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DESCRIPTION:
Ltr furnishing hydrologic engineering studies for the Keowee-Toxaway development of the Duke Power Co, Oconee Nuclear Sta.

PLANT NAMES: Oconee Nuclear Sta. Units 1-2-3

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LBC&W ASSOCIATES OF SOUTH CAROLINA ▫ 1800 GERVAIS STREET, COLUMBIA, SOUTH CAROLINA 29202

November 15, 1972

Mr. L. G. Hulman
Senior Hydraulic Engineer
Site Analysis Branch
Directorate of Licensing
Atomic Energy Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

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Dear Mr. Hulman

1. In accordance with contract # AT(49-24)-008, dated 31 October 1972, and associated understandings, I have made hydrologic engineering studies pertaining to the Keowee-Toxaway development of the Duke Power Company's Oconee Nuclear Station in Oconee County, South Carolina. A concise summary of my findings and conclusions is presented herein. Supporting technical details in documented form are available for your review if desired.

2. The assignment related specially to the following:

a. Computation of probable maximum flood (PMF) hydrographs of inflow into Jocassee and Keowee Reservoirs, respectively;

b. Routing of the PMF hydrographs through Jocassee and Keowee Reservoirs under critical assumptions, to determine hydrographs of reservoir stages and outflow rates;

c. Computation of wave characteristics and vertical heights of runup on embankments of the Jocassee, Keowee and Little River Dams, respectively, that might coincide with maximum reservoir stages during the probable maximum floods;

d. A summary of conclusions regarding estimates referred to above, particularly as they relate to the safety of the dams against failure during extreme floods.

3. The policy concepts, methods, hydrometeorological criteria, and basic flood routing assumptions adhered to in the assignment conform essentially with those adopted by the Atomic Energy Commission to govern the determination of spillway capacities and freeboard requirements for very large dams, generally as summarized in the February 1972 draft, Standard Format and Contents of Safety Analysis Reports for Nuclear Power Plants.

6374

PERTINENT DATA

4. Following is a brief summary of physical features that relate to the studies:

a. Keowee Lake, controlling 439 square miles, is formed by a 150-foot high earthfill dam on the Keowee River and a 170-foot high earthfill dam on Little River; a "connecting canal" joins lakes formed by these two dams, and is large enough to allow the two lakes to act as one. The Keowee and Little River Dams each have top elevations of 815' msl. On each dam the upstream embankment is surfaced with dumped rock for erosion protection above elevation 772' msl, which has a slope at 1' V to 2.0' H. The downstream embankment has a slope of 1' V to 2.5' H.

b. The 385-foot high rockfill Jocassee Dam, located about 12 miles upstream from Keowee Dam, controls 148 square miles of the total 439 square mile basin above the Keowee-Little River Dams. The top elevation of the embankment is 1125' msl. Upstream and downstream rockfill embankments each have a slope of 1' V to 1.75' horizontal in the upper 100 feet of elevation, which includes the zone considered in estimating potential wave runup effects.

c. Keowee Lake has a gross storage capacity of 956,000 acre-feet at a normal full-pool elevation of 800' msl, with a surface area of 18,372 acres (29 square miles). The Jocassee Reservoir has a gross storage capacity of 1,160,000 acre-feet at a normal full-pool elevation of 1,110 feet msl, and a surface area of 7565 acres (12 square miles).

d. The Keowee Dam spillway consists of four tainter gates, 38' W x 35' H, with a crest elevation of 765' msl and a total discharge capacity of 106,000 cubic feet per second at a normal full-pool level of 800' msl. The Jocassee spillway has two tainter gates, 38' W x 33' H, crest elevation 1077' msl, with a combined capacity of 46,200 cfs at a normal full-pool level of 1,110 msl.

e. In addition to spillways, the Keowee and Jocassee Dams have power turbines capable of discharging substantial quantities of water. Operating plans for Jocassee Dam provide for releases up to 15,000 cfs through power turbines to augment spillway discharges during floods, if needed. However, such turbine operations could be precluded by interruptions in power loadings or for other reasons under emergency conditions associated with extreme floods. Accordingly, in the studies reported herein, releases through power turbines were assumed as zero in routing the Probable Maximum Flood through the reservoirs.

CRITICAL FLOOD ESTIMATES

5. Probable Maximum Precipitation (PMP) estimates for the 439 square mile basin above Keowee Lake, and relevant sub-division thereof, were obtained from Hydrometeorological Report No. 33 of the U. S. Weather Bureau (now NOAA). Alternative areal distributions of PMP quantities were tested to develop critical flood producing relations. The Probable Maximum Flood from the 148 square mile basin above Jocassee Dam would result when the heaviest PMP concentration occurred over this area; the critical PMF hydrograph at Keowee Dam would result with the heaviest PMP amounts concentrated over the 291 square mile intermediate area between Jocassee and the dams forming Keowee Lake. PMF hydrographs were computed by application of synthetic unit hydrographs to estimates of PMP rainfall-excess assuming an infiltration index of .05 inch per hour. The synthetic unit hydrographs were derived for component drainage areas tributary to full reservoirs to account for the accelerating effects of unusually large water surfaces of Lake Keowee and Lake Jocassee at normal full-pool elevations, which represent more than 9 percent of the total 439 square mile drainage area. The selection of coefficients used in developing synthetic unit hydrographs were based on studies of unit hydrographs derived from analyses of major floods.

6. The computed PMF hydrograph of inflow into Jocassee Lake had a peak of 245,000 cfs, and a runoff volume of 210,000 acre-feet (26.6 inches runoff from 148 sq. mi.). Assuming the reservoir would be filled to elevation 1,110' msl at the beginning of the PMF, and all releases made through the two spillway gates, a peak reservoir stage of 1,122.5' msl was computed; stages exceeding 1,119.7' msl would prevail for 12 hours. The peak rate of reservoir outflow through the spillway would be 72,000 cfs.

7. The computed PMF hydrograph of inflow into Lake Keowee had a peak of 450,000 cfs, and a runoff volume of 550,000 acre-feet (23.5 inches runoff from 439 square miles). Assuming the reservoir would be initially filled to elevation 800' msl, and all releases made through the four spillway gates, a peak reservoir level of 809.8' msl was computed; levels exceeding 806.6' msl would prevail for 12 hours. These values are predicated on the assumption that all concurrent releases from Jocassee Reservoir are made through the spillway, without flows through power turbines.

FREEBOARD FOR WAVE ACTION

8. Following is a review of the apparent adequacy of existing dams to safely accommodate wave action in Lake Jocassee and Lake Keowee in the event high winds blowing toward the dams should prevail for several hours while reservoir levels are equal to or near the maximum elevations indicated for PMF conditions. Relevant procedures and computational aids contained in publications by the Army Corps of Engineers (EC 1110-2-27, and ETL 1110-2-8, dated 1 August 1966) were used in the analyses.

9. Wind records and analyses show that wind velocities as high as 35 to 40 miles per hour over-land, for durations of 1 to 6 hours, may occur infrequently in the vicinity of Lake Jocassee and Lake Keowee. Research studies indicate that over-land wind velocities of 35 to 40 mph would accelerate approximately 25 percent over the open water surfaces near the dams - that is to over-water velocities of 44 to 50 mph. Whether or not such winds might coincide with peak reservoir levels during the PMF, and be oriented over the "effective fetch" in a critical direction toward the respective dams, is largely a matter of conjecture. In general, studies show that wind directions tend to change substantially over local areas as storm centers move, even though velocities in various directions may persist at high rates for several hours. In general recognition of the improbability of the most critical wind velocity-duration-direction relations coinciding with maximum reservoir levels, the publications cited above provide for adoption of "design wind" criteria that are considered reasonable on the basis of available data and design objectives involved. Estimates based on these criteria are used as aids to over-all judgement of possible wave effects on project features. In the instant case, a "design wind" corresponding to an over-land velocity of 25 mph for a period of 6 hours was considered reasonable in estimating heights of runup that might be expected during the PMF. However, the possible effects of wave action that could conceivably result from winds equal to 40 mph over-land were also considered to assure that hazards from possible breaching of the dams from wave erosion would not exist even during extreme conditions. (Wind velocities cited herein refer to "over-land" rates; however, corrections for velocity increases over water have been accounted for in wave computations).

10. The Jocassee Dam top elevation of 1125' msl provides a freeboard of 2.5' above the computed maximum reservoir level during the PMF elevation 1122.5' msl. Computations indicate that a sustained wind velocity equivalent to 25 mph over-land, acting on a 2.5-mile "effective fetch," could result in "significant waves" (h_s) 1.9 feet high, which would break and run up the face of Jocassee Dam to a vertical height of approximately 2.5 feet above reservoir levels prevailing during the PMF; a negligible amount of wave splash or over-wash from waves exceeding h_s might pass over the crest of the dam. For corresponding conditions, a sustained wind velocity equal to 40 mph over-land would produce runup approximately 1.5 feet higher, and moderate amounts of wave-splash and wave over-wash might pass over the crest of the dam for a period of a few hours. In view of the characteristics of the rockfill embankments of Jocassee Dam, it is concluded that this wave action would not be sufficient to represent any risk of breaching of the embankment of Jocassee Dam.

11. The Keowee Dam top elevation of 815' msl provides a freeboard of 5.2 feet above the computed maximum reservoir level during the PMF elevation 809.8' msl. A sustained wind velocity comparable to 40 mph over-land, blowing toward the dam over an effective fetch of 2.2 miles would produce significant waves 3.2' high, capable of running up 4.0 feet on the riprap embankment (slope 1:2); the maximum wave in a spectrum of 100 waves would run up about one foot higher. Accordingly, computations indicate that Keowee Dam is high enough to prevent wave over-wash under the most cirtical PMF conditions. The same conclusion is applicable to Little River Dam, where the effective fetch (1.9 miles) is less than for the Keowee Dam.

CONCLUSIONS

12. Procedures and Criteria. The policy concepts, methods, hydrometeorological criteria, and basic flood routing assumptions used in the subject studies are consistent with sound engineering practices associated with the design of very large dams in the United States; they foster a safe degree of conservatism in evaluations pertaining to the projects covered by this report.

13. Jocassee Dam and Reservoir.

a. The Probable Maximum Flood hydrograph of inflow into Lake Jocassee would have a peak discharge of approximately 245,000 cfs, and a runoff volume of 210,000 acre-feet.

b. A maximum reservoir level of 1,122.5' msl could be attained in Lake Jocassee during the PMF under the most adverse circumstances considered reasonably possible.

c. The top elevation of 1,125' msl of Jocassee Dam provides a freeboard allowance for possible wave runup on the rockfill embankment equal to 2.5 feet above the peak PMF reservoir level (1,122.5' msl) estimated herein. It is remotely possible that sustained wind velocities (equal to 25 to 40 mph over land), blowing toward the dam could cause wave runup and some wave over-wash of the Jocassee embankment for a few hours during the PMF. However, the rockfill composition of the dam embankment is such as to preclude breaching of the embankment from wave wash of thegeneral magnitude indicated.

14. Keowee and Little River Dams.

a. The Probable Maximum Flood Hydrograph of inflow into Lake Keowee would have a peak discharge of approximately 450,000 cfs and a runoff volume of 550,000 acre-feet.

b. A maximum reservoir level of approximately 810.' msl could be attained in Lake Keowee during the PMF under the most critical circumstances considered reasonably possible.

c. It is remotely possible that sustained wind velocities (40 mph or less over land), blowing toward the dams during the PMF could cause wave runup on the riprap covered face of each dam approaching crest elevation 815' msl.

Albert L. Cochran

ALBERT L. COCHRAN
Director of Special Projects
Lyles, Bissett, Carlisle & Wolff

ALC:ad

JUL 19 1971

Docket Nos. 50-269
50-270
and 50-287

John A. Blume & Associates, Engineers
ATTN: Mr. Roland L. Sharpe
612 Howard Street
San Francisco, California 94105

Ref: Contract No. AT(49-5)-3012

Gentlemen:

A copy of the Division of Reactor Licensing's letter dated July 9, 1971, to the Duke Power Company is enclosed for your information.

Sincerely,

Original Signed by
Paul S. Check

for Richard C. DeYoung, Assistant Director
for Pressurized Water Reactors
Division of Reactor Licensing

Enclosure:
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Mr. John A. Blume &
Associates, Engineers
ATTN: Mr. Roland L. Sharpe
612 Howard Street
San Francisco, California 94105

Reference: Contract AT(49-5)-3012

Dear Mr. Sharpe:

Two copies of Amendment No. 21 dated September 17, 1970, to the application for licenses submitted by the Duke Power Company are enclosed for your review.

Please consider this amendment in connection with your review of the Oconee Nuclear Station application.

Sincerely,

Original Signed by
Charles G. Long

Richard C. DeYoung, Assistant Director
for Pressurized Water Reactors
Division of Reactor Licensing

Enclosure:
As stated above

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Docket Nos. 50-269
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Mr. John A. Blume & Associates, Engineers
Attn: Mr. Roland L. Sharpe
812 Howard Street
San Francisco, California 94105

Reference: Contract AT(49-5)-3012

Dear Mr. Sharpe:

Two copies of Amendment No. 21 dated September 17, 1970, to the application for licenses submitted by the Duke Power Company are enclosed for your review.

Please consider this amendment in connection with your review of the Oconee Nuclear Station application.

Sincerely,

Richard C. DeYoung, Assistant Director
for Pressurized Water Reactors
Division of Reactor Licensing

Enclosure:
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Mr. John A. Blume &
Associates, Engineers
ATTN: Mr. Roland L. Sharpe
612 Howard Street
San Francisco, California 94105

Reference: Contract AT(49-5)-3012

Dear Mr. Sharpe:

Two copies of Amendment No. 19 dated September 8, 1970, and Amendment No. 20 dated September 14, 1970, to the application for licenses submitted by the Duke Power Company are enclosed for your review.

Please consider this amendment in connection with your review of the Oconee Nuclear Station application.

Sincerely,

Original Signed by
Charles G. Long

Richard C. DeYoung, Assistant Director
for Pressurized Water Reactors
Division of Reactor Licensing

Enclosure:
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