2.4.5 PROBABLE MAXIMUM SURGE AND SEICHE FLOODING

REVIEW RESPONSIBILITIES

Primary - Mechanical and Civil Engineering Branch (EMEB)

Secondary - None

I. AREAS OF REVIEW

In this section of the site safety assessment for an early site permit application, the hydrometeorological design basis is developed to determine the extent of flood protection required for safety-related systems for a nuclear power plant or plants of specified type that might be constructed on the proposed site. The areas of review include the characteristics of the assumed probable maximum hurricane or other probable maximum wind storms and the techniques, methodologies, and parameters used in the determination of the design surge and/or seiche. Antecedent water levels, storm tracks, methods of analysis, coincident wind-generated wave action and wave runup on safety-related structures, potential for wave oscillation at the natural periodicity, and the resultant design bases for surge and seiche flooding are also reviewed.

II. ACCEPTANCE CRITERIA

The EMEB acceptance criteria for this section of this review standard are based on meeting the requirements of 10 CFR Parts 52 and 100 as they relate to evaluating the hydrologic characteristics of the site.

Specific criteria necessary to meet the relevant hydrologic requirements of 10 CFR Parts 52 and 100 are as follows:

Section 52.17(a) of 10 CFR Part 52 and Section 100.20(c) of 10 CFR Part 100 require that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

To satisfy the hydrologic requirements of 10 CFR Parts 52 and 100, the applicant's safety assessment must contain a description of the surface and subsurface hydrologic characteristics of the region and an analysis of the potential for flooding due to surges or seiches. This description must be sufficient to assess the acceptability of the site and the potential for a surge or seiche to influence the design of structures, systems, and components important to safety for a nuclear power plant or plants of specified type that might be constructed on the proposed site.

Meeting this requirement provides a level of assurance that structures, systems, and components important to safety for a nuclear power plant or plants of specified type that might be constructed on the proposed site could be designed to withstand the most severe flooding likely to occur as a result of storm surges or seiches.

Note: Though not required at the early site permit stage, the applicant for a combined license (COL) will need to demonstrate compliance with General Design Criterion 2 as it relates to structures, systems, and components important to safety being designed to withstand hurricanes and seiches.

If it has been determined that surge and seiche flooding estimates are necessary to identify flood design bases, the applicant's analysis will be considered complete and acceptable if the following areas are addressed and can be independently and comparably evaluated from the applicant's submission.

1. All reasonable combinations of probable maximum hurricane, moving squall line, or other cyclonic wind storm parameters are investigated, and the most critical combination is selected for use in estimating a water level.

2. Models used in the evaluation are verified or have been previously approved by the staff.

3. Detailed descriptions of bottom profiles are provided (or are readily obtainable) to enable an independent staff estimate of surge levels.

4. Detailed descriptions of shoreline protection and safety-related facilities are provided to enable an independent staff estimate of wind-generated waves, runup, and potential erosion and sedimentation.

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

6. Combinations of surge levels and waves that may be critical to design of a nuclear power plant or plants of specified type that might be constructed on the proposed site are considered, and adequate information is supplied to allow a determination that no adverse combinations have been omitted.

7. If Regulatory Guide 1.59, Position 2, is elected by the applicant, the design basis for flood protection of all safety-related facilities identified in Regulatory Guide 1.29 must be shown to be adequate in terms of time required for implementation of any emergency procedures. The applicant must also demonstrate that all potential flood situations that could negate the time and capability to initiate flood emergency procedures are provided for in the less severe design basis selected.

This section of the safety assessment may also state with justification that surge and seiche flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

Hydrometeorological estimates and criteria for development of probable maximum hurricanes for east and Gulf Coast sites, squall lines for the Great Lakes, and severe cyclonic wind storms for all lake sites by the Corps of Engineers, National Oceanic and Atmospheric Administration (NOAA), and the staff are used for evaluating the conservatism of the applicant's estimates of severe windstorm conditions, as discussed in Regulatory Guide 1.59. The Corps of Engineers and NOAA criteria require variation of the basic meteorological parameters within given limits to

determine the most severe combination that could result. The applicant's hydrometeorological analysis should be based on the most critical combination of these parameters.

Data from publications of NOAA, the Corps of Engineers, and other sources (such as tide tables, tide records, and historical lake level records) are used to substantiate antecedent water levels. These antecedent water levels must be as high as the "10% exceedence" monthly spring high tide, plus a sea level anomaly based on the maximum difference between recorded and predicted average water levels for durations of 2 weeks or longer for coastal locations or the 100-yr recurrence interval high water for the Great Lakes. In a similar manner, the storm track, wind fields, effective fetch lengths, direction of approach, timing, and frictional surface and bottom effects are evaluated by independent staff analysis to ensure that the most critical values have been selected. Models used to estimate surge hydrographs that have not previously been reviewed and approved by the staff are verified by reproducing historical events, with any discrepancies in the model being on the conservative (i.e., high) side.

Criteria and methods of the Corps of Engineers as generally summarized in Reference 32 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. 32) are used to evaluate the adequacy of protection from flooding, including the static and dynamic effects of broken, breaking, and nonbreaking waves. Regulatory Guide 1.102 provides further guidance on flood protection. Regulatory Guide 1.125 provides guidance for using physical models in assessing flood protection.

III. REVIEW PROCEDURES

Requirements and procedures governing issuance of early site permits for approval of proposed sites for nuclear power facilities are specified in 10 CFR Part 52. Information required for such a permit includes a description of the site's hydrometeorological characteristics. For this type of review, the procedures below should be followed.

The staff will evaluate the applicant's analysis, including all of the assumptions, techniques, and models used. If satisfied with their technical soundness and applicability to the problem, the staff's evaluation will be focused on the conservatism of parameters used by the applicant.

If not satisfied with the applicant's techniques, the staff will perform a simplified analysis of the controlling surge and seiche flooding level (coincident with wind-generated wave activity) and the resulting effects (static and dynamic) to the safety-related facilities of a nuclear power plant or plants of specified type that might be constructed on the proposed site using simplified calculational procedures or models with demonstrably conservative coefficients and assumptions. If the applicant's estimates of critical water level are no more than 5% less conservative than the staff's estimates,[1] staff concurrence will be stated. If the applicant's estimates are more than 5% less conservative, the analysis is repeated using more realistic techniques. The staff will develop a position based on the analysis; resolve, if possible,

[1] Based on the difference between normal water levels and the flood event.

differences between the applicant's and staff's surge and seiche flooding design basis; and write the safety evaluation report (SER) input accordingly. The specific review procedures are described below.

In general, the conservatism of the applicant's estimates of flood potential from surges and seiches is judged against the criteria indicated in subsection II above and as discussed in Regulatory Guide 1.59. If the site is not near a large body of water, the staff findings may be prepared a priori. Methods of the Corps of Engineers and National Oceanic and Atmospheric Administration (NOAA) (HUR 7-97 and amendments, Ref. 40) are used to develop the critical probable maximum hurricane (PMH) parameters for the site. The Corps of Engineers model SURGE (or other verified models) may be used to estimate the maximum surge stillwater elevations at coastal sites. Coincident wind-generated waves and runup are estimated from publications by the Corps of Engineers (Ref. 32). Reports of NOAA and the Corps of Engineers are used to estimate probable maximum wind fields over the Great Lakes. Models such as Platzmann's (Ref. 25), or other verified models, may be used to estimate the maximum surge or seiche stillwater elevation for Great Lakes sites; coincident wind-generated waves and runup are estimated as above.

Two-dimensional models (Refs. 17, 28, and 44) include seiching effects. Seiching potential is evaluated using one-dimensional models by comparing the natural period of oscillation (resonance) of the water body with the estimated meteorologically induced wave periods. Resonance of a water body may be calculated by the methods presented in Reference 32 or standard texts. Generally, a demonstration that the water body cannot generate or sustain waves of the required period for resonance is satisfactory to discuss the possibility of damaging seiching. Similarly, seismically induced seiching is precluded if the natural period of oscillation of the water body is dissimilar from the period of seismic excitation. If resonance is possible, the maximum seiche must be considered in the selection of the critical flood design bases.

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 early site permit reviews, the findings will summarize the applicant's and staff's estimates of critical water level (including wind-generated wave levels) at the site. If the estimates meet the criteria (described in subsection II above), staff concurrence will be stated. If the applicant's estimates do not meet the criteria in subsection II above, and a nuclear power plant or plants of specified type that might be constructed on the proposed site may be adversely affected, a statement requiring use of the staff's estimates for the design basis will be made. If the flood conditions do not constitute a design basis, the statement will so indicate.

If Regulatory Guide 1.59, Position 2, is elected by the applicant for protection, a statement describing lesser design bases will be included in the findings with the staff conclusion of adequacy.

A sample statement for an early site permit review follows:

> As set forth above, the design basis hurricane-induced high and low stillwater levels were established during the early site permit review at elevations 6.7 m (22.0 ft) MSL and -2.3 m (-7.5 ft) MSL, respectively. These levels are based upon the estimated water levels, exclusive of wave action, that would occur during passages of a probable

maximum hurricane (PMH) to the south and north, respectively, of the proposed plant site.

Therefore, the staff concludes that the applicant has adequately described the surface and subsurface hydrologic characteristics of the region and the potential for flooding due to surges or seiches. The applicant's description is sufficient to meet the requirements of 10 CFR Part 52 and 10 CFR Part 100 with respect to surge and seiche flooding.

V. IMPLEMENTATION

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

This section will be used by the staff when performing safety evaluations of early site permit applications submitted by applicants pursuant to 10 CFR Part 52. 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 to 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. G. Birkhoff, "Hydrodynamics; a Study in Logic, Fact and Similitude," Princeton University Press (1960).

4. B. R. Bodine, "Storm Surge on the Open Coast: Fundamentals and SimplifiedPrediction," Technical Memorandum No. 35, Corps of Engineers, Coastal Engineering Research Center (1971).

5. C. L. Bretschneider, "Hurricane Surge Predictions for Chesapeake Bay," Miscellaneous Paper 359, U.S. Army Beach Erosion Board (1959).

6. C. L. Bretschneider and J. I. Collins, "Prediction of Hurricane Surge; An Investigation for Corpus Christi, Texas and Vicinity," NESCO Technical Report No. SN120, prepared by National Engineering Science Co. for U.S. Army Engineer District, Galveston (1963).

7. R. Dorrenstein, "Wave Setup on a Beach," NHRP Report No. 50, Proc. of the Second Technical Conference on Hurricanes, U.S. Weather Bureau, pp. 230241 (1962).

8. G. E. Dunn and B. I. Miller, "Atlantic Hurricanes," Louisiana State University Press, Revised Edition (1964).

9. J. C. Fairchild, "Model Study of Wave Set-Up Induced by Hurricane Waves at Narragansett Pier, Rhode Island," U.S. Army Beach Erosion Board Bulletin, Vol. 12, pp. 9-20 (1958).

10. H. Fortak, "Concerning the General Vertically Averaged Hydrodynamic Equations with Respect to Basic Storm Surge Equations," Report No. 51, National Hurricane Research Project, U.S. Weather Bureau, p. 70 (1962).

11. J. C. Freeman, Jr., L. Baer, and C. H. Jung, "The Bathystrophic Storm Tide," Jour. of Marine Research, Vol. 16, No. 1 (1957).

12. H. E. Graham and D. E. Nunn, "Meteorological Considerations Pertinent to Standard Project Hurricane, Atlantic and Gulf Coasts of the United States," Report No. 33, National Hurricane Research Project, U.S. Weather Bureau and Corps of Engineers (1959).

13. D. L. Harris, "The Effect of a Moving Pressure Disturbance on the Water Level in a Lake," Meteorological Monographs, Vol. 2, No. 10, American Meteorological Society, pp. 46-57 (1957).

14. D. L. Harris, "Characteristics of the Hurricane Storm Surge," Technical Paper No. 48, U.S. Department of Commerce (1963).

15. D. L. Harris, "A Critical Survey of the Storm Surge Protection Problem," The Eleventh Symposium on Tsunami and Storm Surges, pp. 47-65 (1967).

16. B. Haurwitz, "The Slope of Lake Surfaces Under Variable Wind Stresses," Technical Memorandum No. 25, U.S. Army Beach Erosion Board (1951).

17. J. J. Leendertse, "Aspects of a Computational Model for Long-Period Water Wave Propagation," Memorandum RM-5294-PR, prepared for United States Air Force, Project Rand (1967).

18. M. S. Longuet-Higgins and R. W. Stewart, "Radiation Stress and Mass Transport in Gravity Waves, with Application to 'Surf Beat,'" Jour. of Fluid Mechanics, Vol. 13, pp. 481-504 (1962).

19. M. S. Longuet-Higgins and R. W. Stewart, "A Note on Wave Set-Up," Jour. of Marine Research, Vol. 21, pp. 4-10 (1963).

20. M. S. Longuet-Higgins and R. W. Stewart, "Radiation Stress in Water Waves; a Physical Discussion, with Application," Deep-Sea Research, Vol. 11, pp. 529-562 (1964).

21. C. Marinos and J. W. Woodward, "Estimation of Hurricane Surge Hydrographs,' Jour. Waterways and Harbors Division, Proc. Am. Soc. Civil Engineers, Vol. 94, No. WW2, pp. 189-216 (1968).

22. M. Miyazaki, "A Numerical Computation of the Storm Surge of Hurricane Carla 1961 in the Gulf of Mexico," Technical Report No. 10, Dept. of Geophysical Sciences (1963).

23. V. A. Myers, "Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida," Hydrometeorological Report 32, U.S. Weather Bureau (1954).

24. G. W. Platzmann, "A Numerical Computation of the Surge of 26 June 1954 on Lake Michigan," Geophysica, Vol. 6 (1958).

25. G. W. Platzmann, "The Dynamical Prediction of Wind Tides on Lake Erie," Technical Rpt. No. 7, Contr. CWB-9768, Dept. of Geophysical Sciences, University of Chicago (1963).

26. L. Prandtl, "The Mechanics of Viscous Fluids," in "Aerodynamic Theory," W. F. Durand, Ed., Springer-Verlag, Berlin, Volume III, Div. 6 (1935).

27. R. O. Reid, "Modification of the Quadratic Bottom-Stress Law for Turbulent Channel Flow in the Presence of Surface Wind-Stress," Technical Memorandum No. 93, U.S. Army Beach Erosion Board (1957).

28. R. O. Reid and B. R. Bodine, "Numerical Model for Storm Surges in Galveston Bay," Jour. Waterways and Harbors Division, Proc. Am. Soc. Civil Engineers, Vol 94, No. WW1, pp. 33-57 (1968).

29. T. Saville, Jr., "Experimental Determination of Wave Set-Up," NHRP Report No. 50, Proc. of the Second Technical Conference on Hurricanes, pp. 242252 (1962).

30. T. Saville, E. McClendon, and A. Cochran, "Freeboard Allowances for Waves in Inland Reservoirs," Jour. Waterways and Harbors Division, Proc. Am. Soc. Civil Engineers, Vol. 88, No. WW2, pp. 93-124 (1962).

31. "Waves in Inland Reservoirs: Summary Report on CWI Projects CW-164 and CW-165," Technical Memorandum No. 132, U.S. Army Beach Erosion Board (1962).

32. "Shore Protection Planning and Design," Technical Report No. 4, Third Edition, Corps of Engineers Coastal Engineering Research Center (1966), and "Shore Protection Manual" (1974).

33. "Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams," Engineer Circular No. 1110-2-27, U.S. Army Corps of Engineers (1966).

34. "Computation of Freeboard Allowances for Waves in Reservoirs," Engineer Technical Letter No. 1110-2-8, U.S. Army Corps of Engineers (1966).

35. W. C. Van Dorn, "Wind Stress on an Artificial Pond," Jour. of Marine Research, Vol. 12 (1953).

36. T. Von Karman, "Mechanische Ahnlickeit und Turbulenz (Mechanical Similitude and Turbulence)," Proc. of the 3rd International Congress for Applied Mechanics, Stockholm, Vol. I, pp. 85-93 (1920).

37. P. Weylander, "Numerical Prediction of Storm Surges," Advances in Geophysics, Vol. 8, pp. 316-379 (1961).

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

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

40. "Interim Report - Meteorological Characteristics of the Probable Maximum Hurricane, Atlantic and Gulf Coasts of the United States," U.S. Weather Bureau Memorandum HUR 7-97, and HUR-97A (1968).

41. U.S. Atomic Energy Commission, Crystal River Nuclear Power Plant Docket No. 50-302, letter to Florida Power Corporation requesting additional information regarding hydrologic engineering and hurricane surge verification, October 12, 1973.

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

43. ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites" .

44. Y. J. Tsai and Y. C. Chang, "Prediction and Verification of Storm Surges in Lake Ontario and Lake Erie," 17th Conference on Great Lakes Research, International Association for Great Lakes Research, August 12-14, 1974, Hamilton, Ontario.

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

46. J. J. Dronkers, "Tidal Computations in Rivers and Coastal Waters," North-Holland Publishing Company, Amsterdam Publishers, John Wiley and Sons, Inc., New York, 1964.

47. F. D. Masch et al., "Analysis of Hurricane Tides at Padre Island, Texas," Proceedings, 12th Coastal Engineering Conference, American Society of Civil Engineers, Vol. III, Chapter 123, pp. 2031-2050, September 1970.

48. C. Taylor and J. M. David, "A Finite Element Model of Tides in Estuaries," International Symposium on Finite Element Methods in Flow Problems, Swansea, U.K., January 1974.

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

50. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."

51. Pararas-Carayannis, George. Verification Study of a Bathystrophic Storm Surge Model. U.S. Army, Corps of Engineers Coastal Engineering Research Center, Washington, D.C., Technical Memorandum No. 50, May 1975

52. Bunpapong, M., Reid, R.O., and Whitaker, R. E. 1985. “An Investigation of Hurricane-Induced Forerunner Surge in the Gulf of Mexico,” Technical Report CERC-85-5, U. S. Army EngineerWaterways Experiment Station; Vicksburg, MS.

53. Butler, H. L. 1978 (Aug - Sept). “Coastal Flood Simulation in Stretched Coordinates,” Proceediws of the Sixteenth Coastal Engineering Conference, American Society of Civil Enqineers, vol. 1, p 1030.

54. Butler, H. L. 1982 (Mar). “Finite Difference Numerical Model for Long-Period Wave Behavior: With Emphasis on Storm SurgeModeling,” Seminar on Two-Dimensional Flow Modeling, Hydrologic Engineering Center, Davis, CA.

55. Committee on Tidal Hydraulics. 1980. “Evaluation of Numerical Storm Surge Models,” Technical Bulletin No. 21, Office, Chief of Engineers, U. S. Army, Washington, DC.

56. Harris, D. L. 1982. “Data Requirements for the Evaluation of Storm Surge Models,” U. S. Nuclear Regulatory Commission, Washington, DC.

57. Kite, G. W. 1978. Frequency and Risk Analysis in Hydrology, Water Resources Publications, Fort Collins, CO.

58. Tetra Tech, Inc. 1981. “Coastal Flooding Storm Surge Model,” Parts 1, 2, and 3, Prepared for the Federal Emergency Management Agency.

59. U. S. Water ReSources Council. 1980. “An Assessment of Storm Surge Modeling,” Washington, DC.

60. Wanstrath, J. J. 1977 (Sep). “Nearshore Numerical Storm Surge and Tidal Simulation,” Technical Report H-77-17, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.