U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 2.4.4 POTENTIAL DAM FAILURES (SEISMICALLY INDUCED)

REVIEW RESPONSIBILITIES

Primary - Site Analysis Branch (SAB)

Secondary - None

I. AREAS OF REVIEW

In this section of the safety analysis report (SAR) the hydrogeologic design basis is developed to assure consideration in plant design of any potential hazard due to the failure of upstream and downstream water control structures from seismic causes. These hazards include flood waves (bores) from severe breaching of upstream dams and the potential loss of water supply due to failure of a downstream dam.

When data are provided to show that seismic events will not cause failures of upstream dams that could produce the governing flood at the plant, this section may contain additional data and other information to support a contention that the dams are equivalent to seismic Category I structures and will survive a local equivalent of the safe shutdown earthquake (SSE) or will survive the operating basis earthquake (OBE). In such cases the areas of review will include items necessary to justify such a classification. Such review would be referred to the SAB Geology, Seismology, and Foundation Engineering Section for evaluation. The balance of this review plan applies to non-Category I structures, and to the hydrologic analysis of those Category I structures that could be affected by flood waves caused by upstream failures.

Where analyses are provided in support of either a conclusion that a probable maximum flood (PMF) should be the design basis flood for a stream, or that a postulated or arbitrarily assumed seismically-induced flood is the design basis flood for a stream, the areas of review consist of the following:

1. Conservatism of modes of assumed dam failure and deposition of debris downstream.

2. Consideration of full flood control reservoirs.

3. Conservatism of downstream flow rates and levels depending on whether failure is postulated with an equivalent SSE coincident with a 25-year flood, or an OBE coincident with a flood approximately half as severe as a PMF.

4. Flood wave attenuation to downstream dams, or to the site, whichever would be encountered first.

5. Potential for multiple dam failures; flood wave effects and potential for failure of downstream dams.

6. Hydraulic failure of downstream dams induced by upstream failures.

7. Dynamic effects on exposed plant facilities of possible bores.

8. Conservatism (see item 3 above) of ambient flow conditions for downstream dam failures that can influence safety-related water supplies.

II. ACCEPTANCE CRITERIA

The staff will review the applicant's analyses and independently estimate the coincident river flows at the site and at the dams being analyzed (see Figure 2.4.4). The acceptable "worst conditions" to be postulated for analysis of upstream failures in lieu of substantiation of seismic resistance capability are: (1) a 25-year flood on a full reservoir coincident with the dam-site equivalent of the SSE, and (2) a standard project flood (a flood about half the severity of a PMF) on a full reservoir coincident with the dam site equivalent of the OBE.

For SAR Section 2.4.4.1 (Dam Failure Permutations): the location of dams and potentially "likely" or severe modes of failure must be identified. The potential for multiple, seismically-induced dam failures (of closely spaced dams) and the domino failure of a series of dams, including the resulting flood surge-caused failure of intermediate structures, must be discussed. First-time use of analytical hydraulic failure models will require complete model description and documentation. Acceptance of the model (and subsequent analyses) is based on the staff review of model theory, available verification, and application. A determination of the peak flow rate and water level at the site for the worst possible combination of dam failures and a summary analysis (that substantiates the condition as the critical permutation) must be presented, along with a description (and the bases) of all coefficients and methods used. Also, the effects of other concurrent events on plant safety, such as blockage of the river and waterborne missiles must be considered.

For SAR Section 2.4.4.2 (Unsteady Flow Analysis of Potential Dam Failures): the effects of coincident and antecedent flood flows (or low flows for downstream structures) on initial pool levels must be considered. Use of the methods given in References 1 or 3 is acceptable for determination of initial pool levels. Depending on the estimated failure mode, the "gradually varied unsteady flow profiles" program (Ref. 9) used by the Corps of Engineers or the Tennessee Valley Authority model (Ref. 8) may provide an acceptable analysis.

For SAR Section 2.4.4.3 (Water Level at Plant Site): computations, coefficients, and methods used to establish the water level at the site for the most critical dam failures must be summarized. Comparison with the HEC-2 program (Ref. 2) or unsteady flow models (Refs. 8 and 9) with adequate site-related coefficients, serves as a basis for acceptance. Coincident wind-generated wave activity should be considered in a manner similar to that discussed in Standard Review Plan 2.4.3.

III. REVIEW PROCEDURES

The review procedures are outlined in Figure 2.4.4. In general, the conservatism of the applicant's estimate of flood potential and low water levels from seismically-induced structure failures is judged against the criteria indicated above. When required, an analysis is performed using simplified, conservative procedures (such as instantaneous failure, coincident one-half PMF flows, minimal flood wave attenuation, and extrapolated site discharge-rating curves). Techniques for such analyses are identified in standard hydraulic design references and text books, such as those listed in the reference section. If no potential flood problem exists, the staff safety evaluation report (SER) input is written accordingly. If the simplified analysis indicates a potential flooding problem, the analysis is repeated using a more refined technique, and additional information and data are requested from the applicant if necessary. Detailed failure models, such as those of the Corps of Engineers and the Tennessee Valley Authority, are utilized to identify the outflows from various failure modes. Models of the Corps of Engineers or the Tennessee Valley Authority are used to identify the outflow characteristics and resultant water level at the site (Refs. 4, 8, 13, 14, 15).

The above reviews are performed only when applicable to the site or site region. Some items of review may be done on a generic basis.

IV. EVALUATION FINDINGS

For construction permit (CP) reviews, the findings will consist of a statement comparing the applicant and staff evaluations of the design-basis maximum and minimum water levels caused by seismically-induced dam failures. If staff findings are similar to the applicant's, staff concurrence in the applicant's estimates will be stated. If the staff estimates substantially higher or lower water levels or flows, and if the plant may be adversely affected, a position requiring use of the staff bases will be stated. If no seismically-induced dam failure review was undertaken at the construction permit stage (of the scope described), this fact will be indicated.

For operating license (OL) reviews of cases for which detailed seismically-induced dam failure analyses were made during the CP review, the CP-stage conclusions will be referenced. In addition, any further review done to reaffirm the maximum or minimum water levels based on any new information will be described and the results and conclusions stated.

Sample statements for CP reviews follow:

"The distance (more than 300 miles) to upstream reservoirs of appreciable size is such that the staff considers their arbitrarily assumed failure, under AEC criteria of

reasonably postulated combinations of floods and earthquakes, would not constitute a threat to the plant worse than that due to a severe runoff-type flood or to hurricane-induced surge.

"Dam failure-caused 'worst case' floods were evaluated by the applicant based upon failures with consideration of only the location and sizes of upstream impoundments, and not on inherent capability of such structures to resist earthquakes, volcanic activity and severe landslide-induced floods. The most severe flood of this kind was estimated based upon an assumed catastrophic failure of Dam A some 420 miles upstream. The peak flow at the site from such a flood was estimated to be 3,000,000 cfs. This flow is estimated to occur about two days after the dam failure and reach elevation 41 feet MSL. Smaller dams on the river between Dam A and the site were also evaluated for such a flood and, it was concluded, would probably also fail.

"A volcanically-induced flood was assumed to cause a domino-type failure of the three dams on the tributary B River from a volcanic eruption of Mt. D. The evaluation indicated such an event could cause the second most severe artificial flood that would reach the site. This event was estimated to produce a peak flow at the site of 3,300,000 cfs and a water level of 39 feet MSL."

V. REFERENCES


1. "Flood Hydrograph Package," HEC-1, Corps of Engineers Hydrologic Engineering Center, Davis, California, October 1970.

2. "Water Surface Profiles," HEC-2, Corps of Engineers Hydrologic Engineering Center, Davis, California, February 1972.

3. "Reservoir System Operation for Flood Control," HEC-5, Corps of Engineers Hydrologic Engineering Center, Davis, California, May 1973.

4. 'Routing of Floods Through River Channels," EM 1110-2-1408, Corps of Engineers, March 1960.

5. Hunter Rouse, ed., "Engineering Hydraulics," John Wiley & Sons, Inc., New York (1950).

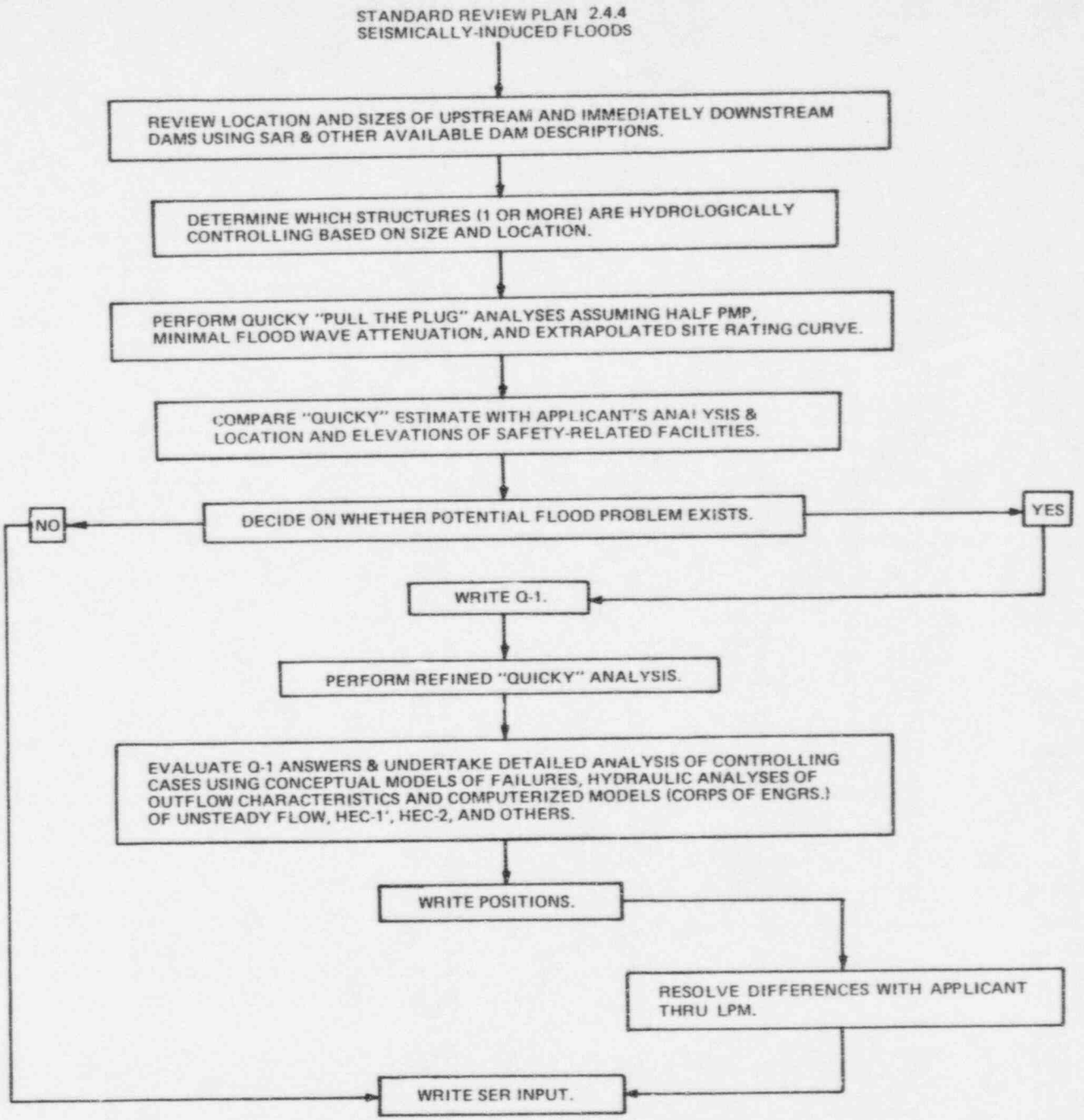
6. Ven Te Chow, "Open-Channel Hydraulics," McGraw-Hill Book Co., New York (1959).

7. Ven Te Chow, ed., "Handbook of Applied Hydrology," McGraw-Hill Book Co., New York (1964).

8. J. M. Garrison, J. P. Granju, and J. T. Price, "Unsteady Flow Simulation in Rivers and Reservoirs," Jour. Hydraulics Division, Proc. Am. Soc. of Civil Engineers Vol. 95, No. HY5, pp. 1559-1576 (1969).

9. "Gradually Varied Unsteady Flow Profiles," 723-62-L2450, Corps of Engineers Hydrologic Engineering Center, Davis, California, March 1969.

FIGURE 2.4.4


STANDARD REVIEW PLAN 2.4.4
SEISMICALLY-INDUCED FLOODS
REVIEW LOCATION AND SIZES OF UPSTREAM AND IMMEDIATELY DOWNSTREAM DAMS USING SAR & OTHER AVAILABLE DAM DESCRIPTIONS.
DETERMINE WHICH STRUCTURES (1 OR MORE) ARE HYDROLOGICALLY CONTROLLING BASED ON SIZE AND LOCATION.
PERFORM QUICKY "PULL THE PLUG" ANALYSES ASSUMING HALF PMP, MINIMAL FLOOD WAVE ATTENUATION, AND EXTRAPOLATED SITE RATING CURVE.
COMPARE "QUICKY" ESTIMATE WITH APPLICANT'S ANALYSIS & LOCATION AND ELEVATIONS OF SAFETY-RELATED FACILITIES.
DECIDE ON WHETHER POTENTIAL FLOOD PROBLEM EXISTS.
NO
YES
WRITE Q-1.
PERFORM REFINED "QUICKY" ANALYSIS.
EVALUATE Q-1 ANSWERS & UNDERTAKE DETAILED ANALYSIS OF CONTROLLING CASES USING CONCEPTUAL MODELS OF FAILURES, HYDRAULIC ANALYSES OF OUTFLOW CHARACTERISTICS AND COMPUTERIZED MODELS (CORPS OF ENGRS.) OF UNSTEADY FLOW, HEC-1', HEC-2, AND OTHERS.
WRITE POSITIONS.
RESOLVE DIFFERENCES WITH APPLICANT THRU LPM.
WRITE SER INPUT.

10. R. A. Baltzer and C. Lai, "Computer Simulation of Unsteady Flows in Waterways," Hydraulics Division, Proc. Am. Soc. of Civil Engineers, Vol. 94, No. HY4, pp. 1083-1117 (1968).

11. J. J. Stoker, "Numerical Solution of Flood Prediction and River Regulation Problems," Reports I and II, New York Univ. (1953-54).

12. V. L. Streeter and E. B. Wylie, "Hydraulic Transients," McGraw-Hill Book Co., New York, pp. 239-259 (1967).

13. W. A. Thomas, "A Method for Analyzing Effects of Dam Failures in Design Studies," Corps of Engineers Hydrologic Engineering Center, Davis, California, (for presentation at the ASCE Hydraulics Division Specialty Conference, Cornell University, August 1972).

14. "Flow Through a Breached Dam," Military Hydrology Bulletin No. 9, Corps of Engineers (1957).

15. "Floods Resulting from Suddenly Breached Dams, Conditions of High Resistance," Misc. Paper No. 2-374, Report 2, Corps of Engineers (1961).

16. Bureau of Reclamation, "Flood Routing," Chapter 6/0 in "Flood Hydrology," Part 6 in "Water Studies," Volume IV, U. S. Department of the Interior (1947).

17. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Revision 2.

SRP 2.4.5