ARIZONA DEPARTMENT OF WATER RESOURCES
OFFICE OF DAM SAFETY AND FLOOD MITIGATION
Dam Safety Section

PMF Studies for Evaluation of Spillway Adequacy
General Guidelines

Revised March 2004

Inflow design floods (IDFs) for jurisdictional dams in Arizona are almost always some percentage, up to and including 100 percent, of the probable maximum flood (PMF). Percentages of the PMF are calculated by reducing the ordinates of the PMF flood hydrograph(s). Therefore, IDF studies almost always begin with an assessment of the PMF.

All PMF studies submitted for evaluation of the spillway adequacy of existing or proposed jurisdictional dams should satisfy the following general requirements.

<u>Watershed Hydrology</u>

- 6-hour local and 72-hour general storm probable maximum precipitation (PMP) depths should be calculated using procedures described in Hydrometeorological Report No. 49 (HMR 49).

- Time-distribution for the 6-hour local PMP should be calculated using procedures described in HMR 49. The hypothetical storm used in the HEC-1 Program (i.e. the ‘PH’ Record) is not acceptable.

- HMR 49 does not include guidance for the time-distribution for the 72-hour general storm PMP. The worksheets used to develop the general storm provide the distribution by day and by 6-hour period for the largest day. The Department has previously approved use of the following distribution:

    1st Day: Second Largest Day uniformly distributed

    2nd day: Largest Day sequenced as follows:

    A. Third largest 6-hr period uniformly distributed
    B. Second largest 6-hr period uniformly distributed
    C. Largest 6-hr period uniformly distributed
    D. Fourth largest 6-hr period uniformly distributed

    3rd day: Smallest Day uniformly distributed

- Site-specific PMP depths and distributions may be accepted if independently reviewed by a qualified third-party meteorologist at the dam owner’s expense.

- The potential for rainfall coupled with snowmelt should be considered where applicable.

- Rainfall-runoff analyses should be performed following an appropriate industry-recognized methodology. Examples of acceptable methodologies include:
    - USBR Flood Hydrology Manual
    - ADOT Highway Drainage Design Manual
    - USACE Flood Runoff Analysis – EM 1110-2-1417
    - Drainage Design Manual for Maricopa County, Arizona, Hydrology
    - NRCS National Engineering Handbook – Part 630 Hydrology

  The selected methodology should be clearly identified including a statement of justification explaining why it is the most appropriate method for the watershed being considered. If the selected methodology is not one of those included in the list above, then upon request a copy of the reference should be provided along with the study.

- The rainfall-runoff model should be "verified" using one or more of the following:
    - Known reservoir or streamflow data during one or more severe storms on the watershed or nearby similar watershed(s);
    - 100-year discharge by flood frequency analysis on the watershed or nearby similar watershed(s);
    - 100-year discharge by indirect method(s).

  The ADOT and Maricopa County drainage design manuals provide procedures for verification by indirect methods. Watershed characteristics that may explain differences between the model results and those predicted by indirect methods should be discussed and examined.

- The verified rainfall-runoff model should be modified to account for increased rates of runoff during the PMF (i.e. decreased losses and shortened lag time or time of concentration).

- Other dams within the contributing watershed should generally not be assumed to fail during floods equal to or smaller than their own IDF, even if they have inadequate spillway capacities.

- Other dams within the contributing watershed should be assessed for the level of flood attenuation they provide during the PMF. If expected to be significant they should be included in the analysis.

- Watershed conditions used for estimation of the PMF should include foreseeable future (e.g. 10 years) changes in land-use.

- Deliverables accompanying the study should at a minimum include:
    - Total and excess rainfall hyetographs and discharge hydrographs for major sub-basins;
    - Inflow hydrographs for all reservoirs;
    - One or more channel cross-sections showing maximum water surfaces for major routing reaches

- Documentation accompanying the study should at a minimum include:

    - Local and general PMP computation sheets;
    - Topographic mapping of watershed including types/sources, scales, and dates;
    - Drainage area boundaries including the study area boundary, major sub-basin boundaries, and concentration points;
    - Channel cross-sections for routing reaches including sources.
    - Soils maps;
    - Land-use maps;
    - Copy of references used for selecting specific basin parameters (i.e. infiltration rates, curve numbers, runoff roughness coefficients, etc.) if not included in the selected standard methodology;
    - Watershed work maps including sub-basin boundaries and concentration points, time-of concentration or lag flow paths, and hydrograph routing paths;
    - Verification procedures and results;
    - Copies of representative hand-calculations;
    - Hard and electronic copies of all input and output computer files;
    - Discussion of error or warning messages included in computer output;
    - Comparison of results with those from previous studies including a discussion of differences.

<u>Reservoir Routing</u>

- All spillway and outlet elevation-discharge relationships should be calculated using appropriate industry-recognized design guidelines such as:

    - Hydraulics of Broad-Crested Spillways (SCS TR-39, 1968)
    - Hydraulic Design of the Box-Inlet Drop Spillway (SCS AH-301, 1966)
    - Hydraulic Design of Spillways (USACE EM 1110-2-1603, 1990)
    - Hydraulic Design of Reservoir Outlet Works (USACE EM 1110-2-1602, 1980)
    - Discharge Coefficients for Irregular Overfall Spillways (USBR EM No. 9, 1952)
    - Design of Small Dams, 3rd Ed. (USBR, 1987)
    - Handbook of Hydraulics, 7th Ed. (Brater et al., 1996)
    - Etc.

- Discharges through all spillways and outlets should be calculated and summed at one-foot intervals.

- Often, a weir equation is used to calculate the rating curve for an emergency spillway. In general, the weir coefficient varies with weir geometry (i.e. crest width, slope of upstream face, height of crest above the approach channel, etc.). It also varies with overflow depth and thus is usually not constant for the range of discharges. Also, in order for the weir equation to be applicable for the full range of discharges, the channel flow downstream of the weir must be supercritical. If a weir equation is used, the choice of discharge coefficient must be documented with reference(s) or calculations and supercritical flow downstream of the weir must be shown for the range of discharges.

- Energy losses in long, shallow spillway approach channels should be evaluated. The spillway discharge relationship should be related to the reservoir water surface elevation, which may be higher than that immediately upstream of the weir.

- Channel spillways without a clearly defined control section should be analyzed using a step backwater analysis.

- Flood routings for permanent storage reservoirs will normally be required to begin with reservoir storage at the spillway crest elevation. Flood routings for single-purpose flood control dams may be allowed to begin with the reservoir elevation at the invert of the lowest outlet work if 85 percent of the smaller of either (1) the reservoir volume at the spillway crest elevation or (2) the total runoff volume during the 100-year 24-hour storm can be drained within 10 days.

- Level-pool routing procedures are generally acceptable for most flood routings. For very long, narrow reservoirs dynamic-wave routing procedures should be used.

- The inflow design flood should be that resulting from either the six-hour local storm PMP or seventy-two-hour general storm PMP, whichever results in a higher routed maximum reservoir water surface elevation.

- Deliverables accompanying the study should at a minimum include:

    - Elevation-storage relationship for all reservoirs routed via level-pool procedures;
    - Elevation-discharge relationships for all spillways and outlets and combined relationship for all dams;
    - Stage and discharge hydrographs for all reservoirs routed via level-pool procedures;
    - Maximum water surface elevation profile for all reservoirs routed via dynamic-wave procedures.
    - For dams predicted to be overtopped during the IDF:
        - i) Maximum depth and duration of overtopping during the IDF;
        - ii) Maximum percentage of the PMF during which the dam is not predicted to overtop.

- Documentation accompanying the study should at a minimum include:

    - Topographic mapping of the dam and reservoir including types/sources, scales, and dates;
    - Centerline profile of spillway starting upstream of the approach channel and terminating downstream of the stilling basin, if present;
    - One or more spillway cross-sections, as applicable;
    - Reservoir cross-sections used in dynamic-wave routing;
    - Centerline profile of outlet works showing conduit dimensions and entrance/exit conditions;
    - Copies of any design tables, charts, or nomographs used for predicting the hydraulic performance of spillway or outlet works;
    - Copies of representative hand calculations;
    - Hard and electronic copies of all input and output computer files;
    - Discussion of error or warning messages included in computer output;
    - Comparison of results with those from previous studies including a discussion of differences.