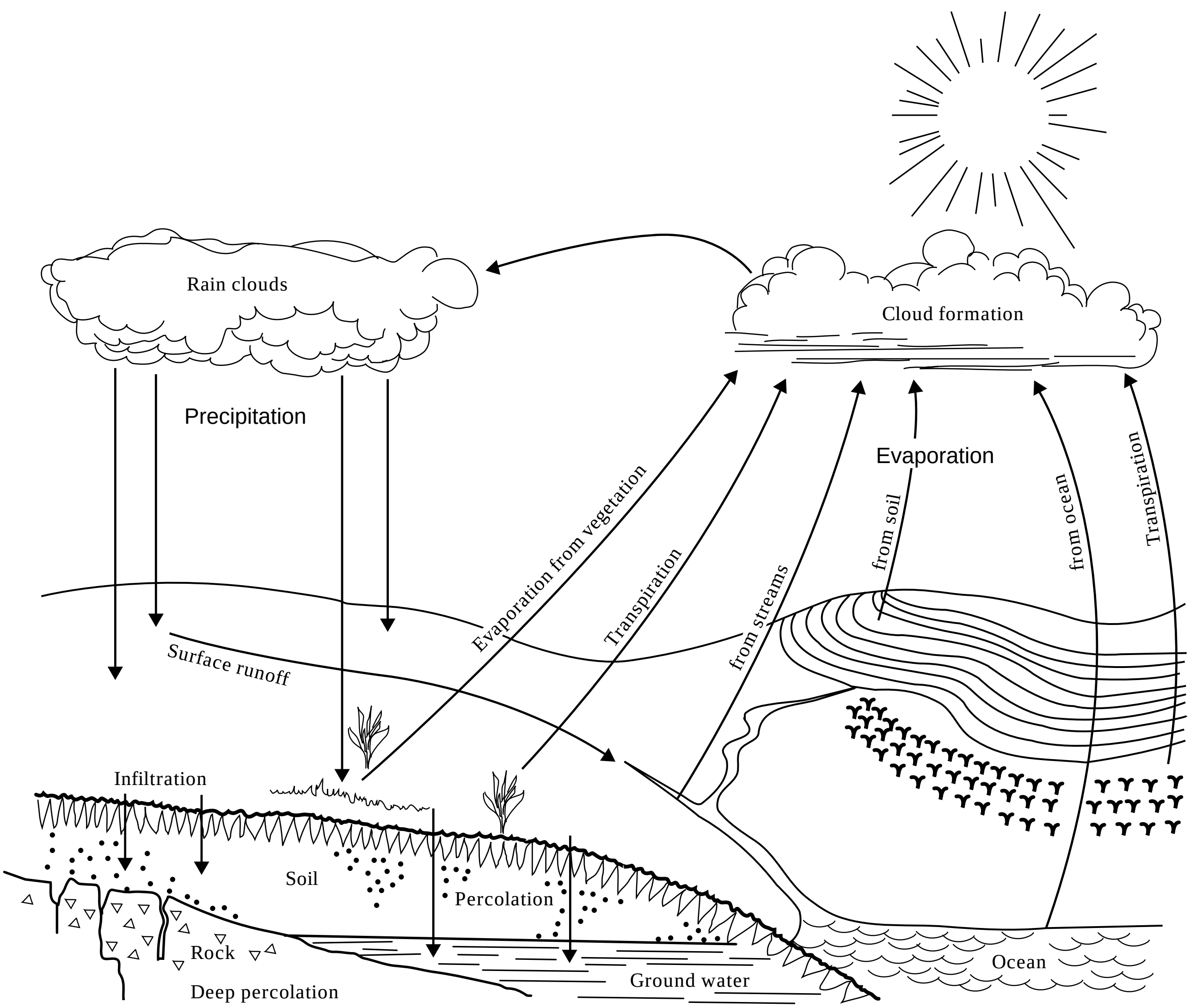
United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

Part 630 Hydrology
National Engineering Handbook

Chapter 2 Procedures



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Chapter 2 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. 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. It is the basis on which recommendations for or against the project are founded. A summary of the evaluation is included in a work plan, which is the official document for carrying out, maintaining, and operating the project. The hydrology is not difficult, but it is complex. The procedures described in this chapter serve both as a guide to hydrology studies and as a unifying introduction to succeeding chapters of part 630.

A project evaluation begins with a preliminary investigation (PI), which is a brief study of a potential project to estimate whether a detailed investigation is justified (see chapter 3). If it is, information from the PI is used in writing a work outline that gives the desired scope, intensity, and schedule of the planning study; its estimated cost; the personnel needed; and the completion date for a work plan.

An important part of the planning study is the hydrologic evaluation, in which 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 (see chapter 1). National Resources Conservation Service (NRCS) policy determines the number and kind of analyses. Nevertheless, the basic evaluation procedure does not vary. It is flexible because some tasks can be done simultaneously or in a preferred sequence and nearly all tasks can be done by a preferred method, but the general plan is invariable. The work outline schedule follows the plan in principle. The plan, schedule, and chapters in part 630 are related as shown in the following sections.

630.0201 Work outline plan and schedule relationship

(a) Data collection

Base maps, project area maps (chapter 3), rainfall data (chapter 4), and runoff data (chapter 10) are collected early in the study. Field surveys provide stream cross sections and profiles (chapter 6) and dam site maps. Interviews with local NRCS personnel provide data on hydrologic soil-cover complexes (chapters 7, 8, and 9) and runoff curve numbers (chapter 10).

(b) Computations

Storm runoffs (chapter 10), snowmelt runoffs (chapter 11), special effects of land use and treatment (chapter 12), and the relations of stream stages to inundation (chapter 13) and discharge (chapter 14) are computed early in this phase of the study. Travel times and lags (chapter 15) are computed for use in hydrograph construction (chapter 16) and flood routing (chapter 17). Runoff or peak discharge frequencies (chapter 18), transmission losses (chapter 19), and watershed yield (chapter 20) are computed only if they are required in the study.

(c) Analyses

Four conditions of a watershed are studied in accordance with NRCS policy. In order of study they are:

1. Present—Condition of the watershed at the time of the survey; and the base to which the proposed project is added.
2. Future with no project—Expected future condition of the watershed with no project action taken.
3. With future land use and treatment measures—Proposed land use and treatment measures are added to the first condition. The measures are described in the National Watershed Manual.
4. With future land use and treatment measures and structures—Watershed protection and flood prevention structures are added to the third condition. The structures are described in the National Watershed Manual.

This order makes the analysis fall into a natural sequence in which measures that are first to affect runoff are first to be evaluated. Flood routings for the present condition give the discharges from which present flood damages are computed in the economic evaluation. The routings are modified (chapter 12) to give discharges for determining the effects of land use and treatment. New routings or further modifications (chapter 17) are made for the third condition to give discharges for determining the effects of structures. Generally, it is the third condition that is studied at great length because an optimum number and location of structures are desired. 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 design are given in chapter 21, TR60, and section IV of the Field Office Technical Guide (FOTG).

630.0202 Hydrologic evaluation process

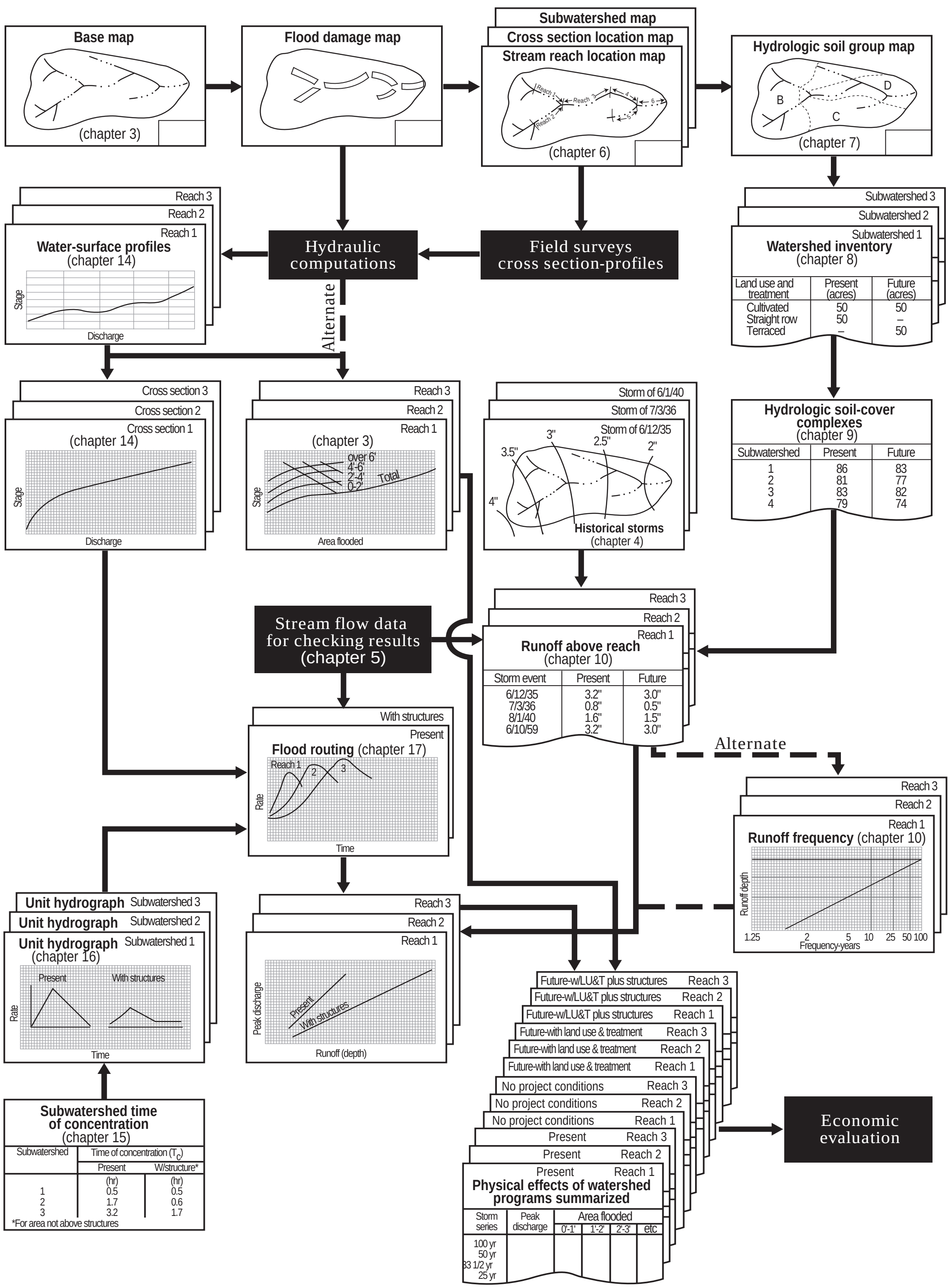
In both the computational and analytical phases, use of hydrologic and hydraulic computer models can substanially reduce the work time. Such models can estimate runoff hydrographs; route hydrographs through reservoirs, lakes, channels, and flood plains; combine hydrographs as necessary; and determine stage/discharge/acres flooded relationships. Two frequently used NRCS computer models include Technical Release 20 (Project Formulation - Hydrology, 1983) and Part 630, chapter 31, Computer Program for Water Surface Profiles (1994). The Corps of Engineers also have several hydrologic and hydraulic models that can be useful in project analyses.

(a) Work sequence

The sequence of work in the hydrologic evaluation is shown in figure 2–1. The forms of maps, graphs, and tables are simplified representations of the various standard forms used in the different States. The preliminary investigation, which precedes the evaluation, is described in chapter 3. The design hydrology comes later, and details are given in chapter 21.

After evaluation for the present conditions (the first condition) is completed, the early steps of the evaluation process do not always need to be repeated for the remaining conditions. Evaluations for future conditions should include one that considers the future with no project measures and that accounts for expected future land use changes without any project. Depending on the nature of these expected changes, the hydrologic soil-cover complexes and corresponding runoff curve numbers would be altered, affecting the runoff hydrographs. The condition with the future land use and treatment measures would start the evaluation process at the hydrologic soil-cover complexes step. At this step the soil-cover complexes would be modified to reflect different land use/treatment conditions, which would ultimately again be reflected in the flow hydrographs. Finally, the condition with future land use and treatment measures plus structural measures would start the evaluation process at the unit hydrograph step by modifying the unit hydrograph to reflect the structures being in place.

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



Of the basic data needed in the evaluation, only the historical rainfall and streamflow data are likely to be unavailable; the rest are obtainable from field surveys. Lacking rainfall and runoff data, the procedure goes as shown in figure 2–2. The rainfall-frequency data shown in the figure are from U.S. Weather Bureau, National Weather Service, and NOAA publications (see part 630, chapter 4). Direct checks on runoff cannot be made, but indirect checks can be made if nearby watersheds are gaged (see table 5–2).

Some steps in the procedures of figures 2–1 and 2–2 are taken in an entirely different way in the methods for regional analysis.

(b) Analysis methods

(1) Regional analysis method

This method estimates the magnitudes and frequencies of peak discharges or runoff volumes for ungaged watersheds by using relationships from nearby gaged watersheds. Some of the hydraulic work, construction of hydrographs, and flood routing are reduced or eliminated from the evaluation, but not from the design hydrology. The method in its simplest form is as follows:

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

Step 2 Construct frequency lines (chapter 18) for peak discharges or runoff volumes of the gaged watersheds.

Step 3 Plot peak discharges or runoff volumes for selected frequencies (only the 2- and 100-year frequencies if the frequency lines are straight) of each gaged watershed against its drainage area size. Use log-log paper for the plotting, and make straight-line relationships for each frequency. A simple regression between log (drainage area) and log (discharge or runoff volume) aids in estimating this best fit straight line through the data.

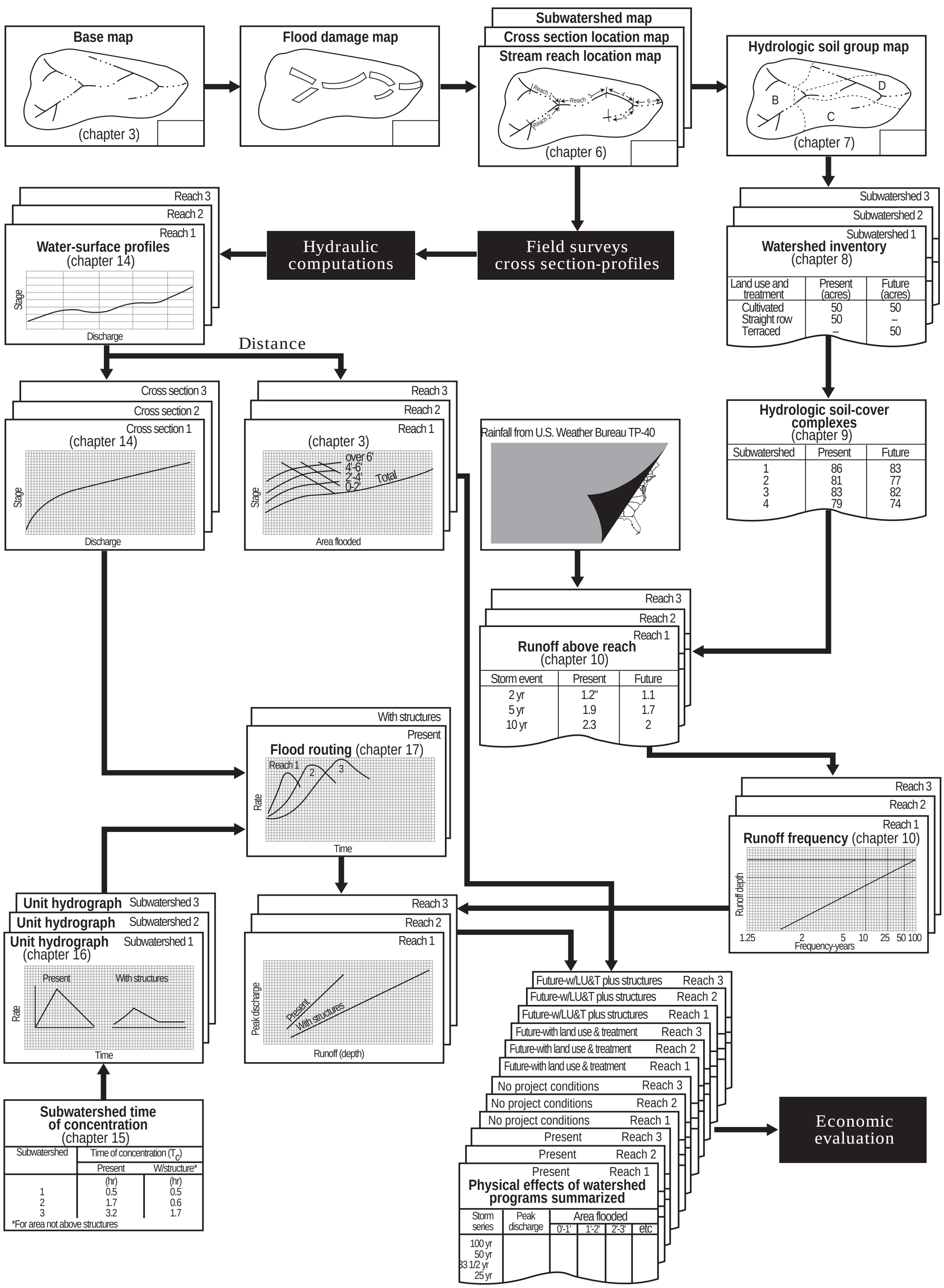
Step 4 Construct the frequency line for the ungaged watershed (or any of its subdivisions). To do this, enter the plot with drainage area, find the magnitudes at each line of relationship, plot the magnitudes at their proper places on probability paper, and draw the frequency line through the points.

Step 5 Apply the frequency lines of step 4 in the procedure for present conditions. Discharges or volumes for with-project conditions are obtained by use of auxiliary relationships described in chapters 12 and 17

In practice the method is more complex, but generally only in step 3. In this step 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
- storm direction
- 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 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

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



- hydrologic soil-cover complex
- geologic region
- infiltration rate
- mean base flow
- mean annual runoff
- watershed shape

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

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

(2) USGS regional regression equations
Another source for determining relative effects of watershed characteristics on discharge is United States Geological Survey (USGS) regional regression equations. The USGS has performed multiple regression analyses on gaged watersheds for each state. They correlated 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. Chapter 21 gives details of the various steps and provides the NRCS criteria of the design hydrology. That chapter also contains design hydrology in outline form for channel improvement, levees, and minor project or onfarm structures.

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