APPENDIX A

TECHNICAL EVALUATION REPORT

HYDROLOGICAL CONSIDERATIONS (SEP, II-3A, B, B.1, C; III-3B)

CONNECTICUT YANKEE ATOMIC POWER COMPANY
HADDAM NECK PLANT

NRC DOCKET NO. 50-213

NRC TAC NO. 41362, 41351, 41340, 41329

NRC CONTRACT NO. NRC-03-79-118

FRC PROJECT C5257

FRC ASSIGNMENT 16

FRC TASK 425

Prepared by

Franklin Research Center
20th and Race Street
Philadelphia, PA 19103

FRC Group Leader: J. S. Scherrer

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

Lead NRC Engineer: G. Staley

June 25, 1982
Revised August 27, 1982

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

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Prepared by:	Reviewed by:	Approved by:
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Date: 8/6/82	Date: 8/6/82	Date: 8/6/82

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CONTENTS

CONTENTS (Cont.)

LIST OF FIGURES

LIST OF TABLES

FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

Mr. J. S. Scherrer, Ms. S. Roberts, Mr. W. Erickson, Mr. F. Vosbury, and Mr. G. J. Overbeck contributed to the technical preparation of this report through a subcontract with WESTEC Services, Inc.

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

This report evaluates the Haddam Neck Nuclear Power Plant for conformance with current safety standards of the U.S. Nuclear Regulatory Commission with respect to (NRC) Systematic Evaluation Program (SEP) Topics II-3.A (Hydrologic Description), II-3.B (Flooding Potential and Protection Requirements), II-3.B.1 (Capability of Operating Plants to Cope with Design Basis Flooding Conditions), II-3.C (Safety-Related Water Supply - Ultimate Heat Sink), and III-3.B (Structural and Other Consequences of Failure of Underdrain Systems). This technical evaluation report (TER) includes independent analyses as needed to identify various hydrologic conditions. The NRC is reviewing other safety topics within the SEP and intends to coordinate an integrated assessment of plant safety after completion of the review of all applicable safety topics and design basis events (DBEs).

1.2 GENERIC BACKGROUND

The SEP was established to evaluate the safety of 11 of the older nuclear power plants. An important element of the program is the evaluation of the plants against current licensing criteria with respect to 137 selected topics, several of which relate to hydrologic assessments of the site.

In a letter dated January 14, 1981 [1], the NRC agreed to the SEP Owners Group's proposed redirection of the SEP, whereby each licensee would submit evaluations of 60% of the SEP topics in time for a review by the NRC staff to be completed by June 1981. Evaluations of the topics not selected by each licensee were the NRC's responsibility.

1.3 PLANT-SPECIFIC BACKGROUND

As part of the agreement between the NRC and the SEP Owners Group, the Licensee, Connecticut Yankee Atomic Power Company (CYAPCO), elected to submit evaluations of SEP Topics II-3.A, II-3.B, II-3.B.1, and II-3.C.

On December 14, 1981, CYAPCO submitted its evaluations of SEP Topics II-3.A [2], II-3.B [3], and II-3.C [4].

In response to NRC questions, the Licensee submitted additional information on SEP Topics II-3.B [5, 6], II-3.A and II-3.C [7], and III-3.B [8].

This TER on hydrologic influences at the Haddam Neck plant reviews the Licensee's evaulations of the four selected SEP Topics and, at the NRC's request, includes an independent review of SEP Topic III-3.B, Failure of Underdrain Systems. The Haddam Neck plant is assessed against the criteria currently used by the NRC for licensing new facilities. CYAPCO will be instructed to inform the NRC whether the as-built facility differs from the licensing basis assumed in this assessment.

2. REVIEW CRITERIA

The reference criteria used for all the hydrology topics were based on the Code of Federal Regulations, Title 10, Part 50 (10CFR50), Appendix A, General Design Criteria, Overall Requirements, Criterion 2, entitled "Design Bases for Protection Against Natural Phenomena." Specific topic review criteria were taken from the following documents:

Standard Review Plan (SRP) [9], Sections

- 2.4.1 Hydrologic Description
- 2.4.2 Floods
- 2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers
- 2.4.4 Potential Dam Failures
- 2.4.5 Probable Maximum Surge and Seiche Flooding
- 2.4.6 Probable Maximum Tsunami Flooding
- 2.4.7 Ice Effects
- 2.4.8 Cooling Water Canals and Reservoirs
- 2.4.9 Channel Diversions
- 2.4.10 Flooding Protection Requirements
- 2.4.11 Cooling Water Supply
- 2.4.12 Groundwater
- 2.4.14 Technical Specifications and Emergency Operation Requirements

Regulatory Guides

- 1.27 Ultimate Heat Sink for Nuclear Power Plants [10]
- 1.59 Design Basis Floods for Nuclear Power Plants [11]
- 1.102 Flood Protection for Nuclear Power Plants [12]
- 1.127 Inspection of Water Control Structures Associated with Nuclear Power Plants [13]
- 1.135 Normal Water Level and Discharge at Nuclear Power Plants [14]

American National Standards Institute N170-1976 [15]

Standards for Determining Design Basis Flooding at Power Reactor Sites.

3. TECHNICAL EVALUATION

3.1 HYDROLOGIC DESCRIPTION (TOPIC II-3.A)

3.1.1 Topic Background

Information pertaining to Systematic Evaluation Program (SEP) Topic II-3.A, Hydrologic Description, for Haddam Neck Plant was independently reviewed. The findings of the review, presented in this section, were derived from several sources, including NRC docketed information and staff files, communications with the U.S. Army Corps of Engineers, Licensee-provided information, the Federal Insurance Administration, the U.S. Geological Survey (USGS), and state and local contacts.

3.1.2 Topic Review Criteria

The current criteria that apply to the hydrologic description are Standard Review Plan, Section 2.4.1 [9] and ANSI N-170-1976 [15].

3.1.3 Evaluation

3.1.3.1 Introduction

Site Location and Facility

The site is located in the Town of Haddam, Middlesex County, Connecticut. The plant is situated on the east bank of the Connecticut river at a point 21 miles south-southeast of Hartford, Connecticut, and approximately 19.2 river miles north of Saybrook Breakwater Light. Figure 1 shows a general site location map.

The site area is approximately 525 acres located immediately upstream from the intersection of the Salmon and Connecticut Rivers. The general plant area was filled and graded from an initial elevation of approximately 12 ft to a final unfinished elevation of 21 ft. This grade is 1.5 ft above the highest recorded river level near the site. At the back, or east side, of the plant, wooded slopes rise steeply above the perpendicular rock cut.

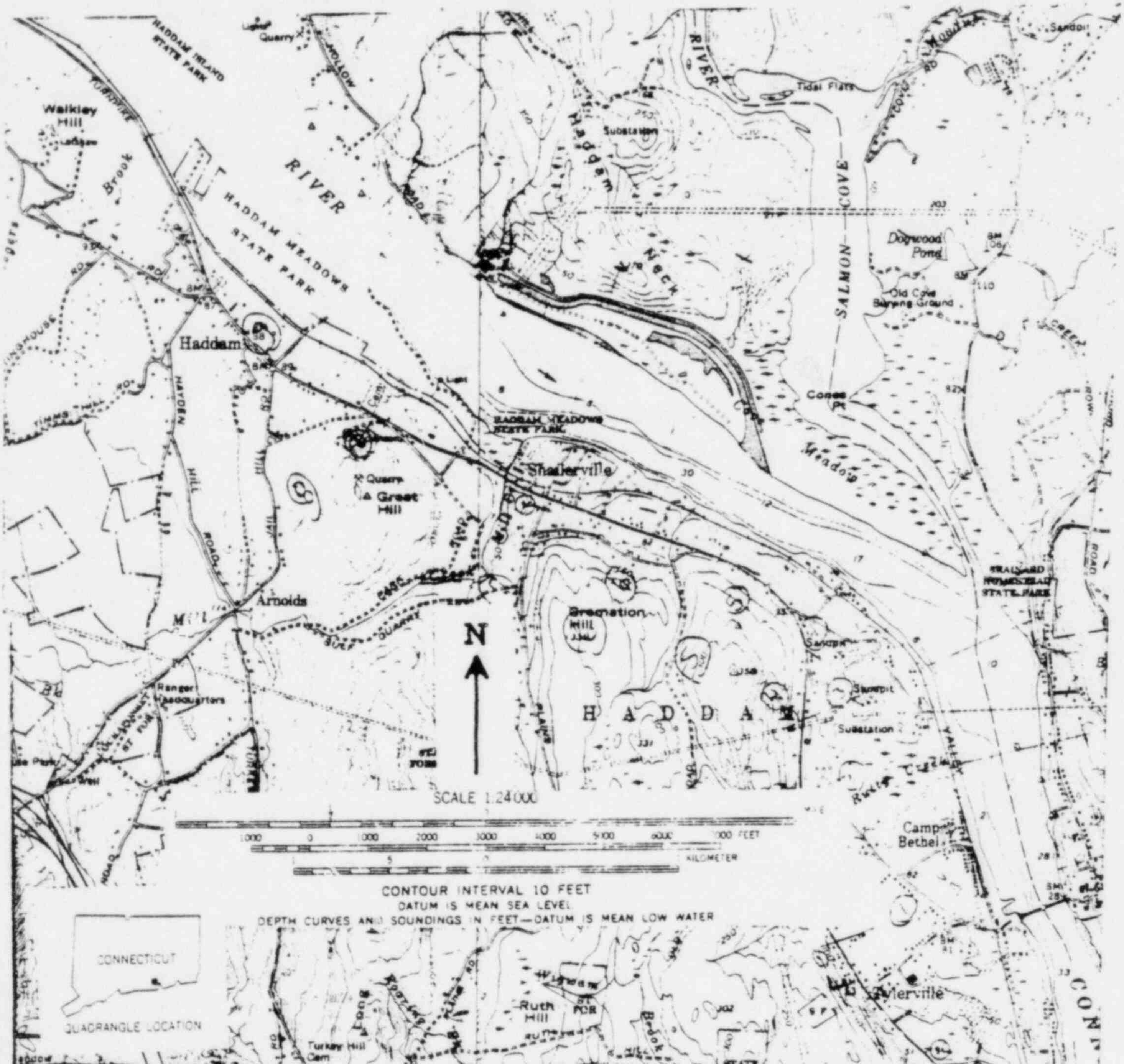


Figure 1. Haddam Neck Plant, General Location Map

Surface Water

The Connecticut River bounds the plant site on the southwest side as shown in Figure 2. Stream flow past the site originates entirely within the Connecticut River watershed, extending from the Canada-New Hampshire border to Long Island Sound. Figure 3 depicts a hydrologic basin map. The watershed width tapers from about 40 miles in northern Connecticut to about six miles at the Sound. The drainage divides are approximately 25 miles apart at the site. The river's source is 375 miles upstream, and the area drained upstream of the plant is approximately 10,900 square miles. The total Connecticut River drainage basin area is approximately 11,250 square miles.

Connecticut River stream flow data are available from the USGS station at Thompsonville, Connecticut. The average discharge for the 33-year period ending September 1961, with adjustment for storage and diversion, was 16,590 cfs. The maximum instantaneous discharge, which occurred on March 21, 1936, was 282,000 cfs at Thompsonville Gage. The corresponding stage elevation was 16.6 ft. Minimum daily flow was 1,060 cfs in 1949 and 1953. A USGS stream gage, Bodkin Rock Gage, is located approximately 28.6 river miles upstream from Saybrook Breakwater Light.

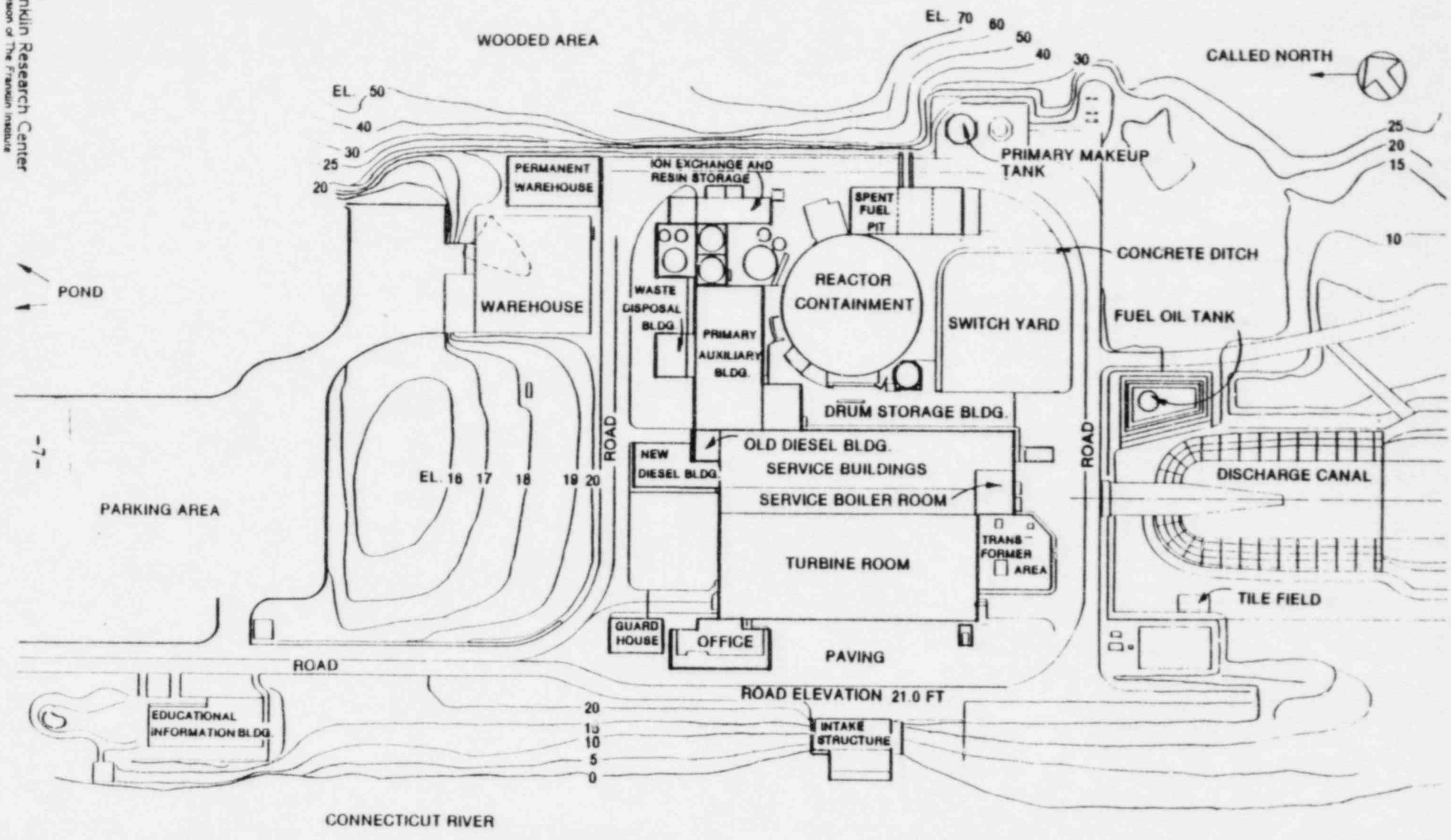
Flooding phenomena of concern at the Haddam Neck site are limited to runoff from precipitation events, such as local site area runoff and runoff from the Connecticut River Basin. Hurricane surges, seiches, and tsunamis do not apply to this site.

Groundwater

The Licensee presented the following information [16]:

"The ground-water conditions are approximately as follows:

The ground-water table general gradient slopes downward toward the river. Water in the saturated zone under the flood plain occurs as 'free' ground water or in a leaky aquifer between alluvium on top and bedrock below or both. Ground water on the hillsides occurs under a mixture of "perched" conditions and in minor quantities in cracks in the rocks. The unsaturated zone on the hillsides is relatively thin. The marshes were fed by the ground-water table (when it rose), by subsurface and overland runoff from the hill slopes, by tidal action and by the Salmon River at times of high discharge.



SCALE 5/8" = ~100'

Figure 2. Site Plan

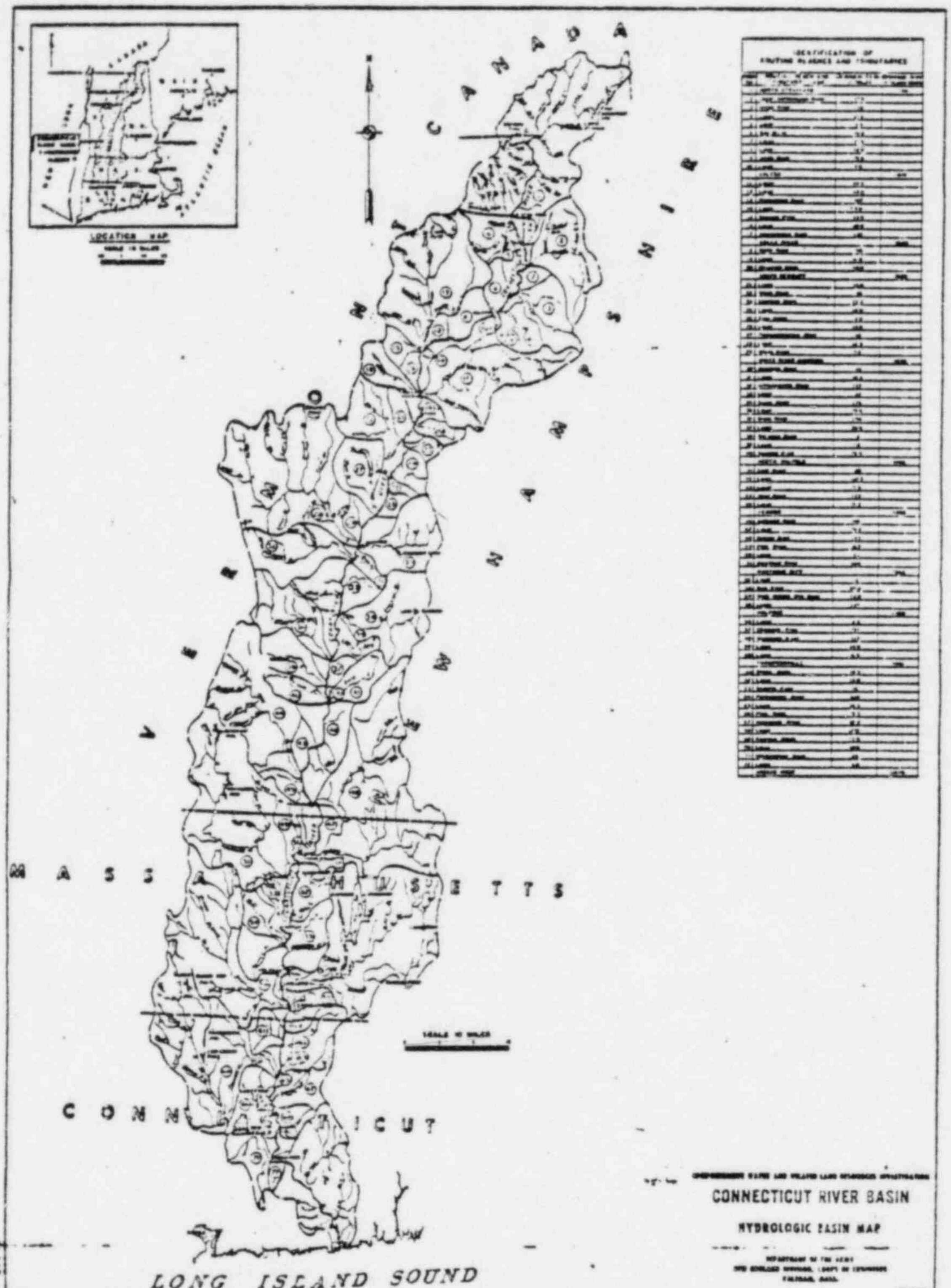


Figure 3. Hydrologic Basin Map, Connecticut River

The top layer of the flood plain consists of low permeability fine sands and silts. The available boring data show fine sands to depths as great as 70 ft below ground surface and sand and gravel to depths as great as 100 ft (the deepest penetration thus far). CANEL site test borings show gravel outwash deposits between the surface layer of alluvium and the bedrock. CANEL pumping tests indicate permeabilities for the outwash deposits to be 3,000 to 4,000 gal per day per square foot."

3.1.3.2 Design Bases

Table 1 shows the design bases of the Haddam Neck plant for several hydrologic events. Original design bases used in construction and design are tabulated in the left column. The center column lists the present design bases, or those proposed and under construction. Design bases according to current NRC criteria are given in the right column. The original design bases and the present or proposed design bases may or may not incorporate a safety factor.

Stream Flooding

The original site design basis flood level was based on a historical (1936) high water mark of the Connecticut River at elevation 19.5 ft msl. The yard grade was then established at 21 ft msl to add a measure of protection from the maximum historic flood. The river discharge during the maximum recorded flood at Bodkin Rock Gage was 267,500 cfs. The Haddam Neck plant design basis flood level is thus 19.5 ft msl.

Local Runoff

The Licensee has described the general philosophy of yard grading: to pitch all areas downward to the river or discharge canal, thus precluding the need for extensive storm drainage system. No changes since construction have altered the drainage system [3]. The Licensee has not presented the original rainfall discharge design basis used for designing yard storm sewers or pitched topography.

Table 1. Design Basis Elevations

Event	Elevation (ft msl) Original 1966	Present 1982	NRC Criteria 1982
1. Flooding			
From Connecticut River without dam failure	19.5 DBFL [6]	30.0 (proposed) [6]	39.5 (PMF) [11]
From local flooding (PMP)	Not considered	21.7 (limiting) [27,35]	21.0 ft (avg. grade) + approx. 11 inches = 21.9 (PMP) [11]
2. Groundwater			
Maximum level	Unknown	21.0 [2]	21.0 [9]
Normal high level	Unknown	Not specified	21.0 [9]
3. Rainfall Loading on Roofs	40 psf [2] (less than 7.7 inches of ponded water) [2]	40 psf [2] (less than 7.7 inches of ponded water) [2]	PMP protection
4. Low Water			
Connecticut River	-2.0 [36]	-2.0 [36]	-5.0 (approx.) [10]

Roof Drainage

The plant roof design incorporated specifications for a structural design live load of 40 psf (equals 7.7 inches of ponded water). However, the Licensee has not provided the original design basis rainfall rate for the roof drainage system design.

Groundwater

The Licensee has not identified the original design basis condition of the groundwater table at the Haddam Neck site; however, the Licensee did suggest [2] that groundwater loading conditions should be evaluated for groundwater rising "at or near grade." The Licensee further stated that the containment building design was such that failure of the pumps (of the underdrain system) would not overstress the structure during a simultaneous flood and earthquake. The design basis hydrostatic load for the screenwell house used a 20 ft msl water elevation [18]. The design basis hydrostatic load for other buildings at the site has not been specified.

Low Water in Connecticut River

The design basis low water level of the Connecticut River is -2.0 ft msl. The Connecticut River is the ultimate heat sink for the Haddam Neck plant reactor.

The original plant design bases are shown in Table 1. Some flood design protection elevations have been changed since construction of the plant. These new elevations are also shown as "present" figures in Table 1. For reference, elevations determined in accordance with present NRC licensing criteria are also presented.

3.1.4 Conclusion

For the purposes of this report, the design basis is adequately described, and adequate hydrologic description is provided.

3.2 FLOODING POTENTIAL AND PROTECTION REQUIREMENTS (TOPIC II-3.B)

3.2.1 Topic Background

Information pertaining to SEP Topic II-3.B for the Haddam Neck plant was independently reviewed. The findings, presented in this section, derived from several sources of information, including NRC docketed information and staff files, communications with the U.S. Army Corps of Engineers, Licensee-provided information, the Federal Insurance Administration, the USGS, the National Weather Service, and state and local contacts.

The purpose of this topic is to identify, under current licensing criteria, the plant and site design basis flood level resulting from all potential flood sources external to the plant and site. It includes the evaluation of submitted documentation and the determination of significant differences between the values of parameters used for design and construction of the plant and those derived in accordance with current licensing criteria. The evaluation addresses the effects of flood and other changes in hydrostatic and hydrodynamic loads on safety-related structures, systems, and equipment, and the adequacy of existing or proposed flood protection measures such as revetments, flood walls and doors, and emergency and administrative procedures.

In particular, this evaluation focuses on the following subjects:

- o flooding of streams and rivers
- o local flooding and site drainage
- o roof drainage
- o groundwater.

Regulatory Guides 1.59 [11] and 1.102 [12] were specifically cited by the NRC's Regulatory Requirements Review Committee for consideration in the backfitting of operating reactors. These guides are used to determine whether the facility design either complies with current criteria or presents equivalent alternatives. Deviations identified in this evaluation and the need for further action will be judged at a later time during an integrated assessment review.

3.2.2 Topic Review Criteria

The current references for reviewing flooding potential are:

- Standard Review Plan, Sections 2.4.2, 2.4.3, 2.4.5, 2.4.6, 2.4.7, 2.4.10, and 2.4.12 [9]
- Regulatory Guides 1.59 [11] and 1.102 [12]
- ANSI Standard N170-1976 [15].

3.2.3 Evaluation

3.2.3.1 Flood History

Considerable information was compiled during and immediately following the March 1936 flood. General elevations were 31.5 ft msl at Cromwell, 29 ft msl at Middletown, 28 ft msl at Bodkin Rock, 25 ft msl at Middle Haddam, 20 ft msl at Shailerville, and 18 ft msl at East Haddam Bridge. Flood heights of about 19.5 ft msl were experienced at the site.

Since 1936, the U.S. Army Corps of Engineers has constructed sixteen reservoirs having an aggregate storage capacity in excess of 500,000 acre-ft. Offsetting this increase in regulated flood control storage has been a reduction in channel storage due to urbanization, highway construction, and the construction of flood protection dikes on the flood plain.

The Licensee did not present a list and location of upstream dams whose failure may affect flood conditions at the site.

The Licensee has not noted experience with flooding of the site due to local runoff from storm precipitation.

3.2.3.2 Flooding of Streams and Rivers

The first consideration of this evaluation is the level of protection required for the Haddam Neck site under current licensing criteria, or the PMF. The second consideration is a description of the plant's present level of protection.

PMF Elevation Definition

Using Regulatory Guide 1.59 [11], the Licensee identified the PMF discharge as 900,000 cfs [3]. Independent evaluation confirmed that the discharge for the 10,900-square-mile drainage area above the plant [16] would be approximately 900,000 cfs using procedures in Regulatory Guide 1.59. The Licensee then chose to reestimate the figure using information supplied by the Army Corps of Engineers [19] and determined that the PMF discharge for the Connecticut River at the Haddam Neck site is 752,000 cfs. No consideration was shown for possible failure of upstream dams during the PMF event.

The elevation of PMF flood waters at the plant site was stated by the Licensee to be between 30 ft and 40 ft msl; no specific elevation was given. Independent evaluation of the stage associated with the Licensee-supplied PMF discharge (752,000 cfs) is 39.5 ft msl, and thus the minimum protection requirement by current criteria is 39.5 ft msl. See Table 2 for existing levels of protection.

The independent determination of the PMF elevation was accomplished by locating a cross section on the Connecticut River adjacent to the Haddam Neck Nuclear Generating Station (Figure 4), describing the geometric elements of the cross section (Figure 5), and plotting a stage vs. discharge curve (Figure 6) based on the normal depth computations for uniform flow using Manning's Equation [24]. The water surface elevation for the PMF was established by locating its position on the stage vs. discharge curve.

The cross section used was taken from USGS 7.5-minute topographic quadrangle maps [25]. The lateral dimensions were scaled from the maps and the vertical dimensions were read directly from the contour lines. Elevations below mean low water were assumed to be below 0.0 ft msl and did not reflect the mean tidal range of 2.5 ft reported on the maps.

In the computation of flow depth, the use of the invert slope was impossible since the reported slope is adverse in the vicinity of the plant. Manning's Equation requires a positive, or downstream, invert slope.

Table 2. Level of Flood Protection of Safety-Related Structures

Safety-Related Structure	Access	Numbers of Access	Elevation
Diesel Generator Building	North	1	13 in + 20.6 ft msl
	Internal	2	21.5 ft msl
Turbine Building	Doors	Multiple	21.5 ft
Primary Auxiliary Building*	East	2	21.5 ft msl
	RHR Pit Covers	2	23 ft msl
	South Access Door	1	21.5 ft msl
	West (Internal)	2	21.5 ft msl
	Resin Pit Covers	1	23 ft msl
	Service Tunnel	Multiple	
Screenwell	Doors	Multiple	21.5 ft
	Pumps		23.5 ft

*Interior flood protection is provided to elevation 23.5 ft msl.

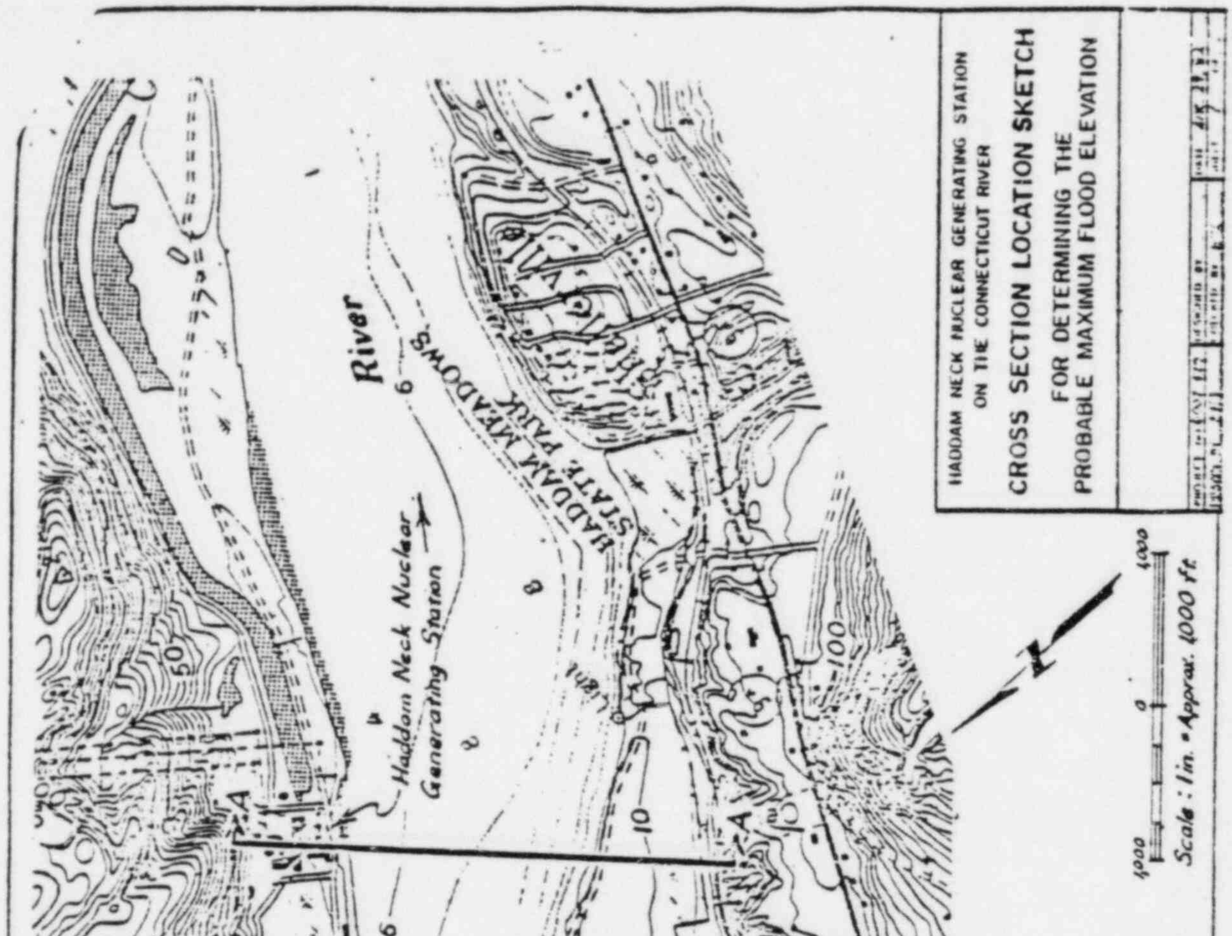


PLATE I

Figure 4. Cross Section Location Sketch

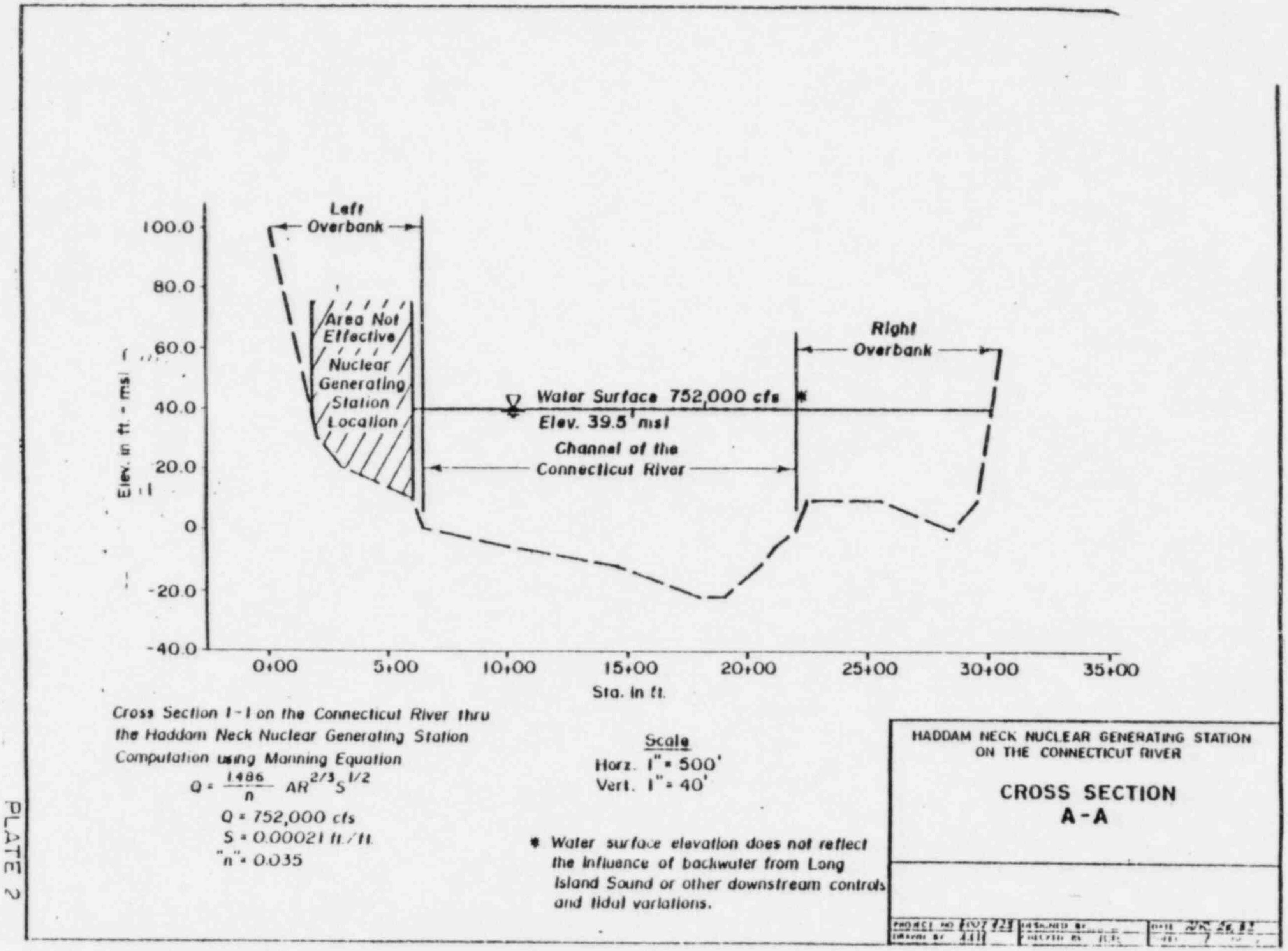


PLATE 2

Figure 5. Cross Section A-A

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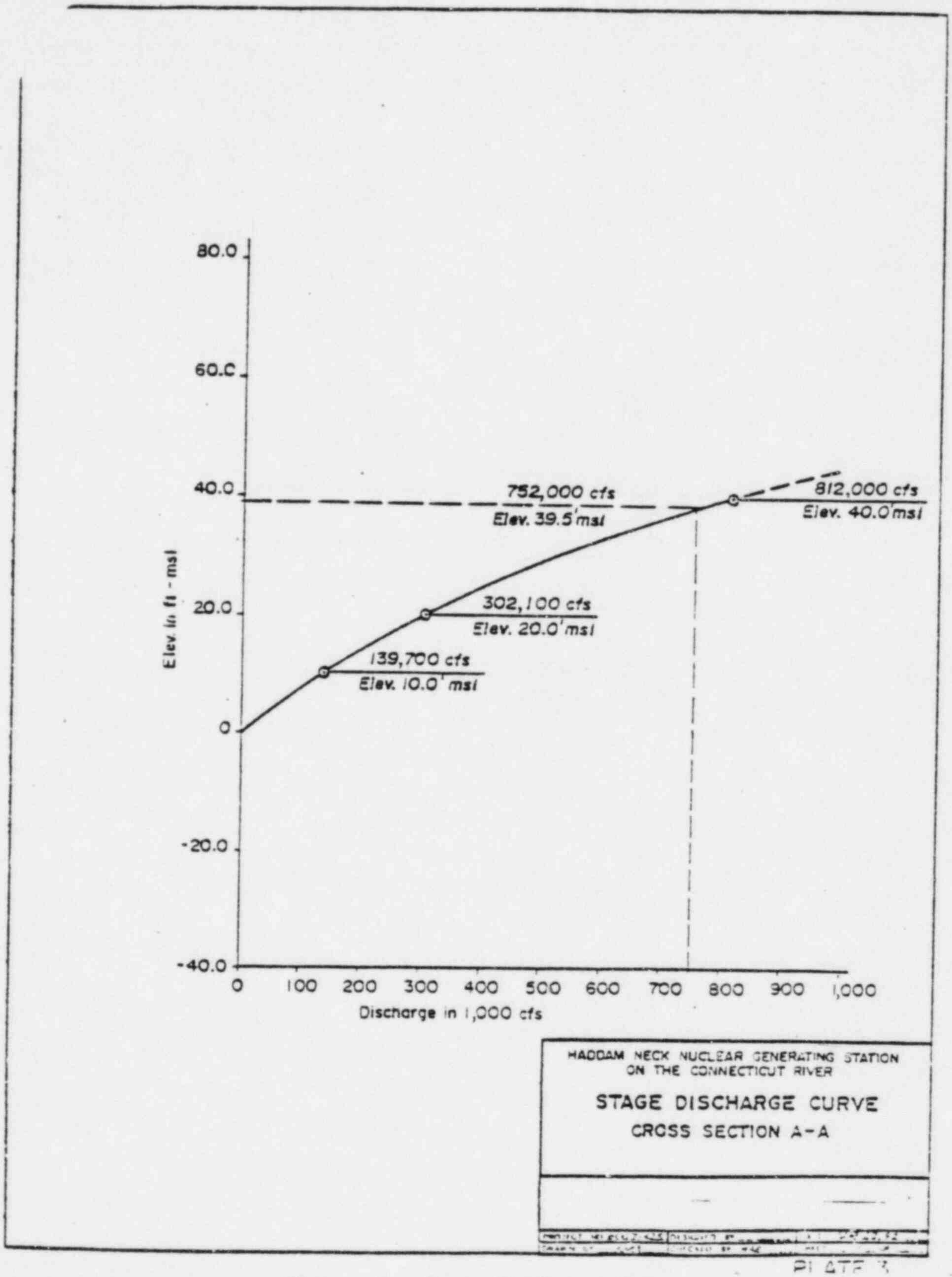

Figure 6. Stage Discharge Curve

The slope was derived from information contained in the U.S. Department of Housing and Urban Development, Federal Insurance Administration (FIA) Report [21]. Plate 01P shows a negative invert slope in the reach of the Connecticut River being studied and does not show enough data downstream to describe the conditions of the invert. Also shown on Plate 01P are backwater conditions from Long Island Sound which have a definite hydraulic impact on the water surface profile.

The FIA study describes the water surface profiles for four discharges in the Connecticut River having frequencies of 10, 50, 100, and 500 years. The discharges adjacent to the generating station for the frequencies are 120,900, 166,600, 186,700, and 230,800 cfs, respectively.

Profiles on plate 01P show definite backwater effects from Long Island Sound for the three lower discharges terminating approximately two miles downstream from the plant site. The upper profile, for a discharge of 230,000 cfs, shows backwater extending past the reach adjacent to the plant.

An average slope of 0.00021 ft/ft was determined from the three lower water surface profiles and assumed to be the invert slope for use in the Manning Equation.

An "n" value of 0.035 was selected to describe the friction and other loss values for use in the Manning Equation. This value falls within the middle range of values used in the FIA report [21], page 9, from 0.012 to 0.070 and is compatible with studies for depth vs. "n" relationships as reported by Chow [26], pages 103-114.

Three discharges for normal depth were computed for water surface elevations of 10.0, 20.0, and 40.0 ft msl. They are 139,700, 302,100 and 812,000 cfs, respectively. A stage vs. discharge curve was plotted from these computations.

The results of this analysis show that the stream discharge for an elevation of 40.0 ft msl is 777,800 cfs and that the elevation of the Licensee-provided PMF flood discharge of 752,000 cfs is 39.5 ft msl.

To test the accuracy of the curve, the 230,000 cfs water surface elevation of 17.2 ft msl, shown in the FIA study [21], was plotted on the curve and a confirmatory discharge of 240,000 cfs was read.

The U.S. Army Corps of Engineers Connecticut River Supplemental Study, 1973, page C-49, [20] assigns a value of 383,000 cfs at Bodkin Rock, the closest measuring point to Haddam Neck, to be the Standard Project Flood (SPF). The water surface profile associated with this discharge, on a plate showing river miles 4 to 28, has an elevation of approximately 23 ft at mile 19.2, which is the approximate location of the Haddam Neck station.

The stage discharge curve shows a value of approximately 360,000 cfs for the 23.0 ft elevation, which is within the range of the accuracy of the information provided for the study.

The stage vs. discharge curve solution provides the best estimate for the water surface elevation of the PMF for the limited information available. Based on the FIA report, downstream controls should modify the curve and it is believed that the modification will result in a higher water surface elevation for discharge above the SPF shown in the Corps report.

Both the Corps report [19] and the FIA study [21] consider the river to be free from clogging debris that should be expected in a flood of a PMF magnitude. Both show a bridge approximately 2.75 miles downstream from the plant site that is high enough to pass the SPF without being overtopped. These analyses show that the water surface will be above the bridge during the PMF.

This condition will probably cause a rise in the water surface not only at the bridge, but also upstream at the plant site. Further investigation to determine the extent of the increase in water surface would require significantly more information and is beyond the scope of this review.

It can be concluded that the minimum water surface elevation for a flow of 752,000 cfs will be approximately 40.0 ft msl based on normal depth conditions, and is probably higher based on other data. Backwater effects as shown on the FIA study [21], should raise the water surface at the plant significantly above the 40.0 ft level.

The effects of dam failure upstream of the Haddam Neck plant site are unknown. The definition of these effects is outside the scope of this report.

Flood Frequency

The Haddam Neck plant is not afforded protection from the PMF. Further information which serves to focus on the plant's present level of protection is provided here. The following evaluation presents the 10-, 50-, 100-, and 500-year flood elevations [21] at the Haddam Neck site, approximately 19.2 river miles from Saybrook Light. The tabulated data presented below include the Standard Project Flood stage as calculated by the Army Corps of Engineers [19]. For reference, yard grade at the Haddam Neck plant is 21 ft msl.

Description or Return Period (yr)	Stage (ft msl)	Discharge (cfs)
10	10.0	120,900
50	13.2	166,600
100	15.1	186,700
500	17.6	230,800
Plant Grade	21.0	323,200
SPF	23.2 [19]	383,000
Proposed Protection Level	30.0	510,000
PMF	39.5 (minimum)	752,000 (approx.)
PMF (Reg. Guide 1.59)	41.6 (approx.)	900,000

Local runoff flood protection adds a measure of protection from static water levels above plant grade resulting from floods of the Connecticut River. The service water pump motors and diesel building limiting flood elevations are approximately 23 ft msl. Therefore, the site and plant systems are protected from static water levels to an approximate standard project flood elevation of the Connecticut River. (To verify that the screenwell, and hence the service water pumps, are protected to the SPF elevation, a conclusive review of SEP Topic III-3.A, Effects of High Water Level on Structures must be performed with consideration for hydrodynamic loads.)

Hydrodynamic forces of the river at flood stage applied to the intake structure are presented to facilitate review of SEP Topic III-3.A. The average velocity of the river when it reaches elevation 30 ft msl would be 6.3 ft/sec, and the resulting average dynamic loading would be 77 lb/ft^2. When the flood stage rises to 40 ft msl, the average velocity would be 6.5 ft/sec and the water would exert an average dynamic force of 82 lb/ft^2 on the intake structure.

3.2.3.3 Local Flooding

Probable Maximum Precipitation

Current NRC criteria require that all plants be protected against effects of local probable maximum precipitation (PMP). The PMP for a 10-sq-mi area at Haddam, Connecticut for a duration of 6 hours is 24.42 in. The PMP for 12 hours is 27.06 in, and for 24 hours, 31.46 in [22]. The hourly increments of PMP are 11.97 in, 3.66 in, 2.93 in, 1.95 in, 2.40 in, and 1.71 in [23]. Normally, protection from the PMP must be provided using only hardened flood protection features. However, in some cases an emergency procedure specifying actions to supplement hardened protection may be considered. Such a procedure would be reviewed in SEP Topic II-3.B.1. No such procedure exists for the Haddam Neck plant.

Local Plant Flooding

1. Findings

The Licensee's study of local flooding potential was reviewed, and independent runoff analyses for this report were performed. The independent review revealed that runoff from the 140-acre watershed north of the plant yard during local PMP will not cause the water level in the pond adjacent to the northwest side of the plant yard (at the diesel generator building and primary auxiliary building [PAB]) to rise above 21 ft 5 in msl. Runoff from the south and southeast of the plant will run off directly to the discharge canal area and will not pond to any significant depth.

2. Analysis

The Licensee's analysis of local flooding [35] was studied. Several of the assumptions by the Licensee in its analysis were found not to be conservative, so further analysis was performed for this report. Other assumptions used by the Licensee were found to be appropriate and were retained in this analysis.

A relatively simplistic, but universally used analysis for quantity of runoff was made using the rational method. Input assumptions were derived, in part, from the Licensee's report. The drainage area provided by the Licensee, 140 acres, was found to be accurate. The coefficient of runoff "c", should, for extreme conservatism, be 1.0, instead of 0.8, which the Licensee used. The rainfall intensity, "i", should be 19.54 in/hr for the maximum 15-minute PMP, instead of 10 in/hr as determined by the Licensee.

This precipitation intensity value is more conservative but was determined by a method universally applicable to small drainage basins. The quantity of flow, Q, resulting from the rational method using revised data is 2760 cfs, in comparison with 1120 cfs calculated by the Licensee.

The surface flow would run off into the pond northwest of the plant yard, where it would be retained by the road, which has an elevation of 21.0 ft msl. Although a discharge pipe runs from the pond under the road, and to the river, its flow is likely to be constricted in flood conditions, and no credit was given for flow through it in the analysis. When the area behind the road is submerged, runoff would flow across a section of the road approximately 1500 ft long and into the Connecticut River. Using the peak quantity of flow of 2758.4 cfs, a slope of 0.04, and a section width of 1500 ft, normal depth calculations show a depth of flow of 5.2 inches across the road. The water surface elevation would be 21 ft 5.2 inches msl, or 21.43 ft msl. If flow is assumed to be critical, then the depth of flow is 5.66 inches. Under this scenario the total height of water is 21 ft 5.7 in msl, or 21.47 ft msl. Because the input assumptions were extremely conservative, the water surface elevations were rounded to 5 in above grade (21 ft plus 5 in or 21.4 ft msl).

3. Levels of Protection

The doorway entrance elevations are listed in Table 2 and are considered to be minimum levels of local flood protection. The lowest level of external protection listed by the Licensee [35] is at the north entrance to the diesel generator building. This entrance is protected by a curb and a step to a total of 13 in above the ground. Plant drawings show that the level of the curb top at this doorway is 21 ft 8 in, approximately 21.7 ft msl [27]. In addition to being the lowest level of local flood protection, it is also the lowest limiting elevation of protection from Connecticut River flooding (21.7 ft msl).

Several structures have lower doorways than the diesel generator building but are not considered to pose flood hazards as a result of these lower doorway elevations. Internal protection is provided to 21 ft 8 in in the diesel generator building, and 23.5 ft msl in the primary auxiliary building (PAB) [35]. The screenwall (pumphouse) door elevation is 21.5 ft msl, but limiting safety-related equipment is at 23.5 ft msl [33]. The turbine building is not listed as a safety-related building in the Licensee's submittal [35].

4. Conclusions

Independent analysis of the Haddam Neck site reveals that runoff from the 140-acre watershed during local PMP will not flood safety-related equipment or structures.

Rooftop Drainage

Current NRC criteria specify that roofs of safety-related structures be designed to withstand PMP with the roof drains fully blocked.

According to the Licensee, the design basis live load for roofs of plant structures is 40 psf [2]. The equivalent depth of ponded water is 7.7 in and thus ponded water not greater than 7.7 in on roofs of safety-related structures is the protection requirement. Unless the parapet height or the difference between high and low points of the roof exceeds 7.7 in, ponded water will not exceed the design basis live loading.

The Licensee has not specified a design basis roof drainage capacity. Some information was provided about roof drains, but many facts which are needed to compute flow rates are unknown [2]. For this reason only compliance with current criteria, ponding during PMP with roof drains fully blocked, will be presented.

PAB, Containment, and Control Room

The Licensee has stated that ponding could not occur on the roofs of the PAB, the control room, or the containment because direct runoff would take place [2, 7]. This statement was confirmed by a site visit [33] and a review of plant drawings [27].

Auxiliary Bay, Warehouse, and Diesel Generator Building

Elevations of high points or parapet heights and low point of the roofs provided by the Licensee show that rooftop high points on the auxiliary bay and the warehouse are 3-3/4 in and 7-1/2 in, respectively, above the low points, and that parapets on the diesel generator building are 6 in high [2, 27]. These roofs will not retain enough water to cause failure of the roofs.

Screenwell Building

The parapets around the edges of the screenwell building are 8 in high, according to the Licensee [2]. This roof could pond water in its low points approximately 4% above the design basis live loading, but no more. This is a minor deviation. However, the rainfall with 24-hour duration and 100-year frequency is 8 in, and exceeds the design basis loading on the screenwell roof by 4% [28].

Turbine Building

Review of plant drawings [27] showed that the parapet height on the turbine building roof is only 8 in above the low points of the roof, whereas the peak of the roof in the center is 14 ft 6 in above the low points of the roof. Water would pond to a depth of 8 in only on the east and west sides of the turbine building. Approximately 1 in away from the east and west parapets, the ponding would decrease to within the design basis. The maximum loading would be only 0.3 in, approximately 4%, above the design basis live load, and would occur only where the roof is directly supported by the walls. This is a minor deviation from NRC standards.

Service Building

The Licensee has indicated that the high points around the edges of the roof on the service building are 16 in above the low point of the roof [2]. This roof could be threatened by ponded water exceeding the design basis live loading. With roof drains fully blocked, the heaviest single hour of PMP would exceed the design basis live loading on the service building.

Summary

The Licensee has shown, and independent review confirms, that the diesel generator building, the PAB, the containment, the control room, and the auxiliary bay are not subject to ponding which would exceed the design basis live loading [2].

Independent review of information provided by the Licensee has shown that the design basis live loading for the screenwell and turbine building roofs can only be exceeded by 1.6 psf, or 4%. The design bases for these two roofs will be exceeded during a 100-year frequency, 24-hour rainfall if all roof drains are blocked, but only in the lowest areas of the roofs. This is a very small deviation from current NRC standards.

The service building roof design live loading could be exceeded by 108%. A precipitation event of only 100-year frequency would surpass the design loading. This loading vastly exceeds the loading acceptable by current NRC standards.

3.2.3.4 Groundwater

The Licensee has provided no information to indicate that the groundwater table cannot rise to plant grade. Well logs recorded for extended periods of time would be acceptable evidence, but none are available. Therefore, the Haddam Neck plant design basis and protection requirement for groundwater elevation should be considered plant grade, 21 ft msl.

It should be recognized that the PMF elevation is well above plant grade and that safety-related structures and systems will be exposed to hydrostatic (and hydrodynamic) loads well above the design basis groundwater elevation. Although a review of issues within SEP Topic III-3.A, Effects of High Water Level on Structures [17, 18], is outside the scope of this evaluation, it appears that plant structures have not been reviewed for structural adequacy under conditions of ponding above elevation 19.5 ft msl, the original design basis flood elevation.

3.2.4 Conclusion

The following conclusions pertaining to specific aspects of flood potential at the Haddam Neck site are presented.

- Flooding of the Connecticut River

Flood Potential

The Haddam Neck site design basis flood was 19.5 ft msl where finished plant grade* is 21.5 ft msl. The PMF of the Connecticut River has a minimum elevation of 39.5 ft msl and an SPF elevation of approximately 23.2 ft msl. Failure of upstream dams during PMF has not been addressed by the Licensee.

Protection Requirements

Flooding protection is available to a limiting elevation (diesel building) of 21 ft, 8 in msl. Hydrodynamic loads, and protection against them, have not been determined for water elevations above the design basis. SEP Topic III-3.A,

*Finished plant grade refers to entrance floor level.

Effects of High Water Level on Structures, should address combinations of hydrodynamic and hydrostatic loads to the standard project flood elevation and the PMF elevation.

Flood protection of the following buildings should be maintained to the SPF elevation (23.9 ft msl):

Turbine Building
Service Buildings
Diesel Buildings
Intake Structure
Primary Auxiliary Building
Fuel Oil Tank
Primary Water Tank
Borated Water Storage Tank
Reactor Containment
Auxiliary Feed Pump Room.

Flood protection to the PMF elevation (minimum 39.5 ft msl) should be maintained for the following buildings and structures:

Intake Structure
Primary Auxiliary Building
Reactor Containment
Diesel Building
Fuel Oil Tank.

o Local Flooding and Site Drainage

The Haddam Neck site is presently protected from local flooding due to a PMP event. The PMP results in sheet runoff to an elevation approximately 5 inches above grade (elevation 21.4 ft msl). This level is below the entrances to all safety-related structures and does not jeopardize normal plant operation.

o Roof Drainage

Assuming that the information provided by the Licensee is accurate, the roof design basis live load will be exceeded during rainfalls less frequent than the PMP for the service building. This report concludes that the roofs of all other buildings are sufficient to support rainfall resulting from the PMP event since loading is less than or very near design basis in all cases.

Suggested modifications which would protect the service building roof from rainfall loading would be a suitable inservice inspection program (similar to that specified in Regulatory Guide 1.127) verifying that the roof drains are functioning.

o Groundwater

Flood Potential

The probable maximum groundwater elevation for the Haddam Neck is controlled by the Connecticut River PMF elevation of 39.5 ft msl. The normal high groundwater elevation for use in combination with appropriate seismic conditions should be plant grade (21.0 ft msl), since the Licensee has provided no conclusive information which would enable any other conclusion.

Protection Requirements

The assessment of structural capability of structures under probable maximum groundwater loads, and seismic loads in combination with normal high groundwater level, should be reviewed under SEP Topic III-3.A, Effects of High Water Level on Structures.

3.3 CAPABILITY OF OPERATING PLANTS TO COPE WITH DESIGN BASIS FLOOD CONDITIONS (SEP Topic II-3.B.1)

3.3.1 Topic Background

Protection against postulated floods can be accomplished by implementing emergency procedures and technical specifications. The purpose of this evaluation is to judge the adequacy of the Haddam Neck plant emergency procedures to preclude flooding of safety-related equipment necessary for maintaining the safe operation and cooldown of the reactor system. This evaluation also addresses the plant technical specifications, if any, for flood control systems and procedures.

3.3.2 Topic Review Criteria

The current references for reviewing capability to cope with design basis flood are:

ANSI N170-1976 [15]

Regulatory Guide 1.59, "Design Basis Flood for Nuclear Power Plants" [11]

Standard Review Plan Sections 2.4.3, 2.4.4, 2.4.5, 2.4.7, 2.4.10, and 2.4.14 [9].

3.3.3 Evaluation

3.3.3.1 Emergency Procedures

Flood Protection

Regulatory Guide 1.59, Design Basis Floods for Nuclear Power Plants, states (in Regulatory Position 1) that safety-related structures, systems, and components identified in Regulatory Guide 1.29, Seismic Design Classification, must be designed to withstand and retain capability for cold shutdown and maintenance thereof under conditions resulting from the worst site-related flood probable at the nuclear power plant (i.e., PMF).

> "As an alternative to designing hardened protection [*] [passive and in-place structural provisions] for all safety-related structures, systems, and components as specified in Regulatory Position 1 above, it is permissible not to provide hardened protection for some of these features if:
>
> a. Sufficient warning time is shown to be available to shut the plant down and implement adequate emergency procedures;
>
> b. All safety-related structures, systems, and components identified in Regulatory Guide 1.29 are designed to withstand the flood conditions resulting from a Standard Project event with attendant wind-generated wave activity that may be produced by the worst winds of record and remain functional;
>
> c. [Not applicable.]
>
> d. In addition to paragraph 2.b above, at least those structures, systems, and components necessary for cold shutdown and maintenance thereof are designed with hardened protective features to remain functional while withstanding the entire range of flood conditions up to and including the worst site-related flood probable (e.g., PMF, seismically induced flood, hurricane, surge, seiche, heavy local precipitation) with coincident wind-generated wave action as discussed in Regulatory Position 1 above." [Underlining added for emphasis]

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*Hardened protection means structural provisions incorporated in the plant design that will protect safety-related structures, systems, and components from the static and dynamic effects of floods. In addition, each component of the protection must be passive and in place, as it is to be used for flood protection, during normal plant operation. Examples of the types of flood protection to be provided for nuclear power plants are contained in Regulatory Guide 1.102.

In the following evaluation, the plant's flood protection design will be compared to these regulatory criteria, and compliance with or deviation from this regulatory position will be identified.

Although Regulatory Guide 1.59 identifies systems and components necessary for shutdown, the approach taken under the SEP program is to evaluate the availability of protection for systems and components identified in multiple SEP Topics [29], as listed below.

The SEP review of the "safe shutdown" [29] subject encompassed all or parts of the following SEP topics, which are among those identified in the Nuclear Reactor Regulation document, "Report on the Systematic Evaluation of Operating Facilities:"

1. Residual Heat Removal (RHR) System Reliability (Topic V-10.B)

2. Requirements for Isolation of High and Low Pressure Systems (Topic V-11.A)

3. RHR Interlock Requirements (Topics V-11.B)

4. Systems Required for Safe Shutdown (Topic VII-3)

5. Station Service and Cooling Water Systems (Topic IX-3)

6. Auxiliary Feedwater System (Topic X).

The review included specific system, equipment, and procedural requirements for remaining in a hot shutdown condition (reactor shutdown in accordance with technical specifications, temperature between 200°F and 350°F) and for proceeding to a cold shutdown condition (temperature less than 200°F).

The present NRC regulatory position identified in Regulatory Guide 1.59, as it applies to the Haddam Neck plant, is as follows:

a. All equipment systems and components identified in Systems Needed For Safe Shutdown [29] and SEP Topic VII-3, Electrical, Instrumentation, and Control Feature of Systems Required for Safe Shutdown [30] should be passively protected to the Standard Project Flood since a reasonably lengthy period of time is available to effect a safe shutdown prior to the PMF.

b. All structures, systems, and components necessary for cold shutdown and maintenance thereof are to be designed with hardened protective features to remain functional throughout the PMF.

Licensee Emergency Procedure

The Haddam Neck site and the systems required to effect and maintain a safe shutdown are presently not protected to the PMF elevation (approximately 40 ft msl). The lowest level of external protection listed by the Licensee [35] is at the north entrance to the diesel generator building. This entrance is protected by a curb and a step to a total of 13 inches above the ground. Plant drawings show that the level of the curb top at this doorway is 21 ft 8 in, approximately 21.7 ft [27]. Therefore, the lowest limiting elevation of protection from Connecticut River flooding is 21.7 ft msl. The SPF elevation as determined by the Army Corps of Engineers [19] is approximately 23.2 ft msl.

The function of a flood emergency procedure is to provide "active" flood protection when an impending flood is predicted. The Licensee has submitted a flood emergency procedure under SEP Topic II-3.B.1 [32] whose function is to add protection to elevation 30 ft msl, approximately 10 ft below the PMF elevation.

The purpose of the following evaluation is to assess the level of protection offered by the emergency procedure as compared with the previously mentioned regulatory position. Two aspects will be discussed. First, the structural aspects of the flood protection plan will be addressed. Secondly, the ability of protected systems to effect and maintain a safe shutdown will be evaluated.

Structural Protection

Regulatory Guide 1.102 [12] states that:

"Temporary flood barriers, such as sandbags, plastic sheeting, portable panels, etc., which must be installed prior to the advent of the DBFL, are not acceptable for issuance of a construction permit. However, unusual circumstances could arise after construction that would warrant consideration of such barriers."

The type of protective devices proposed by the Licensee for protection against a Connecticut River flood (watertight hatch covers and watertight, swinging, bolt-down door covers) can be interpreted as "hardened" protection since these devices will nearly always be in place, can be positioned in the amount of time available after flood warning, and conform to the position identified in Regulatory Guide 1.102. Figure 7, Flood Protection Location Plan, shows the location of these flood protection features.

The proposed flood berm to be built around the fuel storage tank while flooding is in progress is not, however, hardened protection. Protection for this tank should be "hardened" and should be available before the occurrence of a flood.

The Licensee proposes to build a structure to contain stoplogs as a barrier to flood waters at the entrance to the emergency diesel generator building. On May 10, 1982, the exact configuration of this device had not been decided [23]. Assuming this structure can withstand the dynamic and static loading of water, and providing that suitable access ladders are in place, this type of barrier may provide suitable protection for the diesel building for floods as high as 40 ft msl.

The proposed fiberglass service water pump motor sleeves, which are to provide protection against floods above grade (21.5 ft msl), can be considered hardened protection if they can be put in place with little effort and in a short amount of time (i.e., approximately one hour). Further concern exists with respect to the protection afforded these service water pump motors against large floating debris transported down the Connecticut River. When river levels reach above 25 ft, the screenwell house will be nearly submerged and susceptible to collision of floating debris. Louvered windows are immediately adjacent to the service water pump motors. Further, no consideration has been shown to the effects of rising air temperature within the confines of the fiberglass sleeve on successful operation of the service water pump motors.

The Licensee's proposal to caulk around all concrete plugs of the trench entering the PAB may be insufficient. The head of water over these trenches

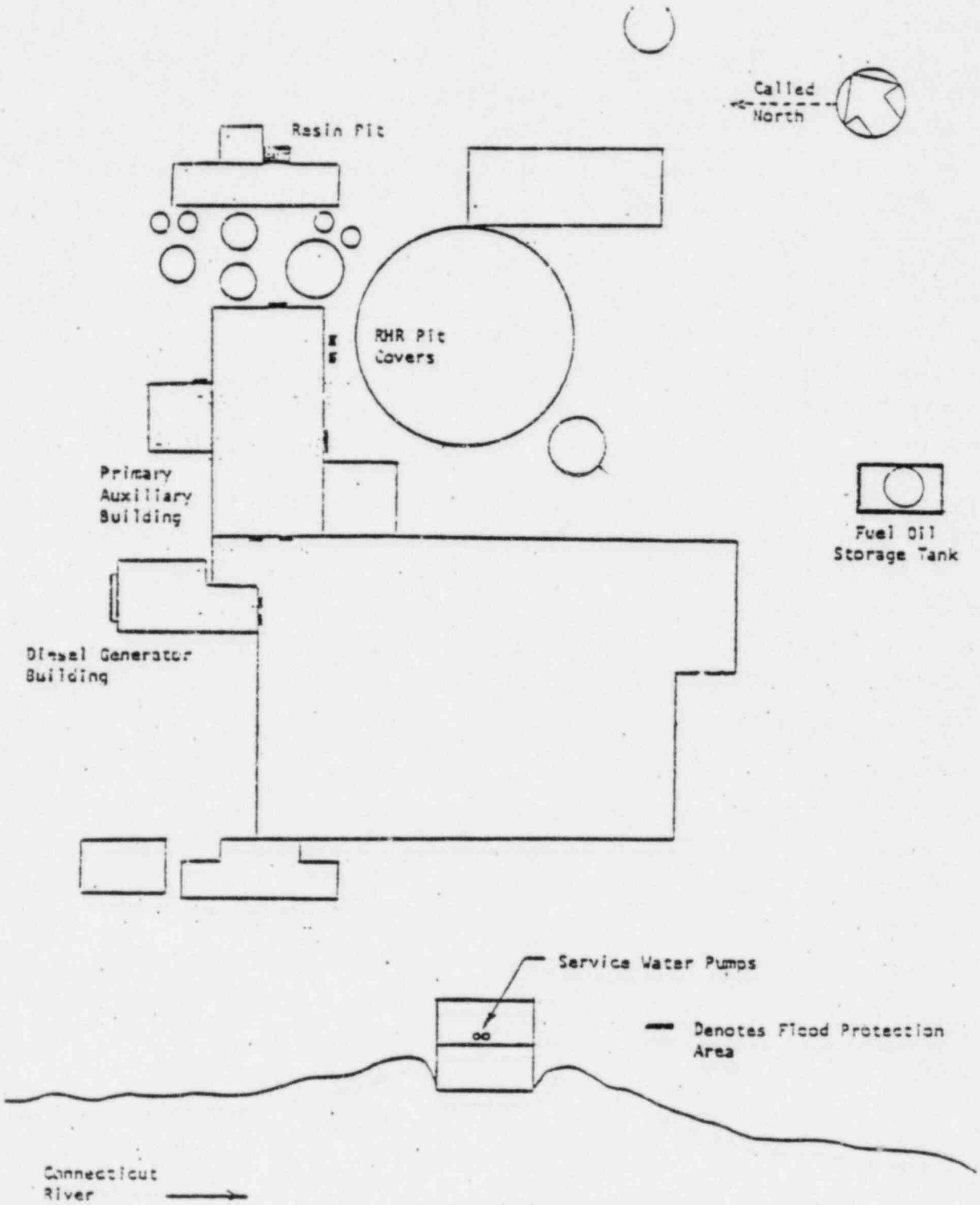

Figure 7. Flood Protection Location Plan

may be sufficient to force water through the trench and into the PAB. Further protection is warranted.

The structural adequacy of safety-related buildings (including the screenwell house) under hydrostatic and hydrodynamic loading conditions should be addressed under SEP Topic III-3.A, Effects of High Water Level on Structures. It should be recognized that the dynamic effects of river water against the screenhouse will be significant during a 30 ft flood and/or the PMF.

Systems to Effect and Maintain Safe Shutdown

The following discussion of the proposed shutdown procedure as identified in the flood emergency procedure is provided. One goal of a flood emergency is to forecast a PMF sufficiently in advance of the occurrence of the flood to allow adequate time to place the plant in a safe shutdown condition. In order to accomplish an ideal normal cooldown, the receipt of a forecast of water elevation exceeding 21 ft msl should be received by the operations director approximately 20 hours before the flood reaches elevation 21 ft msl. This will enable the reactor to be brought to a shutdown condition (200°F) within the normal cooldown rate of 50°F per hour.

The proposed flood emergency procedure states that when a river level of 19.5 ft msl is reached, an orderly shutdown of the plant to hot standby is conducted. When a river level of 20.5 ft msl is reached, a cooldown of the plant to the cold shutdown condition is commenced. As described in Reference 29, the plant is in hot standby when manual adjustments of the controlling group of rods maintain the reactor power level at 1×10^{-7} amperes (intermediate range) and the T_{AVE} at 533 ± 2°F. The pressure of the main coolant will be automatically controlled and maintained at 2000 ± 25 psig. The secondary plant (turbine generator and auxiliaries) is in a hot standby condition with the unit on its turning gear, steam seals on, normal vacuum, steam generator levels manually controlled, and a minimum number of auxiliaries in operation. Reference 29 describes a method of cooling down and depressurizing the reactor from the hot shutdown to a refueling condition. This description includes the four processes necessary to achieve a cold shutdown: (1) boration of the main coolant system to the required cold shutdown concentration, (2) heat injection to the surroundings, (3) depressurization, and (4) long-term cooling.

During a plant visit on May 10, 1982 [33], the Licensee indicated the intent of the flood emergency procedure is to have the reactor coolant system temperature and pressure reduced below the RHR system limits before flood levels reach plant grade. In addition, the flood emergency procedure is intended only to protect those systems and components required for long-term cooling.

The period of time required to reach a reactor coolant system temperature and pressure below the RHR system limits is approximately 19.6 hours. This estimate is based on scoping calculations described in Reference 29. The assumptions used included not exceeding the administrative limit of 50° f/h in cooldown rate, a loss of offsite power, and a single failure of the most limiting component to the cooldown. The Licensee does not plan to provide emergency flood protection for the following: auxiliary feedwater system, steam relief paths, demineralized water storage tank, and primary water storage tank. These systems and structures are normally used in safe shutdown procedures.

Based upon the estimated time required to reach reactor coolant system temperature and pressure below RHR system limits and the short period of time available while flood waters rise from 20.5 to 21.5 ft, it can be concluded that insufficient time is available to place the plant in a long-term cooling mode.

Assuming that the plant has been successfully placed in the long-term cooling mode, primary system makeup due to contraction and normal leakage is required. The Licensee has not proposed to protect the refueling water storage tank, which is the source of makeup during long-term cooling. In addition, the Licensee has proposed to install two service water pump enclosures around the service water pumps. The service water system is an essential system which provides support for the RHR system. Normally the service water system provides cooling water to the component cooling water (CCW) system, which cools the RHR heat exchangers. However, during the site visit, the Licensee stated that the CCW system is not required because the service water system can manually be valved into the RHR heat exchangers through an inplace connection. Since the service water pumps are air-cooled, the Licensee should consider the effects of rising air temperature within the confines of the fiberglass sleeve on successful operation of the service water pump motors.

In Reference 32, the Licensee stated that if the operability of any of the protected systems is lost, "cooling would be provided by natural circulation and streaming through the steam generators. Makeup to the steam generators could be provided with a probable pump feeding into the main feedwater lines. This would be performed on the operating level of the turbine building above the project flood level." Although the Licensee indicated that they are currently purchasing the portable pump, they would consider using this approach only as a last resort. The proposed method does not maintain the plant in a cold shutdown condition. Tests to demonstrate system performance during natural circulation have been conducted on a number of Westinghouse-designed operating plants, including one at Haddam Neck. Each of these tests was begun from an initial hot condition, not from a condition in which the plant is permitted to heat up. In this situation, the thermal driving head is not as well established. Reactor coolant system pressure control is necessary to maintain an adequate subcooling margin and to ensure no disruption of the natural circulation flow. Insufficient technical description of the proposed method and lack of test data does not support a conclusion that the proposed method is a viable mechanism to ensure adequate core cooling.

3.3.3.2 Technical Specifications

There are presently no plant technical specifications which address flooding as a constraint to plant operation.

Two different hydrologic events can jeopardize the function of safety-related plant systems and components. Emergency procedures and/or technical specifications for limiting plant operation can be developed in the event of such occurrences.

As discussed in SEP Topic II-3.B, the plant is presently unprotected from the PMF, the present NRC licensing design basis flood. Partial flood protection to elevation 30 ft msl is proposed through the use of an emergency procedure. This review questions the timing of the initiation of the emergency procedure and suggests earlier initiation of the procedure during the course of the rising flood waters. It is suggested that provisions be made in the plant technical specifications for flood alert emergency procedures. Such emergency procedures should be initiated when the water level reaches approximately 15 ft msl (100-year flood elevation). The purpose of the provision is to ensure a timely and orderly plant shutdown during a severe flood event.

As discussed in SEP Topic II-3.C, the plant design basis low water levels has been exceeded several times within record. This setdown could cause complete loss of the ultimate heat sink (Connecticut River).

Because the phenomenon of low water setdown due to a drop of water level in Long Island Sound is rapid and occurs without sufficient warning to effect a normal shutdown, to establish an emergency procedure as a protection mechanism is considered not feasible. Further, for the long term, plant technical specifications which limit plant operation when water reaches a predetermined elevation (e.g., -1.5 ft msl) is ineffective because a complete loss of the UHS is possible. The UHS must be available for cooling for a period of 30 days.

The net positive suction head of the service water pumps is not maintainable when water is not at least 8 ft over the service water intake bell, elevation -2.5 ft msl. By implementing technical remedial measures, this problem can be overcome. Consider the following:

- o Conducting actual testing to establish the net positive head required for the service water pump, thus enabling a determination of design vs. capability

- o Verifying that the diesel driven fire pumps have sufficient net positive suction heat to enable a crossover to the service water system, realizing that this does not meet single failure criteria

- o Inserting stop logs in the intake structure which would create a well around the service water pump intake, thus maintaining a net positive suction head, to be fed by another pump
- o Changing pumps to those which would require less suction head.

3.3.4 Conclusion

3.3.4.1 Emergency Procedure

The Licensee's proposed emergency flood procedure does not provide protection to the current NRC licensing flood level (PMF - elevation 39.5 ft msl). Further, this procedure, in its present form, should be upgraded to consider technical problems identified in Section 3.3.3. Specifically, further consideration should be shown for the following:

- o The timing of the initiation of the emergency procedure for rising flood waters should be changed. Earlier implementation is recommended.
- o The fuel oil tank should be protected with the hardened protection referenced in Regulatory Guide 1.102.
- o Structural adequacy of buildings should be verified under SEP Topic III-3.A, Effects of High Water on Structures.
- o The adequacy of fiberglass sleeves as suitable flood protection should be verified with consideration for watertightness, structural adequacy, and ability to prevent overheated service water pump motors.
- o Natural circulation and steaming through the steam generators do not maintain cold shutdown.
- o Makeup water supply should be available for the primary system during cooldown.

3.3.4.2 Technical Specifications

Technical specifications which require a flood alert and initiate an emergency flood protection procedure are recommended for occurrences of flood water above 15 ft msl (100-year flood elevation).

Technical specifications which limit operation of the plant when water level drops below a predetermined elevation (-1.5 ft msl) are recommended for the short term. Technical modifications and equipment changes are recommended for the long term.

3.4 SAFETY-RELATED WATER SUPPLY (TOPIC II-3.C)

3.4.1 Topic Background

This topic reviews the acceptability of a particular feature of the cooling water system, namely, the ultimate heat sink (UHS). The review is based on current criteria contained in Regulatory Guide 1.27, Rev. 2, which is an interpretation of General Design Criterion (GDC) 44, "Cooling Water," and GDC 2, "Design Bases For Protection Against Natural Phenomena," of 10CFR50, Appendix A.

GDC 44 requires, in part, that suitable redundancy of features be provided for cooling water systems to ensure that they can perform their safety function. GDC 2 requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena without loss of ability to perform their safety functions. Regulatory Guide 1.27 has been specifically cited by the NRC's Regulatory Requirements Review Committee for consideration in the backfitting of operating reactors. This guide is used in judging whether the facility design complies with current criteria.

The UHS complex, as reviewed under this topic, is the system of cooling water sources, including necessary retaining structures (e.g., a pond with its dam or a cooling tower supply basin), and the canals or conduits connecting the sources to the cooling water system intake structures, but excludes the intake structures themselves. The UHS complex performs two principal safety functions: (1) dissipation of residual heat after reactor shutdown, and (2) dissipation of residual heat after an accident.

Availability of an adequate supply of water for the UHS complex is a basic requirement for any nuclear power plant. Since there are various methods of satisfying the requirement, UHS complex designs tend to be unique to each nuclear plant, depending upon its particular geographical location. Regulatory Guide 1.27 provides UHS examples that the NRC staff has found acceptable.

The UHS must also be able to dissipate the maximum possible total heat, including the effects of a loss of coolant accident (LOCA) under the worst combination of adverse environmental conditions. The maximum tolerable temperature of an UHS such as a cooling pond may significantly limit its ability to dissipate the heat load following a LOCA or plant shutdown, while maximum temperature may not be a significant concern for an UHS such as a large lake, river, or ocean.

Because of the importance of the UHS complex, it should be able to perform its safety function during and following the most severe natural phenomena or accidents postulated at the site. In addition, the UHS complex safety functions should be ensured during other applicable site-related events that may be caused by less severe natural phenomena and accidents in reasonable combination.

3.4.2 Topic Review Criteria

The criteria for evaluating the UHS complex were taken from Regulatory Guide 1.27, "Ultimate Heat Sink For Nuclear Power Plants," and are as follows:

"1. The ultimate heat sink should be capable of providing sufficient cooling for at least 30 days (a) to permit simultaneous safe shutdown and cooldown of all nuclear reactor units that it serves and to maintain them in a safe shutdown condition, and (b) in the event of an accident in one unit, to limit the effects of that accident safely, to permit simultaneous and safe shutdown of the remaining units, and to maintain them in a safe shutdown condition. Procedures for ensuring a continued capability after 30 days should be available.

2. The ultimate heat sink complex, whether composed of single or multiple water sources, should be capable of withstanding, without loss of the sink safety functions specified in regulatory position 1, the following events:

   a. the most severe natural phenomena expected at the site, with appropriate ambient conditions, but with no two or more such phenomena occurring simultaneously,

   b. the site-related events (e.g., transportation accident, river diversion) that historically have occurred or that may occur during the plant lifetime,

   c. reasonably probable combinations of less severe natural phenomena and/or site-related events,

d. a single failure of manmade structural features.

3. The ultimate heat sink should consist of at least two sources of water, including their retaining structures, each with the capability to perform the safety functions specified in regulatory position 1, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source.

4. The technical specifications for the plant should include provisions for actions to be taken in the event that conditions threaten partial loss of the capability of the ultimate heat sink or the plant temporarily does not satisfy regulatory positions 1 and 3 during operation."

In addition to Regulatory Guide 1.27, clarifications are contained in Standard Review Plan (SRP), Sections 2.4.11, "Low Water Considerations," and 9.25, "Ultimate Heat Sink."

3.4.3 Evaluation

The UHS for the Haddam Neck plant is the Connecticut River. Water is drawn directly from the river by four 93,000 gpm circulating pumps and four 6,000 gpm service water pumps.

The open discharge canal receives the circulating water and discharges it into the river at a point approximately 2000 yards downstream of the intake. The canal bottom is generally at -10 ft msl and about 65 ft wide and widens to 700 ft at the river's edge.

3.4.3.1 Vulnerability of the UHS to a Single Failure of Manmade Structural Features

In References 4 and 7, the Licensee did not describe the vulnerability of the UHS to a single failure of manmade structural features. No credible single failure of any structural feature of the Connecticut River can be postulated which would result in a loss of UHS. Therefore, it can be concluded that the UHS satisfies Criterion 2 with respect to single failure of manmade structural features.

3.4.3.2 Vulnerability of the UHS to Missiles

The Licensee stated in Reference 4 that missiles are not considered to pose a threat to the availability of the source water. The Connecticut River is sufficiently large not to be susceptible to damage from missiles from natural phenomena (tornado) or site-related events (turbine missile) that would result in a complete loss of heat sink availability. Based upon this finding, the UHS complies with Criteria 1 and 2 with respect to missiles from severe natural phenomena and site-related events. Further information with respect to missiles is available in SEP Topic III-4.A, III-4.B, III-4.C, and III-4.D.

3.4.3.3 Vulnerability of the UHS to Sedimentation

The channel in front of the intake has been dredged twice: once during construction in 1964, and a second time in 1979. During this period an approximate 4-ft accumulation occurred directly upstream of the intake structure. Over this 15-year period, the accumulation averages to approximately 3 to 4 in per year. The Licensee stated the following in SEP Topic II-3.A:

> "Should silt or debris accumulate within the forebay, it would become obvious at an elevation less than -15'0" when the operation of the circulating water pumps would be affected. Based on an additional distance of 4'6" to the bottom of the service water pumps and the low sedimentation rate of roughly 3 to 4 in per year, it is evident that sufficient warnings exist to assure timely maintenance. Therefore, the potential of sedimentation during normal or flood conditions to a degree capable of affecting the operation of the service water pumps is sufficiently low so as not to be considered a potential safety concern.
>
> The SAR for Topic III-3.C, "Inservice Inspection of Water Control Structures," addresses the inspection that divers perform during each refueling outage to check for, among other items, silt and debris buildup. This inspection will be continued to provide further assurance."

The accumulation of silt and debris could block the intake of the circulating water pumps. However, since the service water pumps intake is 4 ft 6 in above the circulating water pumps, adequate water is available for plant cooldown. This review concludes that the periodic inspection of the forebay by divers should give ample warning of sediment buildup to allow for early corrective action.

3.4.3.4 Vulnerability of the UHS to Low Water Conditions

In Reference 7, the Licensee discussed the probable minimum flow of the Connecticut River. The maximum river water requirements for the plant are:

Circulation Water	4 Pumps at 93,000 gpm each	372,000 gpm
Service Water	3 Pumps at 6,000 gpm each	18,000 gpm
		390,000 gpm ($869\ ft^3/sec$).

The normal safe shutdown requirements are:

Service Water	2 Pumps at 6,000 gpm each	12,000 gpm ($27\ ft^3/sec$).

The source of minimum flow in the river is primarily releases from the main stream dams on the river above the site.

The Hadley Falls site is the first dam encountered upstream of the site. The mininum continuous release required by the dams Licensee is 1660 cfs, which is twice the total required flow by the circulating water pumps and service water pumps, or 60 times the flow of the service water pumps required for safe shutdown.

In Reference 7, the Licensee stated that the hydraulic control of the Connecticut River at the Haddam Neck site is the Long Island Sound. If the river flow were to drop below the 27 cfs needed for safe shutdown, water would be available at the intake due to inflow from Long Island Sound. A substantial river channel with a bottom elevation of -20 ft msl to -30 ft msl is constantly maintained to provide access for commercial shipping. The river bottom elevation outside the channel in the reach that includes the site averages approximately -7 ft msl or at least 5 ft below the design minimum low water level.

The Licensee concluded that:

"By inspection it is clear that water in the river at the limiting flow conditions will always be available at the intake structure for safe shutdown."

The Licensee stated that:

"... the mean low-water level of the Long Island Sound as developed for Millstone Unit 3 (Ref: Question 2.11, Amendment No. 22 to the Millstone unit 3 PSAR, Docket No. 50-423) is -2.6' msl (-1.6 mlw). By inspection the design extreme low-water level of -2.0' is appropriate."

The Licensee's analysis did not address the effect of the minimum low water level at the intake structure resulting from an occurrence of a PMH which causes maximum depression of the water surface (setdown) at the site. However, Question 2.11 of the Millstone 3 PSAR stated that the probable maximum setdown determined to occur on Long Island Sound is -6.3 ft msl.

Assuming that the lowest water elevation at the plant site will be higher than -6.3 ft msl, a conservative extrapolation was performed to develop an approximate elevation for the maximum probable setdown at the site. By using a conservative water surface slope for the reach from the Saybrook Breakwater to the site, a water surface elevation of -5.0 ft msl was determined and is a very rough approximation of the probable maximum setdown which could occur at the Haddam Neck site (see Table 1, Item 4). According to USGS data from the Connecticut River at the Thompsonville gage, 5% of the time in an average year the river flow will be less than 3,000 cfs. Approximately 3,000 cfs is required to bring the elevation of the river from -6.3 ft msl to -5.0 ft msl.

The determination of the probable maximum setdown at Haddam Neck which considers the combined influence of the Long Island Sound control and Connecticut River influence is outside of the scope of this review. However, it is evident that the maximum setdown would produce a probable maximum low which is significantly below the design extreme low water level.

A review of historical data was conducted to determine the frequency of river level dropping below the design low water level (-2.0 ft msl). Historical data for the Connecticut River at the CANEL Pier, given in Table 3, were transposed 2 miles downstream to the Haddam Neck site (see Note 1). From the data, it was determined that river level dropped below -2 ft msl at least 11 times during the 13 years from 1969 through 1981. (The data presented are the monthly low water level. Since the data only show the lowest level during

Note 1: The Haddam Neck plant river level is 0.4 ft less than that recorded at the CANEL Pier.

Table 3. Historical Minimum Monthly Low Water Level
CANEL Pier, Connecticut River

WY/Month[1]	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Oct.	-0.86	-1.09	-0.43	-0.31	-0.89	-0.50	-0.65	+0.26	-0.07	+0.62	-0.94	-0.27	-1.13
Nov.	-0.05	+0.41	-0.25	-0.61	+0.20	-1.12	-0.14	+0.59	-0.54	+0.55	-0.52	-0.33	-1.15
Dec.	-1.23	+0.04	-0.57	-1.24	-0.09	+0.01	-0.09	-0.27	-1.53	-0.39	<u>-1.80</u> (2)	-1.46	-1.54
Jan.	-1.19	-0.69	-1.28	-0.99	+1.38	+0.03	-0.32	-0.58	<u>-2.09</u> (2)	-0.10	-0.71	<u>-1.65</u>	<u>-1.64</u>
Feb.	-1.16	0.00	-1.1[illegible]	<u>-1.71</u>	+0.30	+0.57	-0.59	+0.87	<u>-1.60</u> (3)	+0.12	-0.76	-1.17	-0.84
March	-0.36	-0.57	-0.44	-0.11	+0.48	+0.77	+0.11	+1.04	+0.52	-1.12	+0.69	<u>-1.81</u>	-0.11
April	+1.29	+1.78	+0.79	+0.93	+1.64	+1.13	+0.87	+1.43	+1.25	+2.75	+2.37	+1.19	+0.16
May	+0.89	+0.45	+1.05	+0.49	+1.40	+1.28	+0.09	+1.11	-0.45	+0.38	-0.10	+0.60	-0.04
June	-0.13	-0.20	-0.36	+0.72	+0.41	+0.06	-0.29	-0.20	-0.19	+0.18	-0.61	-0.50	-0.24
July	-0.41	-0.65	-0.51	+0.54	-0.13	-0.15	-0.14	-0.30	-0.62	-0.39	-0.56	-0.57	-0.47
Aug.	-0.21	-0.54	-0.50	-0.13	-0.32	-0.40	-0.44	-0.50	-0.48	-0.34	-0.40	-0.48	-0.33
Sept.	-0.25	-0.58	-0.51	-0.41	-0.24	-0.14	-0.55	-0.25	-0.70	-0.27	-0.57	-1.00	-0.63

1. WY 1969 = Oct. 1968 to Sept. 1969.
2. Occurred two times during month.
3. Occurred three times during month.

NOTE: Underlined values would produce a river level less than -2 ft msl at the Haddam Neck plant.

the month, they do not indicate the number of times the level was lower than the design low.)

The required net positive suction head (NPSH) for the service water pumps is -2.5 ft msl. This takes into account an added 0.5 ft drop through the screens, as shown in Figure 8.5-1 of the Haddam Neck FSAR.

Since the pumps have insufficient NPSH any time the river level drops below -2 ft msl, the UHS is lost.

Therefore, it must be concluded that the UHS does not meet the requirements of Regulatory Guide 1.27 concerning the ability of the UHS to maintain its safety functions.

3.4.3.5 Vulnerability of the UHS to Reasonably Probable Combinations of Less Severe National Phenomena and/or Site-Related Events

In References 4 and 7, the Licensee did not describe the vulnerability of the UHS to reasonably probable combinations of less severe natural phenomena and/or site-related events. A review of the UHS design compared to less severe natural or site-related events did not identify reasonably probable combinations which would produce an effect worse than those previously identified (e.g., maximum setdown).

3.4.4 Conclusion

Criterion 1 of Regulatory Guide 1.27 was established for heat sinks where the supply may be limited and/or the temperature of plant intake water from the heat sink may become critical. Similarly, Criterion 2 was established to ensure that the heat sink function would not be lost due to natural phenomena, site-related events, or a single failure of man-made structural features.

Criterion 3 was established to provide a high level of assurance that the UHS would be available when needed. The Regulatory Guide suggests that the UHS consist of at least two sources of water, unless it can be demonstrated that there is an extremely low probability of losing a single source. For an open loop system such as that found at the Haddam Neck plant, there should be at least two aqueducts connecting the source with the intake structure. At least two discharge aqueducts are recommended in design to carry the cooling water away, thereby precluding plant flooding. This criterion holds unless it can be demonstrated that the probability is extremely low that a single aqueduct will fail to function as a result of natural or site-related phenomena. An UHS design that satisfies the intent of Criteria 2 and 3 then must also be capable of providing sufficient cooling for simultaneous safe shutdown and cooldown of all nuclear reactor units that it serves and to maintain them in a safe shutdown condition for 30 days as described in Criterion 1.

The Haddam Neck UHS partially complies with Criterion 2. The UHS is capable of withstanding the following events without loss of the sink safety function:

- o Reasonably probable combination of less severe natural phenomena and/or site-related events
- o a single failure of man-made structural features.

Access to the UHS by the plant is lost during the following events:

- o The most severe natural phenomena, a maximum setdown, will decrease the river level below that required by the intake structure
- o the site-related events that historically have occurred or that may occur during the plant lifetime. Historical data shows that the river level dropped below the design low water level on a minimum of 11 occasions in the past 13 years.

The Haddam Neck UHS does not comply with Criterion 3. The Licensee has not demonstrated that there is an extremely low probability of losing the capability of a single source. Specifically the UHS is susceptible to low river level which causes a loss of the intake structure function.

Since the Haddam Neck UHS partially complies with Criterion 2 and does not comply with Criterion 3, it cannot be concluded that the UHS is capable of providing sufficient cooling for safe shutdown and cooldown of the reactor that it serves and of maintaining it in a safe shutdown condition for 30 days.

Criterion 4 requires that the plant technical specifications include provisions for actions to be taken in the event that conditions threaten partial loss of the UHS. This criterion was established to ensure that the manner in which plant technical specifications were written was such that the plant would be placed in a safe condition or provisions would be implemented if a condition existed which threatened the availability of the UHS. An example of such a condition might be the prediction of a severe hurricane offshore which may cause a setdown to occur, or a low river discharge in combination with predicted neap tide, both jeopardizing access to the UHS.

In each of these situations, technical specifications requiring the plant to be placed in a safe shutdown condition or implementation of procedures to mitigate the consequences of a threatened partial loss of the UHS would be prudent. The Licensee has not addressed this criterion and does not have technical specifications which include provisions for actions to be taken in the event that the plant requires protection from low water during severe hurricane conditions. Therefore, the Haddam Neck facility does not comply with Criterion 4.

3.5 STRUCTURAL AND OTHER CONSEQUENCES OF FAILURE OF UNDERDRAIN SYSTEMS (TOPIC III-3.B)

3.5.1 Topic Background

Some plants rely on underdrain systems to limit the groundwater table elevation to a level which will not jeopardize the structural integrity of the containment, or other buildings. Prior to the SEP program, little information was available which would enable an assessment of the underdrain system at the Haddam Neck site.

Information pertaining to SEP Topic III-3.B for the Haddam Neck site was obtained from the Licensee via a request for information [31]. The Licensee's response [32] elaborated on the design basis of the mat sump system.

Unlike other hydrology topics within the review of the Haddam Neck site, the NRC has lead responsibility for Topic III-3.B, Underdrain Failure. Information from this SEP Topic will interface with SEP Topic III-3.A, Effects of High Water Level on Structures.

3.5.2 Topic Review Criteria

The following references were used as review criteria for this topics:

Standard Review Plans 2.4.13, 2.4, and 3.8 2.4.12

BTP HGEB-1.

3.5.3 Evaluation

3.5.3.1 System Description

The dewatering system at the Haddam Neck site consists of a collector system, drain system, and a discharge system.

The collector sytem is a 6-inch layer of "popcorn" concrete, which drains into a cistern south of the containment building. Water is removed from the cistern by two sump pumps, running alternately, discharging into an open drainage ditch which runs east/west toward the service building. This discharge water empties into a site drain which drains to the discharge canal further south. The original system was used to de-water the site during construction. The final drainage system was designed to maintain the groundwater level below the mat, minimizing uplift pressures. Consideration for pump failure was made by designing the containment for groundwater levels of 12 ft msl under normal conditions. The system is not safety-grade.

3.5.3.2 Structural Considerations

The original design basis groundwater level for containment design is 12 ft msl, in comparision to the elevation determined in accordance with present NRC licensing criteria which is plant grade, 21 ft (see SEP Topic II-3.B). Buoyant forces on the containment do not result in uplift of the containment building [32]. The hydrostatic pressure due to a PMF (elevation 39.5 ft msl) are more severe than those for groundwater to plant grade.

An evaluation of the structural adequacy of the containment and other buildings should be considered under SEP Topic III-3.A, adding a seismic load to the new design groundwater elevation of 21 ft msl.

3.5.3.3 Radionuclide Pathway from Containment

The mat sump system is located completely exterior to the containment structure. Therefore, material released inside could not escape via the mat sump system.

3.5.4 Conclusion

The mat sump system is not a safety-grade system, but was designed to lower groundwater level to add a measure of protection against groundwater influx.

Consideration for pump failure was incorporated within the design by designing the containment for groundwater levels of 12 ft msl whereas 21 ft msl is plant grade. An evaluation under SEP Topic III-3.A using the new groundwater elevation (21 ft msl) in combination with the appropriate seismic load should be considered.

The mat sump system does not provide a pathway to the environment for radionuclide release inside the containment building.

4. CONCLUSIONS

4.1 SEP TOPIC II-3.A, HYDROLOGIC DESCRIPTION

For the purposes of this review, the hydrologic environment at the Haddam Neck site is adequately described.

4.2 SEP TOPIC II-3.B, FLOOD POTENTIAL AND PROTECTION REQUIREMENTS

The following conclusions pertaining to specific aspects of flood potential at the Haddam Neck site are presented.

- Flooding of the Connecticut River

  Flood Potential

  The Haddam Neck site design basis flood is 19.5 ft msl where finished plant grade is 21.5 ft msl. The probable maximum flood (PMF) of the Connecticut River has a minimum flood elevation of 39.5 ft msl and a standard project flood (SPF) elevation of approximately 23.2 ft msl. Failure of upstream dams during PMF has not been addressed by the Licensee.

  Protection Requirements

  Flooding protection is available to a limiting elevation (diesel building) of 22.6 ft msl. Hydrodynamic loads, and protection against them, have not been determined for water elevations above the design basis. SEP Topic III-3.A, Effects of High Water Level on Structures, should address combinations of hydrodynamic and hydrostatic loads for both the SPF elevation and the PMF elevation.

  Flood protection to the SPF elevation should be maintained for the following structures:

Turbine building	Fuel oil tank
Service buildings	Primary water tank
Diesel buildings	Borated water storage tank
Intake structure	Reactor containment
Primary auxiliary building	Auxiliary feed pump room.

  Flood protection to the PMF elevation should be maintained for the following buildings and structures:

  Intake structure
  Primary auxiliary building
  Reactor containment
  Diesel building
  Fuel oil tank.

- Local Flooding and Site Drainage

  The Haddam Neck site is presently protec ed from local flooding due to a PMP event. The PMP results in sheet runoff to an elevation approximately 5 in above grade (elevation 21.4 ft msl). This level is below the entrances to all safety-related structures and does not jeopardize normal plant operation.

- Roof Drainage

  Assuming that the information provided by the Licensee is accurate, the roof design basis live load will be exceeded during rainfalls less frequent than the PMP for the service building. This report concludes that the roofs of all other buildings are sufficient to support rainfall resulting from the PMP event since in all cases the loading would be less than or very near to the design basis live load.

- Groundwater

  Flood Potential

  The probable maximum groundwater elevation for the Haddam Neck site is controlled by the Connecticut River PMF elevation of 39.5 ft msl. The normal high groundwater elevation for use in combination with appropriate seismic conditions should be plant grade (elevation 21.0 ft msl), since the Licensee has provided no conclusive information which would enable any other conclusion to be reached.

  Protection Requirements

  The assessment of structural capability of structures under probable maximum groundwater loads, and seismic loads in combination with normal high groundwater level, should be reviewed under SEP Topic III-3.A, Effects of High Water Level on Structures.

4.3 SEP TOPIC II-3.B.1, CAPABILITY TO COPE WITH DESIGN BASIS FLOODING CONDITIONS

Emergency Procedure

The Licensee's proposed emergency flood procedure does not provide protection to the current NRC licensing flood level (PMF - elevation 39.5 ft msl). Further, this procedure, in its present form, should be upgraded to consider technical problems identified in Section 3.3.3. Specifically, further consideration should be shown for the following:

- The timing of the initation of the emergency procedure should be changed. Earlier implementation is recommended.
- The fuel oil tank should be protected with hardened protection referenced in Regulatory Guide 1.102.
- Structral adequacy of buildings should be verified under SEP Topic III-3.A, Effects of High Water on Structures.
- The adequacy of fiberglass sleeves as suitable flood protection should be verified with consideration for water tightness, structural adequacy, and ability to prevent overheated service water pump motors.
- Makeup water supply for primary system during cooldown.

Technical Specifications

Technical specifications which require a flood alert and initiate an emergency flood protection procedure are recommended for occurrences of flood water above 15 ft msl (100-year flood elevation).

Technical specifications which limit operation of the plant when water level drops below a predetermined elevation (-1.5 ft msl) are recommended for the short term. Modifications and equipment changes are recommended for the long term.

4.4 SEP TOPIC II-3.C, SAFETY-RELATED WATER SUPPLY

The Haddam Neck ultimate heat sink complex does not function during maximum setdown and combinations of other historical phenomena which have produced low water levels below the design low water level. Full compliance with Regulatory Guide 1.27 has not been demonstrated.

4.5 SEP TOPIC III-3.B, STRUCTURAL AND OTHER CONSEQUENCES OF FAILURE OF UNDERDRAIN SYSTEMS

The mat sump system is not safety grade, and failure could enable groundwater to rise to plant grade (see SEP Topic II-3.B). An evaluation under SEP Topic III-3.A, using new groundwater elevation is recommended.

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