TRIP 8-A: GEOTECHNICAL CONSIDERATIONS AT SHOREHAM NUCLEAR POWER STATION

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INTRODUCTION

Long Island Lighting Company's Shoreham Nuclear Power Station is one of the largest engineering projects ever undertaken in eastern Long Island. It has required geotechnical considerations of a scope unique to nuclear-fueled electric generating facilities, and has been scrutinized closely by the general public and by various governmental regulatory agencies. This field trip will provide an opportunity to discuss the geotechnical investigations and decisions that are a part of nuclear power plant siting, design, licensing, and construction, and will include a tour of the facility itself, which is scheduled for completion in 1977.

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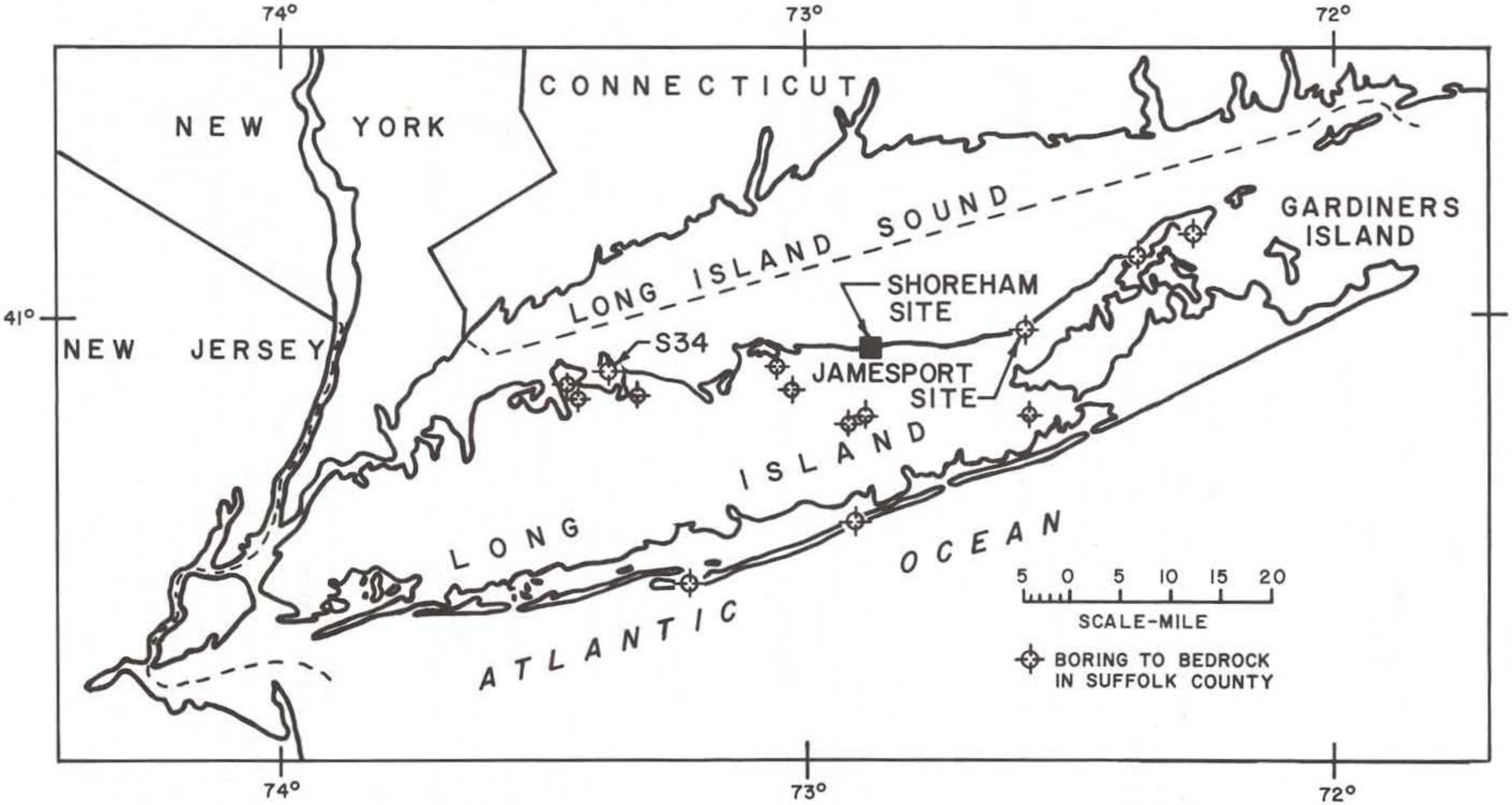
GEOLOGIC SETTING

Shoreham Nuclear Power Station is located on the north shore of central Long Island, at the approximate landward edge of the Atlantic Coastal Plain (Figures 1 and 2). The crystalline rocks of the New England Piedmont slope gently seaward an estimated 1100 ft beneath the site. Overlying this deeply weathered remnant of the Fall Zone peneplain (Suter and others, 1949) is a thick sequence of unconsolidated coastal plain sediments of Upper Cretaceous to possibly Tertiary age. Long Island itself owes its existence to a somewhat linear accumulation of glacial debris unconformably overlying the coastal plain deposits. The island is separated from New England by a glacially overdeepened channel.

Bedrock

Because of its considerable depth, little is known of the basement rock beneath central and eastern Long Island. A few deep wells and test borings have penetrated bedrock in Suffolk County (Figure 1), but most of these simply recorded weathered schist and gneiss (Jensen, personal comm., 1973). Between 1948 and 1950, the U.S. Geological Survey, as part of a detailed groundwater investigation for the War Department, drilled two deep test wells into bedrock at the site of what is now Brookhaven National Laboratory, about 9 miles south of the Shoreham site. deLaguna (1963, p. A11-A12) describes the rock as a "hard, banded, granitic gneiss" with a composition of "about 50 percent plagioclase (oligoclase and andesine) feldspar, about 50 percent quartz, about 1 percent biotite, and a trace of



REFERENCE: JENSEN AND SOREN, 1971

FIGURE 1 INDEX MAP

garnet". This is capped by 15 to 30 ft of weathered rock.

At the site of Long Island Lighting Company's proposed Jamesport Nuclear Power Station, about 15 miles east of Shoreham, two bedrock borings were recently completed. There, 30 to 60 ft of saprolite and weathered rock were encountered overlying fresh rock (at 1100 ft below sea level). The rock was found to be a granitic gneiss, with foliation indistinct and occasionally lacking. It is composed of 35 to 45 percent microcline, 25 to 35 percent quartz, 20 to 30 percent sodic plagioclase, 2 percent biotite, 0.5 percent each of muscovite and garnet, and a trace of zircon.

An age of 254± 9 million years was determined from biotite from the Jamesport rock by Geochron Laboratories, using the K-Ar method. This is believed to be the first date ever obtained from Suffolk County basement rock, and is consistent with what is known of southern New England rocks (Zartman and others, 1970). Concentric zonation of plagioclase and possible secondary intergrowths, particularly of quartz and plagioclase, suggest that a Permian stage of metamorphic recrystallization is responsible for the K-Ar date.

It is suggested, notably by Sanders (1963) and Rodgers (1968), that the Triassic basin of southern New England may extend southward beneath the Sound and beneath Long Island. However, although aeromagnetic patterns characteristic of the Triassic basin trend south-southwestward into western Long Island (U.S. Naval Oceanographic Office, 1964-1966), no borings have been drilled to bedrock in Long Island Sound south of the apparent termination of the Triassic basin in New Haven Harbor. Bedrock borings on Long Island have encountered only crystalline rock (Jensen, personal comm., 1973; deLaguna, 1963). The Duck Island well (S34) at Northport Bay is believed by some to have recovered Triassic rock; however, this is unsubstantiated. Furthermore, three wells within a 5 mile radius of S34 recorded gneiss (Figure 1), imposing a considerable restriction on the extent of any possible Triassic rocks.

Coastal Plain Sediments

As is the case with basement rock, much less is known of the nature and extent of the deeper coastal plain deposits in Suffolk County than in western Long Island. The most thorough discussion of these units is by Suter and others (1949). Jensen and Soren (1974) have provided considerable additional geologic information for Suffolk County, particularly with reference to the configuration of the major stratigraphic interfaces.

At the Shoreham plant site it is believed that 200 ft of the Lloyd Sand Member of the Upper Cretaceous Raritan Formation overlies a deeply weathered bedrock surface at an approximate elevation of -1000 ft. The Lloyd sand is a grayish-white, fine to coarse, quartz sand and gravel. It grades locally into a clayey sand with clay intercalations. Like all the Cretaceous deposits on Long Island, the Lloyd sand increases in thickness from the northwest to the southeast and may reach 550 ft thick in southern Suffolk County.

A similar thickness of the clay member of the Raritan Formation

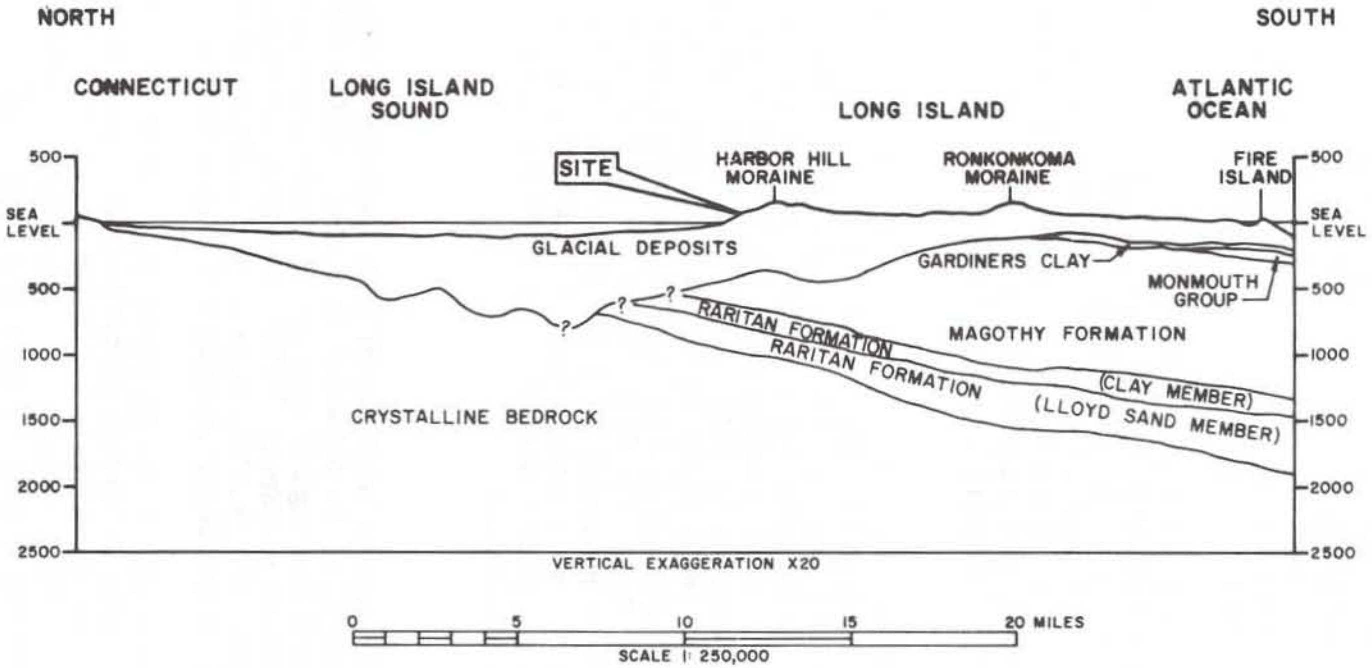


FIGURE 2 GENERALIZED GEOLOGIC SECTION THROUGH THE SHOREHAM SITE

REFERENCES:
JENSEN AND SOREN, 1974
SUTER, DELAGUNA, AND PERLMUTTER, 1949
U.S. GEOLOGICAL SURVEY, 1967

is believed to overlie the Lloyd sand. The clay member is predominantly a clay and silty clay with sandy intercalations. It is commonly gray in color, but may show multicolored banding. Its contact with the overlying Magothy Formation is considered gradational.

The major stratigraphic unit in the Upper Cretaceous of Long Island is the Magothy Formation. It is typically a fine sand with angular quartz grains and interstitial kaolin. It is commonly gray or white in color but may locally be brown, buff, yellow, red, or pink. The lower part of the formation tends to contain coarser material just above the Raritan clay member. However, Long Island Lighting Company's recent deep borings at Jamesport did not encounter typical basal Magothy Formation. The Magothy was encountered by test borings at the Shoreham site and the adjacent Shoreham West site (alternate site for the proposed Jamesport Nuclear Power Station) at elevations of -100 ft to -150 ft. This is considered to be an unusually shallow occurrence, resulting from glacial deformation. The contact between the Upper Cretaceous (Magothy) and Pleistocene deposits is an erosional unconformity.

The uppermost Cretaceous unit found on Long Island is the Monmouth Greensand. It is a dark greenish-gray, glauconitic and occasionally lignitic marine clay, silt, and clayey and silty sand. It is limited in extent to the south coastal area of Suffolk County and may reach 200 ft in thickness. It has not been encountered in any of the borings at the site.

Pleistocene Geology

Late Pleistocene glaciation is responsible not only for the physiography of Long Island, but for the very existence of the island. In Suffolk County, nearly all engineering structures, including Shoreham Nuclear Power Station, are founded in glacially derived sediments. These deposits are also the principal source of groundwater.

The Manetto Gravel was considered by Fuller (1914) to be the earliest of the Pleistocene deposits; other workers have assigned it a possible Pliocene age. It is typically a stratified, fine to coarse gravel, with well-rounded particles of quartz and occasional granite cobbles and boulders mixed with coarse, yellow sand. The unit has not been identified from borings in the site area, although it would be difficult to distinguish from glacial outwash deposits.

At the adjacent Shoreham West site, test borings encountered 20 to 50 ft of dark, grayish-green silty and clayey fine sand. Occasional clay layers; infrequent, isolated, rounded quartz pebbles; a variable mica content; and possible reworked glauconite further characterize the material. The unit unconformably overlies the Magothy Formation at elevations between -80 and -140 ft. Of particular interest are the marine and brackish water shells and shell fragments. Some of the foraminifera were tentatively identified, by genera, as Quinqueloculina (Carboniferous to Recent) and Elphidium (Eocene to Recent). We have concluded that the material is Gardiners Clay, of probable Sangamon (interglacial) age. This is consistent with the observation by Weiss (1954, p. 145) that "... any fossiliferous material of Pleistocene age overlain by glacial deposits may be called

Gardiners." Gardiners Clay was not encountered at the Shoreham plant site. Discontinuous layers of similar material in higher stratigraphic levels are believed to be of glacial or Recent origin.

At the Shoreham West site, the Gardiners Clay grades upward into a generally gray, silty, micaceous, nonfossiliferous fine sand. This is very likely what Fuller (1914) defined as Jacob Sand. At the Shoreham site and the Jamesport site (near its type locality), Jacob Sand overlies Magothy Formation. Test borings at all three sites encountered a gradation upward from Jacob Sand into typical Wisconsinan outwash sands and gravels.

All three sites are founded on the Harbor Hill Moraine, which extends nearly the length of Long Island's north shore. In the vicinity of Shoreham Nuclear Power Station, the moraine is composed principally of outwash deposits of light brown, fine to coarse, clean sand and gravel, with occasional large, erratic boulders. Thin layers of till are infrequent. The present irregular topography of the moraine is a result of the kame and kettle style of outwash accumulation.

Glacial shove and drag has caused considerable deformation of the Pleistocene and the Upper Cretaceous (Magothy) deposits. Contours drawn on several subsurface interfaces at the Shoreham West site show a pattern of asymmetric folding, with the principal stress directed from the northeast. It is this folding and possible imbricate thrusting (Kaye, 1964; Mills and Wells, 1974) which is believed responsible for the anomalously shallow occurrences of the Magothy Formation.

Recent deposits in the Shoreham site area include beach sand, dune sand (particularly capping the shore bluffs), and river and salt water marsh deposits.

Figures 3 and 4 show the pre- and post-construction geology of Shoreham Nuclear Power Station. Figure 5 is an oblique aerial view of the site during construction.

Seismicity of Site Region

The earthquake history of the site area has been determined by Weston Geophysical Research, Inc., for Long Island Lighting Company, by a thorough examination of technical publications and a literature search in the libraries of newspapers and other publications of Long Island, New York City, Boston, and Bridgeport, Connecticut. Historical records date back over 300 years to the first permanent Dutch settlement in the area in 1606. References to earthquakes in these records consist mainly of felt reports of earthquakes whose epicenters were located outside the eastern Long Island area. An earthquake on December 18, 1737, near New York City was the first reported earthquake whose epicenter was within the eastern New York - Long Island area. The region within 200 miles of the site has been characterized by infrequent earthquakes of low to moderate intensity and magnitude.

Seismic instrumentation was first installed in the northeastern U.S. in the early 1900's and has been gradually improved and increased. It is now capable of locating any earthquake of magnitude 4.0 (local magnitude) and most earthquakes of magnitude 3.0 within a 200 mile radius of the

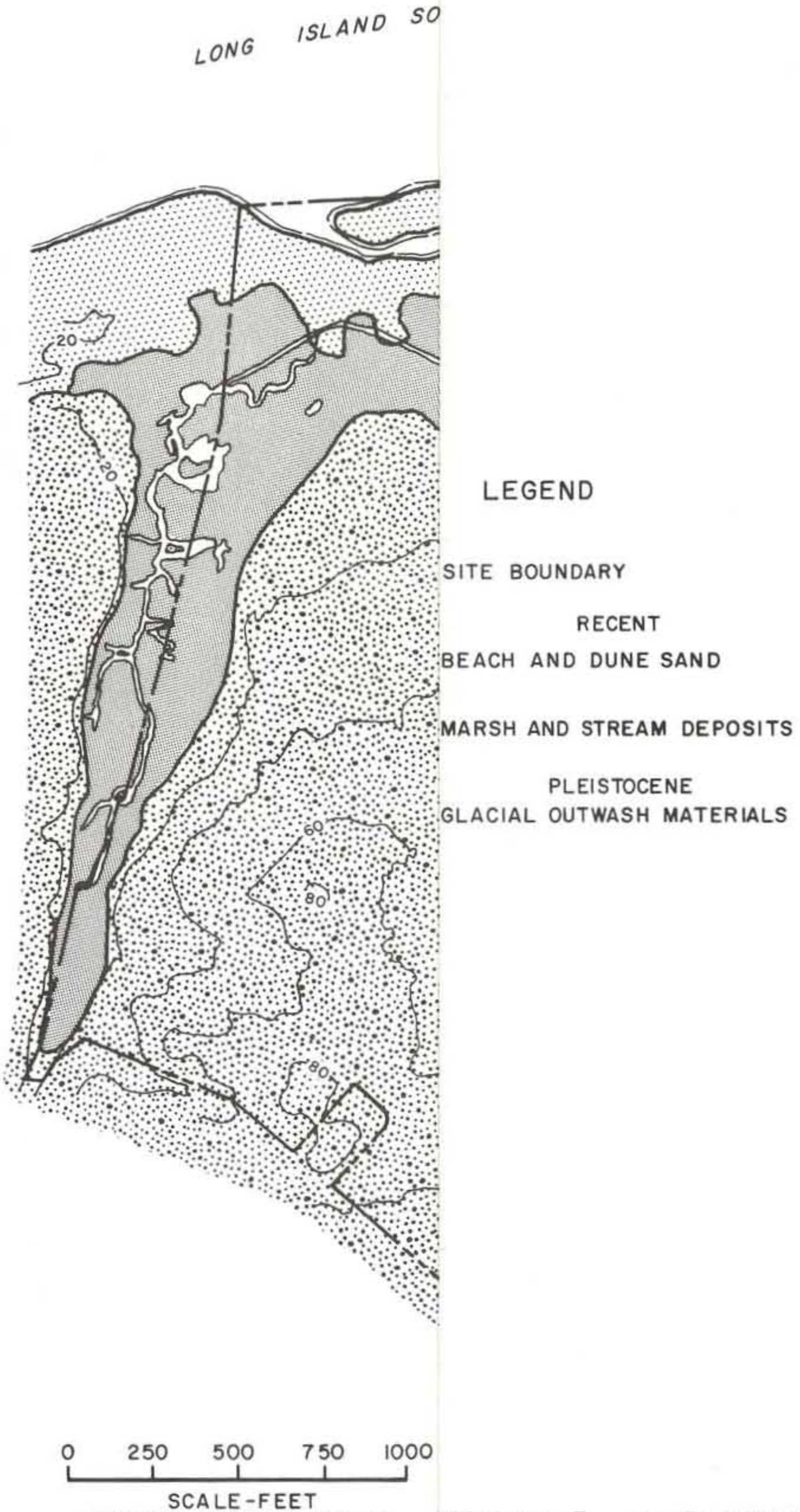
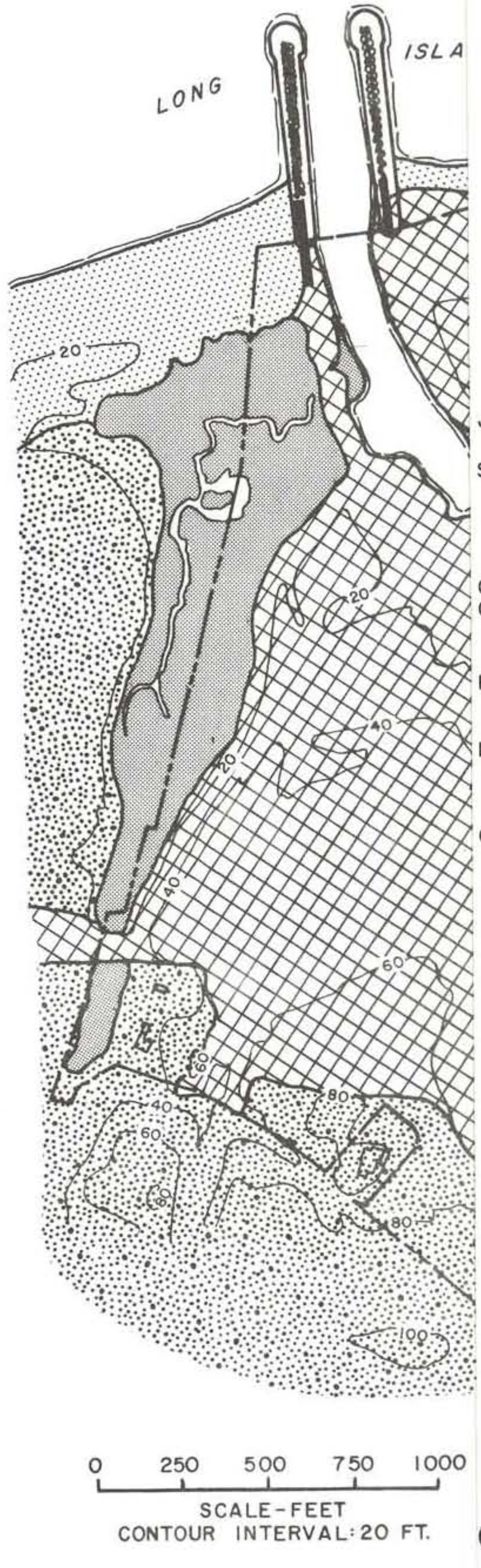


FIGURE 3 PRE-CONSTRUCTION SITE GEOLOGIC MAP



LEGEND

JETTY

SITE BOUNDARY

CONSTRUCTION AFFECTED AREAS
CUT AND/OR FILL

RECENT

BEACH AND DUNE SAND

MARSH AND STREAM DEPOSITS

PLEISTOCENE

GLACIAL OUTWASH MATERIALS

GURE 4 POST-CONSTRUCTION SITE GEOLOGIC MAP

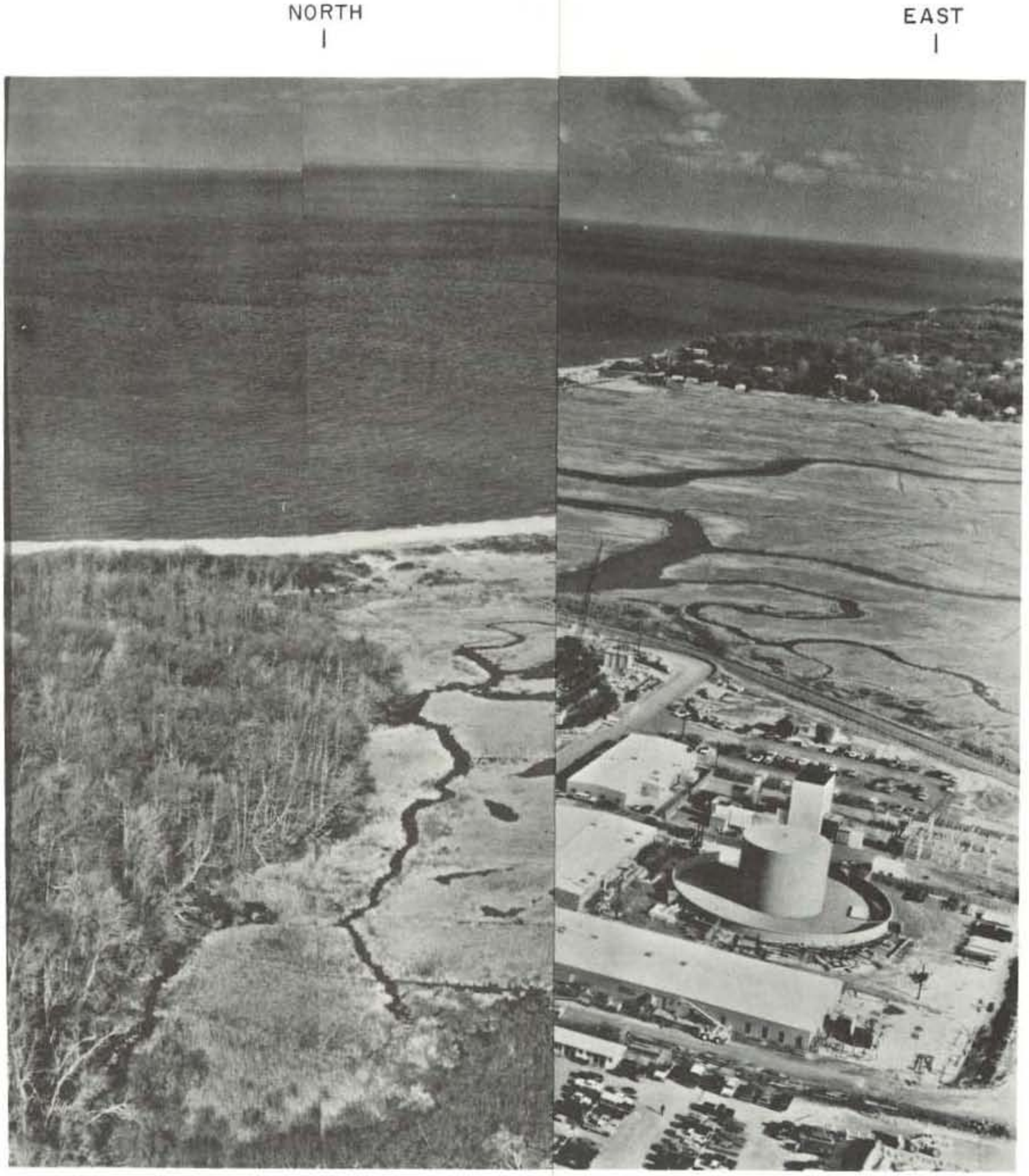


FIGURE 5 OBLIQUE VIEW OF SHOREHAM NUCLEAR POWER STATION-UNIT I

Shoreham site.

Concentrations of earthquake epicenters are located in the northern New Jersey - southeastern New York area, south central Connecticut, the Cape Ann area of Massachusetts, and the central New Hampshire region. The highest intensity for any earthquake has been assigned to the earthquake of November 18, 1755, which occurred off the coast of Massachusetts in the vicinity of Cape Ann. Outside the 200 mile area, earthquakes of epicentral intensities VIII, IX, and X (MM) have occurred along the St. Lawrence River Valley. Only two earthquakes occurring within 50 miles of the site were of sufficient intensity to be felt at the site. One occurred on May 16, 1791, in central Connecticut, and had an estimated site intensity of IV-V (MM). The other occurred on July 19, 1937, in western Long Island, with a site intensity of less than III.

NUCLEAR POWER PLANT SITING CRITERIA

Nuclear power plants are among the most complex and expensive of all engineering endeavors. Like conventional fossil-fueled systems, they consist of a number of individual components, each having its own special requirements. Some of these components, such as heat exchangers, turbines, generators, switching stations, cooling systems, and waste control systems, are common to all thermal electric generating stations. Others, such as the reactor containment vessel and the emergency core cooling system, are peculiar to nuclear-fueled facilities.

The geologic and seismic requirements for siting a nuclear power plant are really little different from any other large engineered structure whose failure could endanger man or his environment. The foundations must provide safe support for all structures and must include margins of safety against the effects of high winds and tectonic movements such as faulting.

The site itself must also be safe from the effects of flooding, unusual rises in the water table, and large sea waves or tsunamis. These requirements are valid for any type of power generating facility. The difference lies in the degree of precaution which must be exercised. Because of the nature of the nuclear fuel, criteria applied to the basic foundation design requirements are much more stringent than those applied to engineered structures of equal risk, such as large dams.

Applicable Documents

Before issuing a Construction Permit for a nuclear power plant at a given site, the U.S. Nuclear Regulatory Commission (formerly the Atomic Energy Commission) requires that the applicant submit a Preliminary Safety Analysis Report (PSAR). The form of this report is set forth in "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants". The geologic and seismic investigations required are described in 10 CFR part 100, Appendix A of the Federal Register: "Seismic and Geologic Siting Criteria for Nuclear Power Plants." Based largely on its review of the PSAR, the NRC judges whether the proposed facilities "...can be built or operated without undue risk to the health and safety of the public" (Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants; Revision 1, 1972).

Required Investigations

An applicant for a Construction Permit is required to investigate all seismic and geologic factors that may affect the design and operation of the proposed nuclear facility. A summary of the required investigations is given below. Due to the precise language used in 10 CFR part 100, Appendix A, it has been necessary to closely duplicate much of the wording of the original document.

Vibratory Ground Motion. The objective of this investigation is to obtain the necessary information to be able to describe and design for the vibratory ground motion which would occur during the severest earthquake possible in the site area, considering the regional and local geology and the past seismic history. This earthquake is called the Safe Shutdown Earthquake (SSE). A nuclear plant must be designed to be able to cease operation safely and maintain the effectiveness of the reactor cooling system after experiencing an earthquake of this magnitude.

In order to satisfy this criterion, a complete geologic and hydrologic investigation of the site must be undertaken. Local tectonic structures must be identified and evaluated with respect to their potential effects on the site. The rock and soil beneath the site must also be evaluated for their behavior during prior earthquakes as well as for their potential behavior during future earthquakes. All historically reported earthquakes which have affected or could have affected the site must be listed to include the date of occurrence, the magnitude or intensity, and a plot of the epicenter. Where past earthquakes could have caused a maximum ground acceleration of at least 0.1 g at the foundation of the proposed plant, the acceleration or intensity and duration of ground shaking at the foundations is to be estimated. Epicenters of historically reported earthquakes within 200 miles of the site must be related to geologic structures. If this cannot be done (which is the case in eastern United States), the epicenters must be correlated with tectonic provinces if within 200 miles of the site. Any faults within 200 miles of the site must be evaluated to determine if they are to be considered as "capable faults." A capable fault is defined as a fault which has experienced movement at least once in the past 35,000 years or movement of a recurring nature within the past 500,000 years, or has shown macro-seismicity which can be directly related to the fault.

Surface Faulting. This part of the investigation is concerned with determining whether and to what extent the proposed plant is to be designed for surface faulting. Any evidence of fault offset near or at the ground surface must be thoroughly investigated. Any fault greater than 1,000 ft long and within 5 miles of the site must be evaluated to determine if it is a capable fault. All earthquakes which can be associated with faults greater than 1,000 ft long within 5 miles of the site must be listed to include the date of occurrence, magnitude, and a plot of the epicenter. For capable faults greater than 1,000 ft long within 5 miles of the site, the length must be measured, its relationship to other tectonic features must be determined, and the nature, amount, and history of movement must be determined. In addition, the outer limits of the fault must be determined by mapping the fault for 10 miles along its trend in both directions from its nearest approach to the site.

Seismically Induced Floods and Water Waves. Satisfaction of this criterion includes determination of the effects which might be expected as a result of large waves or tsunamis which have occurred or might occur at the site. For sites near lakes or rivers, floods or waves caused by dam failures and landslides into lakes must also be considered.

NUCLEAR SITE SELECTION AND INVESTIGATION

Many considerations are involved in the selection of a nuclear power plant site, not the least of which are a large reliable source of coolant water, adequate available acreage, and proximity to the intended users. After a site (or sometimes several alternate sites) has been tentatively chosen, a preliminary geotechnical investigation is undertaken to determine its suitability.

A typical preliminary site investigation would consist of 10 to 15 test borings whose depths would be dictated by the dimensions and anticipated foundation elevations of the deepest plant structures and by a general (or specific) knowledge of local geologic and environmental conditions. Soil and/or rock samples would be recovered and a determination would be made of their ability to support the proposed structures under the anticipated static and possible dynamic loads. Several of the boreholes would then be converted to piezometers for monitoring groundwater table elevations. In addition, a search of the technical literature would be undertaken to reveal the general geologic and seismic history of the area to obtain basic knowledge of the site region and provide direction for further studies.

Having thus established the suitability of a site, a preliminary plant layout is decided upon. An intensive site investigation is undertaken, with particular emphasis on the proposed locations of the critical (Seismic Category I) structures. Upwards of 100 borings are frequently drilled, both on- and offshore, to provide samples for laboratory analysis and testing. A cross-hole seismic survey is made at the reactor containment location to aid in the analysis of soil or rock stability. A comprehensive study is made of regional seismicity and a detailed structural and general geologic study made of the region and particularly of a 5 mile area around the site. These investigations are frequently supplemented by various remote sensing techniques, such as high and low altitude aerial photography, ERTS (satellite) imagery, side-looking airborne radar (SLAR) imagery, and ground and aeromagnetic surveys. Highly specialized and sophisticated techniques are often required to deal with particular problems, such as dating last movement on certain faults.

The results of these various studies are used not only in the design of the plant, but are presented in the PSAR, are discussed at hearings, and become a matter of public record.

DESIGN CONSIDERATIONS

Sesimic Design

For the eastern United States, where earthquakes cannot be directly related to mapped faults, the NRC requires that a tectonic province approach be used to assign a design earthquake to a nuclear power plant site. The plant must be designed assuming 1) that the largest earthquake which has occurred within the tectonic province of the site could occur adjacent to the site or 2) that the largest earthquake in the adjacent province could occur at the nearest approach of that province to the site. That earthquake is considered which would result in the highest site intensity.

The mapped tectonic features and provinces of southern New England are widely believed to continue south-southwestward along strike beneath Long Island. Such a projection places the Shoreham site in either or both the Merrimack Synclinorium and the Bronson Hill Anticlinorium. Since the largest earthquake in this province was the intensity VII event of 1791 in East Haddam-Moodus, Connecticut (43 miles northeast of the site), the Shoreham structures were designed for an equivalent occurrence adjacent to the site. There are several relationships published (Barosh, Newman, Gutenburg and Richter, Coulter, Waldron and Devine) of ground acceleration versus earthquake intensity. These publications all indicate that 0.16 g is a reasonable, conservative estimate of the peak ground acceleration at the Shoreham site. To ensure very conservative analysis and design, a peak acceleration of 0.2 g has been chosen as the Safe Shutdown (Design Basis) Earthquake. The strong motions would result from a magnitude 6 earthquake with a focus in the lower half of the earth's crust. The duration of strong motion is estimated at 1 second at or close to the maximum horizontal ground acceleration of .2 g and 10 sec. for horizontal ground accelerations greater than .05 g.

Soil Stability

Stability analyses of soils for the support of foundations were based on detailed field investigations including in situ testing of permeability and seismic wave velocity and static and dynamic testing of soil samples to determine their physical properties. Soil moduli were based on loading tests and observation of settlements made at Brookhaven National Laboratory on soils similar in mode of deposition and character to those found at Shoreham.

Since the soils underlying the site are principally sands and gravels to a depth of several hundred feet, the major geotechnical concern was demonstrating that liquefaction would not occur under earthquake loading conditions. Liquefaction occurs when earthquake induced vibrations tend to densify loose granular soils. If the pore water cannot escape quickly enough, some or all of the overburden pressure is carried temporarily by the pore water and there is a proportional drop in shear strength. When the pore water pressure equals the confining pressure the soil temporarily liquefies. A very clear description of this phenomena has been given by Youd (1973).

The susceptibility of a soil to liquefaction is governed by grain size, relative density, and magnitude of earthquake loading. Generally speaking, silts and sands or any combination thereof may liquefy, while open gravels and clays will not. Sands with relative densities greater than 70-75 percent generally will not liquefy except under very large cyclic stresses or very high confining pressures. Naturally as the earthquake induced shear stresses increase, so does the tendency for liquefaction, all other conditions remaining equal. Unfortunately, determining absolutely the strength and relative density of sand deposits extending several hundred feet below the ground is not a simple matter. Although standard penetration resistance (SPR) and testing of undisturbed samples are two widely used means of determining the strength and relative density of sand, considerable controversy still exists concerning both methods. The SPR method consists of relating SPR blow counts to relative density based on a correlation developed by Gibbs and Holtz (1957). The undisturbed sample method consists of measuring the density of the tube sample, then remolding the sample to determine the minimum and maximum unit weight, from which the relative density is calculated. The relationships between relative density and the cyclic shear stress at which liquefaction will occur has been published by Lee and Seed (1967). In addition to these methods at the Shoreham site, remolded samples of sand were subjected to cyclic triaxial tests to confirm the stress at which liquefaction will occur. As a result of these studies it was concluded that a relatively loose zone down to elevation -12 ft would be excavated and replaced with compacted select granular fill in the vicinity of the major structures.

CONSTRUCTION CONSIDERATIONS

Soil Compaction

The soil underlying all of the structures in the general plant area, including the reactor building, turbine building, control building, and radwaste building, was overexcavated to approximately elevation -12 ft and replaced with compacted fill. The compacted backfill consisted of sand excavated from the site and recompacted in thin lifts, using vibratory equipment under carefully controlled conditions, to achieve densities of at least 95 percent of the maximum density as determined in a Modified Proctor compaction test, per ASTM D1557. This provides a pad of very dense, uniform, granular material immediately under the foundations of these structures. The thickness of the pad is 10 ft under the reactor mat and varies with the founding elevations for the other structures.

Excavation and backfill were performed in the dry, using a two stage well point system to draw the groundwater level below the bottom of the excavation. During excavation, the materials were segregated by visual inspection and stockpiled. A sufficient quantity of select granular fill, defined as clean, granular soil, containing not more than 7 percent fines passing the No. 200 sieve, was present in the excavation so the offsite fill was not needed to construct the compacted fill.

Dewatering

The average groundwater level in the general plant area is elevation 10.8 ft. In order to excavate to elevation -12 ft and construct the compacted backfill, local dewatering was necessary. This dewatering was accomplished using a two stage wellpoint dewatering system. The upper stage consisted of a closed loop header at elevation 10 ft and approximately 350 wellpoints pumped by four 2,400 gpm engine driven centrifugal-vacuum pumps. The tips of the wellpoints, including 3-foot screens, were at elevation -21 ft. The initial pumping rate was estimated to be 3,000 gpm. After ten days of pumping, the groundwater level in the excavation area stabilized at approximately elevation -6 ft, and the rate of pumping had dropped to about 2,000 gpm. Excavation proceeded as the groundwater level was drawn down. The lower stage header at elevation 0 (zero) and wellpoints with tips at elevation -24 ft were installed. Excavation continued, closely following the falling groundwater level. Artesian flow, apparently occurring through an earlier exploratory boring, Boring 201, was encountered at elevation -10 ft and was subsequently sealed. The second stage drawdown stabilized at elevation -14 ft and construction of the compacted fill was begun. Pumping of the lower stage wellpoint system was discontinued and the upper stage was returned to service after the compacted fill has been constructed to approximately elevation 0. Dewatering continued until construction of foundations of the structures had been completed, and the compacted backfill was placed to approximately elevation 10 ft.

During dewatering, samples of the groundwater were obtained from observation wells set outside the perimeter of the excavation. Chloride ion concentrations of these samples were measured to detect saltwater intrusion and possible adverse effects on neighboring wells. When saltwater intrusion was detected, a recharging system was designed and installed. This system consisted of a recharge trench located in the northeast section of the excavation area. The recharge trench was designed to receive water from the plant fresh water system for the purpose of establishing a localized hydraulic barrier against saltwater intrusion from the nearby Wading River Creek. Subsequent monitoring of chloride ion concentration indicated that the recharge trench was working effectively.

Other areas of the site requiring localized dewatering for the construction of structures included the circulating water discharge trench, circulating water intake trench, and the screenwell. Dewatering of the trenches was accomplished using a single stage of wellpoints. Dewatering of the screenwell was accomplished using submersible pumps set inside a sheetpile cofferdam.

SITE VISIT

Due to the nature of this particular field excursion, a detailed road log will not be presented here. Instead, a lecture with slides will precede a walking tour of Shoreham Nuclear Power Station.

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FORESHORE AND BACKSHORE NATURAL ENVIRONMENTS OF A BARRIER ISLAND

The tour vehicle will park in the lot at Smith Point County Park. The Fire Island National Seashore begins just west of the County Park campground. The tour will begin with a short walk down the sand trail (locally known as the "Burma Road") which runs along the center of the island.

STOP #1, Artesian Well

At the site of a former Coast Guard station will be Stop #1 to observe an artesian well, and discuss the availability of fresh water on the island, as well as the problems involved in its use.

The trip will continue through the vehicle cut in the primary dune and there will be a brief discussion on the aspects of vehicle use on the island.

STOP #2, Old Inlet Area

Proceeding onto the ocean beach, the tour will begin the 1-1/4-mile walk to the Old Inlet area. Along the way there will be a chance to observe wave action, compare the winter beach form with that of the summer, and note sand transport by wind. There will be a discussion on the formation of the barrier island and its possible future. Other topics for examination will include plant succession and stabilization of the dunes, and important marine life.

Upon reaching the Old Inlet ranger station Stop #2 will include a climb to the observation platform to observe the landforms in the immediate area. Subjects such as overwash, inlet formation, and their relationship to barrier island structure will be discussed and analyzed. The effect of man-made structures will also be discussed.

STOP #3, Salt Marsh Community

The trip will continue by following the boardwalk down to the bay to observe the vegetation of the salt marsh community. Viewing the Great South Bay from the dock the talk will center around the marine life of the bay and its economic importance to the region.

On the return trip to Smith Point the tour will once again follow the Burma Road, observing the plants of the swale and thicket zones, watching for the birds and animals which are present at the Fire Island National Seashore in November.

AN IMPORTANT NOTE: walking through loose sand is tiring. Strong hiking shoes or boots are recommended. Sneakers are inappropriate. Depending on the weather, the trip may be exposed to strong wind and salt spray. Please plan clothing and camera protection with this in mind.