CHAPTER 2

SITE CHARACTERISTICS

This chapter defines the site-related parameters for which the AP1000 plant is designed. The site parameters are in Table 2-1. These parameters envelope most potential sites in the United States. The sections of this chapter follow the standard format and discuss how the specific parameters are used in the AP1000 design and how the Combined License applicant is to demonstrate that the site meets the design parameters.

The site is acceptable if the site characteristics fall within the AP1000 plant site design parameters in Table 2-1. Should specific site parameters or characteristics be outside the envelope of assumptions established by Table 2-1, the Combined License applicant referencing the AP1000 will demonstrate that the design satisfies the requirements imposed by the specific site parameters and conforms to the design commitments and acceptance criteria described in the AP1000 Design Control Document.

2.1 Geography and Demography

The geography and demography are site specific and will be defined by the Combined License applicant.

2.1.1 Combined License Information for Geography and Demography

Combined License applicants referencing the AP1000 certified design will provide site-specific information related to site location and description, exclusion area authority and control, and population distribution.

Site Information – Site-specific information on the site and its location will include political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area.

Exclusion Area – Site-specific information on the exclusion area will include the size of the area and the exclusion area authority and control. Activity that may be permitted within the exclusion area will be included in the discussion.

Population Distribution – Site-specific information will be included on population distribution.

2.2 Nearby Industrial, Transportation, and Military Facilities

The plant has inherent capability to withstand certain types of external accidents due to the specified design conditions associated with earthquakes, wind loading, and radiation shielding. Acceptability for external accidents associated with a given site will be covered in the Combined License application.

Each Combined License applicant referencing the AP1000 will provide analyses of accidents external to the nuclear plant. The determination of the probability of occurrence of potential accidents which could have severe consequences will be based on analyses of available statistical data on the occurrence of the accident together with analyses of the effects of the accident on the plant's safety-related structures and components. If an accident is identified for which the probability of severe consequences is unacceptable, specific changes to the AP1000 will be identified in the Combined License safety analysis report. The criteria for not requiring changes to the AP1000 design is that the total annual frequency of occurrence is less than 10^{-6} per year for an external accident leading to severe consequences. The following accident categories will be considered in determining the frequency of occurrence, as appropriate:

Explosions – Accidents involving detonations of high explosives, munitions, chemicals, or liquid and gaseous fuels will be considered for facilities and activities in the vicinity of the plant where such materials are processed, stored, used, or transported in quantity.

Flammable Vapor Clouds (Delayed Ignition) – Accidental releases of flammable liquids or vapors that result in the formation of unconfined vapor clouds in the vicinity of the plant.

Toxic Chemicals – Accidents involving the release of toxic chemicals from nearby mobile and stationary sources.

Fires – Accidents leading to high heat fluxes or smoke, and to nonflammable gas or chemical-bearing clouds from the release of materials as the consequence of fires in the vicinity of the plant.

Airplane Crashes – Accidents involving aircraft crashes leading to missile impact or fire in the vicinity of the plant.

2.2.1 Combined License Information for Identification of Site-specific Potential Hazards

Combined License applicants referencing the AP1000 certified design will provide site-specific information related to the identification of potential hazards within the site vicinity, including an evaluation of potential accidents and verify that the frequency of site-specific potential hazards is consistent with the criteria outlined in Section 2.2. The site-specific information will provide a review of aircraft hazards, information on nearby transportation routes, and information on potential industrial and military hazards.

2.3 Meteorology

The AP1000 is designed for air temperatures, humidity, precipitation, snow, wind, and tornado conditions as specified in Table 2-1. The Combined License applicant must provide information to demonstrate that the site parameters are within the limits specified for the standard design.

The design wind is specified as a basic wind speed of 145 mph with an annual probability of occurrence of 0.02. Wind loads are calculated for exposure C, which is applicable to shorelines in hurricane prone areas. The site parameters for the design wind may be demonstrated to be acceptable for other exposures or topographic factors by comparison of the wind loads on the structures. For example, for a site at a location with exposure Category D, the wind speed should be equal to or less than 130 mph.

2.3.1 Regional Climatology

The regional climatology is site specific and will be defined by the Combined License applicant.

2.3.2 Local Meteorology

The local meteorology is site specific and will be defined by the Combined License applicant.

2.3.3 Onsite Meteorological Measurement Programs

The onsite meteorological measurement program is site specific and will be defined by the Combined License applicant. The number and location of meteorological instrument towers are determined by actual site parameters.

2.3.4 Short-Term Diffusion Estimates

In the absence of a specific site for use in determining values for short-term diffusion, a study was performed to determine the atmospheric dispersion factors (χ/Q values) that would envelope most current plant sites and that could be used to calculate the radiological consequences of design basis accidents. The χ/Q values thus derived for offsite are provided in Table 2-1.

This set of offsite χ/Q values is representative of potential sites for construction of the AP1000. The values are appropriate for analyses to determine the radiological consequences of accidents. These values were selected to bound 70 to 80 percent of U.S. sites.

The χ/Q values for the control room air intake or the door leading to the control room are dependent not only on the site meteorology but also on the plant design and layout. These χ/Q values are addressed in Appendix 15A. Separate sets of χ/Q values are identified for each combination of activity release location and receptor location.

2.3.5 Long-Term Diffusion Estimates

The long-term diffusion estimates are site specific and will be provided by the Combined License applicant. The site boundary annual average χ/Q shown in Table 2-1 is used to calculate release concentrations at the site boundary for comparison with the activity release limits defined in 10 CFR 20. The value specified is expected to bound atmospheric conditions at most U.S. sites. If a selected site has a χ/Q value that exceeds this reference site value, the release concentrations reported in Section 11.3 would be adjusted proportionate to the change in χ/Q.

2.3.6 Combined License Information

2.3.6.1 Regional Climatology

Combined License applicants referencing the AP1000 certified design will address site-specific information related to regional climatology.

2.3.6.2 Local Meteorology

Combined License applicants referencing the AP1000 certified design will address site-specific local meteorology information.

2.3.6.3 Onsite Meteorological Measurements Program

Combined License applicants referencing the AP1000 certified design will address the site-specific onsite meteorological measurements program.

2.3.6.4 Short-Term Diffusion Estimates

Combined License applicants referencing the AP1000 certified design will address the site-specific χ/Q values specified in subsection 2.3.4. For a site selected that exceeds the bounding χ/Q values, the Combined License applicant will address how the radiological consequences associated with the controlling design basis accident continue to meet the dose reference values given in 10 CFR Part 50.34 and control room operator dose limits given in General Design Criteria 19 using site-specific χ/Q values. The Combined License applicant should consider topographical characteristics in the vicinity of the site for restrictions of horizontal and/or vertical plume spread, channeling or other changes in airflow trajectories, and other unusual conditions affecting atmospheric transport and diffusion between the source and receptors. No further action is required for sites within the bounds of the site parameters for atmospheric dispersion.

With regard to assessment of the postulated impact of an accident on the environment, the COL applicant will provide χ/Q values for each cumulative frequency distribution which exceeds the median value (50 percent of the time).

2.3.6.5 Long-Term Diffusion Estimates

Combined License applicants referencing the AP1000 certified design will address long-term diffusion estimates and χ/Q values specified in subsection 2.3.5. The Combined License applicant should consider topographical characteristics in the vicinity of the site for restrictions of horizontal and/or vertical plume spread, channeling or other changes in airflow trajectories, and other unusual conditions affecting atmospheric transport and diffusion between the source and receptors. No further action is required for sites within the bounds of the site parameter for atmospheric dispersion.

With regard to environmental assessment, the COL applicant will also provide estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 miles from the plant.

2.4 Hydrologic Engineering

The AP1000 is designed for a normal groundwater elevation up to plant elevation 98′ and for a flood level up to plant elevation 100′. For structural analysis purposes, grade elevation is also established as plant elevation 100′. Actual grade will be a few inches lower to prevent surface water from entering doorways.

For a portion of the annex building the site grade will be 107 feet to permit truck access at the elevation of the floor in the annex building and inside containment. Subsection 3.4.1 describes design provisions for groundwater and flooding.

The Combined License applicant will evaluate events leading to potential flooding to demonstrate that the site meets the site parameter for flood level. As necessary, the Combined License applicant may propose measures to protect the plant according to the Standard Review Plan, Section 2.4.10. Events to be considered are those identified in Standard Review Plan, Section 2.4.2.

Adverse effects of flooding due to high water or ice effects do not have to be considered for site-specific nonsafety-related structures and water sources outside the scope of the certified design. Flooding of water intake structures, cooling canals, or reservoirs or channel diversions would not prevent safe operation of the plant.

2.4.1 Combined License Information

2.4.1.1 Hydrological Description

Combined License applicants referencing the AP1000 certified design will describe major hydrologic features on or in the vicinity of the site including critical elevations of the nuclear island and access routes to the plant.

2.4.1.2 Floods

Combined License applicants referencing the AP1000 certified design will address the following site-specific information on historical flooding and potential flooding factors, including the effects of local intense precipitation.

- Probable Maximum Flood on Stream and Rivers – Site-specific information that will be used to determine the design basis flooding at the site. This information will include the probable maximum flood on streams and rivers.

- Dam Failures – Site-specific information on potential dam failures.

- Probable Maximum Surge and Seiche Flooding – Site-specific information on probable maximum surge and seiche flooding.

- Probable Maximum Tsunami Loading – Site-specific information on probable maximum tsunami loading.

- Flood Protection Requirements – Site-specific information on flood protection requirements or verification that flood protection is not required to meet the site parameter for flood level.

No further action is required for sites within the bounds of the site parameter for flood level.

2.4.1.3 Cooling Water Supply

Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

2.4.1.4 Groundwater

Combined License applicants referencing the AP1000 certified design will address site-specific information on groundwater. No further action is required for sites within the bounds of the site parameter for ground water.

2.4.1.5 Accidental Release of Liquid Effluents in Ground and Surface Water

Combined License applicants referencing the AP1000 certified design will address site-specific information on the ability of the ground and surface water to disperse, dilute, or concentrate accidental releases of liquid effluents. Effects of these releases on existing and known future use of surface water resources will also be addressed.

2.4.1.6 Emergency Operation Requirement

Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

2.5 Geology, Seismology, and Geotechnical Engineering

Combined License applicants referencing the AP1000 certified design will address site specific information related to basic geological, seismological, and geotechnical engineering of the site and the region, as discussed in the following subsections.

2.5.1 Basic Geological and Seismic Combined License Information

Combined License applicants referencing the AP1000 certified design will address the following regional and site-specific geological, seismological, and geophysical information as well as conditions caused by human activities:

- Structural geology of the site
- Seismicity of the site
- Geological history
- Evidence of paleoseismicity
- Site stratigraphy and lithology
- Engineering significance of geological features
- Site groundwater conditions
- Dynamic behavior during prior earthquakes
- Zones of alteration, irregular weathering, or structural weakness
- Unrelieved residual stresses in bedrock
- Materials that could be unstable because of mineralogy or unstable physical properties
- Effect of human activities in the area

2.5.2 Vibratory Ground Motion

The AP1000 is designed for a safe shutdown earthquake (SSE) defined by a peak ground acceleration (PGA) of 0.30g and the design response spectra specified in subsection 3.7.1.1, and Figures 3.7.1-1 and 3.7.1-2. The AP1000 design response spectra were developed using the Regulatory Guide 1.60 response spectra as the base and modified to include additional high frequency amplification at a control point at 25 Hz. The peak ground accelerations in the two horizontal and the vertical directions are equal.

The AP1000 is also evaluated for a safe shutdown earthquake (SSE) defined by a peak ground acceleration (PGA) of 0.30g and the design response spectra specified in Appendix 3I, and Figures 3I.1-1 and 3I.1-2. These design response spectra are applicable to certain east coast rock sites.

2.5.2.1 Combined License Seismic and Tectonic Characteristics Information

Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the vibratory ground motion aspects of the site and region:

- Seismicity
- Geologic and tectonic characteristics of site and region
- Correlation of earthquake activity with seismic sources
- Probabilistic seismic hazard analysis and controlling earthquakes
- Seismic wave transmission characteristics of the site
- SSE ground motion

The site-specific ground motion response spectra (GMRS) are determined in the free-field on the ground surface. For sites with soil layers that will be completely excavated to expose competent material, the GMRS is specified on an outcrop or a hypothetical outcrop that will exist after excavation. Motions at this hypothetical outcrop are developed as a free-surface motion, not as an in-column motion. Competent material may be defined as in-situ material having a shear wave velocity equal to or greater than 1000 fps. The Combined License applicant must demonstrate that the proposed site meets the following requirements:

1. The free field peak ground acceleration at the finished grade level is less than or equal to a 0.30g SSE.

2. The site-specific ground motion response spectra (GMRS) at the finished grade level in the free-field are less than or equal to the AP1000 certified seismic design spectra (CSDRS) given in Figures 3.7.1-1 and 3.7.1-2.

3. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8,000 feet per second, the site-specific ground motion may be defined at the foundation level as the foundation input response spectrum (FIRS) and shown to be less than or equal to the CSDRS given in Figures 3.7.1-1 and 3.7.1-2.

4. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8000 feet per second and there are thin layers of soft material overlying the rock, the site-specific peak ground acceleration and spectra may be developed at the top of the competent rock and shown at the foundation level to be less than or equal to those given in Figures 3I.1-1 and 3I.1-2.

5. Foundation material layers are approximately horizontal (dip less than 20 degrees), and the median estimate of the low strain shear wave velocity of the soil below the foundation of the nuclear island is greater than or equal to 1000 feet per second.

6. For sites where the nuclear island is founded on soil, the median estimate of the strain-compatible soil shear modulus and hysteretic damping is compared to the values used in the AP1000 generic analyses shown in Table 3.7.1-4 and Figure 3.7.1-17. Properties of soil layers within a depth of 120 feet below finished grade are compared to those in the generic soil site analyses (soft soil, soft-to-medium soil, and upper bound soft-to-medium soil).

7. In lieu of (1) to (6) above, a site-specific evaluation can be performed as described in subsection 2.5.2.3.

Where features of the site are not within the parameters specified for the AP1000, site-specific soil structure interaction analyses may be performed using the 2D SASSI models described in Appendix 3G for variations in site conditions that can be represented in these models. Results should be compared to the results of the 2D SASSI analyses described in Appendix 3G. Such analyses may be used to demonstrate that local features, such as soil degradation properties or backfill, are bounded by the design cases.

2.5.2.2 Site-Specific Seismic Structures

The AP1000 includes all seismic Category I structures, systems and components in the scope of the design certification.

2.5.2.3 Sites with Geoscience Parameters Outside the Certified Design

If the site-specific spectra at foundation level exceed the response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. This evaluation will consist of a site-specific dynamic analysis and generation of in-structure response spectra to be compared with the floor response spectra of the certified design at 5-percent damping. The site design response spectra at the foundation level in the free-field given in Figures 3.7.1-1 and 3.7.1-2 were used to develop the floor response spectra. They were applied at foundation level for the hard rock site and at finished grade level for the soil sites. The site is acceptable for construction of the AP1000 if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra for each of the locations identified below:

- Containment internal structures at elevation of reactor vessel support — Figure 3G.4-5

- Containment operating floor — Figure 3G.4-6
- Auxiliary building north east corner at elevation 135′ — Figure 3G.4-7
- Shield building at fuel building roof — Figure 3G.4-8
- Shield building roof — Figure 3G.4-9
- Steel containment vessel at polar crane support — Figure 3G.4-10

Site-specific soil structure interaction analyses are performed using the 3D SASSI models described in Appendix 3G. The site-specific soil structure interaction analyses use the site-specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site-specific ground motion time history must satisfy the regulatory requirements for statistical independence and enveloping of the site design spectra at 5% damping. Floor response spectra determined from the site-specific analyses are compared against the design basis of the AP1000 described above. These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

If the site-specific spectra at foundation level at a rock site exceed the response spectra in Figures 3I.1-1 and 3I.1-2 at any frequency, a site-specific evaluation can be performed similar to that described in Appendix 3I.

2.5.3 Surface Faulting Combined License Information

Combined License applicants referencing the AP1000 certified design will address the following surface and subsurface geological, seismological, and geophysical information related to the potential for surface or near-surface faulting affecting the site:

- Geological, seismological, and geophysical investigations
- Geological evidence, or absence of evidence, for surface deformation
- Correlation of earthquakes with capable tectonic sources
- Ages of most recent deformation
- Relationship of tectonic structures in the site area to regional tectonic structures
- Characterization of capable tectonic sources
- Designation of zones of quaternary deformation in the site region
- Potential for surface tectonic deformation at the site

2.5.4 Stability and Uniformity of Subsurface Materials and Foundations

Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the stability and uniformity of subsurface materials and foundations.

- Excavation
- Bearing capacity

- Settlement
- Liquefaction

2.5.4.1 Excavation

Excavation for the nuclear island structures below grade may use either a sloping excavation or a vertical face as described in subsequent paragraphs. If backfill is to be placed adjacent to the exterior walls of the nuclear island, the Combined License applicant will provide information on the properties of backfill and its compaction requirements as described in subsection 2.5.4.6.3 and will evaluate its properties against those used in the seismic analyses described in subsection 3.7.2.

For the vertical face alternative, excavation in soil for the nuclear island structures below grade will establish a vertical face with lateral support of the adjoining undisturbed soil or rock. One alternative is to use a soil nailing method. Soil nailing is a method of retaining earth in-situ. As the nuclear island excavation progresses vertically downward, holes are drilled horizontally into the adjoining undisturbed soil, a metal rod is inserted into the hole, and grout is pumped into each hole to fill the hole and to anchor the “nail” rod.

As each increment of the nuclear island excavation is completed, nominal eight to ten inch diameter holes are drilled horizontally through the vertical face of the excavation into adjacent undisturbed soil. These “nail” holes, spaced horizontally and vertically on five to six feet centers, are drilled slightly downward to the horizontal. A “nail”, normally a metal bar/rod, is center located for the full length of the hole. The nominal length of soil nails is 60 percent to 70 percent of the wall height, depending upon soil conditions. The hole is filled with grout to anchor the rod to the soil. A metal face plate is installed on the exposed end of the rod at the excavated wall vertical surface. Welded wire mesh is hung on the wall surface for wall reinforcement and secured to the soil nail face plates for anchorage. A 4,000 psi to 5,000 psi non-expansive pea gravel shotcrete mix is blown onto the wire mesh to form a nominal four to six inch thick soil retaining wall. Installation of the soil retaining wall closely follows the progress of the excavation and is from the top down, with each wire mesh-reinforced, shotcreted wall section being supported by the soil “nails” and the preceding elevations of soil nailed wall placements. The shotcrete contains a crystalline waterproofing material as described in subsection 3.4.1.1.1.

Soil nailing as a method of soil retention has been successfully used on excavations up to 55 feet deep on projects in the U.S. Soils have been retained for up to 90 feet in Europe. The state of California CALTRANS uses soil nailing extensively for excavations and soil retention installations. Soil nailing design and installation has a successful history of application which is evidenced by its excellent safety record.

The soil nailing method produces a vertical surface down to the bottom of the excavation and is used as the outside forms for the exterior walls below grade of the nuclear island. Concrete is placed directly against the vertical concrete surface of the excavation.

For excavation in rock and for methods of soil retention other than soil nailing, four to six inches of shotcrete are blown on to the vertical surface. The concrete for the exterior walls is placed against the shotcrete. The shotcrete contains a crystalline waterproofing material as described in subsection 3.4.1.1.1.

2.5.4.2 Bearing Capacity

The maximum bearing reaction determined from the analyses described in Appendix 3G is less than 35,000 lb/ft^2 under all combined loads, including the safe shutdown earthquake. These analyses use uniform soil springs below the basemat. The Combined License applicant will verify that the site-specific allowable soil bearing capacities for static and dynamic loads at the site will exceed this demand.

The evaluation of the allowable capacity of the soil is based on the properties of the underlying materials (see subsection 2.5.4.5.2), including appropriate laboratory test data to evaluate strength, and considering local site effects, such as fracture spacing, variability in properties, and evidence of shear zones. The allowable bearing capacity should provide a factor of safety appropriate for the design load combination, including safe shutdown earthquake loads.

If the shear wave velocity or the allowable bearing capacity is outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed using the AP1000 basemat model and methodology described in subsection 3.8.5. The safe shutdown earthquake loads are those from the AP1000 analyses described therein. Alternatively, bearing pressures may be determined from a site-specific analysis using site-specific inputs as described in subsection 2.5.2.3. For the site to be acceptable, the bearing pressures from the site-specific analyses, including static and dynamic loads, need to be less than the capacity of each portion of the basemat.

2.5.4.3 Settlement

The Combined License applicant will address short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the foundation consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure. The settlement under the nuclear island footprint is represented in the distribution of subgrade stiffness.

The AP1000 does not rely on structures, systems, or components located outside the nuclear island to provide safety-related functions. Differential settlement between the nuclear island foundation and the foundations of adjacent buildings does not have an adverse effect on the safety-related functions of structures, systems, and components. Differential settlement under the nuclear island foundation could cause the basemat and buildings to tilt. Much of this settlement occurs during civil construction prior to final installation of the equipment. Differential settlement of a few inches across the width of the nuclear island would not have an adverse effect on the safety-related functions of structures, systems, and components.

2.5.4.4 Liquefaction

The Combined License applicant will demonstrate that the potential for liquefaction is negligible.

2.5.4.5 Subsurface Uniformity

Soil structure interaction and foundation design are a function of the uniformity of the soil or rock below foundation. Although the design and analysis of the AP1000 is based on soil or rock conditions with uniform properties within horizontal layers, it includes provisions and design margins to accommodate many non-uniform sites. This subsection identifies the requirements for site investigation that may be used to demonstrate that:

- A site is "uniform" based on the criteria outlined in subsection 2.5.4.5.3. If the site can be demonstrated to be "uniform," no further site specific analysis is required to qualify the site for the AP1000.

- A "non-uniform" site is acceptable to locate the AP1000 based on the criteria for acceptability outlined in subsection 2.5.4.5.3. Some non-uniform sites are acceptable as described in subsection 2.5.4.5.3 based on evaluation performed as part of design certification. Other non-uniform sites may be shown to be acceptable as described in subsection 2.5.4.5.3.1 using site-specific evaluation as part of the Combined License application.

Considerations with respect to the materials underlying the nuclear island are the type of site, such as rock or soil, and whether the site can be considered uniform. If the site is non-uniform, the non-uniform soil characteristics, such as the location and profiles of soft and hard spots, should be considered. These considerations can be assessed with the information developed in response to Regulatory Guides 1.132 and 1.138. The geological investigations of subsections 2.5.1 and 2.5.4.6.1 provide information on the uniformity of the site, whether it may be geologically impacted, and whether the bedrock may be sloping or undulatory.

A survey of 22 commercial nuclear power plant sites in the United States focused on site parameters that affect the seismic response such as the depth to bedrock, the type and characteristic of the soil layers, including the variation of shear wave velocities, the depth to the ground water level, and the embedment depth of the plant structures. Of the 22 sites, 11 are rock sites where competent rock exists at relatively shallow depths. At the other sites, the depth to bedrock varies from about 50 feet (Callaway) to well in excess of 4,000 feet (South Texas). A review of these 11 soil sites – all of which are marine, deltaic, or lacustrine deposits – did not reveal any significant variation of soil characteristics below the nuclear island footprint. There was one possible nonuniform site, Monticello, which is underlain by glacial deposits; the geologic description is such that there might be lateral variability in the foundation parameters within the plan dimension of the plant. The review of the 22 commercial nuclear power plant sites in the United States suggests that the majority of AP1000 sites exhibit "uniform" soil properties within the nuclear island footprint.

2.5.4.5.1 Site Investigation for Uniform Sites

For sites that are expected to be uniform, based on the geologic investigation outlined in subsections 2.5.1 and 2.5.4.6.2, Appendix C to Regulatory Guide 1.132 provides guidance on the spacing and depth of borings of the geotechnical investigation for safety-related structures. Specific language in the Regulatory Guide suggests a spacing of 100 feet supplemented with borings on the periphery and at the corners for favorable, uniform geologic conditions.

For foundation engineering purposes, a series of primary borings should be drilled on a grid pattern that encompasses the nuclear island footprint and 40 feet beyond the boundaries of the nuclear island footprint. The 40-foot extension for the grid of borings is established from a Boussinesq analysis of the zone of influence of the foundation mat which shows that the net change in the effective vertical overburden stress is less than 7 percent at a distance of 40 feet from the edge of the foundation mat. The grid need not be of equal spacing in the two orthogonal directions, but it should be oriented in accordance with the true dip and strike of the rock in the immediate area of the nuclear island footprint. If geologic conditions are such that true dip and strike are not obvious, or if the dip is practically flat, then the orientation of the grid can be consistent with the major orthogonal lines of the nuclear island. The depth of borings should be determined on the basis of the geologic conditions. Borings should be extended to a depth sufficient to define the site geology and to sample materials that may swell during excavation, may consolidate subsequent to construction, may be unstable under earthquake loading, or whose physical properties would affect foundation behavior or stability. At least one-fourth of the primary borings should penetrate sound rock or, for a deep soil site, to a maximum depth of 250 feet below the foundation mat. At this depth of 250 feet, the change in the vertical stress during or after construction for the combined foundation loading is less than 10 percent of the in-situ effective overburden stress. Other primary borings may terminate at a depth of 160 feet below the foundation (equal to the width of the structure).

2.5.4.5.2 Site Investigation for Non-uniform Sites

At sites that are determined to be non-uniform or potentially non-uniform during the course of the geological investigations outlined in subsections 2.5.1 and 2.5.4.6.2, the investigation effort is extended to determine if the site is acceptable for an AP1000.

As the AP1000 foundation/structural system is robust, the probability of being able to show compliance for all but the worst of sites is high, unless liquefaction or faulting is prevalent on the site. As stated in Regulatory Guide 1.132, where variable conditions are found, spacing of boreholes should be smaller, as needed, to obtain a clear picture of soil or rock properties and their variability. Where cavities or other discontinuities of engineering significance may occur, the normal exploratory work should be supplemented by secondary borings or soundings at a spacing small enough to detect such features. The depth of the secondary borings is 160 feet below the foundation mat. At this depth, the maximum change in vertical stress during or after construction is about 11 percent of the in-situ effective overburden stress. The depth of borings should be extended beyond 160 feet if the geologic investigation indicates the possible presence of karst conditions, under-consolidated clays, loose sands, intrusive dikes, or other forms of geologic impacts at depth greater than 160 feet.

2.5.4.5.3 Site Foundation Material Evaluation Criteria

The AP1000 is designed for application at a site where the foundation conditions do not have extreme variation within the nuclear island footprint. This subsection provides criteria for evaluation of soil variability. The subsurface may consist of layers and these layers may dip with respect to the horizontal. If the dip is less than 20 degrees, the generic analysis using horizontal layers is applicable as described in NUREG/CR-0693 (Reference 2). The physical properties of the foundation medium may or may not vary systematically across a horizontal plane. The recommended methodology for checking uniformity is to calculate from the boring logs a series of “best-estimate” planes beneath the nuclear island footprint that define the top (and bottom) of each layer. The planes could represent stratigraphic boundaries, lithologic changes, and unconformities, but most important, they should represent boundaries between layers having different shear wave velocities. Shear wave velocity is the primary property used for defining uniformity of a site.

The distribution of bearing reactions under the basemat is a function of the subgrade modulus, which in turn is a function of the shear wave velocity. The Combined License applicant shall demonstrate that the variation of subgrade modulus or shear wave velocity across the footprint is within the range considered for design of the nuclear island basemat. The farther that the non-uniform layer is located below the foundation, the less influence it has on the bearing pressures at the basemat. Lateral variability of the shear wave velocity at depths greater than 120 feet below grade (80 feet below the foundation) do not significantly affect the subgrade modulus.

If a site can be classified as uniform, it qualifies for the AP1000 based on analyses and evaluations performed to support design certification without additional site-specific analyses. For a site to be considered uniform, the variation of shear wave velocity in the material below the foundation to a depth of 120 feet below finished grade within the nuclear island footprint shall meet the criteria outlined below:

- The depth to a given layer indicated on each boring log may not fall precisely on the postulated “best-estimate” plane. The deviation of the observed layers from the “best-estimate” planes should not exceed 5 percent of the observed depths from the ground surface to the plane. If the deviation is greater than 5 percent, additional planes may be appropriate or additional borings may be required. This thereby diminishes the spacing.

- For a layer with a low strain shear wave velocity greater than or equal to 2500 feet per second, the layer should have approximately uniform thickness and should have a dip no greater than 20 degrees, and the shear wave velocity at any location within any layer should not vary from the average velocity within the layer by more than 20 percent.

- For a layer with a low strain shear wave velocity less than 2500 feet per second, the layer should have approximately uniform thickness and should have a dip no greater than 20 degrees, and the shear wave velocity at any location within any layer should not vary from the average velocity within the layer by more than 10 percent.

2.5.4.5.3.1 Site-Specific Subsurface Uniformity Design Basis

Many sites that do not meet the above criteria for a uniform site are acceptable for the AP1000. The key attribute for acceptability of the site for an AP1000 is the bearing pressure on the underside of the basemat. A site having local soft or hard spots within a layer or layers does not meet the criteria for a uniform site. Non-uniform soil conditions may also require evaluation of the AP1000 seismic response as described in subsection 2.5.2.2.

As described in subsection 3.8.5, the nuclear island foundation is designed specifically for bearing pressures of 120 percent of those of the uniform soil properties case. Evaluation criteria are defined to evaluate sites that do not satisfy the site parameters directly. The design basis provided below is included to provide a clear specification of the design commitment and evaluation criteria required to demonstrate that a site-specific application satisfies AP1000 requirements. Application of the

AP1000 to sites using this site-specific evaluation is not approved as part of the AP1000 design certification and the evaluation should be provided and reviewed as part of the Combined License application.

Rigid Basemat Evaluation

A site with nonuniform soil properties may be demonstrated to be acceptable by evaluation of the bearing pressures on the underside of a rigid rectangular basemat equivalent to the nuclear island. Bearing pressures are calculated for dead and safe shutdown earthquake loads. The safe shutdown earthquake loads used for the evaluation are associated with one of the AP1000 design soil cases evaluated for design certification. The soil case representative of the site-specific soil is used. For the site to be acceptable, the bearing pressures from this analysis need to be less than or equal to 120 percent of the bearing pressures calculated in similar analyses for a site having uniform soil properties.

Alternatively, the safe shutdown earthquake loads may be determined from a site-specific seismic analysis of the nuclear island using site-specific inputs as described in subsection 2.5.2.2. For the site to be acceptable, the bearing pressures from the site-specific analyses need to be less than or equal to 120 percent of the bearing pressures calculated in rigid basemat analyses using the AP1000 design ground motion at a site having uniform soil properties.

Flexible Basemat Evaluation

For sites having bedrock close to the foundation level, the assumption of a rigid basemat may be overly conservative because local deformation of the basemat will reduce the effect of local soil variability. For such sites, a site-specific analysis may be performed using the AP1000 basemat model and methodology described in subsection 3.8.5. The safe shutdown earthquake loads are those from the AP1000 design soil case representative of the site-specific soil. Alternatively, bearing pressures may be determined from a site-specific soil structure interaction analysis using site-specific inputs as described in subsection 2.5.2.2. For the site to be acceptable, the bearing pressures from the site-specific analyses, including static and dynamic loads, need to be less than the capacity of each portion of the basemat.

2.5.4.6 Combined License Information

Combined License applicants referencing the AP1000 design will address the following site specific information related to the geotechnical engineering aspects of the site. No further action is required for sites within the bounds of the site parameters.

2.5.4.6.1 Site and Structures – Site-specific information regarding the underlying site conditions and geologic features will be addressed. This information will include site topographical features, as well as the locations of seismic Category I structures.

2.5.4.6.2 The Combined License applicant will establish the properties of the foundation soils to be within the range considered for design of the nuclear island basemat.

Properties of Underlying Materials – A determination of the static and dynamic engineering properties of foundation soils and rocks in the site area will be addressed. This information will include a discussion of the type, quantity, extent, and purpose of field explorations, as well as logs of borings and test pits. Results of field plate load tests, field permeability tests, and other special field tests (e.g., bore-hole extensometer or pressuremeter tests) will also be provided. Results of geophysical surveys will be presented in tables and profiles. Data will be provided pertaining to site-specific soil layers (including their thicknesses, densities, moduli, and Poisson's ratios) between the basemat and the underlying rock stratum. Plot plans and profiles of site explorations will be provided.

Properties of Materials Adjacent to Nuclear Island Exterior Walls – A determination of the static and dynamic engineering properties of the surrounding soil will be made to demonstrate they are competent and provide passive earth pressures greater than or equal to those used in the seismic stability evaluation for sliding of the nuclear island. Seismic stability requirements are satisfied if the soil layers below and adjacent to the nuclear island foundation are composed predominantly of rock, or sand and rock (gravel), or sands that can be classified as medium to dense (standard penetration test having greater than 10 blows per foot). If the soil below and adjacent to the exterior walls is made up of clay, sand and clay, or other types of soil other than those classified above as competent, then the Combined License applicant will evaluate the seismic stability against sliding as described in subsection 3.8.5.5.3 using the site-specific soil properties.

Laboratory Investigations of Underlying Materials – Information about the number and type of laboratory tests and the location of samples used to investigate underlying materials will be provided. Discussion of the results of laboratory tests on disturbed and undisturbed soil and rock samples obtained from field investigations will be provided.

2.5.4.6.3 Excavation and Backfill – Information concerning the extent (horizontal and vertical) of seismic Category I excavations, fills, and slopes, if any will be addressed. The sources, quantities, and static and dynamic engineering properties of borrow materials will be described in the site-specific application. The compaction requirements, results of field compaction tests, and fill material properties (such as moisture content, density, permeability, compressibility, and gradation) will also be provided. Information will be provided concerning the specific soil retention system, for example, the soil nailing system, including the length and size of the soil nails, which is based on actual soil conditions and applied construction surcharge loads. If backfill is to be placed adjacent to the exterior walls of the nuclear island, information will be provided concerning compaction of the backfill and any additional loads on the exterior walls of the nuclear island. Information will also be provided on the waterproofing system along the vertical face and the mudmat. Information will be provided on the mudmat to demonstrate its ability to resist the structural bearing and shear loads described in subsection 2.5.4.2. The maximum bearing pressure is 240 psi. The mudmat may be designed as structural plain concrete in accordance with ACI 318-02 (Reference 1). This requires the specified concrete compressive strength to be no less than 2500 psi. The commentary states this requirement is imposed in the code because "lean concrete mixtures may not produce adequately homogeneous material or well formed surfaces." If the Combined License applicant proposes to use a concrete with strength less than 2500 psi, the applicant must demonstrate that the mix will result in an acceptable homogeneous material.

2.5.4.6.4 Ground Water Conditions – Groundwater conditions will be described relative to the foundation stability of the safety-related structures at the site. The soil properties of the various layers under possible groundwater conditions during the life of the plant will be compared to the range of values assumed in the standard design in Table 2-1.

2.5.4.6.5 Liquefaction Potential – Soils under and around seismic Category I structures will be evaluated for liquefaction potential for the site specific SSE ground motion. This should include justification of the selection of the soil properties, as well as the magnitude, duration, and number of excitation cycles of the earthquake used in the liquefaction potential evaluation (e.g., laboratory tests, field tests, and published data). Liquefaction potential will also be evaluated to address seismic margin.

2.5.4.6.6 Bearing Capacity – The Combined License applicant will verify that the site-specific allowable soil bearing capacities for static and dynamic loads are equal to or greater than the values documented in Table 2-1, or will provide a site-specific evaluation as described in subsection 2.5.4.2. The acceptance criteria for this evaluation are those of Standard Review Plan 2.5.4 as follows:

- The static and dynamic loads, and the stresses and strains induced in the soil surrounding and underlying the nuclear island, are conservatively and realistically evaluated.
- The consequences of the induced soil stresses and strains, as they influence the soil surrounding and underlying the nuclear island, have been conservatively assessed.

2.5.4.6.7 Earth Pressures – The Combined License applicant will describe the design for static and dynamic lateral earth pressures and hydrostatic groundwater pressures acting on plant safety-related facilities using soil parameters as evaluated in previous subsections.

2.5.4.6.8 Soil Properties for Seismic Analysis of Buried Pipes – The AP1000 does not utilize safety related buried piping. No additional information is required on soil properties.

2.5.4.6.9 Static and Dynamic Stability of Facilities – Soil characteristics affecting the stability of the nuclear island will be addressed including foundation rebound, settlement, and differential settlement.

2.5.4.6.10 Subsurface Instrumentation – Data will be provided on instrumentation, if any, proposed for monitoring the performance of the foundations of the nuclear island. This will specify the type, location, and purpose of each instrument, as well as significant details of installation methods. The location and installation procedures for permanent benchmarks and markers for monitoring the settlement will be addressed.

2.5.4.6.11 Settlement of Nuclear Island **–** Data will be provided on short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the foundation consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure.

2.5.5 Combined License Information for Stability of Slopes

Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of soil and rock slopes, the failure of which could adversely affect the nuclear island.

2.5.6 Combined License Information for Embankments and Dams

Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of embankments and dams, the failure of which could adversely affect the nuclear island.

2.6 References

1. American Concrete Institute (ACI), “Building Code Requirements for Structural Concrete,” ACI 318-02.

2. NUREG/CR-0693, “Seismic Input and Soil Structure Interaction,” February 1979.

Table 2-1 (Sheet 1 of 3) **SITE PARAMETERS**	
Air Temperature	
Maximum Safety [(a)]	115°F dry bulb/80°F coincident wet bulb 85.5°F wet bulb (noncoincident)
Minimum Safety [(a)]	-40°F
Maximum Normal [(b)]	100°F dry bulb/80.1°F coincident wet bulb 80.1°F wet bulb (noncoincident) [(d)]
Minimum Normal [(b)]	-10°F
Wind Speed	
Operating Basis	145 mph (3 second gust); importance factor 1.15 (safety), 1.0 (nonsafety); exposure C; topographic factor 1.0
Tornado	300 mph
Seismic	
SSE	0.30g peak ground acceleration [(c)]
Fault Displacement Potential	None
Soil	
Average Allowable Static Bearing Capacity	Greater than or equal to 8,600 lb/ft^2 over the footprint of the nuclear island at its excavation depth
Maximum Allowable Dynamic Bearing Capacity for Normal Plus SSE	Greater than or equal to 35,000 lb/ft^2 at the edge of the nuclear island at its excavation depth
Shear Wave Velocity	Greater than or equal to 1,000 ft/sec based on low-strain best-estimate soil properties over the footprint of the nuclear island at its excavation depth
Lateral Variability	Soils supporting the nuclear island should not have extreme variations in subgrade stiffness Case 1: For a layer with a low strain shear wave velocity greater than or equal to 2500 feet per second, the layer should have approximately uniform thickness, should have a dip not greater than 20 degrees, and should have less than 20 percent variation in the shear wave velocity from the average velocity in any layer. Case 2: For a layer with a low strain shear wave velocity less than 2500 feet per second, the layer should have approximately uniform thickness, should have a dip not greater than 20 degrees, and should have less than 10 percent variation in the shear wave velocity from the average velocity in any layer (see subsection 2.5.4.5).

Table 2-1 (Sheet 2 of 3)

SITE PARAMETERS

Liquefaction Potential	None
Missiles	
Tornado	4000 - lb automobile at 105 mph horizontal, 74 mph vertical 275 - lb, 8 in. shell at 105 mph horizontal, 74 mph vertical 1 inch diameter steel ball at 105 mph horizontal and vertical
Flood Level	Less than plant elevation 100′
Ground Water Level	Less than plant elevation 98′
Plant Grade Elevation	Less than plant elevation 100′ except for portion at a higher elevation adjacent to the annex building
Precipitation	
Rain	19.4 in./hr (6.3 in./5 min)
Snow/Ice	75 pounds per square foot on ground with exposure factor of 1.0 and importance factors of 1.2 (safety) and 1.0 (non-safety)
Atmospheric Dispersion Values - χ/Q[e]	
Site boundary (0-2 hr)	≤ 1.0 x 10^{-3} sec/m^3
Site boundary (annual average)	≤ 2.0 x 10^{-5} sec/m^3
Low population zone boundary	
0 - 8 hr	≤ 2.2 x 10^{-4} sec/m^3
8 - 24 hr	≤ 1.6 x 10^{-4} sec/m^3
24 - 96 hr	≤ 1.0 x 10^{-4} sec/m^3
96 - 720 hr	≤ 8.0 x 10^{-5} sec/m^3
Population Distribution	
Exclusion area (site)	0.5 mi

Notes:

(a) Maximum and minimum safety values are based on historical data and exclude peaks of less than 2 hours duration.
(b) Maximum and minimum normal values are the 1 percent exceedance magnitudes.
(c) With ground response spectra as given in Figures 3.7.1-1 and 3.7.1-2. Seismic input is defined at finished grade except for sites where the nuclear island is founded on hard rock.
(d) The noncoincident wet bulb temperature is applicable to the cooling tower only.
(e) For AP1000, the terms "site boundary" and "exclusion area boundary" are used interchangeably. Thus, the χ/Q specified for the site boundary applies whenever a discussion refers to the exclusion area boundary.

Table 2-1 (Sheet 3 of 3)

SITE PARAMETERS

Control Room Atmospheric Dispersion Factors (χ /Q) for Accident Dose Analysis

χ/Q (s/m^3) at HVAC Intake for the Identified Release Points(1)

	Plant Vent or PCS Air Diffuser(3)	Ground Level Containment Release Points(4)	PORV and Safety Valve Releases(5)	Steam Line Break Releases	Fuel Handling Area(6)
0 - 2 hours	3.0E-3	6.0E-3	2.0E-2	2.4E-2	6.0E-3
2 - 8 hours	2.5E-3	4.5E-3	1.8E-2	2.0E-2	4.0E-3
8 - 24 hours	1.0E-3	2.0E-3	7.0E-3	7.5E-3	2.0E-3
1 - 4 days	8.0E-4	1.8E-3	5.0E-3	5.5E-3	1.5E-3
4 - 30 days	6.0E-4	1.5E-3	4.5E-3	5.0E-3	1.0E-3

χ/Q (s/m^3) at Control Room Door for the Identified Release Points(2)

	Plant Vent or PCS Air Diffuser(3)	Ground Level Containment Release Points(4)	PORV and Safety Valve Releases(5)	Steam Line Break Releases	Fuel Handling Area(6)
0 - 2 hours	1.0E-3	1.0E-3	4.0E-3	4.0E-3	6.0E-3
2 - 8 hours	7.5E-4	7.5E-4	3.2E-3	3.2E-3	4.0E-3
8 - 24 hours	3.5E-4	3.5E-4	1.2E-3	1.2E-3	2.0E-3
1 - 4 days	2.8E-4	2.8E-4	1.0E-3	1.0E-3	1.5E-3
4 - 30 days	2.5E-4	2.5E-4	8.0E-4	8.0E-4	1.0E-3

Notes:

1. These dispersion factors are to be used 1) for the time period preceding the isolation of the main control room and actuation of the emergency habitability system, 2) for the time after 72 hours when the compressed air supply in the emergency habitability system would be exhausted and outside air would be drawn into the main control room, and 3) for the determination of control room doses when the non-safety ventilation system is assumed to remain operable such that the emergency habitability system is not actuated.
2. These dispersion factors are to be used when the emergency habitability system is in operation and the only path for outside air to enter the main control room is that due to ingress/egress.
3. These dispersion factors are used for analysis of the doses due to a postulated small line break outside of containment. The plant vent and PCS air diffuser are potential release paths for other postulated events (loss-of-coolant accident, rod ejection accident, and fuel handling accident inside the containment); however, the values are bounded by the dispersion factors for ground level releases.

4. The listed values represent modeling the containment shell as a diffuse area source, and are used for evaluating the doses in the main control room for a loss-of-coolant accident, for the containment leakage of activity following a rod ejection accident, and for a fuel handling accident occurring inside the containment.
5. The listed values bound the dispersion factors for releases from the steam line safety & power-operated relief valves and the condenser air removal stack. These dispersion factors would be used for evaluating the doses in the main control room for a steam generator tube rupture, a main steam line break, a locked reactor coolant pump rotor, and for the secondary side release from a rod ejection accident. Additionally, these dispersion coefficients are conservative for the small line break outside containment.
6. The listed values bound the dispersion factors for releases from the fuel storage and handling area. The listed values also bound the dispersion factors for releases from the fuel storage area in the event that spent fuel boiling occurs and the fuel building relief panel opens on high temperature. These dispersion factors are used for the fuel handling accident occurring outside containment and for evaluating the impact of releases associated with spent fuel pool boiling.