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Florida Power
CORPORATION

December 19, 1972

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U.S. ATOMIC ENERGY COMMISSION
Regulatory Mail Section

The Director
Directorate of Licensing
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Sir:

In Re: Florida Power Corporation
Crystal River Nuclear Generating Plant
Docket No. 50-302

Enclosed are three (3) executed originals and nineteen (19) conformed copies of Amendment No. 23 to the Application for Licenses for Crystal River Unit 3 Nuclear Generating Plant. Also enclosed are an additional eighty-one (81) copies for a total of 103 copies as previously furnished for your distribution.

Amendment No. 23 consists of revised pages to the Final Safety Analysis Report and Supplement No. 1 contained therein. Specifically, these revisions contain responses to question 2.1 of the Request for Additional Information made in Mr. R. C. DeYoung's letter of January 14, 1972, and to question 2.14 of the Request for Additional Information made in Mr. R. C. DeYoung's letter of July 24, 1972. Both of these questions are concerned with surge level height and safe shutdown during the Probable Maximum Hurricane (PMH).

In addition to Amendment No. 23, we are enclosing twenty-two (22) copies of our response to question 2.1 of the Request for Additional Information made in Mr. R. C. DeYoung's letter of January 14, 1972. This response contains the same information that is contained in Amendment No. 23; however, the response has been organized into a "question and answer" format to facilitate your review.

Please contact us if you require any discussion or clarification of the above information.

Very truly yours,

J. T. Rodgers
J. T. Rodgers
Asst. Vice President
& Nuclear Project Manager

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REPLY TO REQUEST FOR ADDITIONAL INFORMATION

FLORIDA POWER CORPORATION

CRYSTAL RIVER UNIT NO. 3

DOCKET NO. 50-302

2.0 SITE AND ENVIRONMENT

2.1 Provide the following information to support the PMH surge and associated wave estimates:

2.1.1 Question

Detailed computations of the PMH surge stillwater level using probable maximum parameters and the referenced bathystrophic storm tide theory (or another method which can be substantiated), a cross section along the assumed fetch, and the hurricane track.

Answer

The characteristics and effects of the Probable Maximum Hurricane (PMH) were computed from procedures outlined in the following publications:

a. Memoranda HUR 7-97 and 7-97A, prepared by the Hydrometeorological Branch of the National Oceanic and Atmospheric Administration (NOAA).

b. Technical Memorandum No. 35, Storm Surge on the Open Coast: Fundamentals and Simplified Prediction, prepared by the U.S. Army Corps of Engineers, Coastal Engineering Research Center.

c. <u>Estimation of Hurricane Surge Hydrographs</u>, by G. Marinos and J. W. Woodward, ASCE Paper 5945, May 1968, WW2.

d. <u>Technical Report No. 4, 3rd Edition, Shore Protection Planning and Design</u>, prepared by U.S. Army Coastal Engineering Research Center.

The general concept for hurricane protection included the following considerations:

a. Full protection against hurricane tides and wave action for all components which must operate for a safe and orderly shutdown of the nuclear units. This protection will be provided for any intensity hurricane up to and including the Probable Maximum Hurricane (PMH).

b. Continued operation, based on economic analysis of the cost of such protection and the intensity and frequency of the hurricanes. Such continued operation will be maintained below the intensity level of a Probable Maximum Hurricane and will also consider operation up to the same intensity hurricane that the transmission system could be expected to safely withstand. Beyond this point of operation, the plant will be safely and orderly shutdown.

The critical approach path for a hurricane with on-shore winds is from the southwest, tracking on a northeasterly course, as shown on Figure 2-25. However, the approach path of wave trains that will produce the maximum runup levels at the site is along a north-south section with waves approaching the plant from the south, as shown on Figure 2-23. The maximum tidal set-up, however, must be produced by winds blowing on-shore to the east. This concept of maximum wave action occurring perpendicular to the hurricane winds is considered to be a conservative assumption for the maximum surge condition.[1]

The path of approach for a Probable Maximum Hurricane to produce maximum surge heights is from the southwest travelling forward toward the site in a N 63° E (True) direction. The center of the PMH would pass north of the plant site at a distance that results in the maximum winds passing directly over the site area. Surge calculations were calculated along a traverse line intersecting the site at a bearing of N 63° E. Since this traverse is approximately normal to the offshore bottom contours, the surge computations based on the bathystrophic storm tide theory give maximum surge heights. The primary parameters for the PMH, as a result of maximizing to obtain the highest surge level, are as follows:[2]

Central Pressure Index (CPI)	26.70 in. Hg
Asymptotic Pressure	31.25 in. Hg
Radius of Maximum Wind (R)	24 N.M.
Forward Translational Speed (T)	20 Knots
Maximum Wind Speed (V_x)	149.8 mph
Astronomical Tide	4.3 ft.

The maximum storm tide level computed from the above parameters is at elevation 117.6 feet (MLW is at elevation 88.0). This determination considered the topography of the site along the approach path and the critical section shown on Figure 2-24. The maximum storm tide also considered a two-foot reduction due to the effects of backwater storage resulting from the extensive flooding of the surrounding countryside some five hours prior to the peak of the surge hydrograph and runoff into peripheral areas not directly affected by the hurricane surge.[2] The site in this extreme circumstance becomes analogous to a small island in a mountain of water due to the absence of a shore barrier rising to elevation 30. The 30-foot land contour (based on the USGS datum where sea level is 0 feet) is located about 6 nautical miles inland from the site.

The traverse of the wave approaching train is across a reach of natural ground about one mile wide, then over 600 feet of compacted fill, (elev. 98) and against an embankment slope (berm) rising to a top elevation of 118.5 feet, which protects the plant. The effects of breaking waves and wave runup on the embankment slope were determined from a model test conducted in a wave tank at the University of Florida, as discussed in the answer to Question 2.1.5.

2.1.2 Question

Estimate the critical significant and maximum (one percent) wave heights and resulting runup on safety related facilities in the spectrum of waves which can be associated with the PMH.

Answer

Figure 2-24A summarizes the relationships between the still water level, wind generated wave height, breaking wave height, and the wave runup elevation found from the model tests. The maximum (highest 1 percent of the waves) and significant (highest one-third) wave heights were determined by wind vectors normal to the coast, along the traverse, and were calculated using the storm surge computer output.

Unlike the spectrum of wind generated waves, the model tests were conducted with essentially uniform height waves. The curves of maximum and median runup were developed from the total stillwater level curve using Figure 5 of the April 1969 report of the model tests.[1c] The embankment profile giving these results corresponds to the stepped slope that will be constructed at Crystal River Nuclear Station with the exception that the steps were continued above elevation 118.5 to prevent overtopping. The elevation of the water overtopping the elevation 118.5 embankment will be somewhat less than the elevation of the runup on the test slope.

On Figure 2-24A, the intersection of the breaking wave curve and the generated wave height curves show that, with the highest one percent of the waves breaking, the maximum height of the waves that can travel across the fill approaching the plant is 16.5 feet. With the highest 33 percent of the waves breaking, the maximum height of the waves that can reach the protective embankment without breaking are 14.7 feet. When the height of the waves reaching the protective embankment become 10 to 15 feet, the range of wave heights found from the model tests to cause the greatest runup, the results of the model tests become applicable. Until that time the wind generated waves would produce less runup than indicated; the runup is therefore shown as a dotted line. Employing the conservative assumption that the wave height in the model tests was the "maximum" generated wave height (i.e., assuming that all of the waves attacking the embankment are "maximum" waves), Figure 2-24A shows that the model results become applicable at 23.2 hours after the center of the hurricane crosses the continental shelf. This is also the time of maximum still water level. Overtopping of the embankment by the maximum runup begins about hour 22.7 and continues until hour 24.3. In this period the maximum depth of still water at the safety class structures nearest the edge of the embankment (a distance of 100 feet) due to overtopping is estimated to be one foot. At locations along the plant embankment that are not exposed to direct wave attack, overtopping is not expected to occur. Water that does overtop the embankment on the windward side of the plant will drain off the embankment on the lee side.

2.1.3 Question

Document the ability of safety related structures to withstand the static and dynamic effects of the PMH and associated wave action without loss-of-function, and the ability of safety related equipment to operate during such an event.

Answer

The embankment on the South side of the plant must have adequate protection to withstand the dynamic forces of the maximum waves and the ensuing run-up for the Probable Maximum Hurricane. The usual type of protection for this condition would be an adequate thickness, of large size dumped riprap. Because of the absence of suitable riprap material in the area, the use of soil cement on the slopes will prevent erosion of the protective embankment.[1]

The soil to be utilized is crushed limestone, which when mixed with 270 lbs. of Type I cement per cubic yard of soil, is expected to have a minimum compressive strength of 2,000 pounds per square inch. The thickness of the soil cement layer is shown in Figure 2-24.

The mixed material will be spread in 8 inch loose layers and compacted at optimum moisture content to 6 inch compacted layers at approximately 95 percent of maximum density as determined by Proctor-type tests. The material will be placed so that four 6-inch lifts constitute a two foot lift, with a four foot horizontal step back to the next lift along the embankment slope. When completed, the soil cement paving will be covered with erodible material as shown on Figure 2-24. The erodible material will protect the slope from the effects of weathering. The soil cement will afford adequate protection from the waves generated by a PMH. The erodible soil cover will be replaced when necessary.

The material to be placed in the protective embankment will be Zone III material, which is a crushed, friable limerock, placed and compacted in accordance with Specifications for Embankment Construction, SP-5901. The material will be compacted to an average dry density equivalent to 98 percent of the maximum modified dry density with an allowable Relative Compaction variance of two percent.

Although the dynamic force of the waves will be dissipated by the protective slope, it is possible that much smaller waves will exist in the estimated one foot of water at the plant structures. To provide an additional margin of safety, the exposed safety related structures will be conservatively designed to withstand the static and dynamic effects of 1.9 foot waves travelling across 2.4 feet of still water on top of the embankment and striking the structures with runup on the vertical walls extending to elevation 124.0.

Various plant components will be protected from wave action as a result of embankment overtopping for a 1½ hour period following the peak tide of the PMH. Local protection will include the following facilities:

1. Protect building openings with concrete bulkheads or removable stoplogs in:

    a. Fire service buildings - 2 openings
    b. Turbine room - 5 openings
    c. Air shafts - 2 openings
    d. Auxiliary building - 3 openings
    e. Diesel generator building - 2 openings
    f. Equipment access hatch - 1 opening
    g. Water-tight seals
        1) Heat exchanger hatch
        2) Reactor building - 2 seals

2. Build a concrete water barrier up to elev. 124.5 approximately 2 feet from the Turbine Room wall. This barrier will extend from the main transformer toward the west and around to the air shaft on the west of the Turbine Room.

3. Raise walls around air shafts.

4. Replace concrete block walls with structural concrete in fire service building.

5. Raise vent pipes on diesel fuel tanks.

6. Provide drains and diesel powered dewatering pumps for stop-logged areas.

2.1.4 Question

Provide detailed computations of a PMH along a critical traverse which could produce the minimum water level at the site, and verify that sufficient pump suction would exist during such an event.

Answer

Past studies of minimum tide level included: 1) a review of extreme low tides that have been observed in the vicinity of the site during major hurricanes of record;[1a] 2) calculations of sustained hurricane wind speeds to produce a resultant setdown slope of about one foot per mile in the discharge canal;[1b] 3) calculation of maximum wind speeds for off-shore winds from hurricanes approaching the site from either the Gulf or the Atlantic coasts; and 4) calculation of the minimum water level required at the entrance to the intake canal for proper submergence of the nuclear service cooling water pumps in case of shutdown conditions.

The review of extreme low tides that have been associated with severe hurricanes in the area and estimates of minimum tides that could be produced by a PMH, established a figure of -4.7 feet (elevation 83.3) as low water at the site.

Calculations of sustained hurricane wind speeds at the site shoreline and at the western end of the eight mile long intake canal were based upon successive approximations to produce a resultant setdown slope of about one foot per mile in the canal. It was estimated that sustained off-shore hurricane wind speeds on the order of 110 mph at the shore, increasing to 115 mph at the western end of the canal, would be required to produce a resultant setdown slope of about one foot per mile in the canal, and a total setdown elevation of about nine feet below MLW (approximating plant datum 79 feet).[1b]

Calculations of off-shore wind speeds associated with a PMH approaching the site considered two hurricanes, each having a different mode of approach. One mode (Mode I) considered a Gulf hurricane approaching the site on a northeasterly track, where its off-shore winds will produce the maximum setdown condition, as shown on Figure 2-26. The second mode (Mode II) of approach considered a South Atlantic hurricane entering the east coast of Florida, as shown on Figure 2-27, and traversing the peninsula in about eight hours. Maximum wind speeds for each mode were calculated based upon procedures established in HUR 7-97.

For Mode I, the offshore winds will be produced by the left half of the maximum radius storm, and the velocity will be greatest with the storm of lowest forward speed. A minimum forward speed of four knots and attenuation of the storm intensity due to coastal effects produced an offshore wind speed of 97 mph.

The Mode II hurricane of maximum radius was assumed to enter the east coast at 29° N at a forward speed of 20 knots. The determination of wind speed at the site was predicated on the assumption that the storm weakened in crossing the state, losing forward speed, resulting in a weakening of the isovel field and a reduction in maximum wind speed. Assuming the storm becomes stationary at the site, the maximum off-shore wind speed at the site is 98.5 mph. If the forward speed is undiminished in crossing the state, the maximum off-shore wind speed is 111 mph.

The calculated wind speed for both Mode I and Mode II hurricanes was considered to be conservative considering the 110 to 115 mph velocity considerations previously established.[1b] Nevertheless, additional calculations were performed to establish the minimum permissible water level in the canal required for satisfactory operation of the nuclear service pumps. Minimum pump submergence requires a water surface elevation of 70'-10½" in the sump. Considering a maximum flow condition of 34,900 gpm, the low water elevation at the plant end of the intake canal is 73.7 feet. Conservative hydraulic losses in the canal establish a low water elevation eight miles out in the Gulf of 79.0 feet. It is therefore possible to satisfactorily operate the nuclear service pumps with a low water drawdown of about nine feet in the Gulf.

There are no established procedures available for a rigorous analysis for extreme low tides in open bodies of water due to hurricanes, as there are for an analysis of the on-shore surge. The lack of a vertical barrier, the required response of the water to a surface level decrease with time, and the effects of breaking waves, swell and along-shore flow and winds make the condition not susceptible to analysis. It is felt, however, that the ability to satisfactorily operate the NSS pumps during a maximum nine foot drawdown is conservative.

2.1.5 Question

Provide documentation of the model studies of wave runup such as illustrations showing the runup as a function of stillwater level and wave height.

Answer

The critical path of approach to the site from the south, crossing the intake canal and pump house, was duplicated in a wave tank model for Unit No. 3 using existing topography, where applicable, and final grading and construction contours and facilities. Wave tests using the criteria developed from the PMH tidal conditions were conducted by the Department of Coastal and Oceanographic Engineering of the University of Florida to determine the extent of wave run-up on the protective embankment along the south side of the plant.(1c) Since the model accurately represented the characteristics of topography, structures and the protective embankment, the test results include the local effects unique to this site which are not reflected in generalized analytical relationships, but which increase in importance as the waves approach the plant.

The section tested on the approach path includes, progressively: a storage area at elevation 98, the intake canal with bottom elevation 67, the intake structure at top elevation 100, a 30-foot wide embankment behind the intake at top elevation 98, an embankment sloped at 2:1 from elevation 98 to 112.5 to a 4[illegible] foot wide berm at this elevation, then a 2:1 embankment to elevation 118.5 which is grade elevation around the plant. The main building is set back about 100 feet from the top edge of the embankment.

Before the runup tests, experiments were conducted to determine the most adverse test conditions, i.e., the combination of wave period and height which caused the maximum run-up over the tidal range of interest. From these pre-test experiments and periodic checks during the tests, it was found that the <u>maximum</u> runup occurred with a prototype wave period of 5.4 seconds, and prototype wave amplitudes of 10 to 15 feet, the specific height depending on the test case. The wave action testing was conducted at prototype tide levels from elevation 104 to 120 feet in two foot increments.

Initial tests were conducted on a smooth slope embankment, to simulate the run-up effects on erodible fill material overlying a stepped protective paving of soils-cement, having a minimum horizontal thickness of 10 feet. Subsequent tests simulated the run-up effects against the stepped embankment. The test results indicated an overtopping of a smooth slope below tide levels of 110 feet, with occasional overtopping starting at a tide level of 112 feet, and becoming continuous above elevation 114. Tests on the stepped slope revealed no overtopping below tide elevation 112 feet, slight overtopping at 114, becoming continuous above elevation 116 feet.

Considering the conservative assumptions including the maximum wave train approaching the site at right angles to the direction of the PMH winds, and the adverse combination of wave amplitude and period from the model tests, it has been demonstrated that the plant can be amply protected from the effects of a PMH producing a maximum tide elevation of 117.6 feet.

2.1.6 Question

Determine whether wave action within the intake and discharge canals for the PMH can have an adverse effect on safety related structures and equipment.

Answer

The only safety related structures associated with the intake and discharge canals are the Nuclear Services Intake and Outfall

Structures. The Nuclear Service Pumps are located within the Auxiliary Building and are not exposed to wave attack, nor are the buried Nuclear Service pipelines. The intake lines take water from the inundated intake canal at elevation 69.5 and serve the Nuclear Services Pumps, which have adequate submergence at minimum low tide. The discharge lines convey water to the outfall structure at elevation 80, and are always submerged at the exit by the seal pit weir maintaining a water surface above elevation 88.

At the peak tide of the PMH approximately 20 feet of water will cover the site, which is generally at elevation 98, completely inundating the plant canals and all other topographic features. Wave action observed during the model tests indicate that waves approaching the plant from the south in tide levels below elevation 108 broke heaviest over an elevated bank south of the intake canal, which is about 600 feet in breadth at elevation 98. Relatively little breaking was noted past the south bank toward the plant. For higher tide levels, up to elevation 120, the most intense wave breaking occurred immediately before, or upon reaching the intermediate berm between the two sloping faces of the embankment. Protection of the intake structures is provided by a cutoff wall extending downward into competent caprock at the entrance to the structures.

As stated in the Answer to Question 2.1.1, the concept of maximum wave action occurring in a northerly direction (almost perpendicular to the hurricane winds which approach the site in an easterly direction) is considered to be a conservative assumption for the maximum surge condition. If maximum waves are considered to approach the plant in the direction of the hurricane track, they would enter the site generally along the alignment of the canals. In this case the Nuclear Services Intake is afforded protection by the circulating water intake structure, which is recessed within and below the north slope of the intake canal, and the general plant area is sheltered by Units 1 and 2. The discharge structure is completely submerged and is also recessed within and below the south slope of the discharge canal.

For either direction of wave approach, all safety related structures are adequately protected and are designed to withstand the forces associated with maximum wave action.

REFERENCES

(1) Gilbert Associates, Inc., Report No. 1650, Plant Protection Against Hurricane Wave Action, Revised April 24, 1969.

(1a) R. O. Eaton, Supplemental Flood Studies for Crystal River Nuclear Power Plant, (considering ESSA Memorandum HUR 7-97), November 1968.

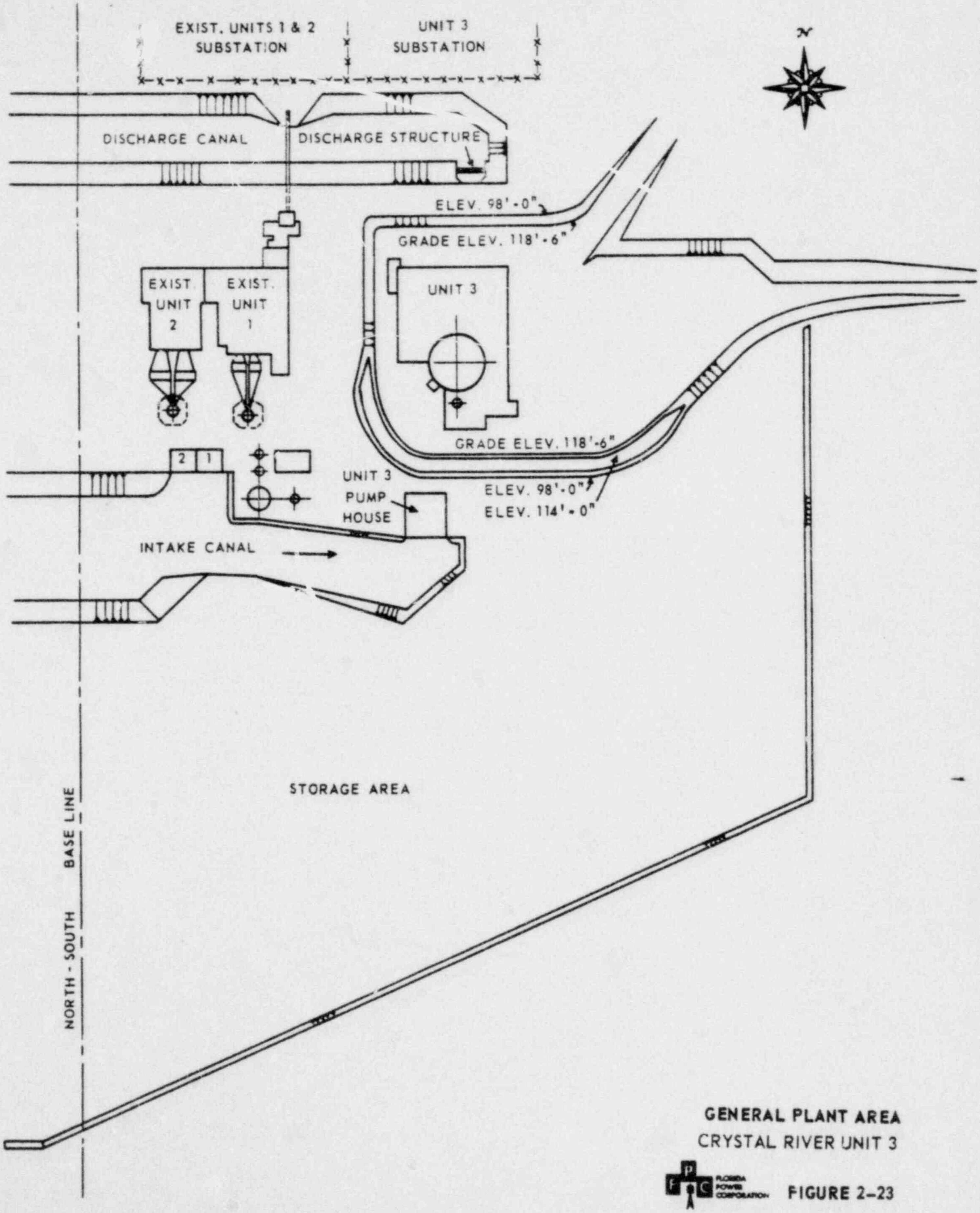
(1b) R. O. Eaton, Wind Speed Estimates for Low Tide Considerations in Barge Canal, Crystal River Nuclear Power Site, January 1969.

(1c) Report on Model Tests to Determine Extreme Run-up at Florida Power Corporation, Crystal River Site, Department of Coastal and Oceanographic Engineering, Florida Engineering and Industrial Experiment Station, University of Florida, April 1969.

(2) Dames & Moore, Report on Hurricane Study, Crystal River Nuclear Station, Crystal River, Florida, for Florida Power Corporation, October 16, 1972.

(3) Gilbert Associates, Inc., Report No. 1773, Hurricane Study, Crystal River Unit No. 3, November 10, 1972.

LIST OF FIGURES

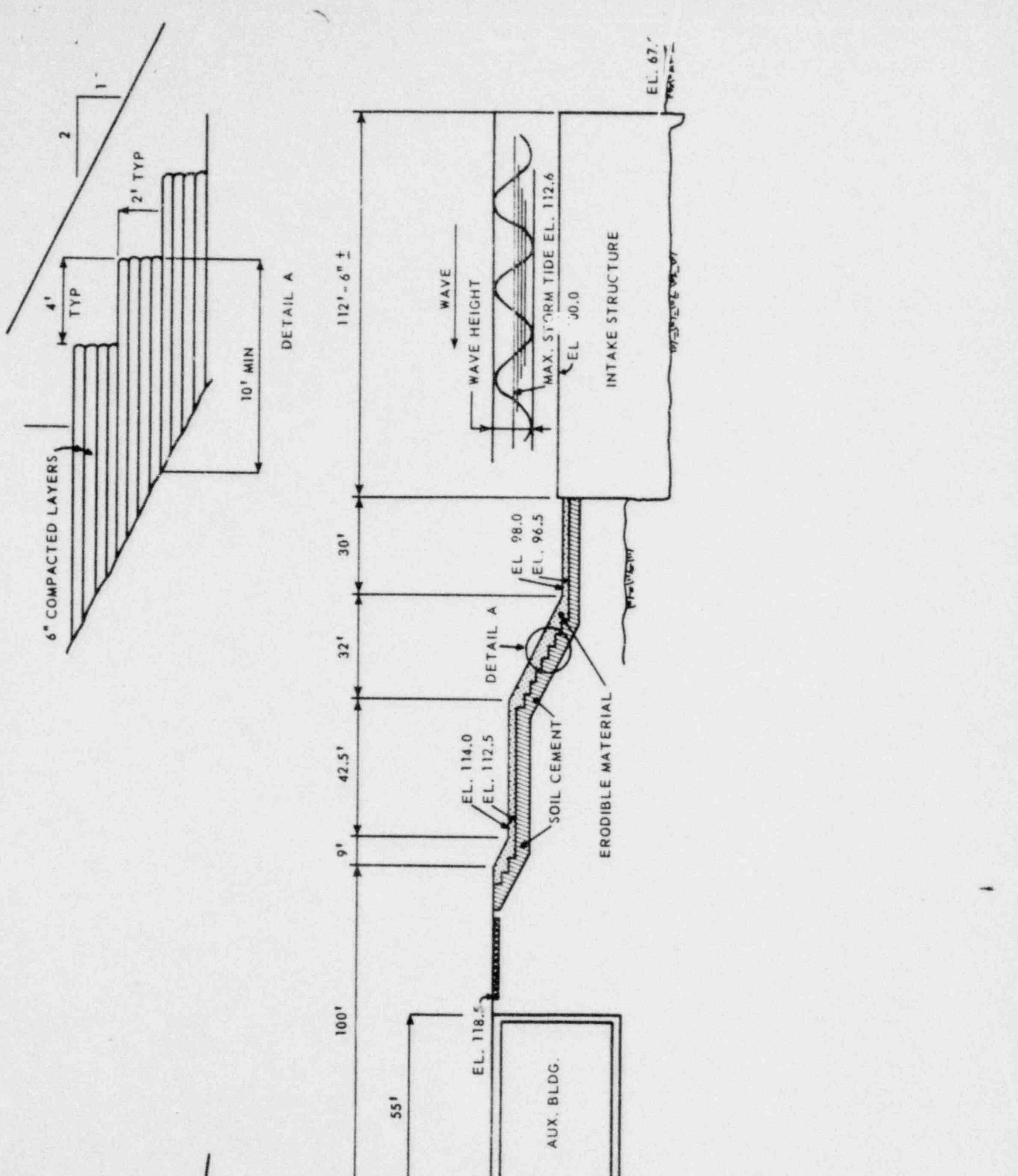


GENERAL PLANT AREA

CRYSTAL RIVER UNIT 3

FLORIDA POWER CORPORATION

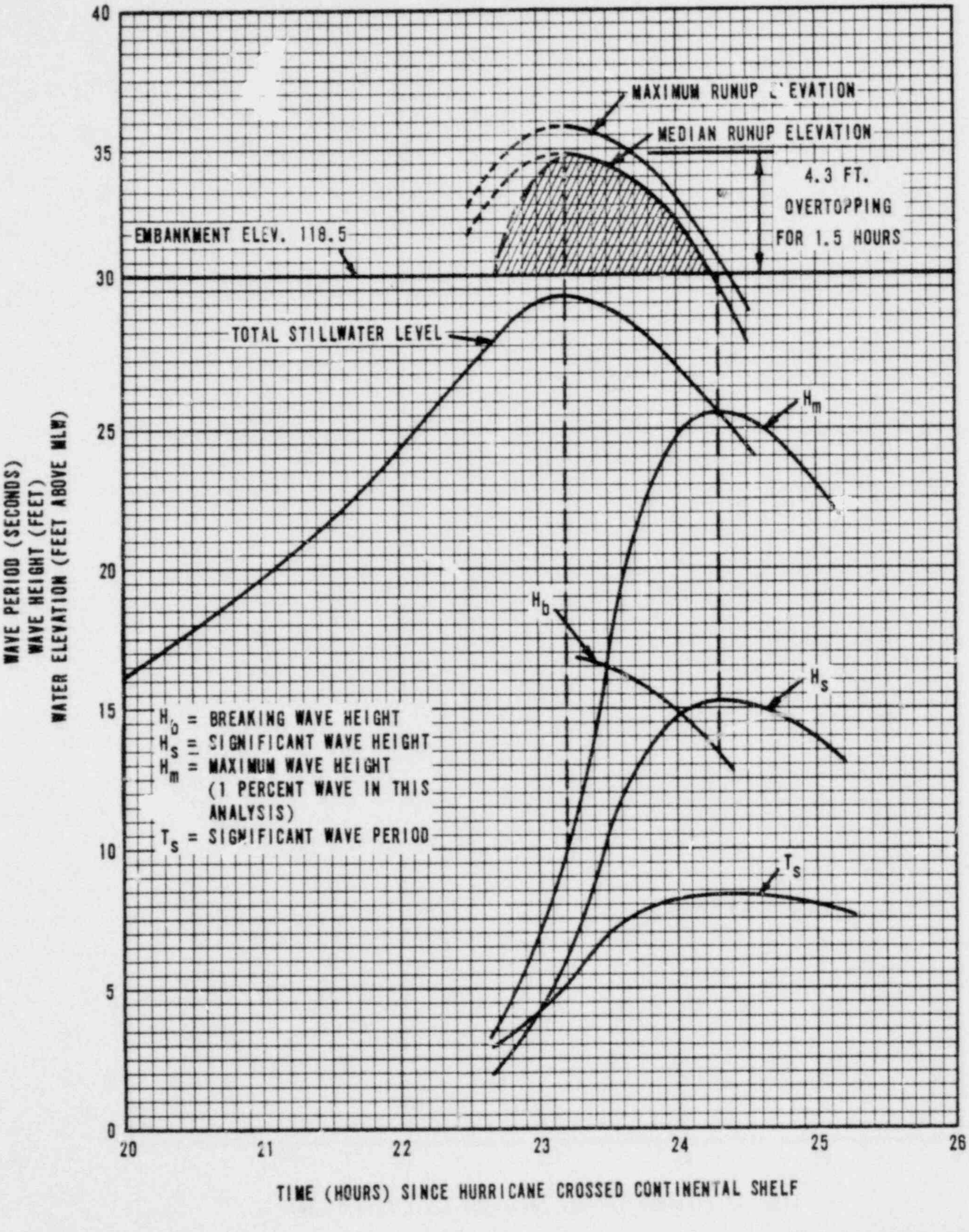
FIGURE 2-23



WAVE ACTION STUDY,
SECTION OF MAXIMUM WAVE ATTACK
CRYSTAL RIVER UNIT 3

FLORIDA POWER CORPORATION

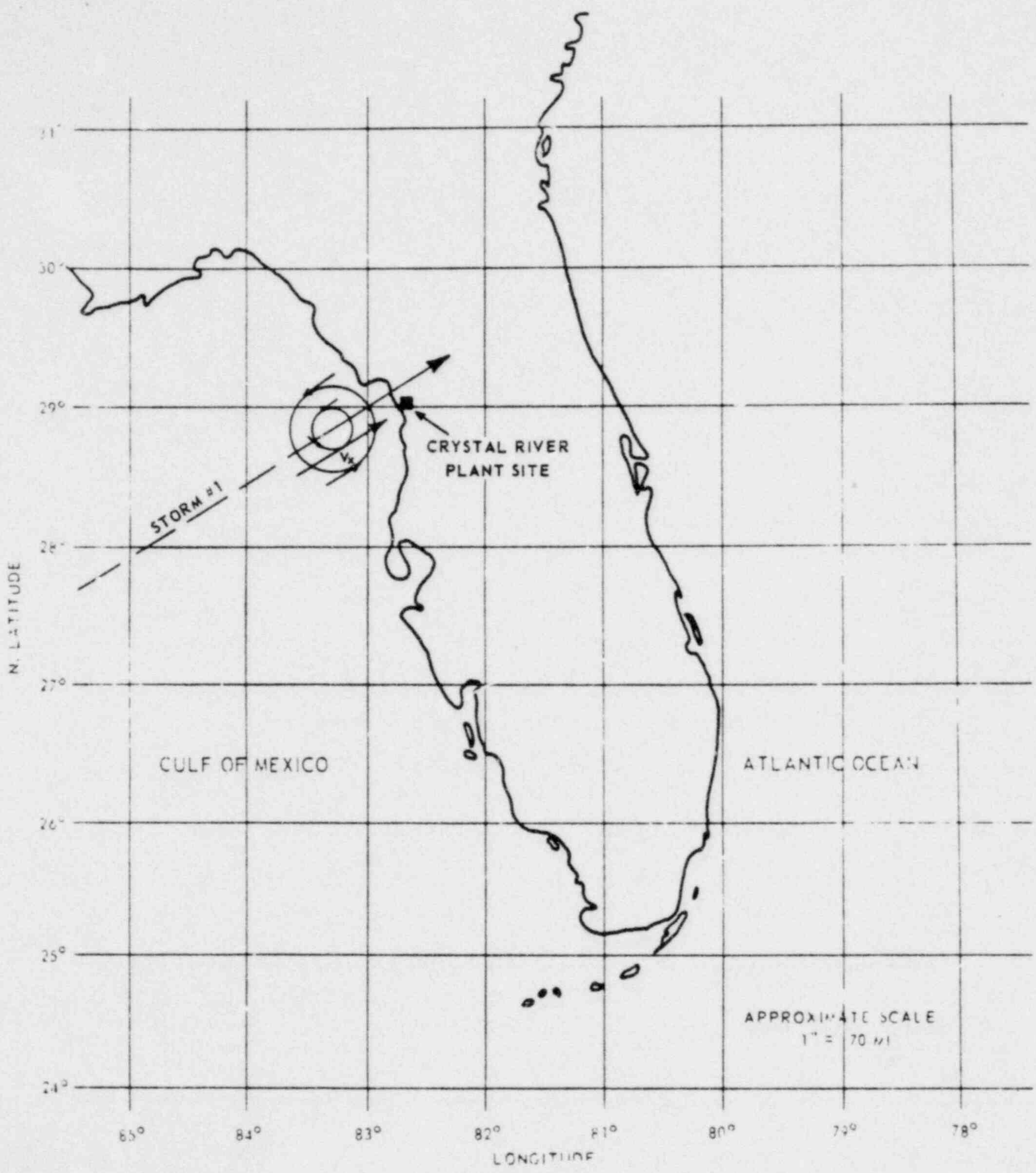
FIGURE 2-24



DESIGN WAVES AND WATER LEVELS VS. TIME

CRYSTAL RIVER UNIT 3

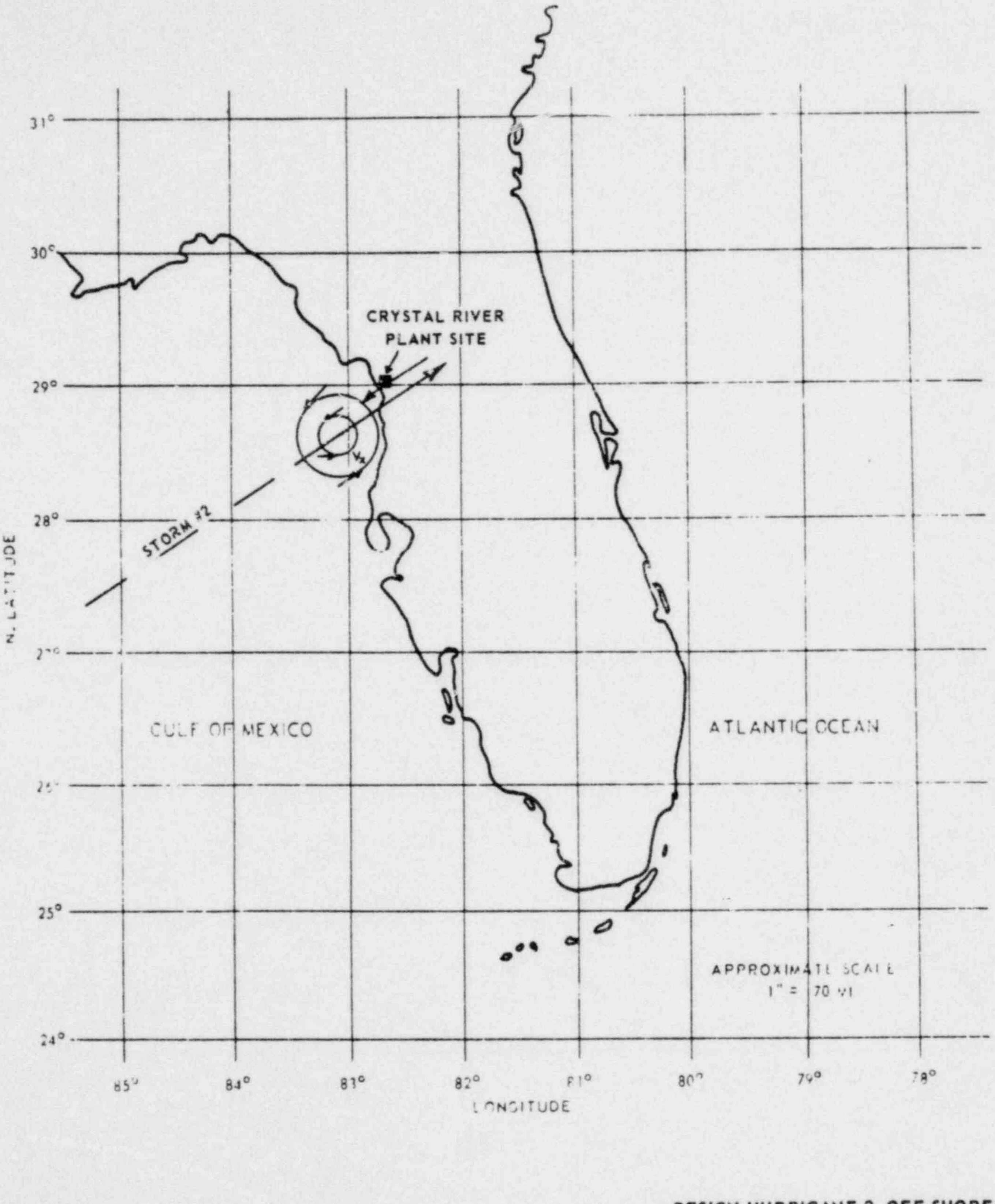
FLORIDA POWER CORPORATION **FIGURE 2-24A**



DESIGN HURRICANE 1, ON-SHORE WINDS
CRYSTAL RIVER UNIT 3

FLORIDA POWER CORPORATION

FIGURE 2-25



DESIGN HURRICANE 2, OFF-SHORE WINDS
CRYSTAL RIVER UNIT 3

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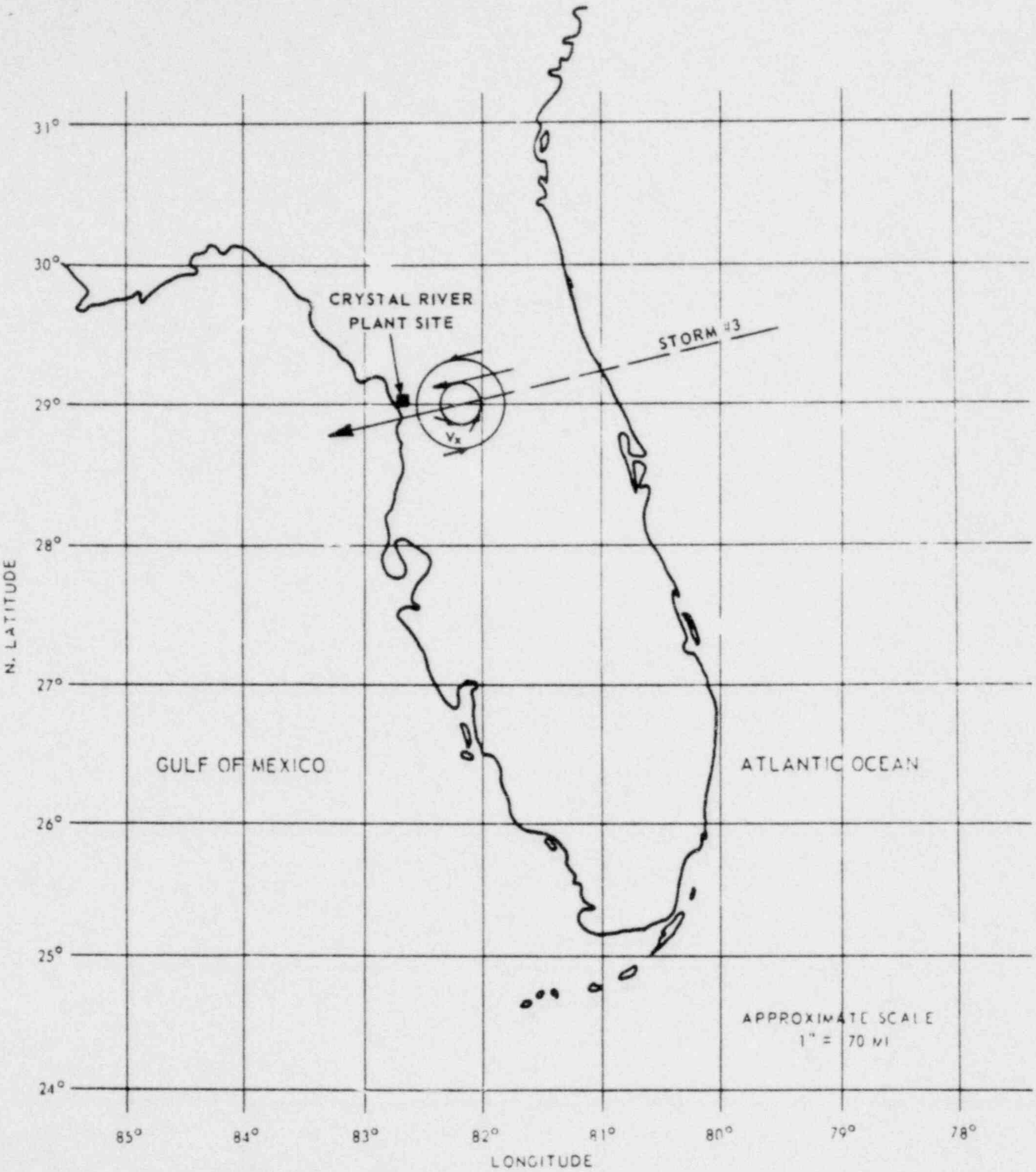
FIGURE 2–26



DESIGN HURRICANE 3, OFF-SHORE WINDS
CRYSTAL RIVER UNIT 3

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FIGURE 2–27