U.S. NUCLEAR REGULATORY COMMISSION

September 1977

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.135

NORMAL WATER LEVEL AND DISCHARGE AT NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Criterion 2 also requires that design bases for these structures, systems, and components reflect:

1. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding region, with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated,

2. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and

3. The importance of the safety functions to be performed.

Paragraph 100.10(c) of 10 CFR Part 100, "Reactor Site Criteria," requires that physical characteristics of the site, including seismology, meteorology, geology, and hydrology, be taken into account in determining the acceptability of a site for a nuclear power reactor.

This guide sets forth methods acceptable to the NRC staff for determining normal ground and surface water levels and surface water discharges for use in analyses of the effect of design basis natural and accidental events on structures and systems at nuclear power plants. This guide also suggests data sources and acceptable methods for determining such water levels and discharges.

B. DISCUSSION

Some structures and systems at most nuclear power plants are continually subject to fluctuating live loads that result from variations in ground water levels, discharges and water levels in streams, or water levels in lakes and oceans. Structures that extend below ground surface into the local ground water aquifer (or aquifers) must withstand the resulting hydrostatic pressure. Structures that are affected by surface water discharges and levels include dams, levees, breakwaters, canals, and intake and discharge structures. In considering the effects of design basis events[1] such as earthquakes, tornadoes, and hurricanes and the effects of design basis accidental events such as plane crashes, transportation accidents, explosions, fires, and loss-of-coolant accidents (LOCAs), the designer must include in his calculations the loads caused by the water level (or discharge), as well as the load on the structure or system caused by the design basis event being considered. This water level (or discharge) is referred to in this guide as the normal water level (or discharge).

Since the design basis events have a very low probability of occurrence, the water level (or discharge) used in combination with the design basis event need not represent a condition with low

[1] Design basis events are those natural events that there is virtually no risk of exceeding, such as the Probable Maximum Hurricane, Safe Shutdown Earthquake, and other natural events of similar low probability of occurrence, and accidental events, such as explosions, plane crashes, and fires.

probability of occurrence. As used in this guide, the term *normal water level (or discharge)* means that water level (or discharge) that has a probability of approximately 0.5 of occurrence at the time of interest.

Some design basis events may actually consist of a series of events such as an earthquake followed by one or more aftershocks. This fact is important if the earthquake could affect the normal water level (or discharge) and result in a different water level (or discharge) when the aftershocks occur. For example, the initial earthquake could affect an underdrain system to lower ground water levels at the time of the aftershocks. Similarly, a dam failure caused by the initial earthquake could substantially change the discharge in a river at the time of the aftershocks. Under such conditions, the normal water level (or discharge) should be assumed only at the time of the initial event, and the water level (or discharge) during the aftershocks should be determined by analysis of the effect of the initial event.

1. Seasonal Occurrence of Design Basis Events

Earthquakes, plane crashes, transportation accidents, explosions, fires, and LOCAs may occur at any time. However, water levels (or discharges) may vary considerably during any year. Accordingly, when determining normal water levels (or discharges) for these events by the methods recommended in this guide, water levels (or discharges) for the entire year should be considered.

On the other hand, floods, hurricanes, and tornadoes are seasonal in most parts of the United States. In determining normal water levels (or discharges) for these seasonal events, such seasonality should be taken into account. For example, tornadoes do not generally occur during the winter months in the northern states. Therefore, the normal water level (or discharge) to be considered with tornado effects should be derived only from data for those months in which tornadoes may be expected to occur.

Similarly, in Florida hurricanes have been recorded in virtually every month, but they are more likely to occur during the late summer and early fall, which is coincidentally the period of the year in which high water levels (or discharges) are most likely to occur. Accordingly, for this type of seasonal variation, the normal water level (or discharge) should be determined only for that period of the year during which the event is most likely to occur or for the appropriate period as indicated by studies of the area.

Floods are seasonal in many parts of the United States. While the surface water levels (or discharges) addressed in this guide are not applicable to floods, it is quite possible that the influence of flood levels on normal ground water levels must be considered.

The following discussions of various water bodies assume that the seasonality of the design events are properly taken into account.

2. Nontidal Streams

Data on stream discharge rates are readily available for thousands of stream-gaging stations operated by the U.S. Geological Survey; U.S. Army Corps of Engineers; Bureau of Reclamation; other Federal, State, and local agencies; power companies; and other organizations. Most such data are in the form of mean daily discharges for varying periods of record. Hydrology textbooks contain acceptable standard methods for transposing these data from the gaging stations to the plant site. Thus, relatively reliable information on stream discharge may be obtained for a plant site located on a nontidal stream. Short-term discharge data are also frequently collected at the sites and should be used to verify the transposed data.

A period of record of at least 50 years is desirable for use in determining the normal water level and discharge at sites on nontidal streams. For many locations, however, such long-term records do not exist. In such cases, periods of record of at least 12 years may be acceptable if it can be demonstrated that the period used includes major wet and dry periods. Where shorter-term data or no data exist, records should be estimated on the basis of weather records and records for other streams in the region. In all cases, watershed development conditions anticipated during the plant lifetime should be considered.

For nontidal streams, the median discharge will be considered the normal discharge. The median discharge may be determined as the 50% point on a flow-duration curve[2] (discharge vs. percent of days when indicated discharge was equalled or exceeded). Acceptable methods of constructing a flow-duration curve are outlined in many publications, e.g., U.S. Geological Survey Water-Supply Paper 1542-A, "Flow Duration Curves," 1959.[3]

It would be desirable to determine the normal water level on nontidal streams by similar means, i.e., use of a stage-duration curve (water level vs. percent of days when indicated level was equalled or exceeded). However, stages (water levels) at gaging stations are not as readily available as are the cor-

[2] The U. S. Geological Survey computes data for most of their gaging stations from which a flow-duration curve may be plotted. It should be noted, however, that such a curve will cover only the period of record available for the gaging station.

[3] Copies are available from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202.

responding discharge data. Therefore, the NRC staff will accept, as the normal water level, the water level corresponding to the normal discharge. Computation of the normal water level by this method requires the establishment of the relationship between river level and discharge (the rating curve) and the application of that relationship to the normal discharge. If the stream has a movable bed, allowance should be made for shifting of the rating curve.

3. The Great Lakes

The levels of some of the Great Lakes have shown upward or downward trends over long periods. For example, Lake Michigan-Huron has shown a slight downward trend over a period of more than 100 years. Such trends should be taken into account in determining the normal level. An acceptable procedure is to adjust the last 50 years of data for the indicated trend before determining the median level. This adjusted 50-year median level should be considered as representing the normal level.

Lunar tides in the Great Lakes may be ignored because their size is negligible.

Because of the size of the Great Lakes, their water levels change very slowly. Therefore, it is not necessary to determine the normal water level from daily data. Mean monthly values are of sufficient accuracy. The Detroit District, U.S. Army Corps of Engineers, collects and publishes monthly data on the levels of the Great Lakes.

4. Unregulated Lakes

As used in this guide, the term *unregulated lakes* means those natural lakes whose outlets are virtually uncontrolled by dams or other structures and those natural lakes that are not appreciably affected by diversions into or out of the lake. *Regulated lakes* are discussed as reservoirs in this guide.

A median level based on 50 years of data is acceptable as the normal water level. This level can be determined from long-term records of the lake level. If only short-term records are available, they may be extended by estimating longer-term data on the basis of records for other lakes, stream discharge and ground water data, and weather records. As with nontidal streams, a shorter record may be acceptable if it can be demonstrated that major wet and dry periods are included. As with the Great Lakes, if a trend can be identified, the data should be adjusted for this trend. Consideration should also be given to potential changes in water use that could significantly alter this median.

In many cases, mean monthly data may be used to compute the median level. However, a study should be made to determine whether the median based on mean monthly records is sufficiently accurate or whether mean daily data should be used. Such a study could consist of computing medians for a short period (e.g., two or three years) from both monthly and daily information and comparing the results.

5. Regulated Lakes and Reservoirs

At their outlets many lakes have dams or other regulating structures, which in effect convert the lake into a reservoir. Regulated lakes are therefore addressed as reservoirs in this guide.

Most reservoirs have at least one level designated as "normal pool" elevation. For some reservoirs, more than one elevation, usually varying with the time of the year, may be considered normal pool. Those reservoirs that have reserved flood control space are frequently of this type. For example, a reservoir in the Sierra Nevada of California might have a given normal pool level for the July-to-November period, followed by a November-to-December period when the level must be drawn down to accommodate potential flood runoff, and a December-to-June period when the level must be kept as closely as possible to the drawndown level but may rise to as high as the top of the flood control pool.

Normal water level should be considered the normal pool level of the reservoir, with due consideration for variations in normal pool level during the year. If the reservoir includes flood control storage, the median of the flood control pool levels for the life of the reservoir should be considered normal for events that are likely to occur during the flood season.

Records of levels of regulated lakes and reservoirs are usually collected by the operator of the reservoir. In some cases, these data are published by the U. S. Geological Survey, U.S. Army Corps of Engineers, or other Federal, State, or local agencies.

6. Oceans

A complete tide cycle averages 12 hours 25 minutes at most points on the shores of the United States. Because of this relatively rapid rate of change of ocean levels, the duration of the design basis event should be considered. Most such events are of short duration, ranging from essentially instantaneous (e.g., plane crashes, explosions, and most transportation accidents) to a few seconds or minutes (e.g., earthquakes, tornadoes, and some transportation accidents). However, hurricanes and fires may last sufficiently long to span the entire tidal range from low to high.

For short duration events, the median tide level may be considered as the normal water level. For

longer duration events, however, it is probable that the tide will be above (or below) the median level for at least part of the time of the occurrence of the event. For these events, therefore, median higher high tide or median lower low tide (see discussion below) should be used as the normal. The choice of median higher high tide or median lower low tide will depend on the event being considered. For example, hurricane winds blowing seaward from land will lower the level of the ocean (setdown). If this will have an effect on a safety-related water supply, the normal water level should be the median lower low tide.

High and low tides do not consistently reach the same levels. The two high tides during a complete 24-hour 50-minute cycle at some locations are of different heights, as are the two low tides. The higher of the two high tides is designated as higher high tide and the lower of the two low tides as lower low tide. Other cyclic variations have also been identified. Tidal heights vary during each lunar month from spring (high) to neap (low) range. The tidal range also has a cyclic variation of somewhat more than 19 years. In addition, tidal heights are affected by variations in barometric pressure and by wind. These meteorological phenomena cause the principal differences between predicted and recorded tidal heights.

In order to ensure that these variations are considered, normal tide levels should be computed from a continuous record of at least 20 years.

A long-term tide record is not available at the exact location of many nuclear power plant sites. Usually, however, a short-term record will have been collected at the site. In this case, the short-term record may be extended by correlation with one or more records for nearby long-term tide stations.

Records of tidal heights are collected and maintained by several agencies but principally by the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce. This agency regularly estimates mean high tide or mean higher high tide, primarily for coastal locations. Data for other locations may be estimated, using the relations given in tide tables, by interpolation.

7. Estuaries

Both freshwater runoff and lunar tides affect water levels in estuaries. Most estuaries are gaged by the U.S. Geological Survey, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, or others. A stage-duration curve should be used to estimate the median water level as the normal water level. This procedure may be used for locations upstream and downstream from the site with the normal water level at the site estimated by interpolation.

A period of record of 20 years (to account for cyclic tidal variations) is acceptable if it can be demonstrated that the period includes major wet and dry periods.

8. Ground Water

Normal ground water level should be the median level over a 20-year period. This length of record will not be available at most sites for nuclear power plants. However, most sites will have one or more short-term records of a year or two. The staff will accept extension of these short-term records by correlation with longer records in the region. The effect of future changes in water use should be considered. The U.S. Geological Survey collects and publishes records for thousands of observation wells throughout the United States and may advise where other data in the region may be obtained.

For those sites at which the applicant plans to lower the ground water level permanently by use of an underdrain system, either pumped or gravity flow, the staff will accept, as normal, the anticipated lower water level for which the system is designed.

Ground water levels to be used for soil liquefaction analyses will be discussed in a regulatory guide now under preparation on liquefaction.

C. REGULATORY POSITION

Analyses of the capability of safety-related structures, systems, and components to resist combinations of loading conditions often require identification of normal water levels or discharges. For the purposes of this guide, *normal water level (or discharge)* means the water level (or discharge) that can be expected at the time of occurrence of design basis natural or accidental events.[4] Subject to the exceptions below, the normal water level (or discharge) will generally be the median water level (or discharge), i.e., that water level (or discharge) that will be equalled or exceeded 50% of the time.

1. Seasonal Occurrence of Design Basis Events

If the design basis event under consideration is seasonal, the normal water level (or discharge) should be determined for that part of the year in which the event is likely to occur.

2. Nontidal Streams

The normal discharge should be the median discharge based on a period of mean daily discharge record, preferably at least 50 years in length. The normal water level should be either (a) the median mean daily water level based on a record of preferably at least 50 years or (b) the water level corresponding to

[4] See Footnote 1.

normal discharge, including consideration of shifting rating curves for streams with movable beds. A shorter period of record (not less than 12 years) is acceptable if longer records do not exist and it can be demonstrated that the period used includes major wet and dry periods.

3. The Great Lakes

Normal water level should be the median mean monthly level based on the latest 50 years of record, with suitable adjustment for demonstrated long-term trends.

4. Unregulated Lakes (Other Than the Great Lakes)

Normal water level should be the median based preferably on 50 years of data. Unless it can be demonstrated that the median based on mean monthly levels is sufficiently accurate, mean daily data should be used. If long-term trends can be identified, the 50-year median should be adjusted for these trends. A shorter period of record (not less than 12 years) is acceptable if longer records do not exist and it can be demonstrated that the period used includes major wet and dry periods.

5. Regulated Lakes and Reservoirs

Normal water level should be the designated normal pool elevation. There may be different designated normal pool elevations at different times of the year. If the reservoir contains flood control space, the normal water level during the flood season should be the median of the flood levels attained during the life of the reservoir.

6. Oceans

For events of short duration (a half hour or less), normal water level should be the median tide based on a 20-year period of record. If the event may have a longer duration, normal water level should be the median higher high tide or median lower low tide based on a 20-year period of record. Choice of higher high or lower low tide should be the most conservative for the event being considered and its consequences.

7. Estuaries

Normal water level should be the median level based on a 20-year period of record. For longer-duration events, median higher high or lower low tide based on a 20-year period of record should be substituted for median tide level.

8. Ground Water

Normal ground water level should be the median level based on 20 years of data. If permanent lowering of the ground water level by using underdrains is planned, normal level should be the design lowered level.

9. Availability of Data

If the minimum periods of record specified in the foregoing positions are not available, standard methods may be used to transpose or extend the available data. Full explanations of the methods used for such procedures should be furnished.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

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 in the evaluation of submittals for construction permit applications docketed after May 1, 1978, unless this guide is revised as a result of suggestions from the public or additional staff review.

If an applicant wishes to use this regulatory guide in developing submittals for applications docketed on or before May 1, 1978, the pertinent portions of the application will be evaluated on the basis of this guide.