## 2.5 GEOLOGY, SEISMOLOGY, AND GEOTECHNICAL ENGINEERING

### 2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

The following Geology and Seismology descriptions were extracted from the 1961 Final Hazards Summary Report and are reported in this section. Newer analyses have been completed since that time, and are reported in subsequent sections of this report.

Geology

Professor James H. Zumberge of the University of Michigan was retained as a consultant on the geology and hydrology of the reactor site and its environs. His findings are reported in Volume Two of the 1961 FHSR.

Seismology

The seismicity of the site area was investigated by Professor James T. Wilson, Professor of Geology, University of Michigan, who was retained as a consultant for this purpose, and his findings are attached in Volume Two of the 1961 FHSR. The probability that earthquakes of significant intensity will occur in the general site area appears to be very low.

The importance of earthquakes to plant design was independently investigated by the Bechtel Corporation. Their summary statement of findings is:

"An investigation of the seismic history indicates that this is a region of low seismic activity. The Coast and Geodetic Survey Publication, Serial 609, Earthquake History of the United States, lists earthquakes in the Michigan area as shown below. All of these are classified as intermediate or minor. The nearest recorded earthquake was the one centered near Menominee, approximately 110 miles from the plant site."

Earthquake History as of October, 1959

| Date | Locality | Rossi-Forel Intensity |
|---|---|---|
| Feb 6, 1872 | Winona, Michigan | 5* |
| Aug 17, 1877 | Southeast Michigan | 4-5 |
| Feb 4, 1883 | Indiana & Michigan | 6 |
| Mar 13, 1905 | Menominee, Michigan | 5 |
| July 26, 1905 | Calumet, Michigan | 8 |
| May 26, 1906 | Keewenaw Peninsula, Michigan | 8-9 |
| Jan 22, 1909 | Houghton, Michigan | 5* |

*Locally felt only.

Since no recorded earthquakes have centered near the plant site, and there is no knowledge of earth tremors having been felt near the site, elaborate or special seismic design features were not considered necessary. However, in keeping with good engineering practice, all structures are designed to resist nominal seismic loading. Structural design of the plant complies with the Uniform Building Code (UBC). Horizontal forces based on Zone 1 are used.

The UBC does not clearly cover the reactor containment vessel or the concrete structure and equipment within. In view of their high degree of rigidity, it appeared prudent to use a seismic factor equal to the maximum expected ground acceleration at the site. A study of the brief earthquake history of the regi n led to the conclusion that an intensity of 7 on the Rossi-Forel scale was a reasonably conservative assumption. This corresponds roughly to a ground acceleration of 0.05 gravity. Therefore, a seismic factor of 0.05 was used for this portion of the plant. This is twice the factor required by the UBC for tanks and similar structures, and appears to be reasonable in view of the high rigidity already mentioned.

For the containment vessel itself, earthquake forces do not govern the design, since the wind force on the vessel at the design velocity of 100 miles per hour is greater than 0.05 times its weight.

### 2.5.1.1 Regional Geology

The following Regional Geology was extracted from the NRC assessment of Systematic Evaluation Program Topic II-4 (Reference 20).

The Big Rock Point site lies within the Great Lakes Section of the Central Lowlands Physiographic Province (Thornbury, 1965). The dominant features of this section were caused by glaciation and include lakes, large and small, prominent end moraines, outwash plains, closed basins forming swamps or lakes, eskers and drumlins, and vast areas of rolling ground moraine between the end moraines. Because of the direction of advance and retreat of the last glaciation, lower peninsula Michigan has a strong surficial northwest-southeast grain. This is also the principle structural trend in Paleozoic rock.

Bedrock beneath the site area consists of limestones and shales of the Traverse Group of Middle Devonian age (395 million years before present (mybp) to 375 mybp)(Harding-Lawson Associates, 1979). Three formations of the Traverse Group are exposed in the site region: the Petoskey, Charlevoix, and Gravel Point formations. The bedrock immediately beneath the site is the Gravel Point formation because the Petoskey and Charlevoix have been eroded away. In the site vicinity, the Gravel Point formation is about 200 feet thick and consists of a variety of rock types but is primarily a gray to brown, fossiliferous limestone that varies from massive to thin bedded. Interbedded with the limestone strata are beds of shale and shaley limestone. Much of the southern shoreline of Little Traverse Bay

from Charlevoix to Petoskey is formed by outcrops of the Gravel Point formation.

The rock in the site is overlain by several tens of feet of till, glacial lakebed, glacial outwash, and windblown deposits.

The site is located in the Central Stable Region Tectonic Province (Eardley, 1962). This province is characterized by major domes, basins, and arches which formed during the Paleozoic Era (570 mybp to 240 mybp). The site lies above the northern flank of the Michigan Basin, which is one of the large tectonic structures in the Central Stable Region.

Bedrock in the site region dips at a low angle to the southeast toward the center of the Michigan Basin. Superimposed on this regional dip in the site region, are gentle undulations caused by the presence of minor synclines and anticlines. These folds strike generally northwest-southeast and plunge to the southeast (Harding-Lawson Associates, 1979). The axes of major folds within Paleozoic rocks of the Michigan Basin also have northwest-southeast trends.

Regional jointing in the northern Michigan Basin have four major vertical joint sets: N52°E, N46°W, N89°W, and N1°E (Holst, 1982). These trends are present in the site region with the northwest set being the most prominent (Harding-Lawson Associates, 1979). The joints are usually tight and widely spaced, but locally they have been widened by solutioning. The sinkholes exposed in the quarries in the area appear to be aligned along major joint trends. Solutioning in the region is discussed in Section 2.5.1.3.

The Michigan Basin has been relatively stable for several hundred million years and is therefore relatively undeformed. Faults have been identified in Paleozoic rocks in the basin, however, no major faults are known in the site area. The faults in the basin are believed to be pre-Pennsylvanian (more than 330 mybp). They do not offset Pleistocene (10,000 years to 2 mybp) glacial deposits. Minor faults related to ancient solution collapse features have been observed in local quarries. Faults have been postulated, based on seismic reflection profiling in Lake Michigan. These faults have been evaluated and interpreted to be not capable (USNRC, 1978). Faulting in the region and site area is discussed in more detail in Section 2.5.2.

2.5.1.2 Site Geology

The following Site Geology was extracted from (Reference 20) the NRC assessment of Systematic Evaluation Program Topic II-4.

The site is located on the south shore of Little Traverse Bay where it opens into the northern end of Lake Michigan. Elevations range from about 580 feet mean sea level (ft. msl) at the lake shore to

+700 ft msl about one mile inland. Elevation at the site is +590 ft msl. From the lake shore to about one mile inland the terrain is a lowland that was once submerged beneath ancestral Lake Michigan. The topography is characterized by low beach ridges with swampy areas in between. From one to five miles from the lake elevations range from +700 to +900. This area is a till plain with drumlins that rise forty to sixty feet above it. A drainage divide is present in that area from which surface water and shallow groundwater flow north to Little Traverse Bay and south to Lake Charlevoix. It is also the probable recharge area for minor artesian zones in the soil beneath the site.

The geology of the site was investigated by Consumers Power Company (CPC) in several phases. Two exploratory boring were drilled into the top of bedrock in May, 1959, and seven additional borings were drilled into rock in February, 1960. In 1979, three borings were drilled to determine the dynamic characteristics of the soil and rock beneath the site.

The site lies within the outcrop belt of Devonian limestones of the Traverse Group, and the rock directly below the plant is the Gravel Point formation. It consists of brown and gray, broken to massive limestone with clay seams and interbedded shale, claystone and siltstone layers (D'Appolonia, 1979). Between depths of about 130 and 190 feet the limestone contains vuggy zones and core recovery and RQD (Rock Quality Designation) percentages were low. The limestone bedrock is overlain by about 40 feet of soil. The upper eight to ten feet consists of dense, fine to coarse sand with gravel and some boulders. Below the sand and extending to bedrock is very dense till. The till consists of clayey, fine to medium sand with limestone fragments, cobbles and boulders. The water table varies seasonally, but is usually several feet above the normal level of Lake Michigan.

The till and massive bedrock beneath the site are competent foundation materials, however, the Gravel Point limestone is susceptible to solutioning. In northeastern lower peninsula Michigan, karst topography is well developed in the Devonian limestones. This may be due to the relatively thin cover of glacial deposits in that area. In the site area solution features are more subtle and apparently far less common, but several significant features have been found. A more detailed discussion of limestone solutioning is included in Section 2.5.1.3.

Other than the slight possibility of cavernous conditions beneath the site, there are no geologic hazards at this site.

### 2.5.1.3 The Potential for Subsidence or Collapse Due to Solutioning

During the NRC Review of Systematic Evaluation Program (SEP) Topic II-4.B, Proximity of Capable Tectonic Structures in Plant Vicinity, two concerns were identified (Reference 20):

1) The possible existence of a large cavern under the site that could ultimately cause subsidence or collapse.

2) The possibility of the development and enlargement of a new cavern during the life of the plant.

The bases for the concerns were: 1) the existence of three large sinks and an open cavern in the Penn-Dixie and Medusa quarries, which are located eight miles to the east and several miles to the southwest respectively; 2) the susceptibility to solutioning of the Traverse Group limestones which comprise the site bedrock; 3) the karst-like topography of the rock surface offshore beneath Little Traverse Bay where there is little or no soil cover; and 4) poor rock recovery in the original site exploratory borings and the discovery in three recent borings of a vuggy zone between 130 and 190' depths.

In their report entitled "Solution Features in the Traverse Group of Northwestern Michigan" Harding-Lawson Associates, geologist consultants for Consumers Power Company, presented data supporting their conclusion that extensive solutioning is not going on in the site area at the present time, nor has it likely been for the past several thousand years. The evidence cited includes: 1) the sinks present in the quarries are filled with undisturbed glacial deposits including sand, gravel and till; thus dating the solution holes as being at least Late Pleistocene age; 2) the open cavern in the Penn-Dixie quarry had been bridged by 60 to 80 feet of rock before excavation and was well below the present level of Lake Michigan, indicating that it probably formed when the level of the Lake was much lower than it is today; 3) movement of groundwater through the rock, related to the wide range of fluctuation of the surface of ancestral Lake Michigan during the Pleistocene, is believed to have caused most of the more geologically recent solutioning activity. The level of Lake Michigan and the local groundwater surface have been relatively stable since the lake reached its present level after the close of the Pleistocene; 4) the site region is covered by a blanket of relatively impermeable soil, causing most precipitation to run off rather than percolate down and move through the rock; 5) extensive karst topography is not apparent at ground surface in the site area.

Based on the evidence available to date, it is not likely that significant solution activity is going on in the rock beneath the site, nor is it likely that there are large caverns beneath the site sufficiently close to the surface to cause subsidence or collapse beneath the plant, as indications of this condition would probably have already been observed during or shortly after coustruction twenty years ago. However, because of the scarcity of information on the condition of site bedrock it was considered prudent to perform additional studies to confirm its competency.

The additional studies were completed and the results and conclusions on these concerns were addressed in (Reference 21) as follows:

CPCo contracted with Commonwealth Associates, Inc (CAI) of Jackson, Michigan, to investigate the possible existence of solution cavities beneath the plant. CAI reported its conclusions in the report "An Investigation Into the Possible Existence of Solution Cavities Beneath the Big Rock Point Nuclear Power Plant Near Charlevoix, Michigan," February 1983. In that report the consultant concluded that the geologic processes that created solution features in the area have not been active since the last episode of glaciation, and there is insufficient information to confirm either the presence or absence of cavities beneath the site.

Evaluation Summary Conclusion

On the basis of the evidence available to date, it is not likely that significant solution activity is going on in the rock beneath the site, nor is it likely that there are large caverns beneath the site sufficiently close to the surface to cause subsidence or collapse beneath the plant, because indications of this condition would probably have been observed during or shortly after construction 20 years ago. The staff concludes that there is insufficient benefit to be gained from conducting additional onsite investigations; therefore, no further action is required.

One other concern raised during SEP Topic II-4.B review (Reference 20) was the possibility of subsidence and collapse due to the dissolution of salt at depth beneath the site. Wold (1980), based on the examination of the available seismic reflection profiles in Lake Michigan interprets the presence of faults, which he attributes to collapse structures formed by the dissolution of salt within the zone of outcrop of Middle Silurian (445 mybp) through Middle Devonian (360 mybp) strata. The site lies within this zone. Based on NRC review, they don't consider this phenomenon to represent a hazard to the site because:

1) the site is underlain by a relatively thick section (400/500 feet) of Upper Devonian rocks with little or no salt deposits (based on studies by Dr. T. Buschbach of outcrops, quarries, hydrocarbon exploratory borings, and water well logs); and

2) the section of rocks that are of concern, in addition to being overlain by a thick sequence of Upper Devonian rocks, are also overlain by 40 feet of glacial deposits. There is no apparent evidence of collapse features at depth in the glacial soil at the site.

Evaluation Summary Resolution

Salt deposits lie at depth beneath the site. It has been postulated that inferred faults in Lake Michigan are the result of collapse due to dissolution of salt. We conclude that this phenomenon doesn't present a hazard to the plant because of thick limestones over the salt deposit, and there is no evidence of it having occurred in at

least the last 10,000 years in the Pleistocene soils that cover rock in the site area.

2.5.2 VIBRATORY GROUND MOTION As discussed in Section 2.5.1 above, the probability of earthquakes of significant intensity to provide vibratory ground motions which would cause major damage at Big Rock Point is very low. As a result of the Systematic Evaluation Program (SEP), (Reference 28) the seismicity of the Big Rock Point vicinity has been recently reviewed by experts employed by the NRC, the SEP Owners Group and by Consumers Power Company (see NUREG/CR-1582 and "Eastern United States Tectonic Structures and Provinces Significant to the Selection of a Safe Shutdown Earthquake," Weston Geophysical, August 1979). Based on approximately 200 years of reasonably reliable earthquake history and the known geological and tectonic structure of the area, the experts seem to agree that a design basis earthquake with a return period of one to ten thousand years would be 0.05 to 0.07 g. Earthquakes of this size do not cause major damage to even poor quality construction.

If, in addition to the above, a minimum design earthquake is assigned for the entire eastern United States without regard to structure or location, the design earthquake increases as in Attachment 1 to the August 4, 1980 NRC letter to approximately 0.10 g. Typical industrial construction is not usually damaged by this level of earthquake. Steel and reinforced concrete construction as used at Big Rock might, at worst, suffer minor cracking.

Finally, preliminary calculated results from the Big Rock structural evaluation indicate that major structural elements of all safety-related structures will remain below code allowable stress when subjected to an 0.11 g earthquake of the type shown in Attachment 1 to the August 4, 1980 letter.

In summary, earthquakes are not very probable at Big Rock Point. Even for long return periods, the earthquake is not predicted to be large enough to cause major damage to quality industrial construction. Preliminary calculations for Big Rock structures show no significant damage occurs to the structures from earthquakes of the size proposed in your letter. Independent work being done for the Big Rock Probabilistic Risk Assessment indicates very long return periods for earthquakes of this size. We conclude that continued operation of the Plant while the seismic analysis is completed is entirely acceptable for the above enunciated reasons.

Summary of Seismic Design Considerations

A summary of the Big Rock Point seismic resistance from Systematic Evaluation Program (SEP) Topic III-6 Seismic Design (Reference 27) is provided below:

The initial seismic criteria as applied to Big Rock Point were based on static requirements of the 1956 edition of the Uniform Building Code. The containment design was based on a 0.05g horizontal static coefficient. The turbine building, concrete stack, intake structure, control room and rad waste storage buildings were designed based on a 0.025g horizontal static coefficient. Piping design for seismic resistance was limited to the reactor vessel supports and NSSS major piping. These components incorporated a 0.05g and a 0.025g horizontal static coefficient in the respective designs. The RDS was designed in 1974 in accordance with seismic design requirements as they existed at that time. These compare with more recent requirements which assume a 0.12g (Reg Guide 1.60) safe shutdown earthquake. The Alternate Shutdown Panel Building design and electrical conduit for alternate safe shutdown also utilized the 0.12g (Reg Guide 1.60) safe shutdown earthquake requirement.

A complete review of the seismic design adequacy of the Big Rock Point Plant was initiated by the NRC staff early in 1979 as a part of Systematic Evaluation Program Topic III-6. Plans were developed by Consumers Power Company and submitted April 25, 1979 with respect to important structures which were to be analyzed. The staff requested that major portions of the primary coolant loop be included in this initial structural analysis in July 1979. Initial structural analyses employed Reg Guide 1.60 Spectra (anchored at .12g) while awaiting staff approval of a site specific seismic response spectra. Preliminary results from analysis of 15 major site structures plus the primary coolant loop were submitted January 9, 1981 with the final report (by D'Appolonia) published August 26, 1981.

In July 1979 (IEB 79-14), the staff required all licensees to verify that the configuration of safety-related piping systems corresponded to that assumed in the plants existing design analysis. This activity resulted in an inspection of approximately 6000 feet of safety-related piping at Big Rock Point including examination of pipe geometry, support design, embedments, attachments and valve location and orientation. Results associated with this activity were published in October 1979, and were to be used eventually as input to the piping design review associated with SEP Topic III-6.

In January 1980, the staff published a formal request for the immediate identification and evaluation of important electrical equipment and its anchorage. As a part of the request, auxiliary failures which could result in the disabling or failure of safety related equipment (such as gas bottles, dollies, etc) were to be identified and evaluated as well. This Systematic Evaluation Program work resulted in the identification, analysis, and anchorage of over 50 equipment items. Among the major equipment important to safety were motor control centers, distribution panels, batteries and transformers. As requested, auxiliary equipment was also evaluated and included tanks, containers, cabinets and lighting located in the vicinity of important safety equipment. The majority of the electrical equipment anchorage work was completed by March, 1981.

In April, 1981 the staff requested a firm schedule for completion of seismic design review activities. Included in their request were not only the primary coolant loop but verification of fluid and electrical distribution system integrity and analyses of the integrity and functionability of important mechanical and electrical equipment. Also requested was justification for continued operation while the additional work was in progress. At this time the cost of evaluating this single SEP topic was well in excess of one million dollars and had at least as much evaluation and analysis awaiting completion as had been accomplished to date. In addition, work was ongoing in the development of resolutions to NRC questions raised with respect to work submitted to date. As part of its justification submitted June 19, 1981, Consumers Power Company questioned the benefits of such an extensive, deterministic based reevaluation of the Big Rock Point structural design. Referenced were the results of the Big Rock Point risk assessment published in March, 1981 which suggested that seismic concerns represented only a small contribution to the total risk of operation. Consumers Power Company proposed the detailed analyses completed to date used in conjunction with augmentation of the Probabilistic Risk Assessment (PRA) arguments would demonstrate a basis for concluding that seismic risk at Big Rock Point was small compared to other contributors, and that further deterministic analyses were not necessary.

In a site visit on June 30, 1981, the staff insisted that the deterministic approach was necessary and that the proposal to use risk assessment as a basis for continued operation had little promise of working. Consumers Power Company submitted a plan for future evaluations with respect to SEP Topic III-6 on July 27, 1981 and on September 29, 1981, the staff concluded that our plan and justification for operation in the interim were acceptable. Justification was based on analysis of plant structures and systems performed to date, apparent inherent seismic resistance of remaining systems and structures, and the low seismic hazard associated with the Big Rock Point site.

In April, 1982, as a part of its review of Consumers Power Company seismic evaluations that had been completed, the staff raised questions with respect to soil properties assumed in these analyses. This placed into question the adequacy of the Reg Guide and site specific spectra used in the analyses. In August 1982, work explicitly aimed at analysis of piping and equipment was suspended (except for model development) while these uncertainties were resolved.

On October 19, 1982, the staff issued a draft Safety Evaluation Report (SER) with respect to the status of the seismic reevaluation of Big Rock Point. This report identified several areas of concern that the staff had with respect to the appropriateness and completeness of analyses performed to date. As a result, the staff stated that they were unable to come to a conclusion with respect to the seismic capability of the Big Rock Point Plant. They did conclude, however, that there existed inherent seismic resistance in the design of the

plant, that operation was justified in the interim while the Integrated Assessment was performed and that alternate approaches to resolving this topic should be investigated.

A meeting was held with the staff in December, 1982 in which Consumers Power Company was encouraged to respond to the staff comments presented in the October SER. The staff concluded that because of the significant cost of continuation of the seismic analysis program it was recommended that Consumers Power Company consider and propose alternate approaches. These approaches could include bounding analyses with selected plant upgrading assessments of the consequences of failures, comparison of probabilistic risk and representative cross-sections of current plants, or combinations thereof. The resulting approaches would be considered in the Big Rock Point Integrated Plant Safety Assessment.

In June, 1983, explicit response to the staff's concern in their draft SER were provided in addition to the alternatives Consumers Power Company was proposing for final resolution of this SEP topic. The alternatives included a comparison of the risks associated with Big Rock Point Plant consequences on the health and safety of the public in comparison with a newer typical facility, as the staff suggested. Also an approach to identifying, evaluating and upgrading the seismic "weak-links" at Big Rock Point was presented with explicit results. Commitments were made to upgrade the report to more completely identify the perceived weaknesses associated with the plant design, if the staff approved of the approach.

In September and November of 1983 the staff and Consumers Power Company presented joint testimony before the Advisory Committee on Reactor Safeguards in regard to the alternate "weak-link" approach. The ACRS was requested to comment on the appropriateness of the proposed approach. In their testimony the staff concluded that the "weak-link" approach was prudent and correct for Big Rock Point. They intended to monitor its implementation in the form of analyses and backfits before concluding as to the level of protection afforded by the plant design against seismic events. Preliminary conclusions by ACRS members indicated that it was not necessary to get Big Rock Point up to the level of a new plant and that the "weak-link" approach was appropriate.

In May 1984, the final Integrated Plant Safety Assessment was published by the staff (Reference 21). In that report, both the staff and the ACRS conclude that the proposed "weak-link" approach is appropriate and that they will continue to monitor its implementation.

NRC Evaluation Conclusions (Reference 21)

The following was extracted from NUREG 0828, Final Report May 1984, Section 4.12 and supports the evaluation above.

During its topic evaluation, the staff concluded that the criteria and analyses supplied by the licensee for structures, buried piping,

and portions of the reactor coolant loop piping were not adequate to resolve questions concerning analytic uncertainty or to quantify the effects of simplifying assumptions. The seismic analyses performed to date are not in accord with either Systematic Evaluation Program (SEP) or Standard Review Plan (SRP) current criteria. The licensee has indicated that it is not economically feasible to perform the analyses required to demonstrate seismic capability and quantify analytical uncertainty. The staff agrees that considerable detailed analysis would be required. As an alternative, the licensee has proposed to evaluate the seismic resistance of equipment important to safety using a combination of probabilistic methods and deterministic analyses....

The staff concurs with the licensee's proposed approach to selective seismic upgrading. The original design of Big Rock Point included a static horizontal load for structures. The seismic analyses performed under Topic III-6 have demonstrated that there is inherent seismic resistance in the design; however, to complete the analysis and any modifications necessary to demonstrate a consistent seismic capability for all safety-related equipment and structures would be very time consuming and expensive because of the lack of original seismic design analyses, the complex nature of the "as-built" plant, and (in some cases) lack of original construction details needed to perform seismic analyses. The offsite dose analyses performed in conjunction with SEP topics and the licensee's PRA have demonstrated that the relative consequences of accidents, even those involving core melt, are very low because of the small plant size and low population distribution around the plant site.

In view of these considerations, the staff concludes that the approach proposed by the licensee (ie, to selectively upgrade the "weak links" in the systems and structures necessary to mitigate accidents that would be expected to result from seismic events) is reasonable and, if properly executed, would provide sufficient seismic resistance so that the health and safety of the public could be ensured.

2.5.2.1 Response Spectra

Various seismic design Response Spectra have been used in the Systematic Evaluation Program to demonstrate the seismic design adequacy of Big Rock Point:

- In the August 4, 1980 NRC letter, the preliminary seismic input ground response spectra recommended for use in the interim until

the final NRC staff decision on Site Specific Spectra at SEP sites was provided at the 50th percentile of 0.102g and 5% damping.

- This Site Specific Response Spectra for SEP Plants Located in the Eastern United States was finalized and issued by NRC letter to all SEP Owners (except San Onofre) June 8, 1981 (reissued June 17, 1981). This Final Site Specific Spectrum recommended ground response spectra (5% damping) was 0.11g.

- In the CPCo April 25, 1979 letter and the July 26, 1979 meeting, we agreed to construct structural models and exercise them using an example spectra. The example spectra is a Reg Guide 1.60 spectra anchored at 0.12g. This seismic input consists of a sample problem earthquake having a zero period horizontal ground acceleration equal to 0.12g.

- In May of 1982, a Site Specific Response Spectrum was prepared for CPCo by Weston Geophysical Corporation and was derived by CPCo independently from the NRC efforts in this area. This report was submitted to the NRC on May 5, 1982. A copy of Attachment 1 from the May 5, 1982 letter is provided as Figure 2.7 of this report and shows a plot of the spectra resulting from the Weston work as well as a 0.12g Reg Guide 1.60 spectrum and the site specific spectrum issued by the NRC (letter of June 8, 1981) of 0.104g.

- In the Spent Fuel Pool Expansion Hearings, an affidavit in support of Motion for Extension of Time (May 3, 1982) was filed noting possible anomalous site conditions which could affect the seismic input ground motion at Big Rock Point.

  The NRC staff issued an "Assessment of Possible Soil Amplification at Big Rock Point Site," June 30, 1982. This evaluation of the possible need to modify the seismic input ground motion because of shallow soil conditions at the site concluded that the original issued ground response spectra are still appropriate (ie, 0.11g).

  Extensive studies of amplification at Big Rock Point may only be of marginal safety significance. The seismic hazard at this site is so low such that the chance that there will be amplified ground motion in excess of the previously identified spectrum (Memorandum from R. Jackson to W. Russell, dated May 20, 1981 attached to the June 17, 1981 NRC letter) is extremely small.

Conclusions

It has been Consumers Power Company's position that safety-related plant improvements or additions should be designed in accordance with current regulatory criteria as practicable within the constraints of the existing plant design and considering the nature of the improvement in terms of its effect on overall plant safety.

In this regard we would intend to use seismic design criteria based either on the Reg Guide 1.60 (0.12g) earthquake or the NRC site specific (0.104g) earthquake as both are acceptable seismic design bases. Big Rock Point is also involved in resolution of unresolved Safety Issue A-46 for Seismic Qualification of Equipment in Operating Nuclear Power Plants through Generic Letter 87-02 as a member of a Seismic Qualification Utility Group (SQUG).

2.5.2.2 Historical Hazard Analysis

The following historical hazard analysis summary was extracted from (Reference 29) and is included in this report to provide additional seismic hazard analysis which justifies the conclusion by the NRC that further extensive studies of amplification at Big Rock Point may only be of marginal safety significance:

The seismic hazard at Big Rock Point is very low. According to a recent compilation of historical and instrumentally recorded earthquakes (NUREG/CR-1577) the closest earthquake occurred at a distance of more than 100 km from the site and this event was of Modified Mercalli Intensity V or less. In addition, Chen and Bernreuter (1982) performed a historical hazard analysis ie, using only actual events in the historic record (not moving them) and a ground motion model which estimates ground motion (peak acceleration) at Big Rock Point from these events. They estimated the return periods associated with peak accelerations at the site. Depending on the ground motion model used the peak acceleration associated with 4000 year return period varied from 0.03g to 0.1g. The high value was determined using a ground motion model that according to Chen and Bernreuter (1982) may over emphasize the distant (over 1000 km) 1811, 1812 New Madrid Earthquakes. Indeed, using the most recent ground motion model (Nuttli and Hermann, 1981), results in peak accelerations on the order of 0.001g at a distance of 1000 km. Excluding the New Madrid events (which according to Chen and Bernreuter, 1982, have estimated return periods on the order of 500 to 1000 years) results in a peak acceleration at Big Rock Point of 0.03g associated with the 4000 year return period. While no attempt is made to correct for completeness of the data or delineate earthquake zones these studies indicate that based upon 200 years of earthquake history the ground motion occurring at Big Rock Point has been very low and that simple projections of this history using current ground motion models, to long return periods on the order of thousands of years yields peak accelerations well below that originally recommended (0.1g) for the site. Based on the above, the chance that Big Rock Point will experience earthquake ground motion of any significance is extremely small.

2.5.2.3 Safe Shutdown Earthquake (SSE)

10 CFR Part 100, Appendix A requires that the Safe Shutdown Earthquake (SSE) be defined by response spectra corresponding to the expected

maximum ground accelerations. Reg Guide 1.60, Revision 1 describes methods for defining this response spectra as follows:

> Maximum (peak) Ground Acceleration specified for a given site means that value of the acceleration which corresponds to zero period in the design response spectra for that site. At zero period the design response spectra acceleration is identical for all damping values and is equal to the maximum (peak) ground acceleration specified for that site.

For the Big Rock Point site, this maximum (peak) ground acceleration is graphically depicted in the Design Response Spectrum in Figure 2.7 as the Reg Guide 1.60 at 0.12g. It should be noted that the 0.12g Reg Guide 1.60 Spectrum envelopes both the NRC Site Specific Spectra and CPCo's Big Rock Point Site Specific Spectra as discussed in 2.5.2.1 above.

#### 2.5.2.4 Operating Basis Earthquake (OBE)

Values have not been tabulated or depicted for the Big Rock Point OBE, however these values are normally one half of the Safe Shutdown Earthquake.

#### 2.5.2.5 Site Specific Seismic Floor Response Spectra

Derivation of Site Specific Seismic Floor Response Spectra for the seismic safety margin evaluation of Big Rock Point Plant are contained in D'Appolonia Report dated August, 1983 (Reference 30) and in (Reference 23).

### 2.5.3 SURFACE FAULTING

The following NRC assessment of the capability of faults in the site region was extracted from Systematic Evaluation Program Topic II-4.B, Proximity of Capable Tectonic Structures in Plant Vicinity (Reference 20):

Major faulting has not been recognized in the subregional area around the site. Although the Michigan Basin has a long history (hundreds of million years) of relative tectonic stability, large-scale structures have been mapped within it, primarily in areas of hydrocarbon exploration and production.

During geological studies in regard to the (proposed) Midland Nuclear site, a pattern of orthogonal northwest-northeast mild deformation was mapped on several Mississippian and Devonian stratigraphic horizons (USNRC, 1982). Faults were inferred to be associated with that pattern. These investigations showed that the inferred faulting could not be demonstrated to extend upward into overlying Pennsylvanian strata, therefore the faults, if they exist are at least Late Mississippian in age (more than 330 mybp). Deformation was also

identified in Pennsylvanian rocks south and east of the Midland site. It was demonstrated however that these distortions were formed by soft sediment deformation that occurred during or shortly after deposition and were not tectonically derived (USNRC, 1982). All faults in the region around the Midland site were concluded to have occurred prior to the Pennsylvanian period (more than 300 mybp). That conclusion is consistent with observations on the regional geologic history of the Michigan Basin (Haxby et al., 1976; Cross, 1982; and Fisher, 1979 and 1982).

The intrabasin structure is dominated by a subparallel set of northwest-southeast anticlinal flextures that are asymmetric in cross-section with the strong dip toward the basinward side. They are best defined in the eastern, southeastern, and central portions of the basin. Several prominent features located far to the south of the plant site, namely the Howell antiline, Albion-Scipio syncline, and the Lucas-Monroe monocline, are postulated (but not proven) as having west-flanking in their Paleozoic strata (USNRC 1982).

Several faults are located on the southeast flank of the Michigan Basin that have mid-Paleozoic displacements. These are the Bowling Green Fault, located in northwestern Ohio, with youngest displacement being of upper Silurian age, and faults associated with the Chatham sag, Ontario, Canada. The latter system of faults, which includes the Electric and Osborn faults, indicates that the Chatham sag was inactive after middle Devonian time (more than 350 mybp).

A series of major folds in the Paleozoic rocks characterizes the Michigan Basin (Holst, 1982). A prominent northwest striking joint set may be related to this structural grain. It is likely that faults are associated with these structures, but based on regional associations, these faults are not capable.

During the staff review of the Wisconsin Electric Company's (WEPCO) Haven site several sources of seismic reflection data indicated the possible presence of NNE and NW trending faults beneath Lake Michigan. The staff reviewed these and other data gained during WEPCOs investigation, and studied the seismicity of the Lake Michigan region. Based on that review (memo from R. Denise to B. Grimes, October 11, 1978) the staff concluded that 1) faulting within Paleozoic strata in the Central Stable Region is widespread in rocks that are Mississippian age and older (320 mybp), therefore, the discovery of faults, or the inference of faulting within Mississippian or older units beneath Lake Michigan is not surprising; 2) no historic earthquake epicenters have been plotted in Lake Michigan, and 3) the faults beneath Lake Michigan are geologically old and pose no potential to increase the earthquake hazard of the region.

There are other structures like those described above within and around the Michigan Basin. All of these structures are considered by the staff to be post Devonian to pre Pleistocene (345 mybp to 1 mybp) with most activity occurring in the Late Paleozoic. This conclusion

is based on the observation that all Paleozoic rocks are affected by the structures, with Mississippian being the youngest; and there is no evidence that the faults cut Pleistocene sediment.

Several minor faults have been reported in the site area. One small fault mapped by Pohl (1929) was reported as not displacing the Petoskey formation, and is therefore more that 360 million years old. Faulting described in the Penn-Dixie quarry (Walden, 1977) is related to solution slumping because they do not extend below the sinkhole in the north wall (Harding-Lawson Associates, 1979).

We assume that there are probably minor faults in bedrock in the site area because faults have been mapped in Paleozoic rocks throughout the Michigan Basin. There is no evidence, however, of fault displacement of Pleistocene soils that cover bedrock in the region. We conclude that there are no faults within the site region that could be expected to localize earthquakes in the site vicinity, or that could cause surface displacements at the site. Based on our review, it is the staff's conclusion that there are no tectonic faults that represent a hazard to the continued safe operation of the Big Rock Point Plant.

Evaluation Summary Conclusion

Geological investigations that have been carried out in the site area and throughout the Michigan Basin have not found any indication of fault movement in the recent geologic past. Evidence has been found throughout the basin that indicates that the latest movement that occurred along known faults was at least 330 million years ago. No evidence has been found that faults displace Pleistocene deposits. No faults have been identified at the site, however, if they exist, they like all known faults in the Michigan Basin are not capable according to Appendix A 10 CFR, Part 100.

## 2.5.4 STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

The following assessment of the foundations and earthworks properties under anticipated loading conditions including earthquakes was extracted from Systematic Evaluation Program Topic II-4.F, Settlement of Foundations and Buried Equipment (Reference 22):

Figure 2.3 on Page 2.1-11 shows the general layout of the plant. In addition to the structures shown in Figure 2.3, an Offshore Intake Structure and Offshore Intake Pipe Line are also part of the plant. These supply the cooling water for the operation and also safe shutdown of the plant. The Offshore Intake Structure is a submerged trestle structure located approximately 1200 feet offshore in Lake Michigan where the depth of water is approximately 30 feet. The Offshore Intake Pipe Line connects the Intake Structure to the Screenwell-Pumphouse/Diesel Generator/Discharge Structure (the total length of the pipeline is about 1450 feet).

Seismic safety margin evaluation of BRP by D'Appolonia (Reference 23) presents detailed description and functions of these safety related structures, systems and components.

(NOTE: Since issuance of the NRC Safety Evaluation Report (Reference 22), BRP has constructed an Alternate Shutdown Panel Building. This building was analyzed for settlement and for the seismic safe shutdown earthquake ground acceleration of 0.12g by CPCo and the following evaluation data is applicable to this structure.)

The foundations of the safety-related structures, systems and components that were considered in the NRC SEP Topic II-4.F settlement evaluations are:

- Reactor Building
- Turbine Building
- Screenwell-Pumphouse/Diesel Generator/Discharge Structure
- Fuel Cask Loading Dock/Core Spray Equipment Room
- Intake Structure (offshore)
- Intake Pipe Line (offshore)
- Buried Fire Main Piping System and Electrical Cables

(NOTE: Alternate Shutdown Panel Building evaluated by CPCo)

Foundation Data

Source of Information

Geotechnical data available for this site are:

1. "Soil Report," Big Rock Point Plant, Charlevoix, Michigan by Soil Testing Service, Inc., March 7, 1960.
2. "Big Rock Nuclear Power Plant, Hydrological Survey," Report by Great Lake Research Division, Institute of Science and Technology, University of Michigan for Consumer Power Company, November 1961.
3. "Geophysical Cross-Hole Survey," Big Rock Point Nuclear Power Plant, Charlevoix, Michigan, January 1979, by D'Appolonia, Consulting Engineers.

The first set of data, Soils Report (1960), presents the geotechnical investigation and analyses performed in connection with the construction of the power plant. The investigation consisted of drilling seven borings and performing laboratory tests on soil samples recovered from the borings.

The second set of data presents a description of the lake bottom as observed by divers during hydrological survey.

The third set of data, Geophysical Cross-Hole Survey Report (1979), presents the geophysical investigations performed to establish the dynamic properties of the materials at the site. This investigation consisted of drilling three borings and performing cross-hole tests to determine the compressional and shear wave velocities as a function of depth.

In addition, data gathered during NRC site visits were also used in the evaluation.

Subsurface Conditions

Plant Site

The plant site (ground surface at average elevation 590.0 feet) has approximately 40 feet thick soil overburden overlying limestone bedrock; the overburden is composed of:

Seven to ten foot thick, medium dense to dense, fine to coarse sand with some gravel and limestone chips, and varying amount of silt. This is a glacial outwash deposit. Standard penetration test (ASTM D1586) blow count ranged from 8 to 33. The ground water table is controlled by the adjoining lake level and is at an approximate depth of 8 feet below ground surface.

Thirty to thirty-five foot thick, fine to coarse sand with some clay, trace of silt and gravel. This is a very stiff cohesive glacial till. The standard penetration test blow count ranged form 19 to 162. Sand lenses were occasionally encountered in this stratum.

The bedrock is limestone. The upper 15 to 17 feet of this is highly fractured and weathered fossiliferous limestone with seams of clay. The core recovery in this zone ranged from 0 to 90 percent and the RQD (Rock Quality Designation) ratio ranged from 0 to 26.

The highly fractured limestone zone is underlain by approximately 75 foot thick limestone with occasional seams of clay. The core recovery in this zone ranged from 40 to 100 percent and the RQD ratio ranged from 0 to 84.

This limestone is underlain by approximately 50 foot thick, highly fractured limestone with vugs. The core recovery in this zone ranged from 10 to 100 percent and RQD ratio was 0.

The fractured vuggy zone is underlain by slightly broken to massive limestone. The core recovery in this zone ranged from 52 to 100 percent and the RQD ratio ranged from 55 to 90. The

deepest boring at the site (201 feet deep) was terminated in this stratum.

Offshore Intake Structure and Offshore Intake Pipe Line

The surficial material on the lake bed along the intake pipe consists of an initial stretch of beach zone followed by boulder-pavement zone and till-cobble zone. Offshore intake structure is located in the till-cobble zone. The intake pipe line runs from the offshore intake structure to the screen well-pumphouse/Diesel Generator/Discharge Structure. Contours and approximate boundary of the lake bottom material found offshore of the BRP site are presented in BRP Hydrological Survey contained in Volume II of this Report.

The beach zone, approximately 250 feet wide, consists of cobbles, pebbles and sand, and is continuously subjected to agitation by wave action. This includes zone of water depth shallower than five feet.

The boulder pavement zone, approximately 500 feet wide, is a spread out area of cobbles and small boulders set closely together on the bottom. Wave erosion has removed the clay and sand content of the glacial till (upper two feet zone) leaving the pebbles, cobbles and boulders to form the lake bottom, termed "boulder Pavement Zone." This boulder pavement is approximately two feet thick and is underlain by glacial till.

In the till-cobble zone, the surficial boulder pavement zone mentioned above is not present and the till is exposed at the lake bottom.

Soil Properties

In addition to the standard penetration test blow counts, the test data available are:

1. insitu moisture content (6 to 10 percent) of till.

2. unconsolidated undrained triaxial shear test on till samples recovered from split-spoon sampler (ASTM D1586) indicated an undrained shear strength of 3 TSF cohesion and 30 degrees angle of internal friction.

It is concluded that this till is very stiff and highly overconsolidated.

2.5.4.1 Settlement of Structures

Plant Site Structures

All the seismic Category I buildings within the plant site are founded on glacial till stratum which is present at the plant site at a nominal depth of eight feet. Based on the available data (presented in Soil Properties above) it is concluded that the glacial till is very stiff (cohesion 3 TSF) and heavily overconsolidated. The

maximum settlement due to the load from the structures was estimated by the applicant during the design stage to be minimal (less than 0.5 inch) and would take place within a short period after load application. (Note, since this evaluation was completed, the Alternate Shutdown Panel Building was constructed, with an analyzed settlement of 0.36 inch.)

The licensee had not initiated any settlement monitoring program and has no records of any settlement monitoring. The plant has been in operation for nearly 20 years and there is no evidence of any excessive settlement. A few minor cracks were noticed during the site visit, but these minor cracks are judged to be of no significance to the safety-related structures. As the structures have been in place for nearly 20 years, the potential for future settlement is negligible.

Offshore Intake Structure

The offshore intake structure is located approximately 1200 feet offshore where the depth of the water is approximately 30 feet. The bottom of the intake structure is approximately 12 feet below the lake bottom (till). A two-foot thick sand bedding was provided and the excavation was backfilled with the excavated soil (till) except the upper two feet was backfilled with boulder and cobble. The intake structure is a light structure and is founded on till stratum. There is no data available on either the estimated or measured settlement of this structure. Underwater inspection by the diver did not reveal any signs of tilt due to excessive differential settlement (Reference 24). Based on the information available, it is concluded that the past and future settlement of this structure is minimal with no significance to the safe operation of this safety-related structure.

Liquefaction and Seismic Settlement

The postulated safe shutdown earthquake (SSE) ground acceleration for BRP is 0.12g. The glacial till, material beneath the mat foundation is a very stiff (approximately 20 percent clay content) material which is not susceptible to liquefaction. The granular material (8 feet thick) occurring above the till is in a dense state. The water table is in the vicinity of the top of the till stratum so this granular material is not susceptible to liquefaction because it is not saturated. Seismic induced settlement of the till or dense granular material would be negligible.

The intake structure is founded in the till material which is not susceptible to liquefaction. The two foot thick sand bedding under the intake structure might liquefy and the consequences would be seismically induced settlement of negligible magnitude with no significance to its safe operation.

## 2.5.4.2 Settlement of Buried Equipment

### Buried Fire Main Piping System (BFMPS) and Electrical Cables

Fire main piping system and electrical cables within the plant site are buried at a minimum depth of six feet below ground surface. The construction details and specifications for these are not all available. In the absence of knowledge on the backfill material assuming that the insitu granular material from the excavation was used for backfill, it is judged that this material is amenable to compaction and a modest compactive effort would result in a dense material estimated to be in the 70 percent relative density range. It is the staff's opinion that, in the plant area, there would be no settlement related loss of support for seismic Category I piping and electrical cables founded on and in this material under static conditions.

### Offshore Intake Pipe Line

The Intake Pipe runs from offshore intake structure to the Screenwell-pumphouse/diesel generator/discharge building. This is a 60-inch inside diameter and 6-inch thick wall reinforced concrete pipe buried in the lake bottom to a total length of 1450 feet, in 16.5 foot sections connected with gasketed joints. The pipe is laid in till material (excavation 12 to 16 feet below bottom of lake bed) on 18-inch thick sand bed. The excavation is backfilled with sand up to one foot above the pipe and with gravel and cobble of six inch size up to the lake bottom. The sand was placed under water by a tremie. There was no compaction control in the specifications. The sand (amenable to compaction) has been subjected to some compaction effort when gravel and cobble stones were dumped on top of the sand. It is the staff's opinion that this material is in the 50 to 60 percent relative density range. The staff is also of the opinion that there would be no settlement related loss of support for this pipe (founded on a 18-inch thick bedding over glacial till) under static conditions.

### Liquefaction and Seismic Settlement

The materials beneath and surrounding the buried Fire Main Piping Systems and Electrical Cables are not susceptible to liquefaction (see 2.5.4.1 above). Also, the seismic (SSE) induced settlement of the till or dense granular material would be negligible.

The till beneath the buried offshore intake pipe is not susceptible to liquefaction. The sand bedding under the intake pipe might liquefy. If it did, the pipe would not be affected because:

a) the pore water would escape to the overlying gravel fill.

b) a very slight settlement (a few hundredths of an inch) would occur.

Hence liquefaction is not a safety problem and also the seismic (SSE) induced settlement would be negligible.

2.5.4.3 Evaluation Summary Conclusions (for Section 2.5.4 above)

Based on review of the CPCo Safety Analysis Report (Reference 25) and information obtained during the site visit, the NRC staff concurs with the licensee's conclusions that:

1. All the seismic Category I structures are founded on competent till material and do not possess any potential for future settlement as the settlement was essentially complete soon after construction. Any future seismic induced settlement should be minimal and will not pose a safety problem.

2. The material beneath and around the seismic Category I structures are not likely to liquefy under postulated SSE with a ground acceleration of 0.12g. The sand bedding under the offshore structures may liquefy and this would result in a seismic induced settlement of negligible magnitude. This would not be a safety concern.

3. Settlement of seismic Category I foundations and buried equipmen is not a safety problem at the Big Rock Point Nuclear Power Plant.

## 2.5.5 STABILITY OF SLOPES

Consumers Power Company and the NRC evaluated Systematic Evaluation Program Topic II-4.D, Stability of Slopes, and determined that there are no significant natural or man made slopes on this site whose failure would affect either the safety of the plant or the attaining of safe shutdown of the plant.

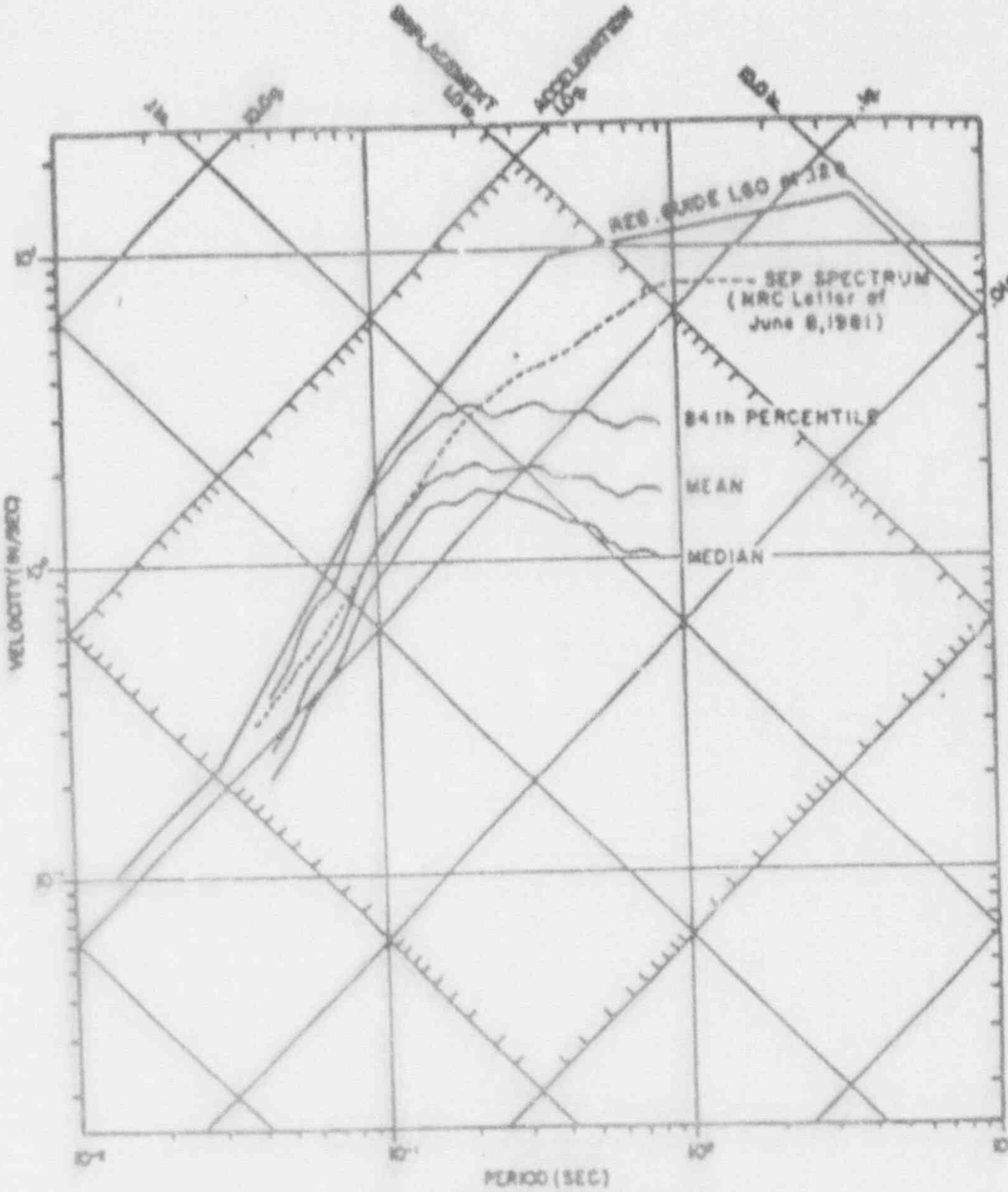
Evaluation Conclusion (Reference 26)

The NRC staff concludes that slopes stability is not a radiological safety concern at the Big Rock Point site.

## 2.5.6 EMBANKMENTS AND DAMS

As described in Sections 2.4 and 2.5.4 of this report, there are no significant embankments or slopes and no dams in the site vicinity. The Systematic Evaluation Program Topic II-4.E Dam Integrity, was determined to be "not applicable" to Big Rock Point as documented in the NRC letter dated April 16, 1979 and confirmed by CPCo in the June 22, 1979 response.

FIGURE 2.7




Response Spectrum for Big Rock Point Nuclear Power Plant, Compared with Reg. Guide 1.60 Spectrum at .12g and SEP Spectrum (NRC Letter of June 8, 1981) 5% Damping

Weston Geophysical



MI0987-0362A-BX01

## CHAPTER 2 REFERENCES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2. Site Emergency Plan, Big Rock Point Plant, Docket No. 50-155

3. County and City Data Book 1983, 10th Edition, U.S. Department of Commerce, Bureau of Census.

4. HMM Document No. 83-600, February 1984, Evacuation Time Estimates for Areas Near the Big Rock Point Nuclear Power Plant.

5. U.S. Department of Commerce Bureau of Census Document PC 80-1-A24 Michigan Number of Inhabitants.

6. Population Characteristics of Northwest Michigan Counties, Developed by Nancy Haywood, Director, Data Research Center, Incorporated. Traverse City, Michigan, June 1980.

7. USNRC letter dated May 13, 1981, SEP Topic II-1.C, Potential Hazards Due to Nearby Industrial, Transportation and Military Facilities (Big Rock Point and Palisades).

8. USNRC Atomic Safety and Licensing Board Initial Decision (on all remaining issues) Docket No. 50-155-OLA, (ASLBP No. 79-432-11LA), Served August 29, 1984, IV O'Neill Contention IID - Risks from Aircraft.

9. USNRC letter dated December 17, 1980, SEP Topic II-2.A, Severe Weather Phenomena.

10. CPCo letter dated March 9, 1981, SEP Topic II-2.A, Severe Weather Phenomena.

11. USNRC letter dated August 3, 1981, SEP Topic II-2.A, Severe Weather Phenomena.

12. CPCo letter dated March 1, 1982, SEP Topic II-2.A - Severe Weather Phenomena; III-2 - Wind and Tornado Loading; and III-4.A - Tornado Missiles.

13. CPCo letter dated April 6, 1982, SEP Topic II-2.C, Atmospheric Transport and Diffusion Characteristics For Accident Analysis.

14. USNRC letter dated October 26, 1982, SEP Topic II-2.C, Atmospheric Transport and Diffusion Characteristics for Accident Analysis.

15. USNRC letter dated October 26, 1982, SEP Hydrology Topics II-3.A, II-3.B, II-3.B.1, II-3.C and III-3.B.

16. CPCo letter dated June 23, 1983, SEP Topics II-3.A Hydrologic Description; II-3.B Flooding Potential and Protection Requirements; II-3.B.1 Capability of Operating Plant to Cope With Design Basis Floods; II-3.C Safety Related Water Supply (Ultimate Heat Sink); III-3.A Effects of High Water Levels on Structures - Response to Safety Evaluation Reports.

17. NRC letter dated December 2, 1982, SEP Topic III-3.A, Effects of High Water on Structures.

18. NRC letter dated March 22, 1984, SEP Hydrology Issues.

19. CPCo letter dated February 2, 1984, Integrated Assessment of Open Issues and Completion Dates for Issue Resolution.

20. NRC letter dated October 12, 1982 SEP Review Topics II-4, Geology and Seismology and II-4.B Proximity of Capable Tectonic Structures in Plant Vicinity.

21. Integrated Plant Safety Assessment - Systematic Evaluation Program, NUREG-0828, Final Report. May 1984.

22. NRC letter dated July 20, 1982, SEP Safety Topic II-4.F, Settlement of Foundations and Buried Equipment.

23. Seismic Safety Margin Evaluation Report, D'Appolonia Consulting Engineers, Inc. (D'Appolonia), Project 78-435 Dec 80, August 81, Revision 1.

24. CPCo letter dated December 21, 1981, SEP Topic III-3.C, Inservice Inspection of Water Control Structures.

25. CPCo letter dated October 19, 1981, SEP Topic II-4.F, Settlement of Foundations and Buried Equipment.

26. NRC letter dated July 6, 1982, SEP Topic II-4.D Stability of Slopes.

27. CPCo letter dated November 21, 1985, Integrated Plan Issue 014 (SEP Topic III-6) Seismic Weak Link Analysis Update.

28. CPCo letter dated October 10, 1980, Response to Staff letter dated August 4, 1980, Proposed Seismic Evaluation Program and Basis for Continued Interim Operation.

29. NRC letter dated June 30, 1982, Assessment of Possible Soil Amplification at Big Rock Point Site.

30. Derivation of Site-Specific Seismic Floor Response Spectra, Seismic Safety Margin Evaluation, D'Appolonia Project No. 78-435, August 1983.