MT530.11 Hydrologic Procedures

The procedures used for hydrologic analysis are dependent on what information is available, the size of the watershed, whether or not the watershed is homogeneous, whether or not a complete hydrograph is needed, and the importance of the analysis.

The best available data should always be used. If there is a stream gage at or near the site, we should make use of that data. The record from a gauge can be useful even if less than five years of data is available and a normal frequency analysis is not feasible. If a Flood Plain Management Study, or Flood Insurance Study is available, the discharge frequency data from that study should be utilized.

Our work in Montana involves streams from a few acres in size to rivers with several thousand square miles of drainage area. There are several hydrology models available to us which meet most of our normal needs. For more complicated and more important analysis there are some standard methods and procedures which may be applied.

If a watershed is non-homogeneous, it requires subdivision to model accurately. Watershed subdivision is required when significantly different conditions affecting runoff volumes or timing are present in the watershed. This occurs where widely different curve numbers are needed (e.g., between forested land and cropland), and where slope patterns are not similar (e.g., steep versus flat topography).

The following is a brief description of the acceptable NRCS models and other acceptable procedures which may be used in Montana for hydrologic analysis. Included is general guidance about when each is appropriate for use. This should not preclude the use of more detailed analysis if necessary to insure the structure meets its functional objective.

(a) EFM2 (Engineering Field Manual, Chapter 2)

(1) The EFM2 method for obtaining design discharge is applicable to homogeneous drainages with less than 2,000 acres and with a flow length of less than 20,000 feet. However, as referenced in the Engineering Field Manual, Chapter 2, Montana Amendment 1 dated February 20, 1990; if alternate methods are used to compute the time of concentration ($T_c$), the charts may be used for homogeneous areas with time of concentration up to five hours.

(2) The Montana Supplements to EFM2 also contain some useful guidance for curve number (CN) calculations, and for storm distributions which are applicable to other NRCS models.

MT530.11(a)(3)

(3) The EFM2 method is recommended for jobs with low hazard and low to moderate cost in homogeneous watersheds with less than 2,000 acres (3.1 square miles), and where a complete hydrograph is not needed. Typical applications are grassed waterways, hillside diversions, feedlot runoff, etc.

(b)(1) TR55 Urban Hydrology

(i) Although this model has some special applications to the analysis of urban area watersheds, it may also be used in rural areas. Like EFM2 there are both handbook and computer solution methods available. The graphical method in TR55 is limited to homogeneous areas. The $T_c$ calculation is not limited and the graphs extend up to a $T_c$ of ten hours. A more reasonable limit for $T_c$ would be about five hours or a drainage area of 20 to 30 square miles.

(ii) The tabular method of TR55 allows for sub-watersheds and the computation of hydrographs. However, TR55 uses a simplified routing method and the method of combining hydrographs is also approximate, so it is better to use the TR20 model instead.

(iii) TR55 is recommended for use on homogeneous drainages up to 20 square miles. It is also recommended for technicians and consultants who need a model with sub-watersheds or hydrographs but don't have enough use to justify learning TR20. It could be applied to watersheds with up to 100 square miles for structures with low risk and low to moderate cost. Typical applications might be grassed waterways, streambank protection, irrigation diversions, stockwater ponds, and urban development analysis.

(b)(2) FOCS (Engineering Tool Kit)

(i) The peak discharge method in the Engineering Tool Kit in FOCS is comparable to EFM2 and TR55 graphical methods. It is applicable to homogeneous areas up to 20 or 30 square miles. The results will vary from EFM2 or TR55 because of different internal computation methods. The FOCS method will normally increase peak discharges from small areas and decrease discharge from large areas. It is probably more technically correct in accordance with the National Engineering Handbook, Section 4, Chapter 16. The differences between the results of various computational methods are well within the accuracy expected from the predictions.

(b)(3) TR20 (Project Formulation Hydrology)

(i) This model allows for numerous sub-watersheds, reach and reservoir routing, diversions, and actual rainfall as well as design storms. It is the NRCS general purpose hydrology event model and meets many of our needs for hydrologic analysis.

MT530.11(b)(3)(ii)

(ii) TR20 may be used for any sized watershed, but a practical upper limit is about 500 square miles. It should be used for all project evaluation hydrology where storm hydrographs are necessary. It can be used to evaluate the use of reservoirs, diversions, levees, etc., on storm hydrographs. Either the 1987 or the 1992 version may be used. The 1992 version will give higher results, particularly with small drainage areas and Type I storms. It is recommended for all watersheds over 20 square miles and all non-homogeneous watersheds where storm hydrographs are needed.

(iii) For larger watersheds, especially those approximately over 50 square miles, the output from models such as TR20 and TR55 should be verified with an analysis of stream gage records in the area. Adjustments may then be made with base flow additions or channel loss factors, or with direct adjustment of curve numbers. The adjustments should not be made arbitrarily and should be physically based.

(b)(4) SITES (formerly DAMS2)

(i) The SITES Model is specifically set up to develop and route the design hydrographs required by policy for the design of dams. This makes evaluation of alternative storage and spillway configurations much easier.

(ii) SITES can handle sub-watersheds with multiple reservoirs, however, for complex watersheds it may be easier to develop the storm hydrographs with TR20 and enter these into the SITES Model.

(iii) SITES should be used for all NRCS dam designs where reservoir routing is needed for the evaluation of a structural spillway or principal spillway. SITES can also be used to analyze erosion in earth spillways.

(b)(5) Statistical Methods

(i) Statistical regression has been used by numerous investigators to estimate peak discharge by frequency from watershed and channel characteristics. The best set of equations for Montana is presently from the U.S. Geological Survey Water-Resources Investigation (WRI) Report 92-4048. It provides regional equations relating peak discharge to drainage area and annual precipitation or elevation data.

(ii) Another widely used method is the NRCS 1971 Report, Hydrology of Mountain Watersheds. It estimates the 25-year peak discharge in cfs/mi$^2$ as a function of the average annual runoff in inches. The average annual runoff is also estimated as a function of the average annual precipitation.

MT530.11(b)(5)(iii)

(iii) Two other U.S. Geological Survey WRI Reports, 82-4092 and 83-4046, provide estimates of peak flow based on channel width for Montana. They provide another independent estimate which is useful for comparison.

(iv) Statistical methods are simple to use and provide a reasonable estimate with a minimum amount of input. They may be used where hydrographs are not needed and the importance of the estimate is low. Typical applications might be for road culverts, 310 permit applications, and streambank protection.

(v) These methods should not be applied outside of the range of data from which they were developed. For the reports listed above, this would include drainage areas from one to about 1,500 to 2,000 square miles. Because of the limited data available on smaller watersheds, and because of the wide variation of runoff with soil and cover, they should not be used for less than about three square miles. For western Montana, there is very little runoff data available from the valley areas. The U.S. Geological Survey reports for the west and northwest regions should not be used where the annual precipitation is less than about 22 inches. The 1971 NRCS Report is also limited to mountain areas and works best in the 25- to 50-inch precipitation zone.

(vi) It is recommended that the latest version of the U.S. Geological Survey regional equations be used as a check for most jobs approximately over 10 square miles of drainage. The computed value should normally be within one standard error of the U.S. Geological Survey equation unless there is a physical reason to explain why it varies so greatly from measured data.

(b)(6) Streamgage Transfer and Special Regional Studies

(i) Measured peak discharge at a site is the best means of determining the design discharge. If the site has 20 years or more of record, with no outliers (values that do not fit the probability distribution curve) and no major hydrologic changes, the frequency analysis of the annual peak flows will give us the value we need. As a federal agency, we have agreed to use the Log-Pearson Type III frequency distribution as recommended by the Water Resource Council in Bulletin 17B. For most of our work, the values printed for each gage in U.S. Geological Survey WRI 92-4048 can be used. Gages not included in 92-4048 had less than ten years of record (in 1988) or were considered inadequate for other reasons. A copy of all U.S. Geological Survey daily value and peak flow records for Montana is maintained in the state office. If we need to do a frequency distribution ourselves, be sure to follow the National Engineering Handbook, Section 4, Chapter 18 and WRC Bulletin 17B guidelines. Bulletin 17B also provides for the treatment of outliers, historical data, two station comparisons, mixed populations, etc., that may be needed in a detailed analysis.

MT530.11(b)(6)(ii)

(ii) Although very few sites will be at a stream gage station, most major streams have or have had one or more gages located on them. Transferring the peak discharge from the station upstream or downstream can be done by using ratios in the regional equations. This method is recommended over using just the regional equations when the drainage area is between 0.5 and 2.0 times the drainage area at the stream gage.

(iii) All of the parameters in the regional equation should be used when making the estimate at the ungaged site. For example, the 25-year peak flow in the U.S. Geological Survey west region should use the following equation:

$$Q_{25u} = (A_u/A_g)^{0.87} (P_u/P_g)^{1.19} Q_{25g}$$

where: $Q_{25u}$ is the 25-year discharge at the ungaged site
$Q_{25g}$ is the 25-year discharge at the gaged site
$A_u$ is the drainage area at the ungaged site
$A_g$ is the drainage area at the gaged site
$P_u$ is the average annual precipitation at the ungaged site
$P_g$ is the average annual precipitation at the gaged site

This procedure may also be applied to a nearby watershed with similar characteristics.

(iv) For larger drainages and for jobs with a high hazard or high cost, it may be advisable to do a special regional study to determine the design discharge or other hydrologic characteristics. Guidance on regionalization and regression techniques can be found in the National Engineering Handbook, Section 4, Chapter 18. A simple graphical technique, described below, can help you decide if the USGS regional equation is appropriate or if a special regression equation should be developed.

a) Find all the stream gages within a 50-mile radius of your site from the map in the back pouch of WRI 92-4048.

b) If there are less than ten gages, expand to a 100-mile radius.

c) Find the watershed characteristics and peak flow for the frequency of your interest from Table 1 of WRI 92-4048.

d) Plot discharge versus drainage area on log-log paper. Note other characteristics (like precipitation or elevation) by the point.

e) Plot the U.S. Geological Survey regional equation on the graph (if necessary, use two or three lines with different values of precipitation or elevation).

MT530.11(b)(6)(iv)f)

f) If the area overlaps into different regions on the map, plot those equations too.

g) Pay special attention to stream gages in the drainage and in similar nearby watersheds and decide whether or not the equation fits the data.

You can also plot estimates from TR20 or TR55 on this graph to help you decide if those results are reasonable.