U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.6 PROBABLE MAXIMUM TSUNAMI FLOODING

REVIEW RESPONSIBILITIES

Primary - Hydrologic & Geotechnical Engineering Branch (HGEB)

Secondary - Geosciences Branch (GB)

I. AREAS OF REVIEW

The geohydrological design basis of the plant (discussed in Regulatory Guide 1.59) is developed in this section of the Safety Analysis Report (SAR) to determine the extent of plant protection required for tsunami flooding and drawdown (outlined in Regulatory Guide 1.102). The areas of review include the hydrologic characteristics of the maximum locally and distantly generated tsunami and the techniques, methodologies and parameters, including the geoseismic parameters of the generators, used in the determination of the design basis tsunami.

Hydrologic analysis techniques, including tsunami formation, propagation and shoaling models, and coincident water levels, including astronomical tide, storm surges and waves, are reviewed.

The Geosciences Branch (GB) as part of its secondary review responsibility will review geologic and seismic characteristics of potential tsunamic faults. Areas of review include earthquake magnitude, focal depth, source dimensions, fault orientation, and vertical displacement. GB will review the applicant's values of the parameters, discussed above, used to model tsunami. The values used may represent upper bounds of the parameters. If there is disagreement with the applicant's proposed values, GB will provide alternative values. GB will provide a written discussion of its review of the geologic and seismic characteristics of potential tsunami sources to be included in the SER input for this section.

II. ACCEPTANCE CRITERIA

Acceptance criteria for this SRP section relate to the following regulations:

1. General Design Criterion 2 (GDC 2) as it relates to structures, systems, and components important to safety being designed to withstand the effects of tsunami.

2. 10 CFR Part 100 as it relates to identifying and evaluating hydrologic features of the site.

3. 10 CFR Part 100, Appendix A as it relates to investigating the tsunami potential at the site and determining the design bases for tsunami flooding.

To meet the requirements of GDC 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A with respect to tsunami and the analysis thereof, the following specific criteria are used:

1. If it has been determined that tsunami estimates are necessary to identify flood or low water design bases, the analysis will be considered complete if the following areas are addressed and can be independently and comparably evaluated from the applicant's submission:

    a. All potential distant and local tsunami generators, including volcanoes and areas of potential landslides, are investigated and the most critical ones are selected.

    b. Conservative values of seismic characteristics (source dimensions, fault orientation and vertical displacement) for the tsunami generators selected are used in the analysis.

    c. All models used in the analysis are verified or have been previously approved by the staff. Regulatory Guide 1.125 provides guidance in the use of physical models of wave protection structures.

    d. Bathymetric data are provided (or are readily obtainable).

    e. Detailed descriptions of shoreline protection and safety-related facilities are provided for wave runup and drawdown estimates. Regulatory Guide 1.102 provides guidance on flood protection for nuclear power plants.

    f. Ambient water levels, including tides, sea level anomalies, and wind waves, are estimated using NOAA and Corps of Engineers publications as described below.

    g. If Regulatory Guide 1.59, Position 2, is adopted by the applicant, the design basis for tsunami protection of all safety-related facilities identified in Regulatory Guide 1.29 must be shown to be adequate in terms of the time required for implementation of any emergency procedures.

2. The applicant's estimates of tsunami runup and drawdown levels are acceptable if the estimates are no more than 5% less conservative than the staff's estimates. If the applicant's estimates are more than 5% less conservative (based on the difference between normal water levels and the maximum runup or drawdown levels) than the staff's, the applicant should fully document and justify its estimates or accept the staff's estimates.

3. This section of the SAR will also be acceptable if it states the criteria used to determine that tsunami flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

III. REVIEW PROCEDURES

The review procedures are outlined in Figure 2.4.6-1. The references used are general geophysical, seismological, and hydrodynamic publications, such as published data by the National Oceanic and Atmospheric Administration (NOAA), and wave propagation models such as those developed by NOAA, WES, and Tetra Tech.

Section 2.4.6 of the applicant's SAR is reviewed to identify any missing data, information, or analysis necessary for the staff's evaluation of potential tsunami flooding. This section is evaluated when the applicant has responded to all the additional information requested. If the site is not near a large body of water with potential tsunami generators, the staff findings may be prepared a priori.

The staff (with input from GB) will review the potential tsunami sources analyzed by the applicant to assure that all locations capable of generating a tsunami of significant magnitude at the site have been considered. The GB staff will evaluate the geoseismic parameters of the tsunami generators, including fault location and orientation, and amplitude and areal extent of vertical displacement, to assure that conservative values have been chosen.

An independent staff analysis, using one of the models listed in the references, may be performed. Staff estimates of tsunami levels are compared with the applicant's. The applicant must justify, to the staff's satisfaction, tsunami levels more than 5% less conservative than the staff's.

As an alternative, the staff may perform an independent evaluation of the applicant's model and its utilization. The model's theoretical basis, its inherent conservatism and applicability to the problem, will be evaluated (this can be done on a generic basis). The conservatism of the models' use, including the conservatism of all input parameters, will be evaluated.

Coincident ambient tide and wave conditions will be evaluated to assure that they are of at least annual severity. Data from publications of NOAA, the Corps of Engineers, and other sources are used to substantiate these conditions chosen.

Criteria and methods of the Corps of Engineers as generally summarized in Reference 15 are used as a standard to evaluate the applicant's estimate of coincident wind-generated wave action and runup.

Criteria and methods of the Corps of Engineers and other standard techniques are used to evaluate the potential for oscillation of waves at natural periodicity.

Criteria and methods of the Corps of Engineers (Ref. 15) are used to evaluate the adequacy of protection from flooding, including the static and dynamic effects of broken, breaking, and nonbreaking coincident waves.

IV. EVALUATION FINDINGS

For construction permit (CP) reviews, the findings will consist of a statement summarizing estimates of the maximum and minimum tsunami water levels, and static and dynamic effects of wave action. A statement of acceptability of the tsunami-induced design basis in meeting the requirements of GDC 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A will be made. If the tsunami conditions do not constitute a design basis, the findings will so indicate. For operating license

(OL) reviews, the findings will consist of the evaluation of any new information on tsunami potential, improvements in predictive models, acceptability of specific design bases, and the acceptability of design provisions.

A sample statement for a CP review follows:

> The staff concludes that the plant design is acceptable with respect to its ability to withstand the effects of tsunami. It therefore meets the tsunami design requirements of GDC 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A. This conclusion is based on the following analysis.
>
> Analyses of tsunamic effects from local and distant generators were performed by the applicant at the staff's direction. The design tsunami results from a magnitude 8.7 earthquake in the Aleutian Trench. A finite difference numerical model was used to analyze tsunami generation and propagation to the continental shelf. Results of this computation were used in a nearshore model to calculate tsunami runup and drawdown. Including the effects of high and low tides of annual occurrence, the maximum tsunami runup and drawdown are estimated as +24.5 feet MLLW and -13.4 feet MLLW, respectively. Wind waves of annual severity were assumed coincident with the tsunami. Plant grade at elevation +55 MLLW is well above the tsunami flood level. The maximum wave runup, at the intake pumphouse, was estimated as +31.2 feet MLLW which is 3.8 feet below the design flood level of +35 feet MLLW. The maximum drawdown, at the location of the inshore intake, was estimated as -21.3 feet MLLW. The intake is designed to be able to draw water down to -30 feet MLLW and will therefore not be affected by low water due to tsunami drawdown.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance of parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 100, "Reactor Site Criteria."

3. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

4. Li-San Hwang, H. Lee Butler, and David J. Divorky, Tetra Tech, Inc., "Tsunami Model: Generation and Open-Sea Characteristics," Bulletin of the Seismological Society of America, Vol 62, No. 6, December 1972.

5. Li-San Hwang, D. Divorky, and A. Yuen, Tetra Tech, Inc., "Amchitka Tsunami Study," Report NVO-289-7, Nevada Operations Office, U.S. Atomic Energy Commission (1971).

6. Li-San Hwang and D. Divorky, Tetra Tech, Inc., "Rat Island Tsunami Model: Generation and Open-Sea Characteristics," Report NVO-289-10, Nevada Operations Office, U.S. Atomic Energy Commission (1971).

7. H. G. Loomis, "A Package Program for Time-Stepping Long Waves into Coastal Regions with Application to Haleiwa Harbor, Oahu," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration (1972).

8. Li-San Hwang and D. Dovorky, "Tsunami Generation," Journal of Geophysical Research, Vol. 75, No. 33 (1970).

9. K. L. Heitner, "Additional Investigations on a Mathematical Model for Calculation of the Run-Up of Tsunamis," California Institute of Technology (1970).

10. R. L. Street, Robert K-C Chan, and J. E. Fromm, "Two Methods for the Computation of the Motion of Long Water Waves - A Review and Applications," NR 062-320, Technical Report 136, Office of Naval Research, distributed as a reprint from the Proc. 8th Symposium on Naval Hydrodynamics, August 1970.

11. B. W. Wilson, "Earthquake Occurrence and Effects in Ocean Areas (U)," Technical Report 69.027, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, February 1969.

12. C. L. Mader, "Numerical Simulation of Tsunamis," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration, February 1973.

13. R. W. Preisendorfer, "Recent Tsunami Theory," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration, August 1971.

14. National Oceanic and Atmospheric Administration, Nautical Charts.

15. "Shore Protection, Planning and Design," Technical Report 4, Third Edition, Corps of Engineers Coastal Engineering Research Center, Third Edition (1966); and "Shore Protection Manual" (1977).

16. B. W. Wilson and A. Trum, "The Tsunami of the Alaskan Earthquake, 1964: Engineering Evaluation," Tech. Memo No. 25, Corps of Engineers Coastal Engineering Research Center (1968).

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

18. Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants."

19. Regulatory Guide 1.102, "Flood Protection Requirements for Nuclear Power Plants."

20. Regulatory Guide 1.29, "Seismic Design Classification."

21. Regulatory Guide 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants."

22. R. L. Wiegel, "Oceanographical Engineering," Prentice-Hall, Inc., Englewood Cliffs, NJ (1964).

23. J. R. Houston and A. W. Garcia, "Type 16 Flood Insurance Study: Tsunami Predictions for Pacific Coastal Communities," Technical Report H-74-3, U.S. Army Engineer Waterways Experiment Station (1974).

24. J. R. Houston, R. W. Whalen, A. W. Garcia, and H. L. Butler, "Effect of Source Orientation and Location in the Aleutian Trench on Tsunami Amplitude Along the Pacific Coast of the Continental United States," Technical Report H-75-4, U.S. Army Engineer Waterways Experiment Station (1975).

25. R. L. Wiegel, "Earthquake Engineering," Prentice-Hall, Inc., Englewood Cliffs, NJ (1970).

26. M. Brandsma, D. Divoky, and L. Hwang, "Tsunami Atlas for the Coasts of the United States," NUREG/CR-1106, USNRC (1979)

27. L. G. Hulman, W. S. Bivins, and M. H. Fliegel, "Tsunami Protection of Coastal Nuclear Power Plants in the United States," Journal of Marine Geodesy (1978).

Figure 2.4.6-1

REVIEW PROCEDURES