U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.3 PROBABLE MAXIMUM FLOOD (PMF) ON STREAMS AND RIVERS

REVIEW RESPONSIBILITIES

Primary - ~~[Hydrologic & Geotechnical Engineering Branch (HGEB)]~~
Structural & Geosciences Branch (ESGB)

Secondary - None

I. AREAS OF REVIEW

In this section of the safety analysis report (SAR), the hydrometeorological design basis is developed to determine the extent of any flood protection required for those structures, systems, and components necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition. The areas of review include the probable maximum precipitation (PMP) potential and precipitation losses over the applicable drainage area, the runoff response characteristics of the watershed, the accumulation of flood runoff through river channels and reservoirs, the estimate of the discharge rate trace (hydrograph) of the PMF at the plant site, the determination of PMF water level conditions at the site, and the evaluation of coincident wind-generated wave conditions that could occur with the PMF. Included is a review of the details of design bases for site drainage (which is summarized in SAR Section 2.4.2); a review of the runoff for site drainage and drainage areas adjacent to the plant site, including the roofs of safety-related structures, resulting from potential PMP; and a review of the potential effects from erosion and sedimentation. The analyses involve modeling of physical rainfall and runoff processes to estimate the upper level of possible flood conditions adjacent to and on site.

Regulatory Guide 1.59 describes two positions with respect to flood protection for which a PMF estimate is required to determine the controlling design basis conditions. If Position 1 is chosen, all safety-related systems, structures, and components must be capable of withstanding the effects from the controlling flood design basis. Position 2 limits the review to specific safety-related structures, systems, and components necessary for cold shutdown and maintenance thereof.

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II. ACCEPTANCE CRITERIA

Acceptance criteria for this SRP section is based on meeting the requirements of 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 floods.

2. 10 CFR Part 100 as it relates to evaluating hydrologic characteristics of the site.

To meet the requirements of the hydrologic aspects of GDC 2 and 10 CFR Part 100 the following specific criteria are used:

The PMF as defined in Regulatory Guide 1.59 has been adopted as one of the conditions to be evaluated in establishing the applicable stream and river flooding design basis referred to in General Design Criterion 2, Appendix A, 10 CFR Part 50. PMF estimates are required for all adjacent streams or rivers and site drainage (including the consideration of PMP on the roofs of safety-related structures). The criteria for accepting the applicant's PMF-related design basis depend on one of the following three conditions:

1. The elevation attained by the PMF (with coincident wind waves) establishes a required protection level to be used in the design of the facility.

2. The elevation attained by the PMF (with coincident wind waves) is not controlling; the design basis flood protection level is established by another flood phenomenon (e.g., the probable maximum hurricane).

3. The site is "dry," that is, the site is well above the elevation attained by a PMF (with coincident wind waves).

When condition 1 is applicable, the staff will assess the flood level (described in subsection III). The assessment may be made independently from basic data, by detailed review and checking of the applicant's analyses, or by comparison with estimates made by others that have been reviewed in detail. The applicant's estimates of the PMF level and the coincident wave action are acceptable if the estimates are no more than 5% less conservative than the staff's estimates. If the applicant's estimates of discharge are more than 5% less conservative than the staff's, the applicant should fully document and justify its estimates or accept the staff's estimates and redesign applicable flood protection.

When conditions 2 or 3 apply, the staff analyses may be less rigorous (described in subsection III). For condition 2, acceptance is based on the protection level estimated for another flood-producing phenomenon exceeding the staff estimate of PMF water levels. For condition 3, the site grade must be well above the staff assessment of PMF water levels. The evaluation of the adequacy of the margin (difference in flood and site elevations) is generally a matter of engineering judgment. The judgment is based on the confidence in the flood level estimate and the degree of conservatism in each parameter used in the estimate.

Appropriate sections of the following documents are used by the staff to determine the acceptability of the applicant's data and analyses. Regulatory Guide 1.59 provides guidance for estimating the PMF design basis. Regulatory Guide 1.29 identifies the safety-related structures, systems, and components, and Regulatory Guide 1.102 describes acceptable flood protection to prevent the safety-related facilities from being adversely affected. Publications of the National Oceanic and Atmospheric Administration (NOAA) and the Corps of Engineers may be used to estimate PMF discharge and water level condition at the site and coincident wind-generated wave activity.

III. REVIEW PROCEDURES

For conditions 1 and 2 (described in subsection II), the methods used for evaluating flooding potential are separated into two parts--PMF on adjacent streams and local PMF. The review procedure is outlined in the attached Figures 2.4.3-1 (for PMF on adjacent streams) and 2.4.3-2 (for local PMF). (The procedure for evaluating the adequacy of site drainage facilities based on a local PMF is outlined in SRP Section 2.4.2.) Corps of Engineers PMF assessments for specific locations or generalized PMF assessments for a geographical area approved by the Chief of Engineers and contained in published or unpublished reports of that agency may be used in lieu of staff-developed analyses. In the absence of such assessments, both large and small basin PMP estimates by NOAA, published techniques of the World Meteorological Organization, and runoff, impoundment, and river routing models of the Corps of Engineers are used by the staff to estimate PMF discharge and water level at the site. A comprehensive review of the applicant's analyses will be performed and a simplified analysis using calculational procedures or models with demonstrably conservative coefficients and assumptions is performed. If the applicant's PMF estimates are within acceptable margins (described in subsection II), the staff positions will indicate concurrence with the applicant's PMF estimates and the SER input will be written accordingly. If the simplified analysis indicates a potential problem with the applicant's estimates, a detailed analysis using more realistic techniques will be performed. The staff will develop a position based on the detailed analysis; resolve, if possible, differences between the applicant's and staff's estimates of PMF design basis; and prepare the SER input accordingly.

Wind-generated wave action will be independently estimated using Corps of Engineers criteria such as the "Shore Protection Manual." When sufficient water depth is available, the significant wave height and runup are used for structural design purposes, and the 1% wave height and runup are used for flood level estimates. Where depth limits wave height, the breaking or broken wave height and runup is used for both purposes.

For condition 3 (i.e., a "dry site"--one not subject to stream flooding by virtue of local topographic considerations), the following procedures apply:

1. Use Corps of Engineers PMF estimates for other sites in the region to develop "regional drainage area vs. PMF discharge (cubic feet per second/square mile)" data, for extrapolation to the site.

2. Envelop the above data points to obtain an estimate of the PMF applicable to the site.

3. Increase the estimate based on a judgment as to the applicability of the basic estimates. An increase in the range of 10% to 50% is generally appropriate.

4. If warranted by relative elevation differences between the site and adjacent stream, estimate the flood level at the site using slope-area techniques or water surface profile computations.

5. Estimate wind (2-yr extreme windspeed) wave runup based on breaking or 1% wave heights. Criteria for estimating windspeed are discussed in ANSI N170 and References ~~[17]~~ 16, ~~[19]~~ 18, and ~~[20]~~ 19.

6. Compare resultant water level with proposed plant grade and lowest safety-related facility that can be affected.

The above items of review 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 summarize the applicant's and staff's estimates of the peak PMF runoff rate and water level (including allowance for coincident wind-generated wave activity) at the site. If the applicant's estimates are within the criteria (described in subsection II), staff concurrence will be stated. If the staff's estimates are 5% more conservative than the applicant's estimates, if the flood conditions may adversely affect the proposed plant, and if the applicant has been unable to support his estimates, a statement requiring use of the staff bases will be made. If the flood conditions do not constitute a design basis, the findings will so indicate.

For operating license (OL) reviews that have received detailed PMF reviews during the CP review, the CP conclusions will be referenced. Any flood potential not identified during the CP review will be noted.

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

A sample statement for a CP review follows:

> The staff concludes that the plant flood design meets the requirements of General Design Criterion 2 and 10 CFR Part 100 and is acceptable. This conclusion is based on the following evaluation:
>
> The probable maximum flood (PMF) resulting from the probable maximum precipitation (PMP) on the ABC River drainage basin yielded an estimated maximum stillwater level at the intake structure on the D & E Canal of about 5.0 feet MSL, which is about 5 feet below its design flood level.
>
> The PMF resulting from a local PMP storm on the drainage basins for the small streams near the site yielded an estimated maximum stillwater level of about 60 feet MSL, which is about 20 feet below plant grade.

The local PMF resulting from the estimated local PMP was found not to cause flooding of safety-related facilities, since the site drainage system will be capable of functioning adequately during such a storm. Catch basins will be provided as part of the storm drainage system and will be located throughout the plant site to drain local areas. The plant yard will be graded with gentle slopes away from high points at the plant buildings, and storm water will drain away from the buildings into the local streams at lower elevations.

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 to parts of the method discussed herein are contained in the referenced regulatory guides.

The provisions of this SRP section apply to reviews of construction permit (CP), operating license (OL), and Preliminary Design Approval (PDA) applications docketed after the effective date of issuance of this revision to SRP Section 2.4.3.

VI. REFERENCES

In addition to the following specific references, Design Memoranda, Civil Works Investigations, and research and development reports of the Corps of Engineers and reports of other Federal and State agencies relevant to flood estimates at a specific site will be used on an "as-available" basis.

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

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

3. Reports of the Corps of Engineers, Department of the Army:

   EM 1110-2-1411, "Standard Project Flood Determinations," March 26, 1952 (rev. March 1965).

   ~~[EE-1110-2-27;-"Policies-and-Procedures-Pertaining-to-Determination-of Spillway-Capacities-and-Freeboard-Allowances-for-Dams;"-February-19;-1968.~~

   EM 1110-2-1405, "Flood Hydrograph Analysis and Computations," August 31, 1959.

   EM 1110-2-1408, "Routing of Floods Through River Channels," March 1, 1960.

EM 1110-2-1406, "Runoff from Snowmelt," January 5, 1960.

EM 1110-2-1603, "Hydraulic Design of Spillways," March 31, 1965.

EM 1110-2-1409, "Backwater Curves in River Channels," December 7, 1959.

Technical Bulletin No. 8, Sacramento District, "Generalized Snowmelt Runoff Frequencies," September 1962.

EM 1110-2-1601, "Hydraulic Design of Flood Control Channels," July 1, 1970.

EM 1110-2-1607, "Tidal Hydraulics," August 2, 1965.

[EE-1308;-"Stone-Protection;"-January-1948;]

EM 1110-2-1410, "Interior Drainage of Leveed Urban Areas: Hydrology," May 3, 1965.

[Technical-Report-No;-4;] "Shore Protection Manual," Coastal Engineering Research Center (CERC), ["Shore-Protection;-Planning-and-Design"-(1966 and-"Shore-Protection-Manual"-(1977)] 1984 or most recent edition.

CETA 79-1, "Wave Runup on Rough Slopes," CERC, July 1979.

Waterways Experiment Station, "Hydraulic Design Criteria," continuously updated.

[TSP37] TM-37, "Riprap Stability on Earth Embankments Tested in Large- and Small-Scale Wave Tanks," CERC, June 1972.

TP 78-2, "Reanalysis of Wave Runup on Structures and Beaches[;]," CERC, March 1978.

ETL 1110-2-120, "Additional Guidance for Riprap Channel Protection," May 1971.

ETL 1110-2-221, "Wave Runup and Wind Setup on Reservoir Embankments," November 1976.

4. Hydrometeorological Reports of the U.S. Weather Bureau (now U.S. Weather Service, NOAA) Hydrometeorological Branch:

No. 1., "Maximum Possible Precipitation Over the Ompompanoosuc Basin above Union Village, Vt." (1943).

No. 2., "Maximum Possible Precipitation over the Ohio River Basin above Pittsburgh, Pa." (1942).

No. 3., "Maximum Possible Precipitation over the Sacramento Basin of California" (1943).

No. 4., "Maximum Possible Precipitation over the Panama Canal Basin" (1943).

No. 5., "Thunderstorm Rainfall" (1947).

No. 6., "A Preliminary Report on the Probable Occurrence of Excessive Precipitation over Fort Supply Basin, Okla." (1938).

No. 7., "Worst Probable Meteorological Condition on Mill Creek, Butler and Hamilton Counties, Ohio" (1937), unpublished. Supplement (1938).

No. 8., "A Hydrometeorological Analysis of Possible Maximum Precipitation over St. Francis River Basin above Wappapello, Mo." (1938).

No. 9., "A Report on the Possible Occurrence of Maximum Precipitation over White River Basin above Mud Mountain Dam Site, Wash." (1939).

No. 10., "Maximum Possible Rainfall over the Arkansas River Basin above Caddoa, Colo." (1939). Supplement (1939).

No. 11., "A Preliminary Report on the Maximum Possible Precipitation over the Dorena, Cottage Grove, and Fern Ridge Basins in the Willamette Basin, Oreg." (1939).

No. 12., "Maximum Possible Precipitation over the Red River Basin above Denison, Tex." (1939).

No. 13., "A Report on the Maximum Possible Precipitation over Cherry Creek Basin in Colorado" (1940).

No. 14., "The Frequency of Flood-Producing Rainfall over the Pajaro River Basin in California" (1940).

No. 15., "A Report on Depth-Frequency Relations of Thunderstorm Rainfall on the Sevier Basin, Utah" (1941).

No. 16., "A Preliminary Report on the Maximum Possible Precipitation over the Potomac and Rappahannock River Basins" (1943).

No. 17., "Maximum Possible Precipitation over the Pecos Basin of New Mexico" (1944), unpublished.

No. 18., "Tentative Estimates of Maximum Possible Flood-Producing Meteorological Conditions in the Columbia River Basin" (1945).

No. 19., "Preliminary Report on Depth-Duration-Frequency Characteristics of Precipitation over the Muskingum Basin for 1- to 9-Week Periods" (1945).

No. 20., "An Estimate of Maximum Possible Flood-Producing Meteorological Conditions in the Missouri River Basin above Garrison Dam Site" (1945).

No. 21., "A Hydrometeorological Study of the Los Angeles Area" (1939).

No. 21A., "Preliminary Report on Maximum Possible Precipitation, Los Angeles Area, California" (1944).

No. 21B., "Revised Report on Maximum Possible Precipitation, Los Angeles Area, California" (1945).

No. 22., "An Estimate of Maximum Possible Flood-Producing Meteorological Conditions in the Missouri River Basin Between Garrison and Fort Randall" (1946).

No. 23., "Generalized Estimates of Maximum Possible Precipitation over the United States East of the 105th Meridian, for Areas of 10, 200, and 500 Square Miles" (1947).

No. 24., "Maximum Possible Precipitation over the San Joaquin Basin, Calif." (1947).

No. 25., "Representative 12-Hour Dewpoints in Major United States Storms East of the Continental Divide" (1947).

No. 25A., "Representative 12-Hour Dewpoints in Major United States Storms East of the Continental Divide," 2nd edition (1949).

No. 26 , "Analysis of Winds over Lake Okeechobee during Tropical Storm of August 26-27, 1949" (1951).

No. 27., "Estimate of Maximum Possible Precipitation, Rio Grande Basin, Fort Quitman to Zapata" (1951).

No. 28., "Generalized Estimate of Maximum Possible Precipitation over New England and New York" (1952).

No. 29., "Seasonal Variation of the Standard Project Storm for Areas of 200 and 1,000 Square Miles East of the 105th Meridian" (1953).

No. 30., "Meteorology of Floods at St. Louis" (1953), unpublished.

No. 31., "Analysis and Synthesis of Hurricane Wind Patterns over Lake Okeechobee, Florida" (1954).

No. 32., "Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida" (1954).

No. 33., "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24, and 48 Hours" (1956).

~~[Draft Report, "All-Season Probable Maximum Precipitation, United States East of the 105th Meridian for Areas From 1,000 to 20,000 Square Miles and Durations from 6 to 72 Hours" (1972).]~~

No. 34., "Meteorology of Flood-Producing Storms in the Mississippi River Basin" (1956).

No. 35., "Meteorology of Hypothetical Flood Sequences in the Mississippi River Basin" (1959).

No. 36., "Interim Report, Probable Maximum Precipitation in California" (1961), revised (1969).

No. 37., "Meteorology of Hydrologically Critical Storms in California" (1962)

No. 38., "Meteorology of Flood-Producing Storms in the Ohio River Basin" (1961).

No. 39., "Probable Maximum Precipitation in the Hawaiian Islands" (1963).

No. 40., "Probable Maximum Precipitation, Susquehanna River Drainage above Harrisburg, Pa." (1965).

No. 41., "Probable Maximum and TVA Precipitation over the Tennessee River Basin above Chattanooga" (1965).

No. 42., "Meteorological Conditions for the Probable Maximum Flood on the Yukon River above Rampart, Alaska" (1966).

No. 43., "Probable Maximum Precipitation, Northwest States" (1966[~~)~~], addendum 1981).

No. 44., "Probable Maximum Precipitation over South Platte River, Colorado, and Minnesota River, Minnesota" (1969).

No. 45., "Probable Maximum and TVA Precipitation for Tennessee River Basin up to 3,000 Square Miles in Area and Durations to 72 Hours" (1969).

No. 46., "Probable Maximum Precipitation, Mekong River Basin" (1970).

No. 47., "Meteorological Criteria for Extreme Floods for Four Basins in the Tennessee and Cumberland River Basins" (1973).

No. 48., "Probable Maximum Precipitation and Snowmelt Criteria for Red River of the North Above Pembinz, and Souris River Above Minot, North Dakota" (1973).

No. 49., Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages (1977).

No. 50., The Meteorology of Important Rainstorms in the Colorado River and Great Basin Drainages (1982).

No. 51., Probable Maximum Precipitation Estimates, United States East of 105th Meridian (1978).

No. 52., Application of Probable Maximum Precipitation Estimates--United States East of the 105th Meridian (1982).

No. 53., Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian (1980). (NUREG/CR-1486)

No. 54., Probable Maximum Precipitation and Snowmelt Criteria for Southeast Alaska (1983).

No. 55., Probable Maximum Precipitation Estimates - United States Between the Continental Divide and the 103rd Meridian (1984).

5. Technical Papers of the U.S. Weather Bureau (now U.S. Weather Service, NOAA):

No. 2., "Maximum Recorded United States Point Rainfall for 5 Minutes to 24 Hours at 207 First Order Stations," Rev. (1963).

No. 5., "Highest Persisting Dewpoints in the Western United States" (1948).

No. 10., "Mean Precipitable Water in the United States" (1949).

No. 13., "Mean Monthly and Annual Evaporation Data from Free Water Surface for the United States, Alaska, Hawaii, and the West Indies" (1950).

No. 14., "Tables of Precipitable Water and Other Factors for a Saturated Pseudo-Adiabatic Atmosphere" (1951).

No. 15., "Maximum Station Precipitation for 1, 2, 3, 6, 12, and 24 Hours:" Part I: Utah (1951); Part II: Idaho (1951); Part III: Florida (1952); Part IV: Maryland, Delaware, and District of Columbia (1953); Part V: New Jersey (1953); Part VI: New England (1953); Part VII: South Carolina (1953); Part VIII: Virginia (1954); Part IX: Georgia (1954); Part X: New York (1954); Part XI: North Carolina (1955); Part XII: Oregon (1955); Part XIII: Kentucky (1955); Part XIV: Louisiana (1955); Part XV: Alabama (1955); Part XVI: Pennsylvania (1956); Part XVII: Mississippi (1956); Part XVIII: West Virginia (1956); Part XIX: Tennessee (1956); Part XX: Indiana (1956); Part XXI: Illinois (1958); Part XXII: Ohio (1958); Part XXIII: California (1959); Part XXIV: Texas (1959); Part XXV: Arkansas (1960); Part XXVI: Oklahoma (1961).

No. 16., "Maximum 24-Hour Precipitation in the United States" (1952).

No. 25., "Rainfall Intensity-Duration-Frequency Curves for Selected Stations in the United States, Alaska, Hawaiian Islands, and Puerto Rico" (1955).

No. 28., "Rainfall Intensities for Local Drainage Design in Western United States for Durations of 20 Minutes to 24 Hours and 1- to 100-Year Return Periods" (1956).

No. 37., "Evaporation Maps for the United States" (1959).

No. 38., "Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian for Areas to 400 Square Miles and Durations to 24 Hours" (1960).

No. 40., "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years" (1961).

No. 42., "Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands" (1961).

No. 43., "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (1962).

No. 47., "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska for Areas to 400 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years" (1963).

No. 48., "Characteristics of the Hurricane Storm Surge" (1963).

6. NWS series of NOAA Technical Reports is a continuation of the former series, ESSA Technical Report Weather Bureau (WB).

ESSA Technical Reports

WB 5., Climatological Probabilities of Precipitation for the Conterminous United States. Donald L. Jorgensen, Techniques Development Laboratory, December 1967, 60 pp.

WB 6., Climatology of Atlantic Tropical Storms and Hurricanes. M. A. Alaka, Techniques Development Laboratory, May 1968, 18 pp.

WB 7., Frequency and Areal Distributions of Tropical Storm Rainfall in the United States Coastal Region on the Gulf of Mexico. Hugo V. Goodyear, Office of Hydrology, July 1968, 33 pp.

WB 8., Critical Fire Weather Patterns in the Conterminous United States. Mark J. Schroeder, Weather Bureau, January 1969, 31 pp.

NOAA Technical Reports

NWS 13., The March-April 1969 Snowmelt Floods in the Red River of the North, Upper Mississippi, and Missouri Basins. Joseph L. H. Paulhus, Office of Hydrology, October 1970, 92 pp. (COM-71-50269).

NWS 14., Weekly Synoptic Analyses, 5-, 2-, and 0.4-Millibar Surfaces for 1968. Staff, Upper Air Branch, National Meteorological Center, May 1971, 169 pp. (COM-71-50383).

NWS 15., Some Climatological Characteristics of Hurricanes and Tropical Storms, Gulf and East Coasts of the United States. Francis P. Ho, Richard W. Schwerdt, and Hugo V. Goodyear, May 1975, 87 pp. (COM-75-11088).

NWS 16., Storm Tide Frequencies on the South Carolina Coast. Vance A. Myers, June 1975, 79 pp. (COM-75-11335).

NWS 17., Estimation of Hurricane Storm Surge in Apalachicola Bay, Florida. James E. Overland, June 1975, 66 pp. (COM-75-11332).

NWS 18., Joint Probability Method of Tide Frequency Analysis Applied to Apalachicola Bay and St. George Sound, Florida. Francis P. Ho and Vance A. Myers, November 1975, 43 pp. (PB-251123).

NWS 21., Interduration Precipitation Relations for Storms - Southeast States. Ralph H. Frederick, March 1979, 66 pp. (PB-297192).

NWS 23., Meteorological Criteria for Standard Project Hurricane and Probable Maximum Hurricane and Probable Maximum Hurricane Windfields, Gulf and East Coasts of the United States. Richard W. Schwerdt, Francis P. Ho, and Roger R. Watkins, September 1979, 348 pp. (PB-80-117997).

NWS 24., A Methodology for Point-to-Area Rainfall Frequency Ratios. Vance A. Myers and Raymond M. Zehr, February 1980, 180 pp. (PB-80-180102).

NWS 25., Comparison of Generalized Estimates of Probable Maximum Precipitation with Greatest Observed Rainfalls. John T. Riedel and Louis G. Schreiner, March 1980, 75 pp. (PB-80-191463).

NWS 26., Frequency and Motion of Atlantic Tropical Cyclones. Charles J. Neumann and Michael J. Pryslak, March 1981, 64 pp. (PB-81-247256).

NWS 27., Interduration Precipitation Relations for Storms--Western United States. Ralph H. Frederick, John F. Miller, Francis P. Richards, and Richard W. Schwerdt, September 1981, 158 pp. (PB-82-230517).

NWS 31., A Monthly Averaged Climatology of Sea Surface Temperature. Richard W. Reynold, June 1982, 37 pp.

NWS 32., Pertinent Meteorological and Hurricane Tide Data for Hurricane Carla. Francis P. Ho and John F. Miller, unpublished.

NWS 33., Evaporation Atlas for the Contiguous 48 United States. Richard K. Fransworth, Edwin S. Thompson, and Eugene L. Peck, June 1982, 26 pp.

[6]7. Unpublished Hydrometeorological Reports of the U.S. Weather Bureau (now U.S. Weather Service, NOAA):

"Rappahannock River above Salem Church Dam Site, Va." (11/28/50).

"Potomac River, Va., Md., W. Va. (12 sub-basins)" (6/29/56).

"Delaware River above Trenton, Chestnut Hill, and Belvidere Dam Sites" (11/19/56).

"Delaware River above Tock's Island Dam Site" (12/16/65).

"St. John River above Dickey Dam Site, and Between Dicky and Lincoln School Dam Sites, Maine" (12/20/66).

"Coosa River above Howell Mill Shoals Dam Site, Ala." (3/3/50).

"Cape Fear River above Smiley Falls Dam site, N.C." (1[illegible]/50).

"Savannah River above Hartwell Dam Site. N.C." (1/5/51).

"Alabama and Apalachicola Rivers, Ala. and Fla." (3/19/52).

"Black Warrior River above Holt Lock Dam Site, Ala." (12/10/59).

"South Fork of Holston River above Boone Dam Site, Tenn." (8/14/50).

"Allegheny River above Allegheny River Reservoir, Pa." (9/28/56).

"Kentucky River, Ky. (2 basins)" (3/12/58).

"New River above Moores Ferry Dam Site, Va." (5/13/63).

"Licking River, Ky, and White River, Ind." (11/9/64).

"Iowa River above Coralville Dam Site, Iowa" (11/20/47).

"Des Moines River above Saylorville, Iowa and Howell Dam Site, Iowa" (3/19/48).

"Salt River, Mo." (1/21/55).

"James River above Jamestown Dam Site, N. Dak." (9/16/48).

"Big Blue River above Tuttle Creek Dam Site, Kans." (10/23/51).

"Republican River at (a) above proposed Milford Dam Site, Kans.; and (b) between Harlan Co. Dam and proposed Milford Dam Site, Kans." (11/24/58).

"Meramec River Basin, Missouri" (12/21/61).

"Republican River above Harlan Co. Res., Neb." (3/7/69).

"Canadian River above Eufaula Dam Site, Okla." (12/19/47).

"White River above Table Rock Dam Site, Mo." (3/19/48).

"Eleven Point River above Water Valley Dam Site, Ark." (3/19/48).

"Kiamichi River above Hugo Dam Site, Okla." (4/9/48).

"Boggy Creek above Boswell Dam Site, Okla." (4/9/48).

"North Canadian River above Optima (Hardesty) Dam Site, Okla." (12/22/49).

"Lower Canadian River, Okla." (6/10/48).

"Gaines Creek Dam Site, Okla." (5/13/48).

"Onapa-Canadian (combined) Dam Site, Okla." (5/13/48).

"Verdigris River above Oologah Dam Site, Okla." (5/4/50).

"Little Red River above Green Ferry, Ark." (7/24/50).

"Grand (Neosho) River above Strawn Dam Site, Kans." (11/14/51).

"Pinon Canyon above Trinidad, Colo." (4/10/52).

"Beaver Reservoir, White River, Ark." (12/1/55).

"Kisatchie Dam Site on Kisatchie Bayou, La." (3/1/56).

"Cypress Creek above Mooringsport, La." (8/27/56).

"Little River above at (a) Millwood Dam Site, Ark.; and (b) Broken Bow, Okla." (5/14/59).

"White River Drainage above Wolf Bayou, Ark." (3/31/66).

"Upper Arkansas River, Colorado (sub-basins)" (2/13/67).

"Arkansas River Drainage Between John Martin Dam, Colo., and Great Bend, Kans." (9/23/69).

"Leon River above Belton Dam Site, Tex." (12/9/47)

"Jemez Creek, N. Mex." (12/9/49).

"Chama River above Chamita Dam Site, N. Mex." (1/18/50).

"Rio Hondo above Two Rivers Reservoir, N. Mex." (12/19/56).

"Richland Creek, Tex." (4/6/56).

"Basque River above Waco Reservoir, Tex." (4/6/56).

"Leon River above Proctor Reservoir Project near Hasse, Tex." (12/5/56).

"Pecos River above Alamogordo Reservoir, N. Mex." (7/24/57).

"Pecos River above Los Esteros, N. Mex." (7/24/57).

"Intervening Drainage between Los Esteros and Alamogordo, N. Mex." (7/24/57).

"Rio Grande between Cerro and Cochiti Dam Site, N. Mex." (2/26/58).

"Combined Drainage of Santa Fe Creek and Rio Galisto above Galisto Dam Site, N. Mex." (2/26/58).

"Lampōsas River above proposed Lamposas Dam Site, Tex." (4/17/58).

"Navasota River, Tex. (7 sub-basins)" (11/2/59).

"Colorado River above Fox Crossing, Tex." (11/12/63).

"Lower Rio Grande, United States and Mexico (between Falcon and Anzalduas Dams)" (7/68).

"Gila River above Coolidge Dam Site, Ariz." (9/14/53).

"Queens Creek, Gila River Basin, Ariz." (4/26/55).

"Bill Williams River above proposed Alamo Dam Site, Ariz." (1/14/58).

"Santa Rosa Wash Basin, Ariz." (8/2/68).

"Black Creek, Ariz." (6/20/69).

"Preliminary Estimate for Drainages North of Phoenix, Ariz." (9/29/72).

"Humboldt River, Devils Gate Dam Site, Nev." (11/20/51).

"Mathews Canyon Dam Site (Virgin River), Nev. and Pine Canyon Dam Site (Virgin River), Nev." (8/9/54).

"Dell Canyon Reservoir, Utah" (8/26/57).

"Las Vegas Wash, Nev." (11/22/60).

"Henderson Wash, Nev." (11/22/60).

"West Fork (Mojave River), Calif." (11/22/60).

"Tahchevah Creek, Calif." (11/22/60).

"San Gorgonio River above Cabazon Dam Site, Calif." (4/13/62).

"Whitewater River above Garnet Dam Site, Calif." (4/13/62).

"Martis Creek, Calif." (3/18/64).

"Merced River, Calif." (6/4/62).

"American River above Folsom Dam, Calif." (8/1/68).

"North and Middle Forks of American River above Auburn Dam Site, Calif." (8/1/68).

"Intervening Drainage between Auburn Dam Site and Folsom Dam" (8/1/68).

"Yuba River above Marysville, Calif." (11/29/68).

"Los Angeles District, Calif. (18 basins in Calif., Nev., and Ariz.)" (12/2/68).

"San Diego River Watershed, Calif. (13 sub-basins)" (3/16/73).

"Skagway River, Alaska" (7/8/47).

"Bradley Lake Basin, Alaska" (5/19/61).

"Chena River, Alaska" (8/1/62)

"Long Lake Portion of the Snettisham Project" (4/19/65).

"Takatz Creek, Baranof Island, Alaska" (2/21/67).

"Tanana River Basin for (a) Chena River above Chena Dam Site, (b) Little Chena River above Little Chena Dam, and (c) Tana River between Tanacross and Nenana, Alaska" (6/5/69).

"Preliminary Estimates, Vicinity of Juneau: Mendenhall River, Lemon Creek, and Montana Creek" (11/7/69).

"Preliminary Estimates, Vicinity of Ketchikan: Whipple Creek near Wards Cove, Carlanna Creek near Ketchikan, Hoadley Creek near Ketchikan, and Ketchikan Creek near Ketchikan" (1/7/74).

"Eastern Panama and Northwest Colombia" (9/65).

"Hypothetical Rainstorms over Rio Atrato Basin, Colombia, South America" (7/67).

"Probable Maximum Thunderstorm Precipitation Estimates Southwest States" (3/30/73).

~~[7. D. R. Weggel, "Maximum Breaker Height," Jour. Waterways, Harbors and Coastal Engineering Division, Proc. Am. Soc. of Civil Engineers, Vol. 98, No. WW4, pp. 529-548 (1972).]~~

[8]7. Technical Note 98, "Estimation of Maximum Floods," WMO-No. 233, World Meteorological Organization (1969).

[9]8. C. O. Clark, "Storage and the Unit Hydrograph," Trans. Am. Soc. Civil Engineers, Vol. 110, No. 2261, pp. 1419-1488 (1945).

[10]9. U.S. Department of Commerce, "Snow Hydrology," PB-151660, undated.

[11]10. Bureau of Reclamation, "Effect of Snow Compaction from Rain on Snow," Engineering Monograph No. 35, U.S. Department of the Interior (1966).

[12]11. Bureau of Reclamation, "Design of Small Dams," Second Edition, U.S. Department of the Interior (1973).

[13]12. Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants."

[14]13. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

[~~15~~]14. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."

[~~16~~]15. Regulatory Guide 1.29, "Seismic Design Classification."

[~~17~~]16. H. C. S. Thom, "New Distribution of Extreme Winds in the United States," Journal of the Structural Division, American Society of Civil Engineers, ST7, July 1968.

[~~18~~]17. ANSI N170, "Standards for Determining Design Basis Flooding at Power Reactor Sites."

18. NUREG/CR-2639, "Historical Extreme Winds for the United States - Atlantic and Gulf of Mexico Coastlines," May 1982.

19. NUREG/CR-2890, "Historical Extreme Winds for the United States - Great Lakes and Adjacent Regions," August 1982.

FIGURE 2.4.3-1

STANDARD REVIEW PLAN SECTION 2.4-3 FLOOD ON STREAMS AND RIVERS

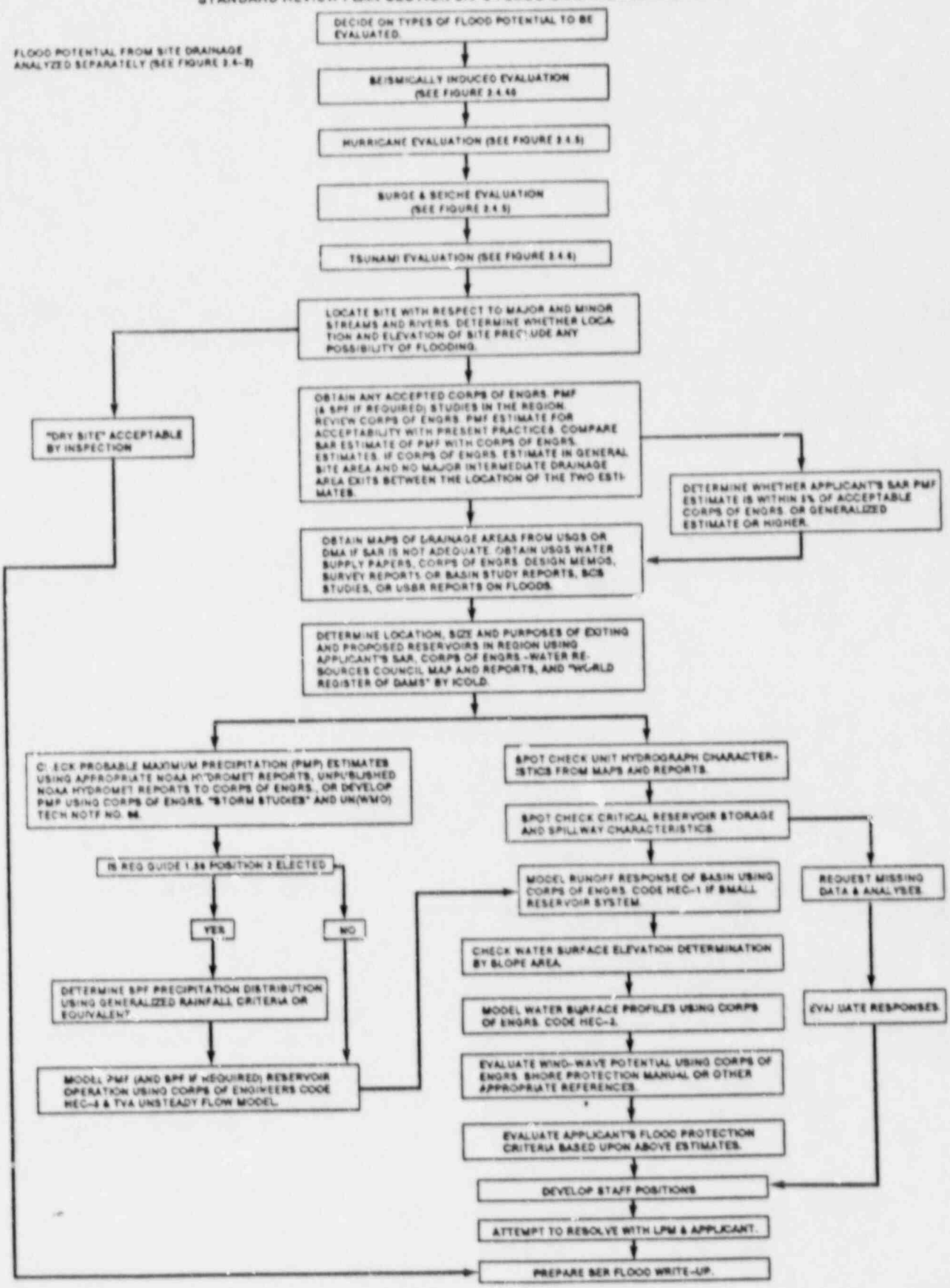

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FIGURE 2.4.3-2
STANDARD REVIEW PLAN SECTION 2.4.3
SITE DRAINAGE AND ADJACENT DRAINAGE