U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.11 COOLING WATER SUPPLY

REVIEW RESPONSIBILITIES

Primary - Hydrologic & Geotechnical Engineering Branch (HGEB)

Secondary - None

I. AREAS OF REVIEW

The purpose of this section of the applicant's safety analysis report (SAR) is to identify natural events that may reduce or limit the available cooling water supply, and to assure that an adequate water supply will exist to operate or shut down the plant under normal and emergency conditions.

Depending on the site, the areas of review include:

1. The worst drought considered reasonably possible in the region.
2. Low water (setdown) resulting from surges, seiches, or tsunami.
3. Low water resulting from icing.
4. The effect of existing and proposed water control structures (dams, diversions, dam failures, etc.).
5. The intake structure and pump design basis in relation to the events described in SAR Sections 2.4.11.1, 2.4.11.2, 2.4.11.3, and 2.4.11.4.
6. The use limitations imposed or under discussion by Federal, state, or local agencies authorizing the use of the water.
7. The range of water supply required by the plant, including minimum operating and shutdown flows, compared to availability.
8. The effects of potential blockage of intakes by sediment and littoral drift.

9. The capability of the ultimate heat sink to provide adequate cooling water under normal and emergency conditions.

II. ACCEPTANCE CRITERIA

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

1. General Design Criterion (GDC) 2 requires that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena.

2. General Design Criterion (GDC) 44 requires an ultimate heat sink capable of accepting the plant's heat load under normal and accident conditions.

3. 10 CFR Part 100 requires that hydrologic characteristics be considered in the evaluation of the site.

4. 10 CFR Part 100, Appendix A requires, in part, that consideration of river blockages or diversion or other failures which may block the flow of cooling water, tsunami runup and drawdown, and dam failures be included in the evaluation of the adequacy of the emergency cooling water supply.

To meet the requirements of the hydrologic aspects of the above regulations, the following specific criteria are used:

Acceptance is based principally on the adequacy of the ultimate heat sink to supply cooling water for normal operation and for safe shutdown, cooldown (first 30 days), and long-term cooldown (periods in excess of 30 days) during adverse natural conditions. In addition, the design basis of the intake system must be adequate to enable delivery of the necessary cooling water to the plant during adverse hydrologic conditions. Where the specific design bases preclude plant operation during severe hydrologically related events, sufficient warning time must be demonstrated so that the plant may be shut down during or in advance of adverse events without causing potential damage to safety-related facilities. In cases where sufficient warning time to permit advance shutdown is considered necessary to protect safety-related components, an item in the plant Technical Specifications will be required.

SAR Section 2.4.11.1 (Low Flow in Rivers and Streams): For essential water supplies the low-flow/low-level design for the primary water supply source must be based on the probable minimum low flow and level resulting from the most severe drought that can reasonably be considered possible for the region. The low flow and level design bases for operation (if different than the design bases for essential water requirements) should be such that shutdowns caused by inadequate water supply will not cause frequent use of emergency systems. In cases where a common source of cooling water for operation and safety is provided, and where operation can affect minimum levels required for safety, the system will be acceptable if technical specifications are provided for shutdown before the ultimate heat sink can be adversely affected.

SAR Section 2.4.11.2 (Low Water Resulting from Surges, Seiches or Tsunami): If the site is susceptible to such phenomena, minimum water levels resulting from setdown (sometimes called runout or rundown) from hurricane surges, seiches, and tsunami must be higher than the intake design basis for essential water supplies. For coastal sites, the appropriate probable maximum hurricane

(PMH) wind fields must be postulated to give maximum winds blowing offshore, thus creating a probable minimum surge level. Low water levels on inland ponds, lakes, and rivers due to surges must be estimated from probable maximum winds oriented away from the plant site. The same general analysis methods discussed in Standard Review Plan Sections 2.4.3, 2.4.5 and 2.4.6 are applicable to low water estimates due to the various phenomena discussed.

SAR Section 2.4.11.3 (Historical Low Water): If historical flows and levels are used to estimate design values by inference from frequency distribution plots, the data used must be presented so that an independent determination can be made. The data and methods of the National Oceanic and Atmospheric Administration, United States Geologic Survey, Soil Conservation Service, Bureau of Reclamation, and the Corps of Engineers are acceptable.

SAR Section 2.4.11.4 (Future Controls): This section is acceptable if water use and discharge limitations (both physical and legal), already in effect or under discussion by responsible Federal, regional, state, or local authorities, that may affect water supply at the plant have been considered and are substantiated by reference to reports of the appropriate agencies. The most adverse possible effects of these controls must be shown and taken into account in the design basis to assure that essential water supplies are not likely to be affected adversely in the future.

SAR Section 2.4.11.5 (Plant Requirements): Acceptance is based on the following required information:

1. Minimum essential cooling water flow rates and levels must be presented (or cross-referenced) and shown to be less than the probable minimum low flows and levels from the applicable sources of supply.

2. Maximum water requirements for normal operation must be presented and (if applicable) shown to be less than the water available under all likely conditions from the sources of supply.

SAR Section 2.4.11.6 (Heat Sink Dependability Requirements): The required data and information are those necessary to determine that the facility meets the criteria of GDC 44 as described in Regulatory Guide 1.27. The analyses will be considered complete and acceptable if the following are adequately addressed:

1. The initial water inventory must be sufficient for shutdown and cooldown of the plant.

2. Water losses (such as seepage, drift, and evaporation) must be conservatively estimated, as suggested in Regulatory Guide 1.27.

3. The design basis hydrometeorology (temperature, dewpoint, etc.) must be as conservative as the criteria of the guide (see SRP Section 2.3).

4. The limit on the heat sink return water temperature must be less than the maximum allowable cooling water inlet design temperature.

5. The heat sink intakes are located such that no potential exists for blockage by littoral drift and/or sediment that would decrease water supply below minimum required levels.

III. REVIEW PROCEDURES

Minimum plant requirements (water level and flow) that are identified in SAR Sections 2.4.11.5 or 9.2.5 are compared to the estimated minimum water levels and flows given in Section 2.4.11.1. If normal operation is not assured at the minimum water supply conditions, and loss of normal operation capability can adversely affect safety-related components, estimates of warning time are reviewed to assure that shutdown or conversion to alternate water sources can be accomplished prior to the trip. For such cases, emergency operating procedures are required, and are reviewed to assure that they are consistent with the postulated conditions. The analysis of the dependability of the ultimate heat sink is reviewed and the conclusions are provided to the Auxiliary Systems Branch (ASB) and Power Systems Branch (PSB). Determination of the dependability of the ultimate heat sink is accomplished by using Regulatory Guide 1.27 as a standard of comparison.

Each source of water for normal or emergency shutdown and cooldown, and the natural phenomena and site-related accident design criteria for each should be identified. A systems analysis is first undertaken of all water supply sources to determine the likelihood that at least one source would survive (1) the most severe of each of the natural phenomena; (2) site-related accident phenomena; and (3) reasonable combinations of less severe natural and accident phenomena. Second, arbitrarily assumed mechanistic failures of water supply structures and conveyance systems are postulated and the systems analysis repeated, to assure that the failure of one component will not cause failure of the entire system. These analyses are coordinated with the ASB and PSB review of the ultimate heat sink and related cooling systems, to avoid duplication. Operating rules for each portion of the system are ascertained to determine the amount of water that can be assumed available in the event of normal or accidental shutdown. If there is evidence of potential structural or mechanical effects, the Structural Engineering Branch (SEB) or Mechanical Engineering Branch (MEB) will be requested by HGEB to ascertain whether the effects are properly considered in the structural or mechanical design bases for the plant. Consultations with the Geosciences Branch (GB), the Accident Evaluation Branch (AEB), SEB, ASB, and PSB are undertaken where design criteria are not firmly established.

The potential for surges in intake sumps (i.e., seiching in intake structures and surges in intake pipes) that could cause adverse effects are reviewed to assure that the effects have been properly incorporated for the intake design. The potential for adverse hydrodynamic effects of a trip of the intake pumps is evaluated based on potential surges in intake sumps.

For multiple purpose (normal operation, normal shutdown, and emergency shutdown) water supply systems, the primary portion of the system is first reviewed to determine that the water supply will be maintained at minimum volume requirements at all times. The secondary portion of the system is then reviewed to determine whether an adequate emergency water supply can be expected to be available during operating conditions such as the regional drought of record (flows must be adjusted for historical and potential future effects). If not, the applicant is requested to provide a technical specification requiring plant shutdown at the point where an adequate shutdown water supply is still assured.

Institutional restraints on water use, such as limitations in water use and discharge permits, are reviewed to assure the plant will have an adequate supply and not exceed limitations imposed upon operation. If a conflict is foreseen, the applicant is requested to either obtain a variance or make a design change to accommodate the limitation.

The potential for blockage of the intakes by littoral drift and sediment is reviewed to assure that the intakes are located and sized to prevent blockage which would preclude use of the safety-related water supply. Applicable literature describing historic sediment accumulations in the site region is reviewed to determine if mitigative measures are required to protect safety-related facilities. Independent estimates of "worst-case" buildups will be made using statistical or deterministic techniques.

For plants using rivers, minimum design service water levels are compared with asymtotic extrapolations of low-flow frequency curves which have been corrected for historical and potential future effects. For ocean or estuary plants, design low water levels are compared with probable maximum hurricane and tsunami-induced low water levels. For Great Lakes plants, design low water levels are compared with minimum historical levels coincident with probable maximum surge or seiche-induced low water levels.

The ability of the ultimate heat sink to provide a 30-day supply of cooling water, as specified in Regulatory Guide 1.27, will be independently evaluated. For those cases where makeup water cannot be assured (e.g., an onsite cooling pond supplied from a nearby river through nonseismic piping), estimates of water loss due to drift, evaporation, blowdown, and seepage are made. Techniques described in References 24 and 25 are used to evaluate the adequacy of the initial water inventory under meteorological conditions of the severity discussed in Regulatory Guide 1.27.

If the ultimate heat sink system is not capable of continued long-term water supply under the criteria in Regulatory Guide 1.27, or the above considerations, the system will be reviewed in two parts: short-term capability and long-term capability. For short-term capability, the AEB, PSB, and the Licensing Project Manager (LPM) will be informed if the independently-estimated supply appears to be less than 30 days. The applicant will be asked to determine whether sufficient personnel and equipment can safely be made available to switch water supply sources in the event of an accident. If emergency procedures are required to obtain the use of alternate water supplies, the applicant's water supply sources and procedures will be reviewed with AEB, PSB, and the LPM to determine that there is continuity of water supply. The time period for which a highly dependable water supply would be available is compared with the time required to obtain water from an alternative supply, and the natural or accident environmental conditions which could prevail.

For long-term water supply capability, different sources and means of obtaining water may be required because of the limited capability of a "short-term" supply. In those cases where different sources are necessary to assure the long-term plant heat removal capability, the alternative sources and the means of supplying water from the sources to the plant should be identified. Any plant design provisions necessary for such situations should also be described or a reference provided to other SAR sections for the descriptions.

Emergency means for obtaining long-term water supplies will be judged on the basis of the time required to obtain such supplies, natural or accident phenomena likely to prevail or to have caused the need for such supplies, and the dependability of the supply itself.

The ability of the ultimate heat sink to provide the plant with cooling water below the design maximum temperature will be evaluated. The design maximum temperature and the heat load of the design basis accident, as specified in Regulatory Guide 1.27, will be provided by ASB. Techniques for selecting the meteorologic conditions for minimum heat transfer and for performing the transient analysis for cooling ponds and spray ponds are provided in References 24 and 25, respectively.

IV. EVALUATION FINDINGS

The findings will indicate the degree of compliance with GDC 2, GDC 44, 10 CFR Part 100, and 10 CFR Part 100, Appendix A.

For construction permit (CP) reviews the findings will summarize the applicant's and staff's estimates of the design basis minimum water flows and levels. If the applicant's estimates are no more than 5% less conservative than the staff's estimates, staff concurrence in the applicant's estimates will be stated. If the applicant's estimates are more than 5% less conservative and if the proposed plant may be adversely affected, a statement of the staff's position (bases) will be made. A similar finding on the design bases for the ultimate heat sink will be made. If technical specification requirements are needed to assure an adequate supply, they will be indicated in the CP statement and required for operation.

For operating license (OL) reviews of plants for which detailed low water reviews were done at the CP stage, the CP conclusions will be referenced. In addition, the results of a review to reaffirm the low water design bases will be noted. If no changes have been made to the ultimate heat sink design since the CP review, the conclusions of the CP will be referenced. However, for both the low water considerations and the ultimate heat sink, an evaluation will be made during the OL review to assure that the design bases have been properly implemented. The availability of long-term water supply will be noted. If no low water and ultimate heat sink review was undertaken at the CP stage (of the scope described), this fact will be noted also.

A sample CP-stage statement follows:

> The normal water supply for the station will be obtained from Lake A. Emergency cooling water will be furnished by the ultimate heat sink reservoir which is not dependent upon the water level in Lake A for its safety function.
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> The minumum lake elevation needed for operation of the pumps supplying makeup water for the circulating and the service water systems is 564.6 feet above International Great Lakes Datum (566.1 feet above mean sea level). The lowest lake level observed at B City during the 70 years of record was 565.7 feet above International Great Lakes Datum (567.2 feet above mean sea level) on February 4, 1936. Recurrence of this low lake level would not affect the plant's ability to obtain water.
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> The applicants calculated the probable minimum lake setdown during a postulated probable maximum windstorm using a one-dimension numerical surge model. The minimum calculated lake level, including an antecedent level equal to the minimum monthly lake level of record, is 549.0 feet above International Great Lakes Datum (550.4 feet

above mean sea level). Since this level is below the minimum necessary for pump submergence, the plant would have to be shut down using water from the ultimate heat sink reservoir, which would not be affected by the postulated low lake level.

The proposed ultimate heat sink will be comprised of Lake A and a rectangular cooling pond located on the site. Normal operation and shutdown will utilize cooling water from the natural draft cooling towers; the makeup for the cooling towers comes from Lake A. If, for any reason, the natural draft cooling towers are unavailable, the onsite pond will be used to shut down the units. The pond will be 1980 feet long and 940 feet wide. The depth of the water will be 11 feet and the pond's embankment will have a freeboard of 5 feet. The submerged intake and discharge pipes will be located at the same end of the pond but separated by a dike running almost the entire length of the pond to prevent short-circuiting between the intake and discharge. The pond must be capable of providing cooling water below the design temperature of 110° Fahrenheit under normal or emergency conditions.

The applicants analyzed the ponds thermal performance assuming a loss-of-coolant accident in one unit, a simulataneous normal shutdown in the other, and meteorological conditions of the severity specified in Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants." The maximum pond temperature calculated was 109.3° Fahrenheit.

We independently modeled the thermal performance of the pond and conclude that it is capable of providing cooling water below the design temperature of 110° Fahrenheit. We conservatively estimated maximum water losses from the pond, assuming meteorological conditions of the severity specified in Regulatory Guide 1.27, and conclude that the initial pond inventory will be sufficient to provide at least a 30-day cooling water supply without makeup.

We evaluated the potential effects of freezing events on the pond's capability of providing emergency cooling water to the plant. Our analysis showed that the intake and discharge pipes will be below the maximum depth of pond freezing that could occur under meteorological conditions of the severity suggested in Regulatory Guide 1.27. In addition, to prevent freezing around the intake and discharge pipes, the intake pumphouse will be heated and the discharge piping will be buried below the frost line, heat traced or the discharge structure will be heated.

We have evaluated the performance of the proposed cooling pond and conclude that, under meteorological conditions of the severity described in Regulatory Guide 1.27, (1) the design will provide sufficient water in the pond to cool the plant for at least 30 days without any makeup and (2) the maximum temperature of the water supplied to the plant will be below the design temperature of 110° Fahrenheit.

Based upon the evaluations described above, we conclude that the cooling water supply for the plant meets the requirements of General Design Criterion 2, 10 CFR Part 100, and 10 CFR Part 100, Appendix A with respect to hydrologic characteristics and that it meets the requirements of General Design Criterion 44 with respect to thermal aspects of the heat transfer system.

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 proposed 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 and NUREGs.

VI. REFERENCES[1]

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

2. 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."

3. 10 CFR Part 100, "Reactor Site Criteria."

4. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

5. L. R. Beard, "Methods for Determination of Safe Yield and Compensation Water from Storage," Seventh International Water Supply Congress, Barcelona, Spain (1966).

6. L. R. Beard, "Statistical Methods in Hydrology," Corps of Engineers (1962).

7. D. K. Brady et al., "Surface Heat Exchange at Power Plant Cooling Lakes," EEI Publication 69901 Edison Electric Institute, New York, Nov. 1969.

8. V. T. Chow (ed), "Handbook of Applied Hydrology," McGraw-Hill Book Company, New York (1964).

9. J. E. Edinger and J. C. Geyer, "Heat Exchange in the Environment," EEI Publication 69-902, Edison Electric Institute, New York, June 1965.

10. G. M. Fair et al., "Water and Wastewater Engineering," Vol. 1, John Wiley & Son Inc., New York (1966).

11. "Scientific Hydrology," Ad Hoc Panel on Hydrology, Federal Council for Science and Technology, Washington, D.C., June 1962.

[1]References for analysis of low water resulting from surges and seiches are in SRP Section 2.4.5. References for analysis of low water resulting from tsunami are in SRP Section 2.4.6.

12. M. B. Fiering, and M. M. Hufschmidt, "Simulation Techniques for Design of Water-Resource Systems," Harvard University Press, Cambridge, Mass. (1966).

13. R. K. Linsley et al., "Hydrology for Engineers," McGraw-Hill Book Company, New York (1958).

14. R. K. Linsley and J. B. Franzini, "Water-Resources Engineering," McGraw-Hill Book Company, New York (1964).

15. A. Maas et al., "Design of Water-Resources Systems," Harvard University Press, Cambridge, Mass. (1962).

16. "Hydrologic Engineering Methods for Water Resources Development," Vol. 1-12, Corps of Engineers Hydrologic Engineering Center, Davis, California (1971).

17. "Reservoir Storage-Yield Procedures," Corps of Engineers Hydrologic Engineering Center, Davis, California (1967).

18. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."

19. "Design of Small Dams," Second Edition, Bureau of Reclamation, U.S. Department of Interior (1973).

20. "Water Surface Profiles," HEC-2, Corps of Engineers Hydrologic Engineering Center (continuously updated).

21. "Reservoir System Analysis," HEC-3, Corps of Engineers Hydrologic Engineering Center (updated).

22. "Monthly Streamflow Simulation," HEC-4, Corps of Engineers Hydrologic Engineering Center (updated).

23. Regulatory Guide 4.4, "Reporting Procedure for Mathematical Models Selected to Predict Heated Effluent Dispersion in Natural Water Bodies."

24. R. B. Codell and W. K. Nuttle, "Analysis of Ultimate Heat Sink Cooling Ponds," NUREG-0693, USNRC (1980).

25. R. B. Codell, "The Analysis of Ultimate Heat Sink Spray Ponds," NUREG-___, USNRC (in preparation).