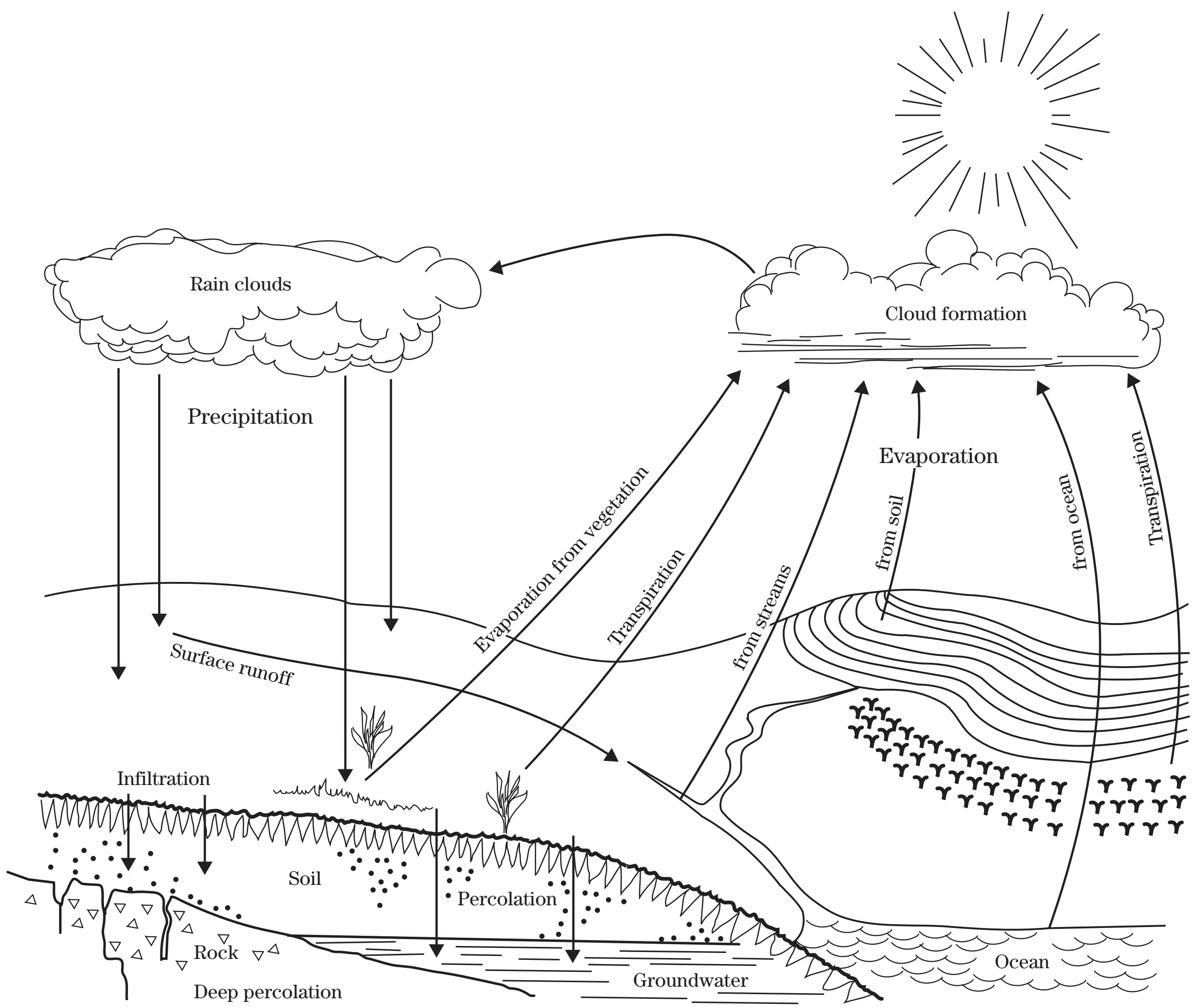
United States Department of Agriculture
Natural Resources Conservation Service

Part 630 Hydrology
National Engineering Handbook

Chapter 2 Watershed Project Evaluation Procedures



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Chapter 2 Watershed Project Evaluation Procedures

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630.0200 Introduction

Hydrology for the evaluation of watershed projects is a major concern in part 630 of the National Engineering Handbook (NEH). The evaluation is a detailed investigation of present (no project) and future (with project) conditions of a watershed to determine whether given objectives will be met. Along with appropriate socioeconomic and environmental assessments, hydrologic evaluations are the bases on which recommendations for or against a project are founded. A summary of the hydrologic evaluation is included in a work plan, which is the official document for carrying out, maintaining, and operating a project. The procedures described in this chapter guide hydrologic studies and introduce succeeding chapters of NEH630.

A watershed project evaluation begins with a preliminary investigation (PI), a brief study to estimate whether detailed investigation is justified (NEH630.03, Preliminary Investigations). If detailed investigation is justified, the PI is used to develop a work outline describing the desired scope, intensity, and schedule of the planning study; its estimated cost; the personnel requirements; and the completion date for a work plan.

Data collection, computation, and analysis are equally important divisions of work. Availability governs the collection of data. Size or cost of project influences the choice of computational and analytical methods. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) policy determines the number and kinds of analyses. Nevertheless, the basic evaluation procedure does not vary. The work outline schedule follows the plan in principle. The plan, schedule, and chapters in NEH630 are related as shown in the following sections.

630.0201 Work outline plan and schedule relationship

(a) Data collection

Base maps, project area maps, rainfall data (NEH630.04, Storm Rainfall Depth), and runoff data (NEH630.05, Streamflow Data) are collected early in the study. Field surveys and remote sensing provide stream cross sections and profiles (NEH630.06, Stream Reaches and Hydrologic Units) and structure data. Interviews with local NRCS personnel provide data on hydrologic soil-cover complexes (NEH630.07, Hydrologic Soil Groups; NEH630.08, Land Use and Treatment Classes; and NEH630.09, Hydrologic Soil-cover Complexes) and runoff curve numbers (NEH630.10, Estimation of Direct Runoff from Storm Rainfall).

Originally all mapping was paper-based, but now it is more common to use remote sensing and geographical information system (GIS) mapping procedures. Remote sensing tools used include digital elevation maps (DEMs), Light Detection and Ranging (LiDAR) data; and other available GIS tools. One of the advantages of this approach is that the data may often times be imported easily into hydrologic and hydraulic computer models.

(b) Computations

Storm runoff (NEH630.10, Estmation of Direct Runoff from Storm Rainfall), snowmelt runoff (NEH630.11, Snowmelt), effects of land use and treatment (NEH630.12, Hydrologic Effects of Land Use and Treatment), the relation of stream stages to inundation (NEH630.13, Stage Inundation Relations), and discharge (NEH630.14, Stage-Discharge Relations) are computed early in this phase of the study. Travel time and lag for each subarea (NEH630.15, Time of Concentration) are computed for use in hydrograph construction (NEH630.16, Hydrographs) and flood routing (NEH630.17, Flood Routing). Runoff or peak discharge frequencies (NEH630.18, Selected Statistical Methods), transmission losses (NEH630.19, Transmission Losses), and watershed yield (NEH630.20, Watershed Yield) are only computed if they are required in the study.

(c) Analyses

Watershed conditions are typically analyzed in a logical sequence. A typical study sequence might be:

1. Present condition—conditions in the watershed at the time of the surveys; and the base to which the proposed project is added. Also forms the basis of comparison of alternatives for potential alternatives.
2. Future with no project condition—expected future conditions of the watershed with no project action taken. Depending upon the funding source and program requirements this condition may or may not have to be evaluated.
3. Future with land use and treatment measures condition—proposed land use and treatment measures are added to the present condition (number 1).
4. Future land use and treatment measure and strutures condition—watershed protection and flood prevention structures, if a part of the plan, are added to the future with land use and treatment measures condition (bullet 3).

Depending upon the number of alternatives evaluated, numbers 3 and 4 may have to be repeated numerous times to fully analyze all alternatives.

This order falls into a natural sequence in which measures that affect runoff first are evaluated first. Flood routings for the present condition give the discharges from which present flood damages are computed in the economic evaluation. The routings are modified (NEH630.12) to give discharges for determining the effects of land use and treatment. New routings of further modifications (NEH630.17) are made for the third condition to give discharges for determining the effects of the structures. Generally, the third condition is studied at great length to optimize the number of structures. While preliminary design is done during the investigation, final design of individual structures is made late in the investigation or after the work plan is approved. The hydrology and NRCS hydrologic criteria for structure design, depending upon the size and type of structure may be found in the Technical Release Number 60, Earth Dams and Reservoirs (TR–60) and section IV (practice standards) of the field office technical guide (FOTG). NEH630.21 describes the procedure used to develop storm hydrographs to meet the design requirements of TR–60.

630.0202 Hydrologic evaluation process

Computer models may be used to develop runoff hydrographs; route hydrographs through stream channels, floodplains, lakes, and reservoirs; combine hydrographs; and determine stage-discharge-acres flooded relations. NRCS developed models that are used most frequently for hydrologic evaluations include WinTR–55, Small Watershed Hydrology; WinTR–20, Project Formulation—Hydrology; and NRCS GeoHydro. For hydraulic evaluations, the U.S. Army Corps of Engineers computer programs HEC–RAS and HEC–GeoRAS are often used.

(a) Work sequence

The hydrologic evaluation sequence is shown in figure 2–1. As represented in the figure, the forms of maps, graphs, and tables are simplified representations of the various standard forms used in different States. The preliminary investigation, which precedes the evaluation is described in NEH630.03, Preliminary Investigations. The design hydrology analysis as described in NEH630.21 comes later.

After the present conditions are evaluated, the early steps of the evaluation process may not need to be repeated for the remaining conditions. Evaluations of future conditions should include one that considers the future with no project measures and accounts for expected land use changes without any project being implemented. Depending on expected changes, the hydrologic soil-cover complexes and corresponding runoff curve numbers would be revised, affecting the runoff hydrographs. The evaluation process for the future land use and treatment measures condition (number 3) starts at the hydrologic soil-cover complex step. At this step, the soil-cover complexes are modified to reflect different land use and treatment conditions which reflect in the flow hydrographs. Finally, the future land use and treatment measures plus structural measures condition (number 4) may require modifying the unit hydrograph to reflect structures in place.

Of the basic data needed in the evaluation, only the historical rainfall and streamflow data are likely to be unavailable. The rest are obtainable through field surveys or remote sensing. Lacking rainfall and runoff data, the procedure goes as shown in figure 2–2. Sources of rainfall-frequency data (NEH630.04) shown in figure 2–2 include the U.S. Weather Bureau, the National Weather Service, NOAA publications, or, in some cases, special rainfall studies. Direct checks on runoff cannot be made, but indirect checks can be made if nearby watersheds are gaged.

Some steps in the procedures of figures 2–1 and 2–2 differ for regional analyses.

(b) Analysis methods

(1) Regional analysis method

This method estimates the magnitudes and frequencies of peak discharges or runoff volumes for ungaged watershed using relationships from nearby gaged watersheds. The method in its simplest form is as follows:

Step 1 Select nearby gaged watershed that are climatically and physically similar to the ungaged watershed. These watersheds compose the region that gives the method its name.

Step 2 Perform a frequency analysis (NEH630.18) for peak discharges or runoff volumes for each of the gaged watersheds.

Step 3 Compile discharge or runoff volume by frequency for the frequency analyses of each watershed.

Step 4 Using log-log paper or some type of statistical analysis software, plot log (peak discharge or runoff volume) versus log (drainage area of the watershed) for selected frequencies. Perform a simple regression analysis to estimate a best fit straight line through the data.

Step 5 Construct the frequency line for the ungaged watershed. To do this, enter the plot with drainage area, find the magnitudes of each line of relationship, plot the magnitudes at their proper places on the probability paper, and draw the frequency line through the points.

Step 6 Apply the frequency lines of step 5 in the procedure for present conditions. Discharges or volumes for with-project conditions are obtained by use of auxiliary relationships described in NEH630.12 and NEH630.17.

Figure 2–1 General process hydrology of watershed project evaluation with streamflow and rainfall data available

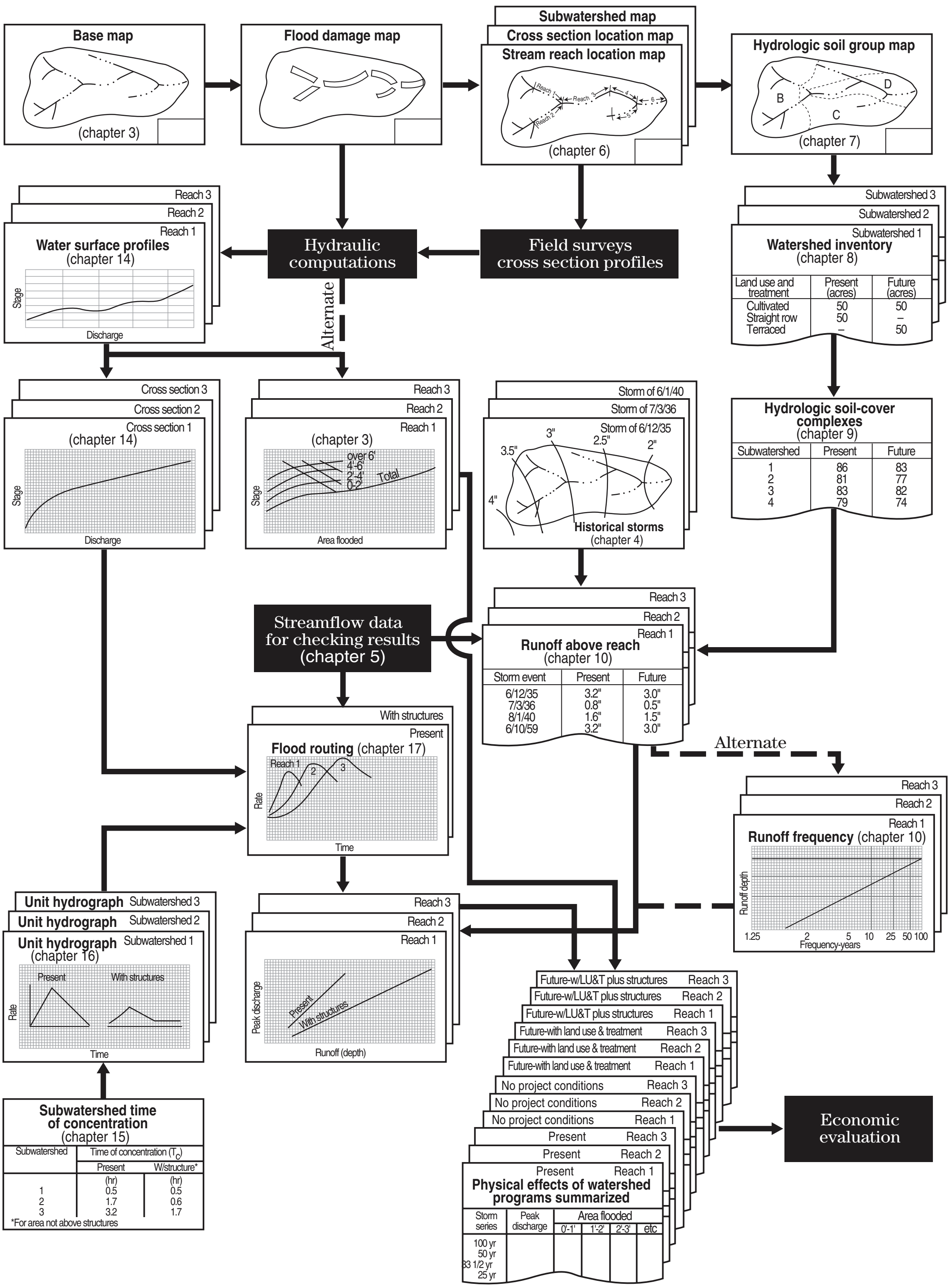
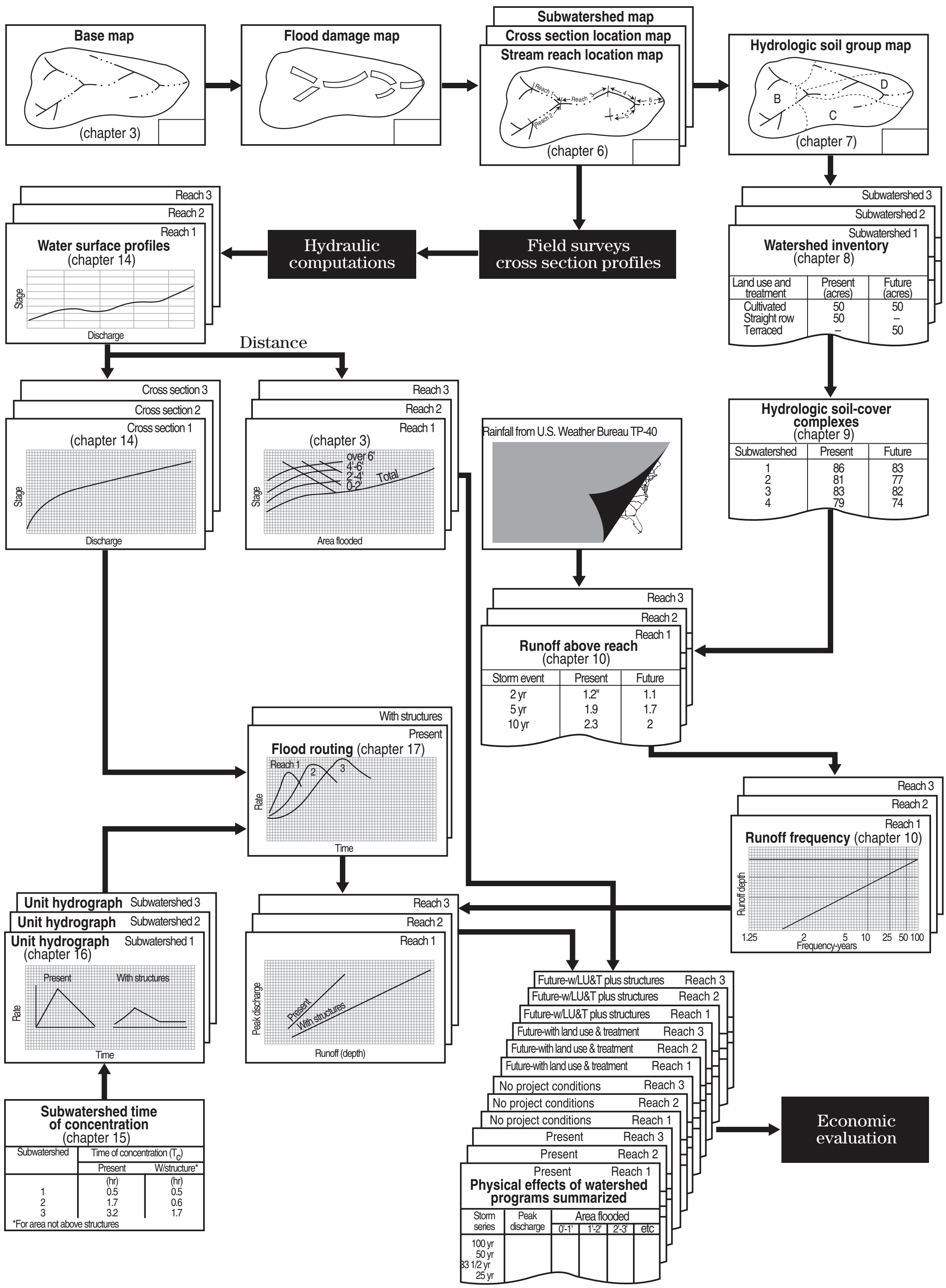


Figure 2–2 General process hydrology of watershed project evaluation with streamflow or rainfall data not available



In practice, the method is more complex, but generally only in step 3. In this step, the variables in addition to drainage area are related to the peaks or volumes. The variables include one or more of the following, alone or in combination, directly or by means of index numbers:

- type of climate
- mean annual precipitation or rainfall or snowfall
- mean seasonal precipitation or rainfall or snowfall
- maximum or minimum average monthly rainfall
- storm pattern
- x-year frequency, y-hour duration rainfall
- mean number of days with rainfall greater than x inches
- mean annual number of thunderstorm days
- mean annual, or seasonal, or monthly, temperature
- maximum or minimum average monthly temperature
- orographic effects
- aspect
- stream density
- stream pattern
- length of watershed
- length to center of gravity of the watershed
- length of main channel
- average watershed width
- altitude
- watershed rise
- main channel slope
- land slope
- depth or top width of main channel near outlet for x-year frequency discharge
- time of concentration
- lag
- time to peak
- percentage of area in lakes or ponds
- extent or depth of shallow soils
- extent of major cover
- hydrologic soil cover complex
- geologic region
- infiltration rate
- mean base flow
- mean annual runoff
- watershed slope

Combinations of these variables are used as single variables in the analysis, one such combination being the product of watershed length and the length to the center of gravity divided by the square root of the main channel slope. Index numbers (NEH630.18) are used for variables, such as geologic region, not ordinarily defined by numerical values.

Multiple regression methods (NEH630.18) must be used if more than one variable appears in the relationship. The only adequate measure of the accuracy of the relationship, and therefore, of the regional analysis, is the standard error estimate in arithmetic units. Computation of the error is illustrated in NEH630.18.

(2) USGS regional regression equations

Another source for determining relative effects of watershed characteristics on discharge is U.S. Geological Survey (USGS) regional regression equations. The USGS has performed multiple regression analyses on gaged watersheds for each state. They correlate such watershed characteristics as drainage area, climatic region, watershed slope, watershed storage, and others, to peak discharge. The regression equations can be useful for transferring data from gaged watersheds to the watershed of interest.

630.0203 Design hydrology

The storage and spillway capacities of floodwater retarding structures are determined as shown by the flowchart in figure 2–3. NEH630.21 provides details of the steps and provides the NRCS hydrologic design criteria for constructing hydrographs for the design storms.

Figure 2–3 Design hydrology for storage and spillways in floodwater retarding structures