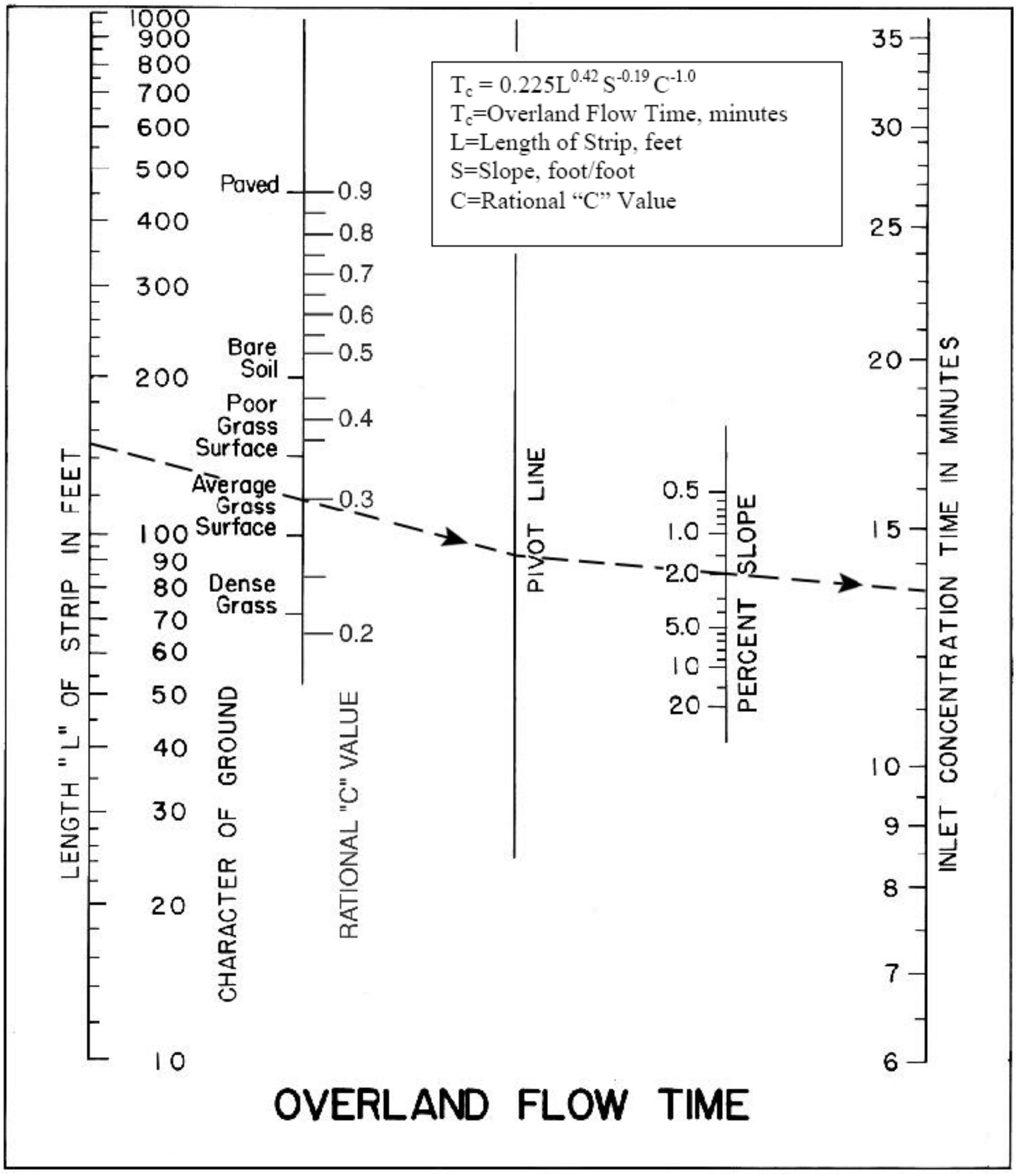
c) Time of Concentration. Time of concentration is the time for runoff to travel from the most hydraulically distant point in the watershed to the point of interest within the watershed. The time of concentration is the sum of the overland flow time, the shallow concentrated flow time and the channel flow time. For almost all drainage areas the maximum length of the overland flow will be approximately 100 meters. Overland flow will normally occur at the upper ends of the drainage or installation catchment area and will occur over relatively smooth surfaces such as parking areas and flat slopes. In areas where shallow ditches occur, the runoff will not be overland flow but will concentrate into shallow channels. Farther downstream the shallow channels such as gutters and surface swales further concentrate into open channel drainages. The following figure illustrates the concept of these flow components.



Source: Reference 3.

The overland flow time of concentration may be determined by the following nomograph in Figure 1. A nomograph is a chart usually containing three parallel scales graduated for different variables so that when a straight line connects values of any two, the related value may be read directly from the third at the point intersected by the line. Notice that the units on this nomograph are U.S. customary units and the result should be obtained first in this unit system and converted to SI units because the nomograph is based on the equation shown on it that uses empirical constants developed in this unit system.

Figure 1. Nomograph for Overland Flow Time of Concentration

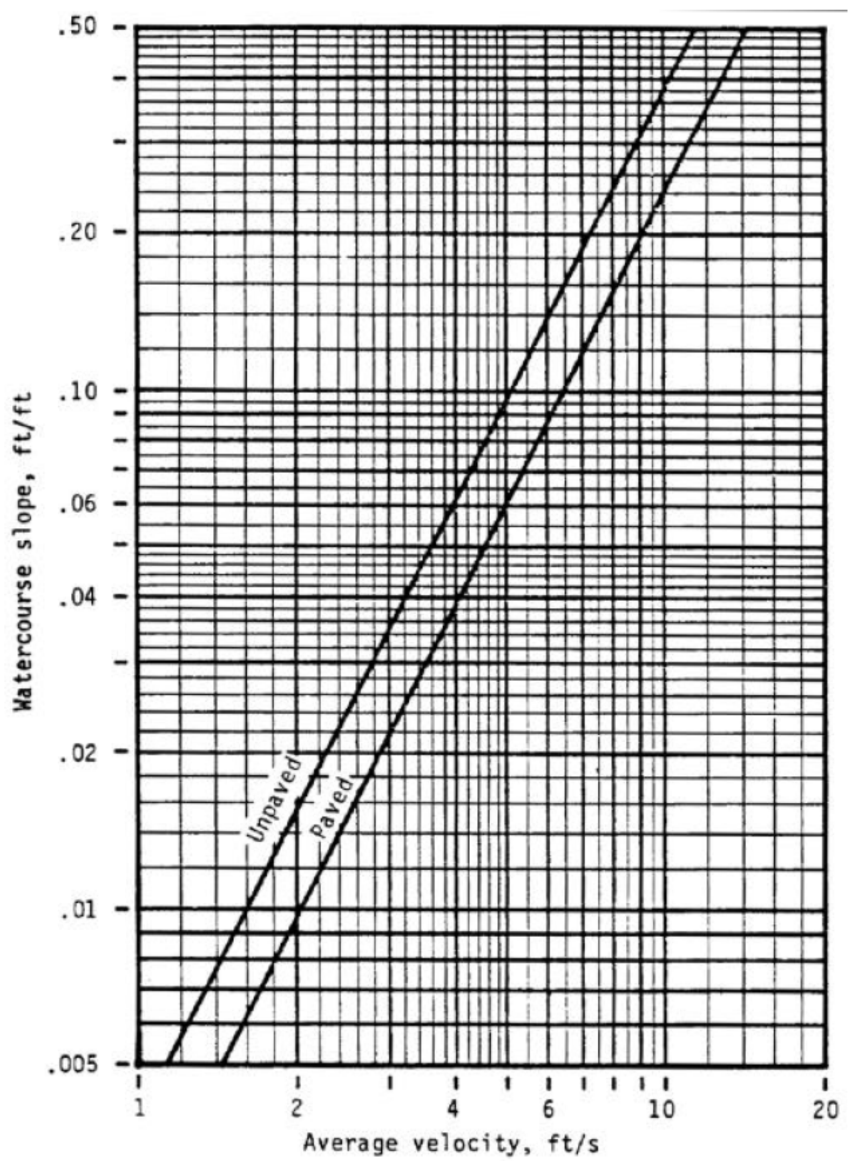


The overland flow time of concentration is determined by drawing a straight line through the flow length of the overland flow and the surface type or rational runoff coefficient and extending this line to the pivot line in the center of the nomograph. A line is then drawn from the intersecting point of the first line and the pivot line through the overland flow slope and extending this line to the concentration time line. Alternately the equation given in the top of Figure 1 can be used to calculate the time of concentration.

Shallow concentrated flow will occur after the maximum length of overland flow; generally within a distance of 100 to 150 meters such as in the depressions on the side of a slope or mountain. The designer should use topographic maps to determine where the shallow concentrated flow will begin and end such as a shallow watercourse. Topographic maps can be obtained from project survey drawings or for areas not within the project limits from Reference 6. The map scale for Afghanistan topographic maps is 1:250,000, and therefore will generally be used in conjunction with a CAD program to enlarge, scale and compute the area from an image file.

Shallow concentrated flow time of concentration is determined by dividing the flow length by the flow velocity. The flow velocity is determined by the following nomograph:

Figure 2. Nomograph for Shallow Concentrated Flow Velocity



Enter the nomograph using the slope of the shallow concentrated flow path and extend a line horizontally until the diagonal line of the appropriate surface type is intersected. From this point, extend the line straight down to determine the average velocity. The average velocity of the above nomograph is expressed in ft/sec. which is converted to m/min by multiplying by 18.29. The equations for these surfaces are:

Unpaved surface: $y = 16.441x^{0.5063}$
Paved surface: $y = 19.794x^{0.4896}$

where
x =slope, ft/ft
y=average velocity, ft/s

Channel flow will occur in swales, ditches or underground culverts that have a sufficient volume to adequately convey the flow. Channel flow time of concentration is determined by dividing the flow length by the flow velocity. The channel flow velocity is determined by Manning's formula as shown below.

$V=(1/n)R^{2/3}S^{1/2}$

Where
V=flow velocity (m/sec)
n=roughness coefficient
R=hydraulic radius, cross sectional flow area/wetted perimeter (m)
S=channel slope (m/m)

Manning's roughness coefficients (n) for various channel surfaces are provided below in Table 2. Total time of concentration is the sum of the overland and shallow travel time plus the concentrated channel travel time, if any.

Table 2. Manning's Channel Roughness Coefficient

Type of Channel and Description	Minimum	Normal	Maximum
LINED CHANNELS (Selected linings)			
a. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Gunite, good section	0.016	0.019	0.023
b. Asphalt			
1. Smooth	0.013	0.013	-
2. Rough	0.016	0.016	-
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1. Minor streams (top width at flood stage <100 ft)			
a. Streams on Plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones/weeds	0.030	0.035	0.040
3. Clean, winding, some pools/shoals	0.033	0.040	0.045
4. Same as above, but some weeds/stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2. Floodplains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.700	0.100	0.160
d. Trees			
1. Dense Willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
3. Major Streams (top width at flood stage > 100 ft)			
The n-value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	-	0.060
b. Irregular and rough section	0.035	-	0.100

Several alternative methods are available for estimation of the time of concentration that are based on empirical relationships for specific geographic areas and caution should be exerted in their application to a specific site. For example, another method for overland time of concentration is Kirpich's formula. It is based on analysis of data for watersheds in the state of Tennessee in the United States and has not been validated for Afghanistan. Note the units are customary US units are used in some of these methods which should be used to provide the results because the formula is based on empirical coefficients derived in that unit system.

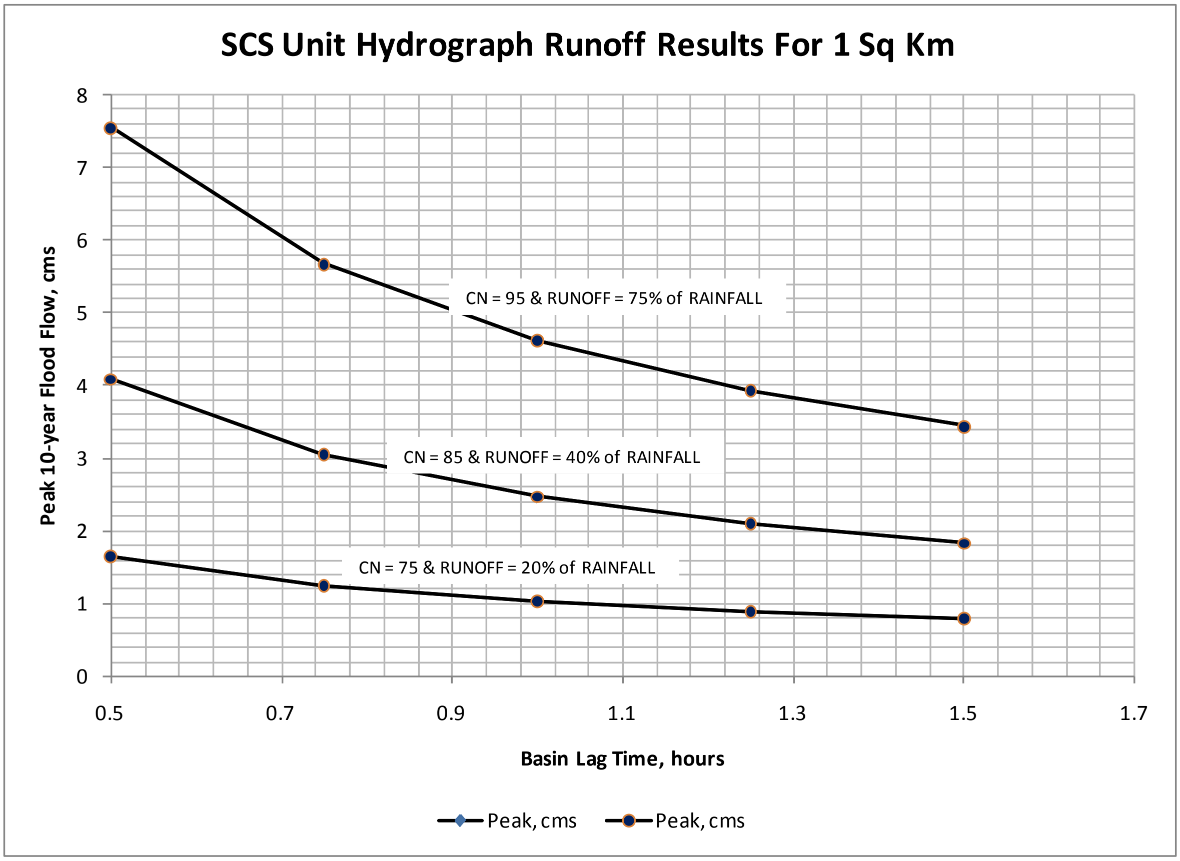
4.2. Soil Conservation Service (SCS) Unit Hydrograph Method

As the drainage basin size increases, the Rational Method becomes less accurate for a number of reasons. The principal reason is that the underlying concept behind the method, namely that the peak rainfall intensity duration is equal to the time of concentration no longer is a reasonable assumption. The water courses in larger basins have flood plains that will reduce larger flood flow rates because they will store flood water in their overbank areas thereby reducing the peak discharge rate. Large basins have more varied topography which correlates to varying times of concentration. Because of these and other limitations, numerous methods for developing unit hydrographs for selected watersheds have developed. **The Rational Method may significantly overestimate the peak discharge rate for larger basins and therefore the limit of 1 square kilometer for it has evolved from engineering experience as a useful upper limit.**

A unit hydrograph is defined as the direct runoff hydrograph (flow rate versus time relationship) from one unit of excess rainfall (usually 1 cm in SI units) generated uniformly over the drainage area at a constant rate for an effective duration of time. References 2 and 3 provide information on the theory and calculation details.

Because the solution to the total hydrograph computation involves successive convolutions of unit hydrographs for the period of the storm, the method is suitable to the use of computer programs for execution. Several programs are available from US Government agencies that are based on a particular unit hydrograph shape known as the SCS unit dimensionless hydrograph; reference 3 shows the location for one such program HEC-1 Flood hydrograph package. This program allows the user to employ the SCS unit hydrograph method with a hypothetical rainfall pattern constructed from data obtained from the intensity-duration-frequency curves (previously described in the rational method) to compute runoff hydrographs. In order to simplify the use of the SCS method for drainage areas in the range of one to two square kilometers which are common on road projects in Afghanistan, graphs have been prepared of peak discharge and runoff volumes have been computed for use shown in Figure 3. Results for other basins sizes can be obtained by the ratio of the drainage areas multiplied times the values from the figure. For large basins (greater than 10 sq km) a factor shown in Appendix C may be applicable.

Figure 3. SCS Unit Hydrograph Results for 1 Sq Km Drainage Area



Caution should be used applying data in Figure 3 for basins greater than two square kilometers in size because the floodplain attenuation effects in larger watersheds are neglected. Use of the curves requires calculating the basin lag defined as 0.6 times the time of concentration and the approximate runoff ratio based on the rational method or from data to develop curve numbers described below. For basins larger than 2 square kilometers or other flood frequency (than 10-year) storms, the design should be based on calculating the runoff using a computer model that supports the SCS method. If more than one basin analysis is required, a computer model should be used to perform hydrologic routing of the individual basins; Figure 3 curves do not include these affects and should not be used to combine more than one basin results.

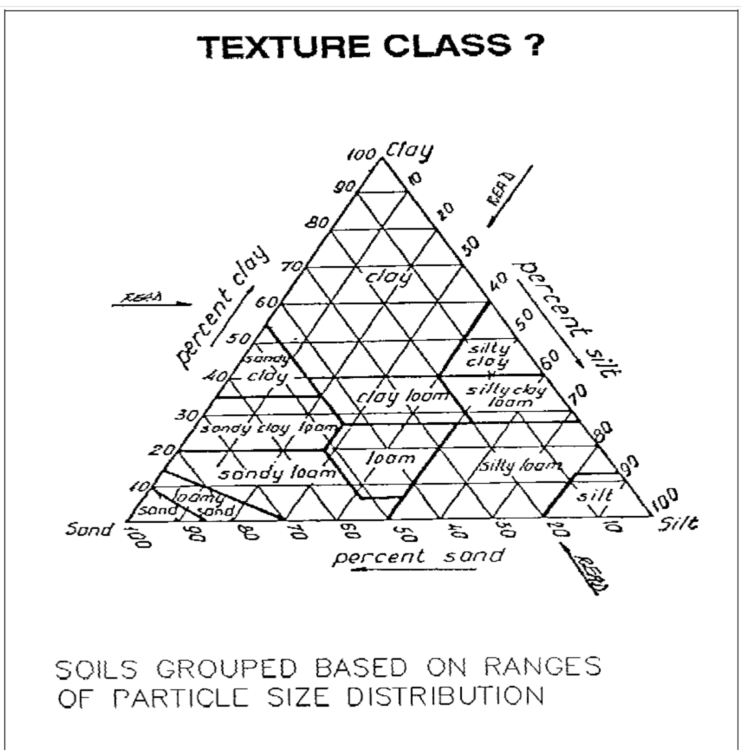
The SCS unit hydrograph technique is described in reference 2. There are two basic parameters required to use this method: basin lag and basin runoff curve number (CN) value. Basin lag is defined by the method as approximately 0.6 times the time of concentration (previously described in the rational method). The curve number is a dimensionless number that is an empirical function of soils slope, and land cover. It is used in the SCS method to determine the amount of rainfall retention over time that the watershed can hold. The excess becomes runoff. The curve numbers were derived empirically for non urban areas in the United States following a long program of collecting measurements at Soil Conservation Service hydrologic field stations of stream flow, precipitation, land cover and soil moisture. Tables of CN values for different hydrologic soil groups and land use are published in several sources.

Soil types are defined as follows:

- Group A: deep sands, deep loess, aggregated silts
- Group B: shallow loess, sandy loam
- Group C: clay loams, shallow sandy loams, and soils high in clay
- Group D: soils that swell when wet, plastic clays, and certain saline soils

Soil classification is defined in the SCS soil classification textural triangle shown in Figure 4. The availability of soil classification in regions of Afghanistan can be determined using internet sources (see References 5 and 6). Surface soil classification from geotechnical reports for project foundation design can also be used as a source of soil information provided the top soil horizon is used for determination of the runoff curve number.

Figure 4. SCS Soil Classification for Soil Groups



The following Table 3 contains an example from Reference 2 of curve number values.

Table 3. SCS Curve Number for Hydrologic Soil Groups

Table 6-5
Runoff CN's for Hydrologic Soil-Cover Complexes
(Antecedent runoff condition II, and I_a = 0.2S)

Cover			Hydrologic Soil Group			
Land use	Treatment or practice	Hydrologic Condition	A	B	C	D
Fallow	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes[1] or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads (dirts)[2]			72	82	87	89
(hard surface)[2]			74	84	90	92

[1] Closed-drilled or broadcast.
[2] Including right-of-way.

5. Design Submittal Documentation

Design analysis reports shall summarize the results of the calculations in a tabular form. The contents of the table shall include the following information:

- basin name/ or culvert number
- drainage area
- calculated time of concentration
- rainfall intensity for design storm
- runoff coefficient in rational method for the basin
- reduction for total area factor
- peak flow rate at the point of concentration (for structure design)

Submittal shall include drawings or sketches that identify the catchments areas used n the calculations.

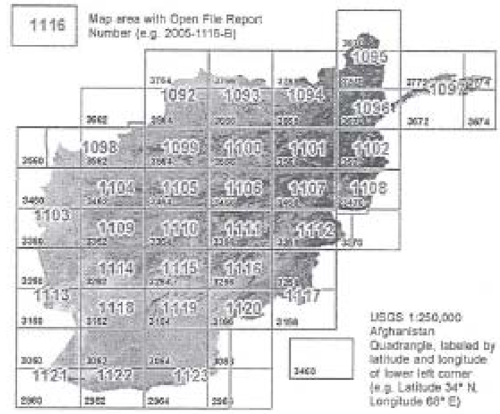
6. References

1. UFC 3 230 17FA Drainage for Areas Other than Airfields. Department of Defense, January 2004.
2. U.S. Army Corps of Engineers. Engineering and Design Flood hydrograph Analysis, EM 110-2-1417, August 1994. Found at http://140.194.76.129/publications/eng-manuals/em1110-2-1417/toc.htm
3. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package. 1998. Found at http://www.hec.usace.army.mil/software/legacysoftware/hec1/hec1.htm
4. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Frequency Analysis (FFA) Program. 1994.
5. European Commission Land Management & Natrual Hazards Unit. Found at http://eusoils.jrc.ec.europa.eu/result.cfm?form.criteria=afghanistan%20and%20soil
6. US Geological Survey Open-File Report 2005-1103 Series of topographic maps found at http://pubs.usgs.gov/of/2005/
7. Civil Engineering Reference Manual, Michael Lindenburg, Profesional Publications, Inc. 2008
8. Washington State Department of Transportation, Hydraulics Manual, March 2005. Found at http://www.wsdot.wa.gov/Design/Hydraulics/
9. UFC 3 230 15FA Surface Drainage Facilities for Airfields and Heliports. Department of Defense, January 2004.

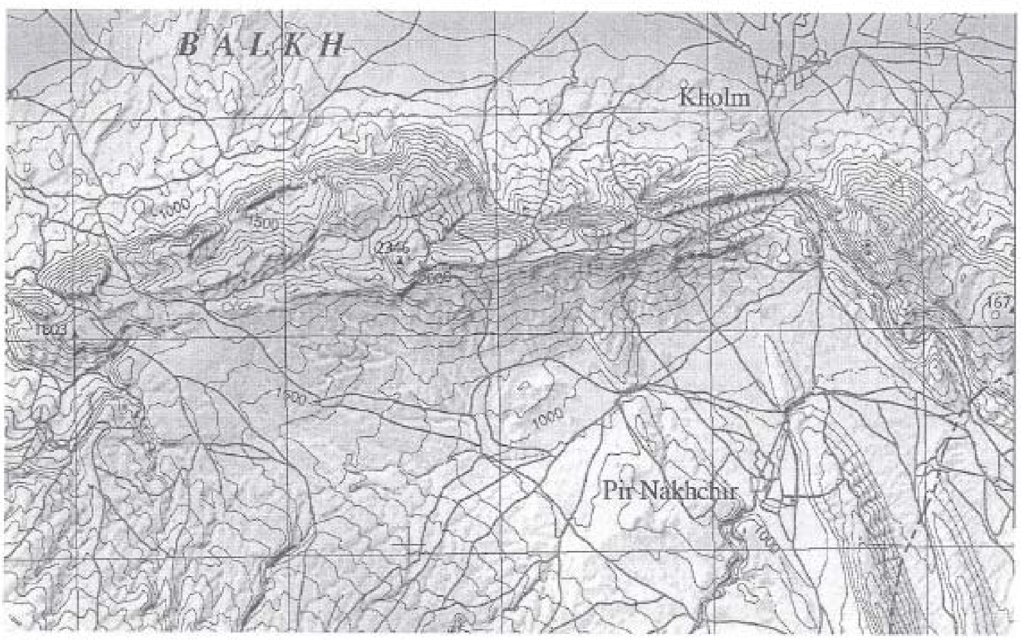
Topographic Map Index Information for

USGS Afghanistan Topographic Maps

The U.S. Geological Survey (USGS) has used TNTmips to prepare a series of 32 topographic maps of Afghanistan at a scale of 1:250,000, in cooperation with the Afghan Geological Survey and Afghanistan Geodesy and Cartography Head Office. These maps provide complete coverage of the country and are published electronically in the USGS Open File Report series as PDF map files that can be printed to scale. Each map covers a quadrangle 1° latitude by 2° longitude in size, or portions of several quadrangles along the border of the country. The complete map references are listed on the reverse side of this page along with a download link, and the index map to the right shows the map areas with report numbers. A companion series of geologic maps has also been published (see the Technical Guide entitled *USGS Afghanistan Geologic Maps*).



The map compilers at the USGS used the Surface Modeling process in TNTmips to generate topographic contours for the maps from Shuttle Radar Topography Mission (SRTM) 85-m digital elevation data. The contours are overlaid on a color shaded-relief image also derived from the SRTM data using the TNT Slope, Aspect, Shading process (now the Topographic Properties process). The stream lines are selected flow path lines generated from the SRTM data using the TNTmips Watershed process. This process automatically generates stream order attributes for the flow paths, and a selection query on the Horton stream order value was used to extract an appropriate density of stream lines for each map. (over)



Portion of *Topographic Map of Quadrangles 3666 and 3766, Balkh (219), Mazar-I-Sharif (220), Qarqin (213), and Hazara Toghai (214) Quadrangles, Afghanistan*, U.S. Geological Survey Open File Report 2005-1093-B, compiled by Robert G. Bohannon. Extract is shown at the published scale of 1:250,000.

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All of the 32 Afghanistan Topographic maps listed below are available for free download as PDF files from: http://pubs.usgs.gov/of/2005. See the index map on the reverse side of this page for locations.

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Topographic Map of Quadrangles 3768 and 3668, Imam-Saheb (215), Rustaq (216), Baghlan (221), and Taloqan (222) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1094-B, compiled by Robert G. Bohannon.

Topographic Map of Quadrangles 3870 and 3770, Maymayk (211), Jamarj-I-Bala (212), Faydz-Abad (217), and Parkhaw (218) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1095-B, compiled by Robert G. Bohannon.

Topographic Map of Quadrangle 3670, Jarm-Keshem (223) and Zebak (224) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1096-B, compiled by Robert G. Bohannon.

Topographic Map of Quadrangles 3772, 3774, 3672, and 3674, Gaz-Khan (313), Sarhad (314), Kol-I-Chaqmaqtin (315), Khandud (319), Deh-Ghulaman (320), and Ertfah (321) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1097-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangle 3564, Chahriaq (Joand) (405) and Gurziwan (406) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1099-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangles 3460 and 3360, Kol-I-Namaksar (407), Ghuryan (408), Kawir-I-Naizar (413), and Kohe-Mahmudo-Esmailjan (414) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1103-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangle 3470 and the Northern Edge of Quadrangle 3370, Jalal-Abad (511), Chaghasaray (512), and Northernmost Jaji-Maydan (517) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1108-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangle 3266, Ourzgan (519) and Moqur (520) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1116-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangle 3162, Chakhansur (603) and Kotalak (604) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1118-B, compiled by Robert G. Bohannon.

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Topographic Map of Quadrangle 3166, Jaldak (701) and Maruf-Nawa (702) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1120-B, compiled by Robert G. Bohannon.

Topographic Map of Quadrangles 3060 and 2960, Qala-I-Fath (608), Malek-Sayh-Koh (613), and Gozar-E-Sah (614) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1121-B, compiled by Robert G. Bohannon.

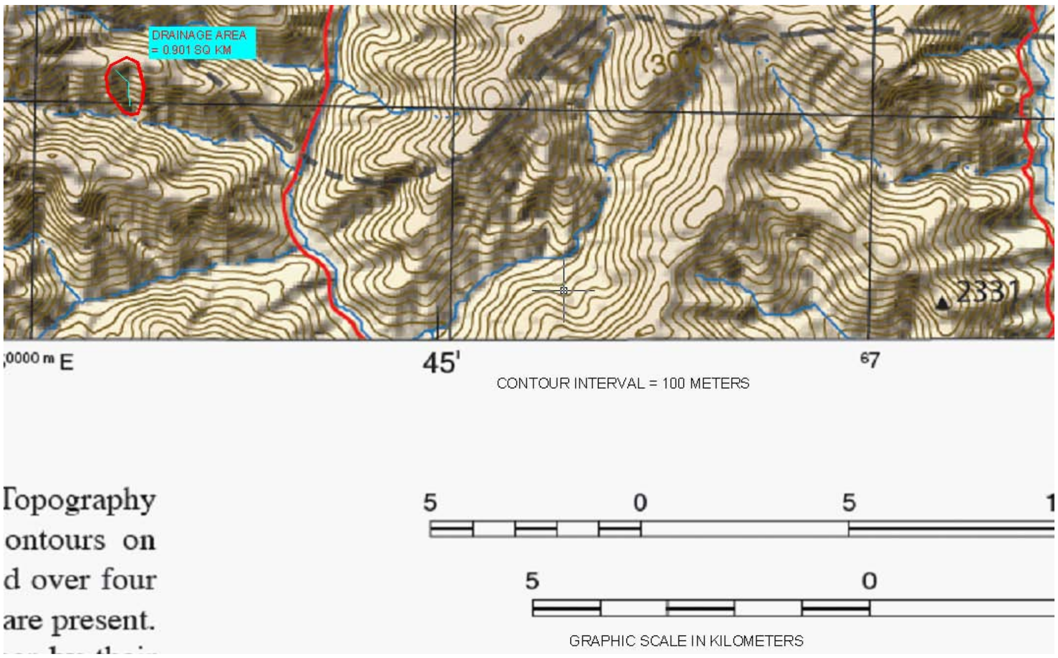
Topographic Map of Quadrangles 3062 and 2962, Charburjak (609), Khanneshin (610), Gawdezereh (615), and Galachah (616) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1122-B, compiled by Robert G. Bohannon.

Topographic Map of Quadrangles 3064, 3066, 2964, and 2966, Laki-Bander (611), Jahangir-Naweran (612), Sreh-Chena (707), Shah-Esmail (617), Reg-Alaqadari (618), and Samandkhan-Karez (713) Quadrangles, Afghanistan. U.S. Geological Survey Open File Report 2005-1123-B, compiled by Robert G. Bohannon.

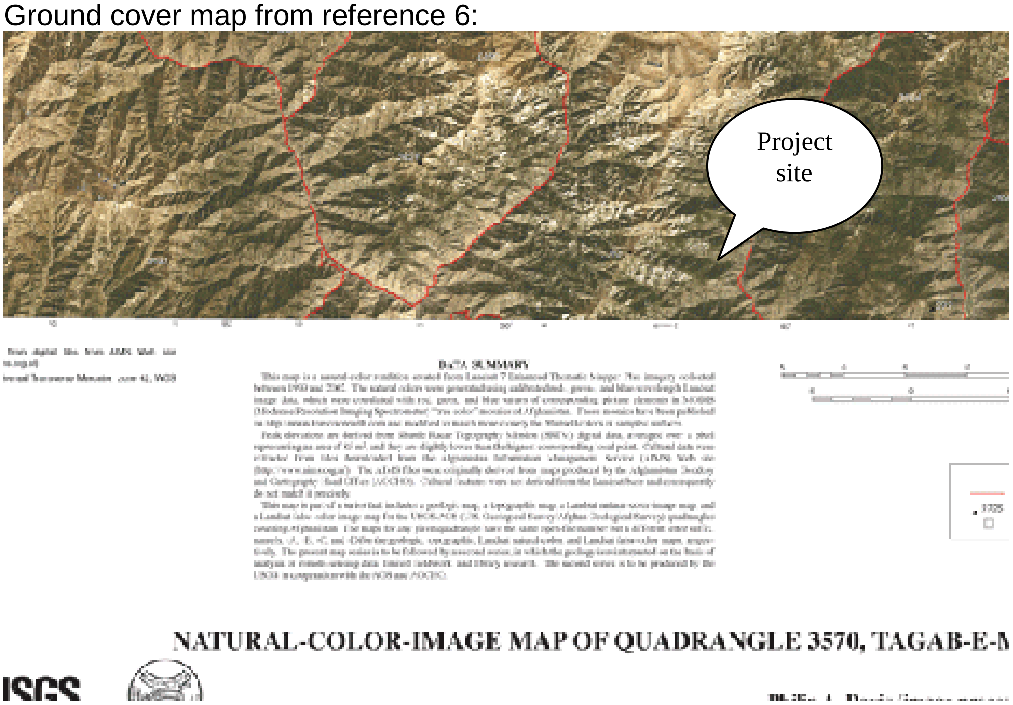
Appendix A Example of Rational Method

A site review for a road project in Nuristan Province has determined that a culvert should be designed based on the ten-year storm peak flow using the rational method. The location of the project is shown on a topographic map obtained from the internet site listed in reference 6. The web site was used to obtain a photograph that shows the ground cover conditions. These are shown below:

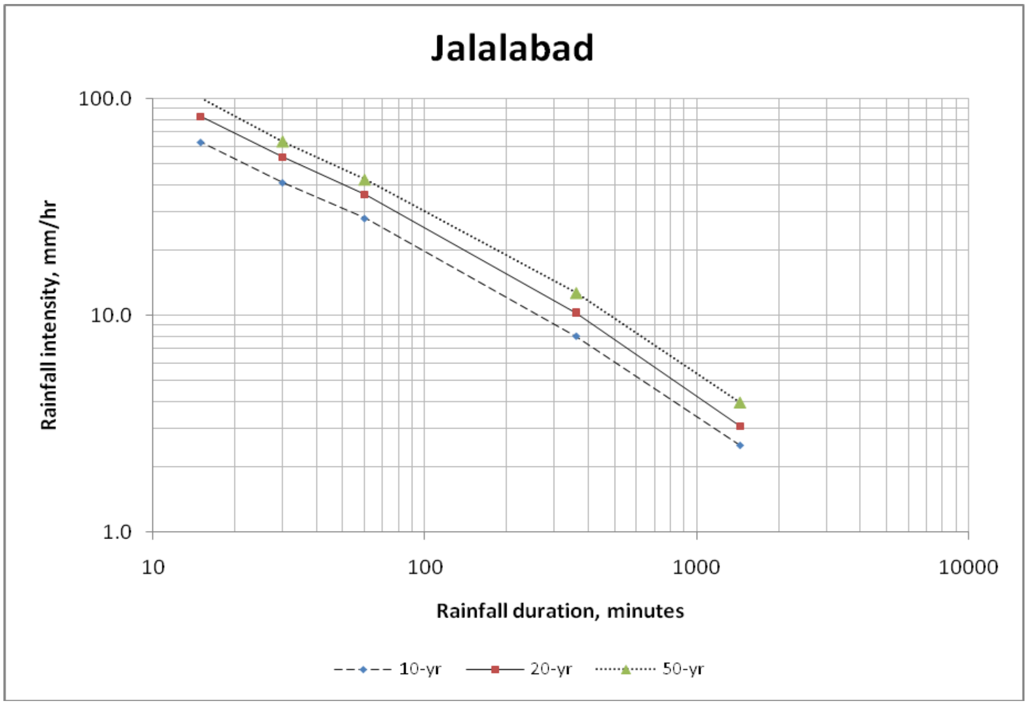
Drainage area map determined using AutoCAD



Ground cover map from reference 6:



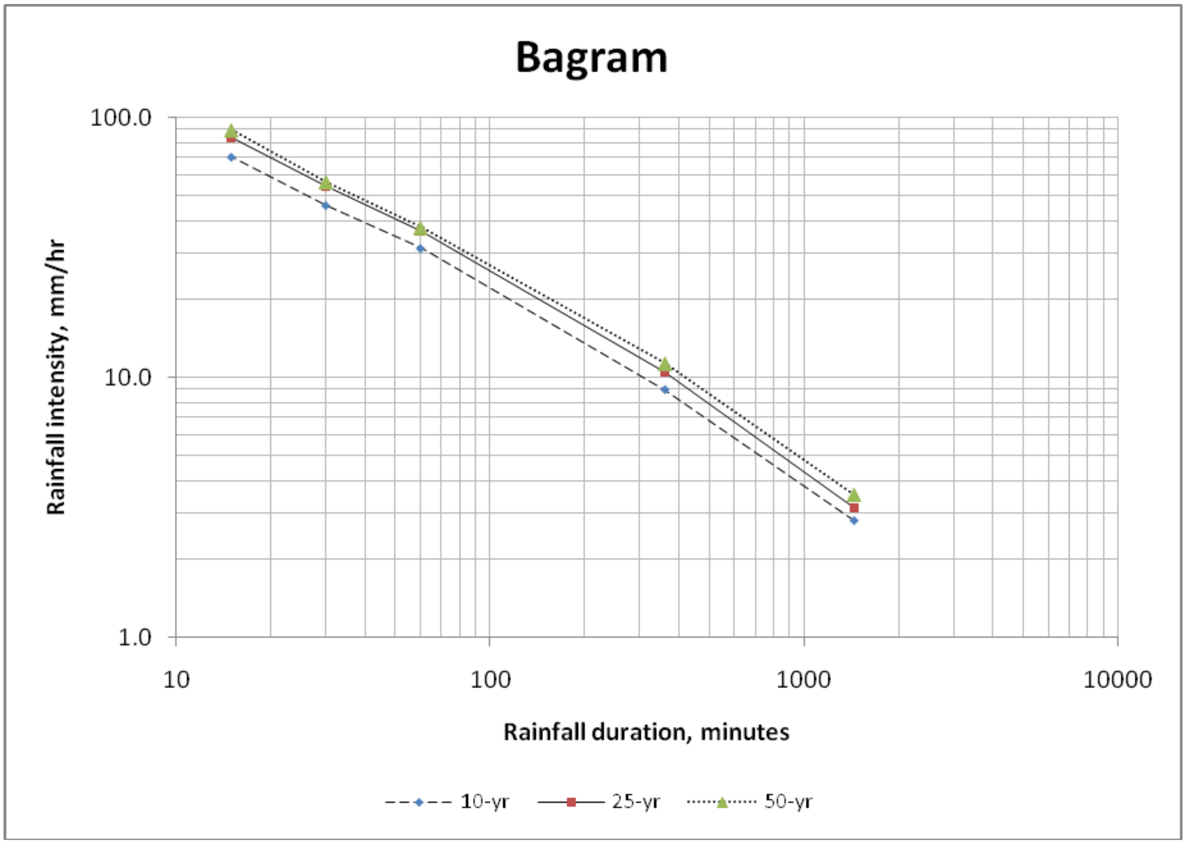
Jalalabad IDF Chart:

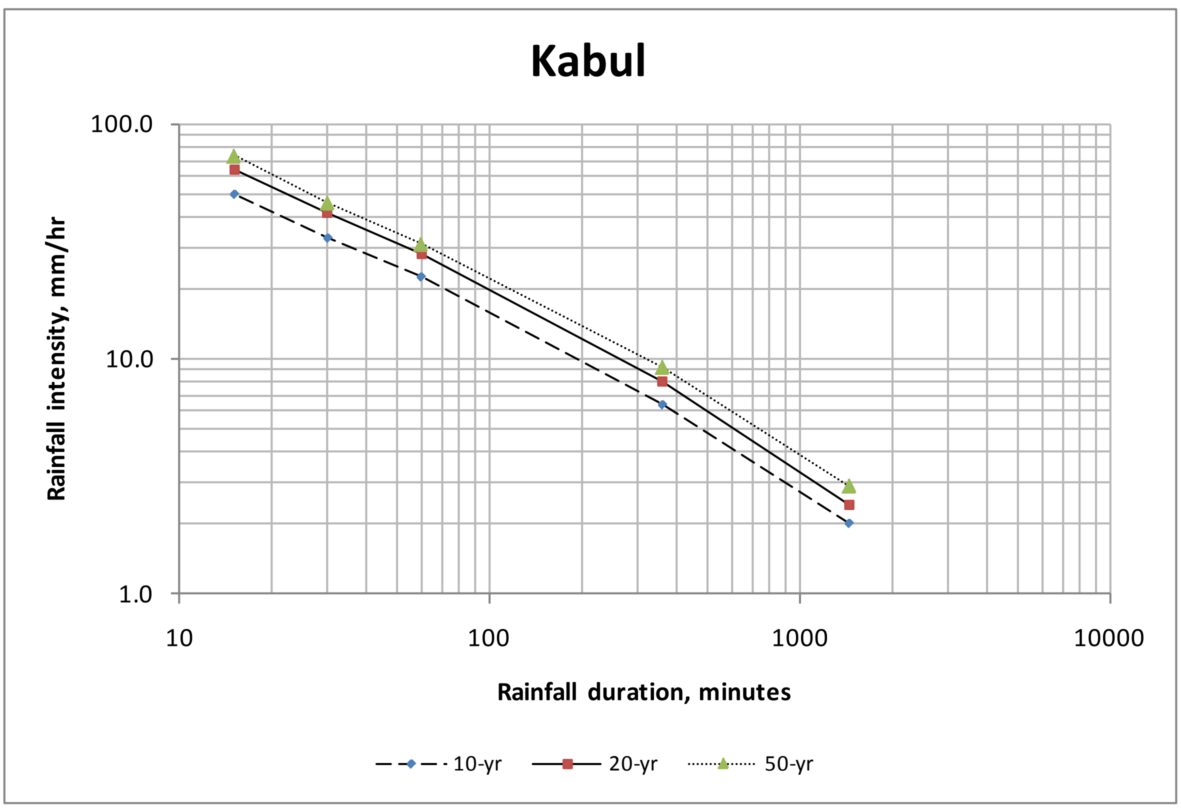


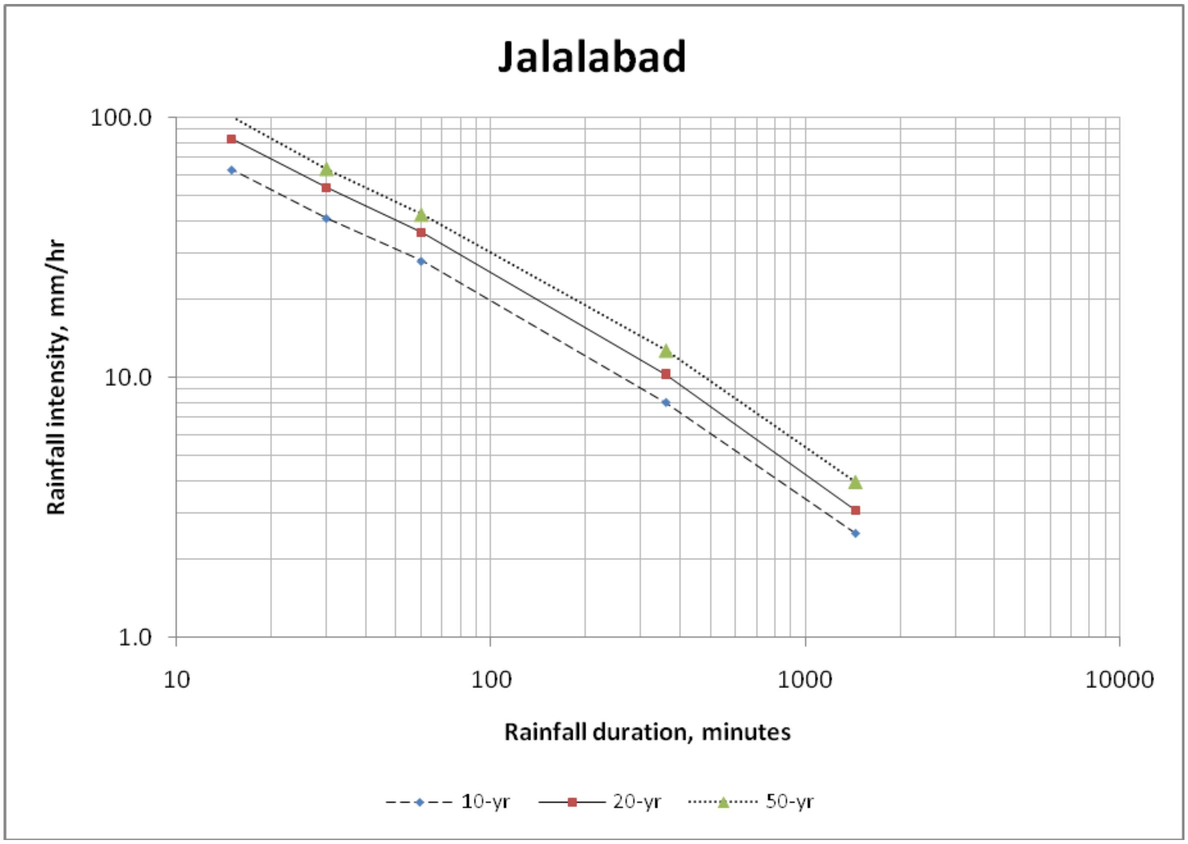
Based on Topographic Map:

Step				
1	To = Overland flow time for concentration = 0.275*(Lo^0.42)*(So^-0.19)*(C^-1.0)			
	So =	Δ Elevation = / Ls	984 / 1,273	Based on map contour over longest flow distance / Longest length required for flow
	So =	0.77		
	Lo (ft) =	492	Length of shallow overland flow (Max = 150 m)	
	C =	0.03	Runoff coefficient from Table 1 0.3 = coefficient for greater than 10% slope, semi desert	
	To =	0.275*(492^0.42)*(0.77^-0.19)*(0.3^-1.0) =	13 minutes	
2	Tc = Watercourse flow time of concentration = L/Vavg = 16.441*(Sc^0.5603)			
	Sc	Δ Elevation = / Lc	1,312 / 1,804	Based on map contour over longest flow distance / Based on map measurement of channel length
	Sc =	0.73		
	Tc =	16.441*(0.73^0.5603) / 1,804 =	129 minutes	
3	T = Total flow time for concentration / Rainfall Duration (minutes) =			
	To + Tc = 14 min + 129 min =		142 minutes	
4	Drainage Area =	0.901 km^2		
5	Ten year storm rainfall intensity =			Based on Area Rainfall Intensity Hydrograph
	I =	14.0 mm/hr		
6	Q = Flow at time of concentration (ratinoal method) = Q = 0.278*C*A*I			
	Q =	0.278*.3*0.901*14.0 =	1.05 m^3 / sec	

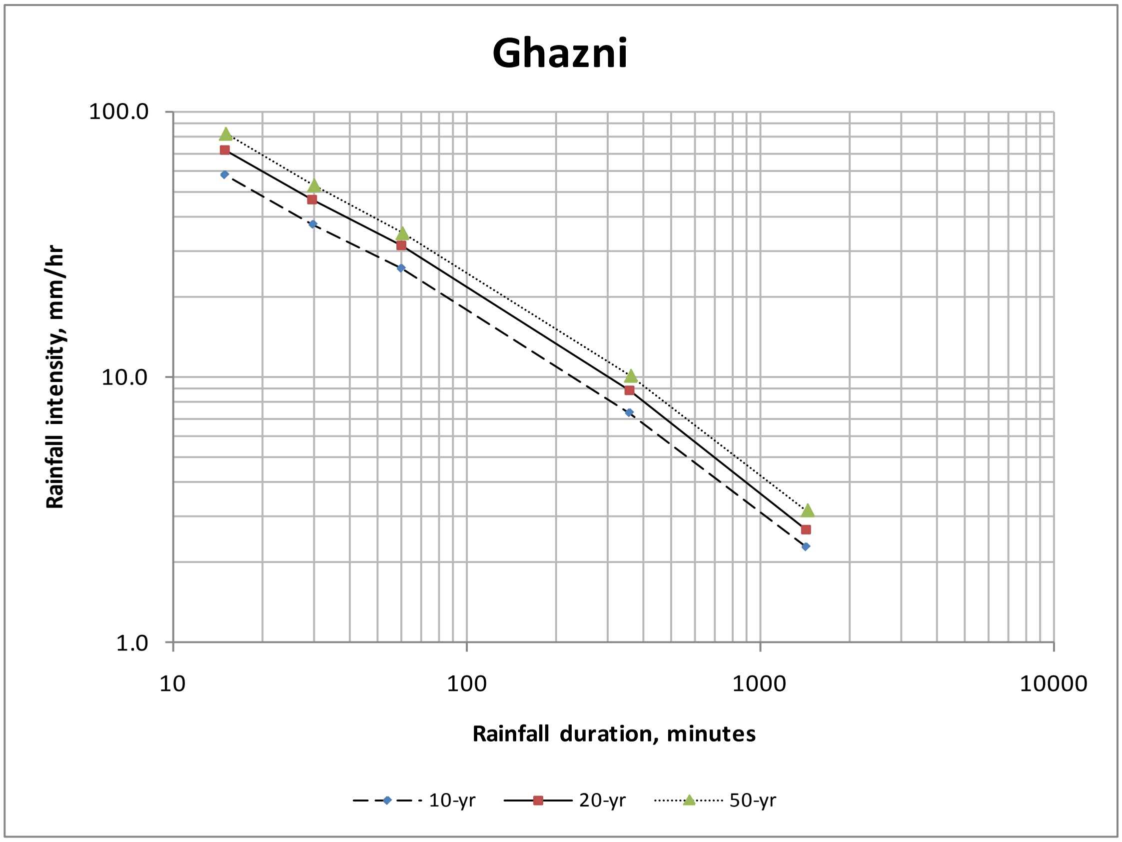
Appendix B Intensity-Duration-Frequency Curves for Selected Project Regions

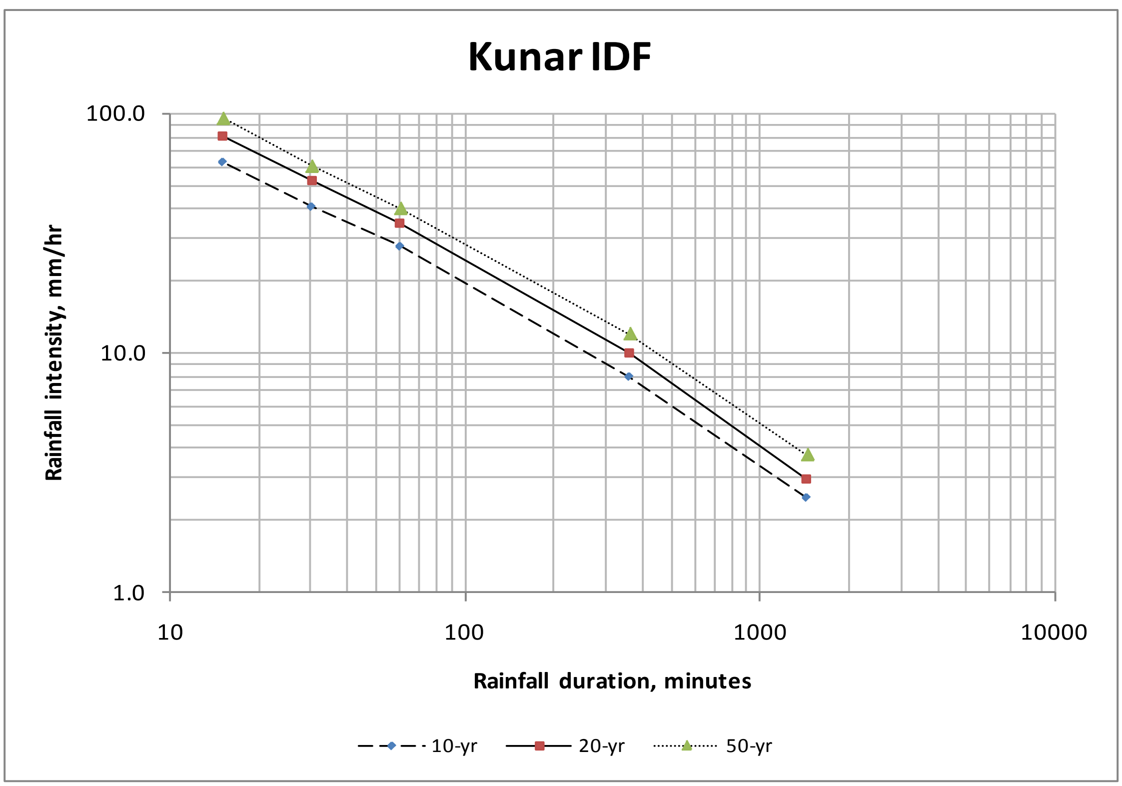


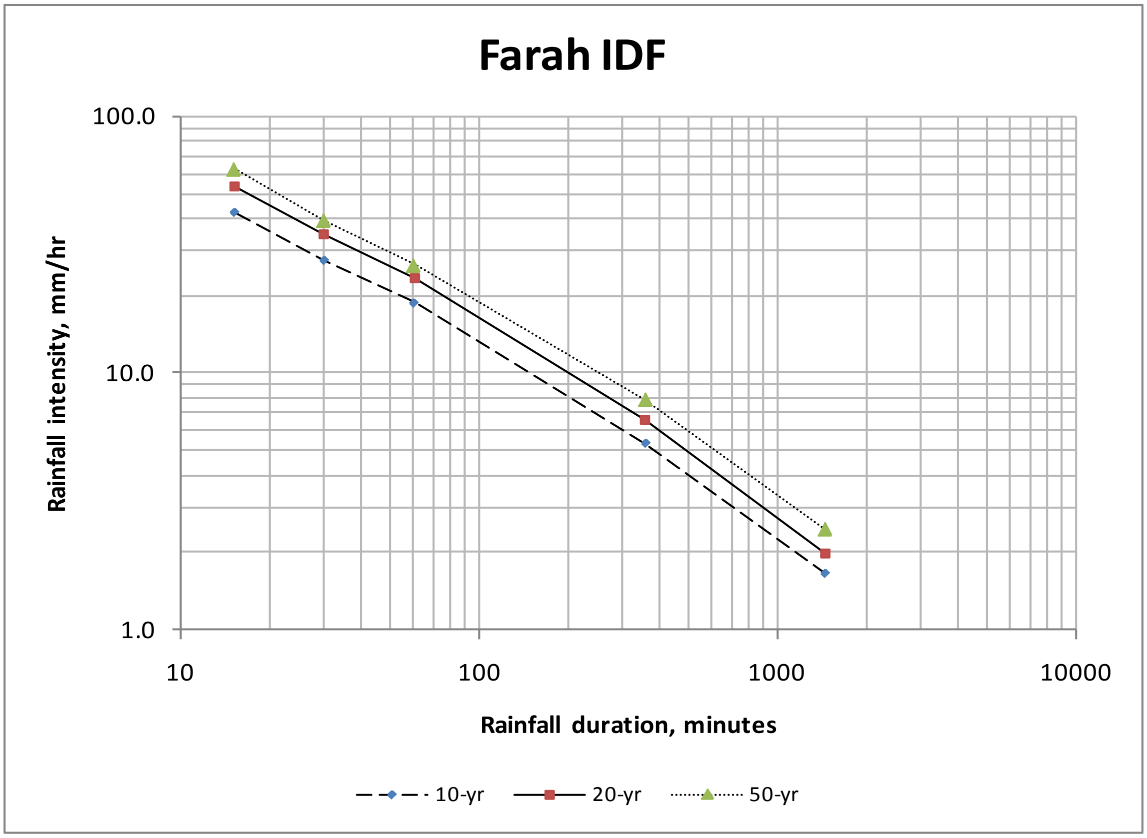


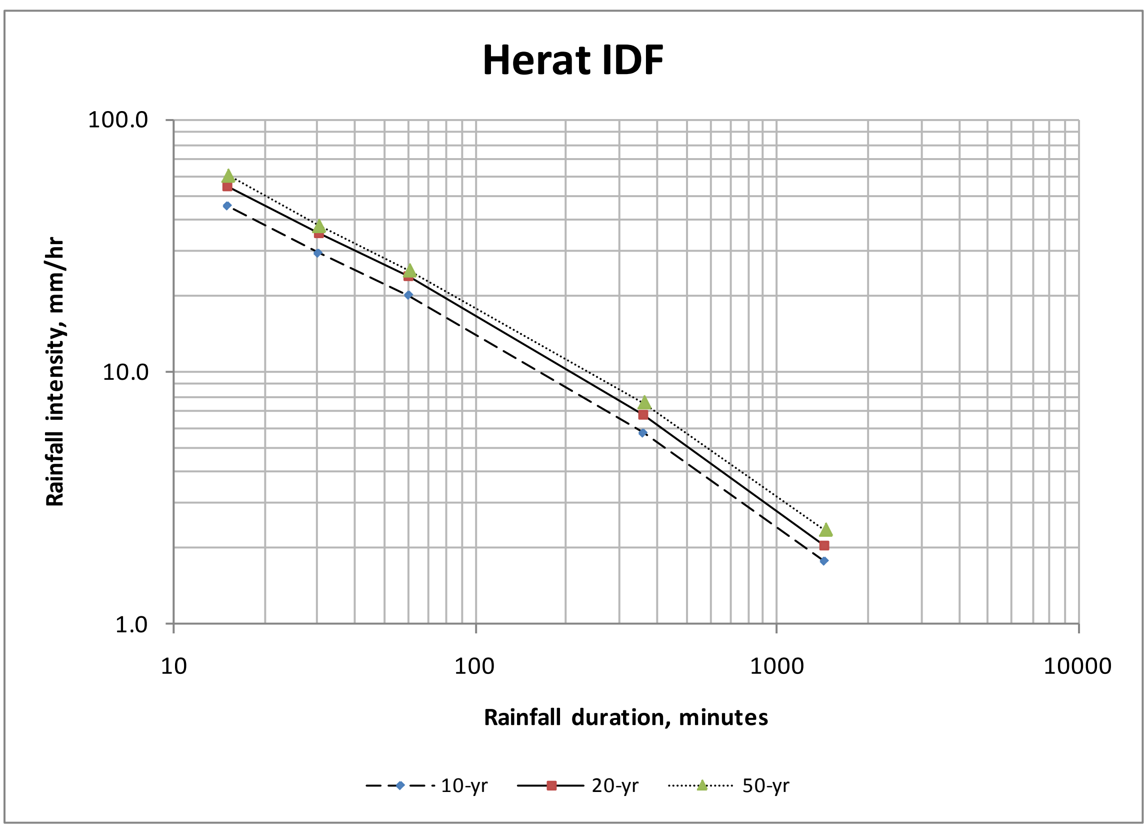

Jalalabad
100.0
10.0
1.0
Rainfall intensity, mm/hr
10
100
1000
10000
Rainfall duration, minutes
10-yr
20-yr
50-yr

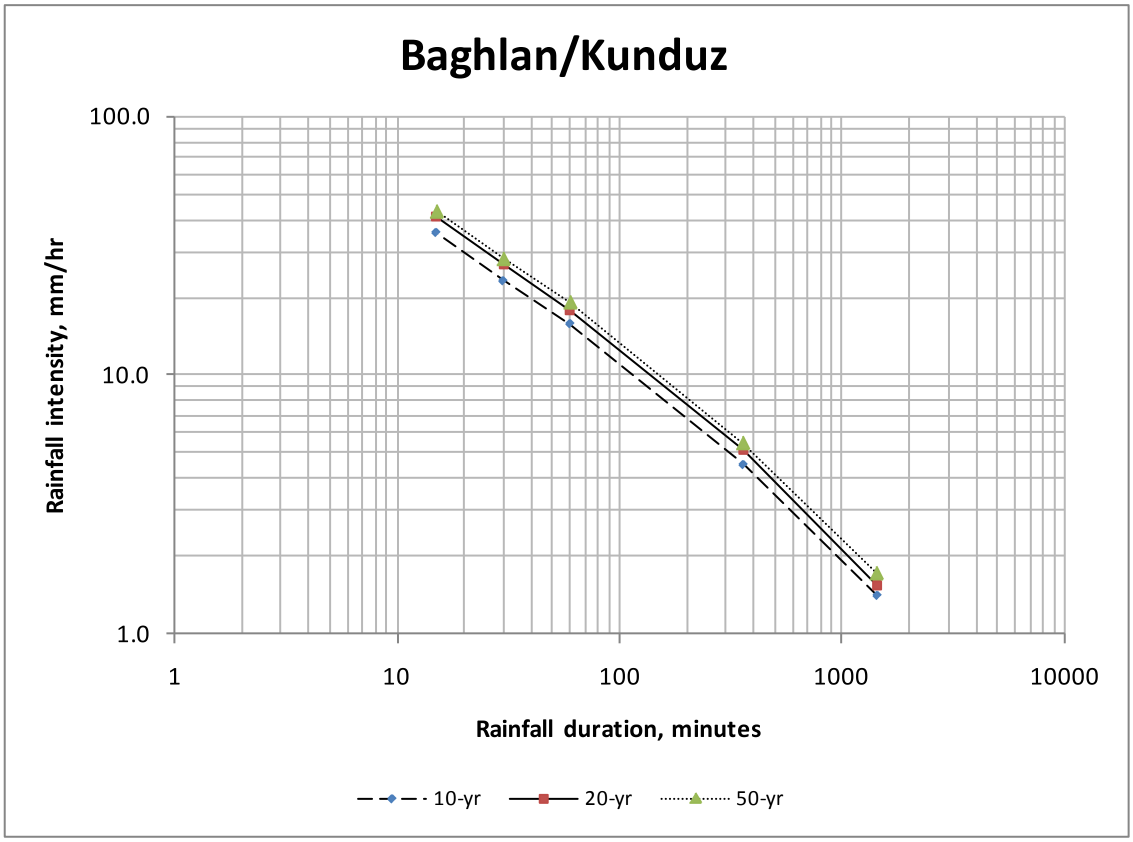

Gardez
100.0
10.0
1.0
Rainfall intensity, mm/hr
10
100
1000
10000
Rainfall duration, minutes
10-yr
20-yr
50-yr


Ghazni
100.0
10.0
1.0
10
100
1000
10000
Rainfall intensity, mm/hr
Rainfall duration, minutes
10-yr
20-yr
50-yr


Kunar IDF
100.0
10.0
1.0
10
100
1000
10000
Rainfall intensity, mm/hr
Rainfall duration, minutes
10-yr
20-yr
50-yr


Farah IDF
100.0
10.0
1.0
10
100
1000
10000
Rainfall intensity, mm/hr
Rainfall duration, minutes
10-yr
20-yr
50-yr


Herat IDF
100.0
10.0
1.0
10
100
1000
10000
Rainfall intensity, mm/hr
Rainfall duration, minutes
10-yr
20-yr
50-yr


Baghlan/Kunduz
100.0
10.0
1.0
Rainfall intensity, mm/hr
1
10
100
1000
10000
Rainfall duration, minutes
10-yr
20-yr
50-yr

Appendix C Area Factor for Point Rainfall Reduction Curves

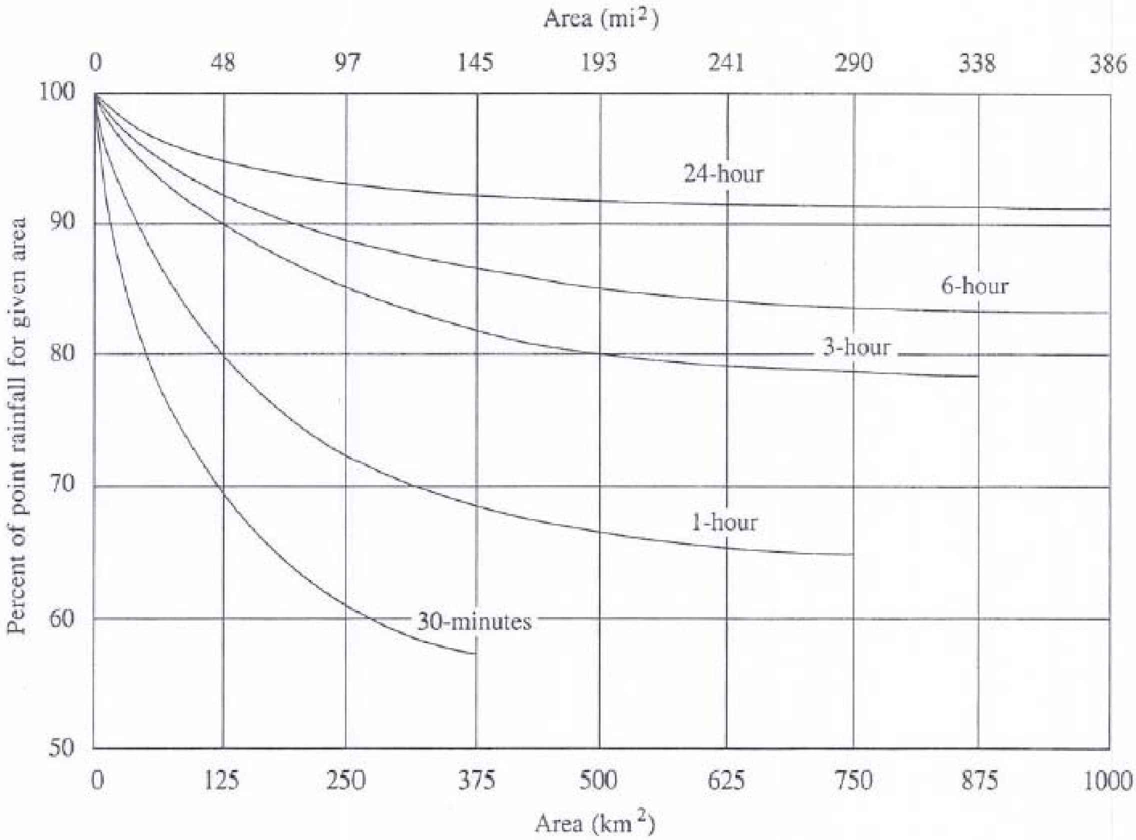


FIGURE 14.1.3
Depth-area curves for reducing point rainfall to obtain areal average values. (*Source*: World Meteorological Organization, 1983; originally published in Technical Paper 29, U. S. Weather Bureau, 1958.)