CHAPTER 2

HYDROLOGY

2–1. General. Hydrologic studies include a careful appraisal of factors affecting storm runoff to insure the development of a drainage system or control works capable of providing the required degree of protection. The selection of design storm magnitudes depends not only on the protection sought but also onthe type of construction contemplated and the consequences of storms of greater magnitude than the design storm. Ground conditions affecting runoff must be selected to be consistent with existing and anticipated arel development and also with the characteristics and seasonal time of occurrence of the design rainfall. For areas of up to about 1 square mile, where only peak discharges are required for design and extensive pondig is not involved, computation of runoff will normally be accomplished by the s-called Rational Method. For larger areas, when suitable unt-hydrograph data are available or where detailed consideration of pondng is required, computation should be by uit-hydrograph and flow-routing procedures.

2–2. Design storm.

a. For such developed portions of military installations as administrative, industrial, and housing areas, the design storm will normally be based on rainfall of 10-year frequency. Potential damage or operational requirements may warrant a more severe criterion; in certain storage and recreational areas a lesser criterion may be appropriate. (With concurrence of the using Service, 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.)

b. 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.

c. Protection of military installations against floodflows originating from areas exterior to the installation will normally be based on 25-year or greater rainfall, again depending on operational requirements, cost-benefit considerations, and nature and consequences of flood damage resulting from the failure of protective works. Justification for the selected design storm will be presented, and, if appropriate, comparative costs and damages for alternative designs should be included.

d. Rainfall intensity will be determined from the best available intensity-duration-frequency data. Basic information of this type will be taken from such publications as (see app A for referenced publications);

Rainfall Frequency Atlas of the United States. Technical Paper No. 40.

Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands. Technical Paper No. 42.

Rainfall-Frequency Atlas of the Hawaiian Islands. Technical Paper No. 43.

Probable Maximum Precipitation and Rainfall Frequency Data for Alaska. Technical Paper No. 47.

TM 5-785/AFM 88-29/NAVFAC P-89.

These publications may be supplemented as appropriate by more detailed publications of the Environmental Data and Information Center and by studies of local rainfall records. For large areas and in studies involving unit hydrography and flow-routing procedures, appropriate design storms must be synthesized from areal and time-distribution characteristics of typical regional rainfalls.

e. For some areas, it might reasonably be assumed that the ground would be covered with snow when the design rainfall occurs. If so, snowmelt would add to the runoff. Detailed procedures for estimating snowmelt runoff are given in TM 5-852-7/AFM 88-19, Chap 7. It should be noted, however, that the rate of snowmelt under the range of hydro-meteorological conditions normally encountered in military drainage design would seldom exceed 0.2 inches per hour and could be substantially less than that rate.

f. In selecting the design storm and making other design decisions, particular attention must be given to the hazard to life and other disastrous consequences resulting from the failure of protective works during a great flood. Potentially hazardous situations must be brought to the attention of the using service and others concerned so that appropriate steps can be taken.

Table 2–1. Typical Values of Infiltration Rates

Description	*Soil group symbol*	*Infiltration, inches/hour*
Sand and gravel mixture	GW, GP SW, SP	0.8-1.0
Silty gravels and silty sands to inorganic silt, and well-developed loams	GM, SM ML, MH OL	0.3–0.6
Silty clay sand to sandy clay	SC, CL	0.2–0.3
Clays, inorganic and organic	CH, OH	0.1–0.2
Bare rock, not highly fractured	--------	0.0-0.1

U.S. Army Corps of Engineers

2–3. Infiltration and other losses.

a. Principal factors affecting the computation of runoff from rainfall for the design of military drainage systems comprise initial losses, infiltration, transitory storage, and, in some areas, percolation into natural streambeds. If necessary data are available, an excellent indication of the magnitudes of these factors can be derived from thorough analysis of past storms and recorded flows by the unit-hydrograph approach. At the onset of a storm, some rainfall is effectively retained in “wetting down” vegetation and other surfaces, in satisfying soil moisture deficiencies, and in filling surface depressions. Retention capacities vary considerably according to surface, soil type, cover, and antecedent moisture conditions. For high intensity design storms of the convective, thunderstorm type, a maximum initial loss of up to 1 inch may be assumed for the first hour of storm precipitation, but the usual values are in the range of 0.25 to 0.50 inches per hour. If the design rainfall intensity is expected to occur during a storm of long duration, after substantial amounts of immediately prior rain, the retention capacity would have been satisfied by the prior rain and no further assumption of loss should be made.

b. Infiltration rates depend on type of soils, vegetal cover, and the use to which the areas are subjected. Also, the rates decrease as the duration of rainfall increases. Typical values of infiltration for generalized soil classifications are shown in table 2-1. The soil group symbols are those given in MIL-STD-619, Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations. These infiltration rates are for uncompacted soils. Studies indicate that compacted soils decrease infiltration values from 25 to 75 percent, the difference depending on the degree of compaction and the soil type. Vegetation generally decreases the infiltration capacity of coarse soils and increases that of clayey soils.

c. Peak rates of runoff are reduced by the effect of transitory storage in watercourses and minor ponds along the drainage route. The effects are reflected in the C factor of the Rational Formula (given below) or in the shape of the unit hydrography. Flow-routing techniques must be used to predict major storage effects caused by natural topography or man-made developments in the area.

d. Streambed percolation losses to direct runoff need to be considered only for sandy, alluvial watercourses, such as those found in arid and semiarid regions. Rates of streambed percolation commonly range from 0.15 to 0.5 cubic feet per second per acre of wetted area.

2-4. Runoff computations.

a. Design procedures for drainage facilities involve computations to convert rainfall intensities expected during the design storm into runoff rates which can be used to size the various elements of the storm drainage system. There are two basic approaches: first, direct estimates of the proportion of average rainfall intensity that will appear as the peak runoff rate; and, second, hydrography methods that depict the time-distribution of runoff events after accounting for losses and attenuation of the flow over the surface to the point of design. The first approach is exemplified by the Rational Method which is used in the large majority of engineering offices in the United States. It can be employed successfully and consistently by experienced designers for drainage areas up to 1 square mile in size. *Design and Construction of Sanitary and Stem Sewers,* ASCE Manual No. 37, and *Airport Drainage,* FAA AC 150/5320-5B, explain and illustrate use of the method. A modified method is outlined below. The second approach encompasses the analysis of unit-hydrograph techniques to synthesize complete runoff hydrography.

b. To compute peak runoff the empirical formula Q=C(1-F)A can be used; the terms are defined in appendix D. This equation is known as the modified rational method.

(1) C is a coefficient expressing the percentage to which the peak runoff is reduced by losses (other than infiltration) and by attenuation owing to transitory storage. Its value depends primarily on surface slopes and irregularities of the tributary area, although accurate values of C cannot readily be determined. For most developed areas, the apparent values range from 0.6 to 1.0. However, values as low as 0.20 for C may be assumed in areas with low intensity design rainfall and high infiltration rates on flat terrain. A value of 0.6 may be assumed for areas left ungraded where meandering-flow and appreciable natural-ponding exists, slopes are 1 percent or less, and vegetal cover is relatively dense. A value of 1.0 may be assumed applicable to paved areas and to smooth areas of substantial slope with virtually no potential for surface storage and little or no vegetal cover.

(2) The design intensity is selected from the appropriate intensity-duration-frequency relationship for the critical time of concentration and for the design storm frequency. Time of concentration is usually defined as the time required, under design storm conditions, for runoff to travel from the most remote point of the drainage area to the point in question. In computing time of concentration, it should be kept in mind that, even for uniformly graded bare or turfed ground, overland flow in “sheet” form will rarely travel more than 300 or 400 feet before becoming channelized and thence move relatively faster; a method which may be used for determining travel-time for sheet flow is given in TM 5-820-1/AFM 88-5, Chap 1. Also, for design, the practical minimum time of concentration for roofs or paved areas and for relatively small unpaved areas upstream of the uppermost inlet of a drainage system is 10 minutes; smaller values are rarely justifiable; values up to 20 minutes may be used if resulting runoff excesses will not cause appreciable damage. A minimum time of 20 minutes is generally applicable for turfed areas. Further, the configuration of the most remote portion of the drainage area may be such that the time of concentration would be lengthened markedly and thus design intensity and peak runoff would be decreased substantially. In such cases, the upper portion of the drainage areas should be ignored and the peak flow computation should be based only on the more efficient, downstream portion.

(3) For all durations, the infiltration rate is assumed to be the constant amount that is established following a rainfall of 1 hour duration. Where F varies considerably within a given drainage area, a weighted rate may be used; it must be remembered, however, that previous portions may require individual consideration, because a weighted overall value for F is proper only if rainfall intensities are equal to or greater than the highest infiltration rate within the drainage area.

In design of military construction drainage systems, factors such as initial rainfall losses and channel percolation rarely enter into runoff computations involving the Rational Method. Such losses are accounted for in the selection of the C coefficient.

c. Where basic hydrologic data on concurrent rainfall and runoff are adequate to determine unit hydrography for a drainage area, the uncertainties inherent in application of the Rational Method can largely be eliminated. Apparent loss rates determined from unit-hydrograph analyses of recorded floods provide a good basis for estimating loss rates for storms of design magnitude. Also, flow times and storage effects are accounted for in the shape of the unit-hydrograph. Where basic data are inadequate for direct determination of unit-hydrographs, use may be made of empirical methods for synthesis. Use of the unit-hydrograph method is particularly desirable where designs are being developed for ponds, detention reservoirs, and pump stations; where peak runoff from large tributary areas is involved in design; and where large-scale protective works are under consideration. Here, the volume and duration of storm runoff, as opposed to peak flow, may be the principal design criteria for determining the dimensions of hydraulic structures.

d. Procedures for routing storm runoff through reservoir-type storage and through stream channels can be found in publications listed in appendix E and in the available publications on these subjects.