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10 CFR 50.4
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August 19, 2008

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

UN#08-032

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Submittal of Supplemental Information for the
Calvert Cliffs Nuclear Power Plant, Unit 3
Combined License Application
Schedule Issue 4 – Design Parameters for Category I Structure
Foundation Dimensions

Reference: Letter from John Rycyna (U.S. NRC) to George Vanderheyden (UniStar Nuclear Energy), "Acceptance Review for Combined License Applications for Calvert Cliffs Nuclear Power Plant, Unit 3," dated June 3, 2008.

In a letter dated June 3, 2008 (Reference), the U.S. Nuclear Regulatory Commission communicated several schedule issues associated with review of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 Combined Operating License (COL) Application. The purpose of this letter is to respond to the item related to design parameters for Category I structure foundation dimensions that is identified in the referenced letter as Schedule Issue 4.

Proposed changes to FSAR Section 2.5.4.10 (Enclosure) are provided to resolve the identified inconsistencies involving the Category I foundation dimensions described in the U.S. EPR FSAR and CCNPP Unit 3 FSAR.

If there are any questions regarding this transmittal, please contact Mr. George Wrobel at (585) 315-0552.

D079
NRO

UN#08-032
August 19, 2008

I declare under penalty or perjury that the foregoing is true and correct.

Executed on August 19, 2008

George Vanderheyden

Enclosure: COLA Markup Pages

cc: U.S. NRC Region I
U.S. NRC Resident Inspector, Calvert Cliffs Nuclear Power Plant, Units 1 and 2
NRC Environmental Project Manager, U.S. EPR Combined License Application
NRC Project Manager, U.S. EPR Combined License Application
NRC Project Manager, U.S. EPR Design Certification Application (w/o enclosures)

Enclosure

COLA Markup Pages

the outline of CCNPP Unit 3, except for the water intake structures that are located near the existing intake basin, also shown in Figure 2.5-129. A listing of the Category I structures with relevant foundation information is as follows (note that foundation elevations may be subject to minor change at this time).

	Foundation elevation (ft)
~~Reactor Building~~	~~44~~
~~Safeguards Buildings~~	~~44~~
~~Fuel Building~~Nuclear Island Common Basemat	~~44~~41.5
Emergency Power Generating Building	~~79~~76
ESWS Cooling Towers	~~63~~59.5
Ultimate Heat Sink Makeup Water Intake Structure	~~-25~~-24.5
Ultimate Heat Sink Electrical Building	-10.5

Foundation excavations result in removing about 2 million cyd of materials. The extent of all excavations, backfilling, and slopes for Category I structures are shown in Figure 2.5-130 through Figure 2.5-134. These sections are taken at locations identified in Figure 2.5-103 and Figure 2.5-104. These figures illustrate that excavations for foundations of Category I structures will result in removing Stratum I Terrace Sand and Stratum IIa Chesapeake Clay/Silt in their entirety, and will extend to the top of Stratum IIb Chesapeake Cemented Sand, except in the Ultimate Heat Sink Makeup Water Intake Structure area. In the Ultimate Heat Sink Makeup Water Intake Structure area, the foundations are supported on Stratum IIc soils, given the interface proximity of Strata IIb and IIc.

The depth of excavations to reach Stratum IIb is approximately 40 ft to 45 ft below the final site grade in the Powerblock area. Since foundations derive support from these soils, variations in the top of this stratum were evaluated, reflected as elevation contours for top of Stratum IIb in CCNPP Unit 3 and in CLA1 areas, as shown in Figure 2.5-135. This figure shows that the variation in top elevation of these soils is very little, approximately 4 ft or less (about 1 percent) across each major foundation area. The extent of excavations to final subgrade, however, is determined during construction based on observation of the actual soil conditions encountered and verification of their suitability for foundation support. Once subgrade suitability in Stratum IIb Cemented soils is confirmed, the excavations are backfilled with compacted structural fill to the foundation level of structures. Subsequent to foundation construction, the structural fill is extended to the final site grade, or near the final site grade, depending on the details of the final civil design for the project. Compaction and quality control/quality assurance programs for backfilling are addressed in Section 2.5.4.5.3.

Permanent excavation and fill slopes, created due to site grading, are addressed in Section 2.5.5. Temporary excavation slopes, such as those for foundation excavation, are graded on an inclination not steeper than 2:1 horizontal:vertical (H:V) or even extended to inclination 3:1 H:V, if found necessary, and having a factor of safety for stability of at least 1.30 for static conditions. These slopes are currently shown as 3:1 H:V in Figure 2.5-130 through Figure 2.5-133.

Excavation for the Ultimate Heat Sink Makeup Water Intake Structure is different than that for other CCNPP Unit 3 structures, as shown in Figure 2.5-134. Given the proximity of this excavation to the Chesapeake Bay, this excavation is made by installing a sheetpile cofferdam that not only provides excavation support but also aids with the dewatering needs. This is addressed further in Section 2.5.4.5.4.

This COL Item is addressed as follows:

{Section 2.5.2.6 describes the development of the horizontal Safe Shutdown Earthquake (SSE) ground motion for the CCNPP Unit 3 site. The selected SSE ground motion is based on the risk-consistent/performance-based approach of NRC Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" with reference to NUREG/CR-6728 and ASCE/SEI 43-05 (refer to Section 2.5.2.6 for references). Any deviation from the guidance provided in Regulatory Guide 1.208 is discussed in Section 2.5.2. Horizontal ground motion amplification factors are developed in Section 2.5.2.5 using site-specific data and estimates of near-surface soil and rock properties presented in Section 2.5.4. These amplification factors are then used to scale the hard rock spectra, presented in Section 2.5.2.4, to develop Uniform Hazard Spectra (UHS), accounting for site-specific conditions using Approach 2A of NUREG/CR-6769. Horizontal SSE spectra are developed from these soil UHS, using the performance-based approach of ASCE/SEI 43-05, accepted by Regulatory Guide 1.208. The SSE motion is defined at the free ground surface of a hypothetical outcrop at the base of the foundation. Section 2.5.2.6 also describes vertical SSE ground motion, which was developed by scaling the horizontal SSE by a frequency-dependent vertical-to-horizontal (V:H) factor, presented in Section 2.5.2.6.}

2.5.4.10 Static Stability

{The area of planned Unit 3 is graded to establish the final site elevation, which ~~is to be at~~will range from about elevation 81 ft to 85 ft ~~at the center of the unit~~in the power block area. The final site grade elevation is preliminary and will be finalized during detailed design. The Reactor, Safeguard, and Fuel Buildings are seismic Category I structures and are supported on a common basemat. For a basemat thickness of 10 ft and top of basemat about 31.5 ft below grade, the bottom of the basemat would be 41.5 ft below the final site grade. The common basemat has an irregular shape, estimated to be approximately 80,000 square feet (sq ft), with outline dimensions of about 363 ft x 345 ft. For bearing capacity and settlement estimation, a representative foundation is adopted. The cruciform-shaped common basemat ~~has an irregular shape, estimated to be~~is modeled as a rectangle 322 ft x 200 ft in plan dimensions, or approximately 64,400 ~~square~~ ft^2~~, or about 322 ft x 200 ft in plan dimensions if a rectangular configuration is considered~~. The dimensions are selected so that the adopted rectangle assumes a shape similar to the overall shape of the foundation without the two wings. This was done to determine a conservative bearing capacity for the foundation. The effect on the bearing capacity and settlement for a common basemat foundation, which assumes a foundation of equal area (80,000 ft^2.), is discussed at the end of this subsection. Similarly, where foundations of other Category I structures are not uniform in shape, a rectangular configuration is also adopted for these foundations for the purpose of bearing capacity and settlement estimation. All Category I structure~~s~~' size and depth ranges are summarized below, as well as the adopted footing size considered in this bearing capacity and settlement evaluation..

Category I Structure	Estimated Foundation Elevation (ft)	Foundation Outline Dimensions ft x ft/[m x m] Area, (ft²)/[m²])Estimated Final Site Grade Elevation (ft)	Estimated Foundation Depth (ft)/[m]*	EstimatedAdopted Footing Size (ft x ft)/[m x m] Area, (ft²)/[m²])
Common BasematReactor	4441.5	85363 x 345 (110.6 x 105.2) (80,000)/[7,432]**	4141.5 [12.6]	322 x 200 [98.1 x 61] 64,400/[5,983]
Essential Service Water System (ESWS) Cooling Towers (UHS)	6359.5	81 8234 x 86 + 150 x 128 (10.3 x 26.2 + 45.7 x 39) 22,124/[2055.4]	18 1922 [6.7]	147 x 96173 x 128 [52.7 x 39] 22,144/[2,057]
Emergency Power Generating Buildings (EPGBs)	7976	822 x 40 x 42 + 98 x 94.5 (2 x 12.2 x 12.8 + 29.9 x 28.8) 12,621/[1,172.5]	36 [1.8]	131 x 93134 x 94 [40.8 x 28.7] 12,596/[1,170.2]
Ultimate Heat Sink UHS Makeup Water Intake Structure	-25-24.5	1068 x 63 (20.7 x 19.2) 4,284/[398]	3534.5 [10.5]	78 x 4768 x 63 [20.7 x 19.2] 4,284/[398]
UHS Electrical Building	-10.5	76 x 35 (23.2 x 10.7) 2,660/[247.2]	20.5 [6.2]	76 x 35 [23.2 x 10.7] 2,660/[247.1]

* below respective final site grade
** approximate area of cruciform-shaped common basemat

Structures locations and designations are shown in Figures 2.5-103 and 2.5-104. Other major structures in the power block area include the Nuclear Auxiliary Building, Access Building, RadWaste Building, and the Turbine Building, which are not Category I structures.

Construction of the Reactorcommon basemat requires an excavation of about 41 to 42 ft (from approximately elevation 85 ft). The resulting rebound (heave) in the ground due to the removal of the soils is expected to primarily take place in Stratum IIc Chesapeake Clay/Silt soils. A rebound of about 2 in is estimated due to excavation for the Reactorcommon basemat, and is expected to take place concurrent with the excavation. Ground rebound is monitored during excavation. The heave estimate wasis made based on the elastic properties of the CCNPP site soils and the response to the unloading of the ground by about 41 to 42 ft of excavation. The magnitude and rate of ground heave is a function of, among other factors, excavation speed and duration that the excavation remains open. Other factors remaining unchanged, shorter durations culminate in smaller values of ground heave. The excavation shall remain open for a period sufficiently long such that ground heave fully develops.}

2.5.4.10.1 Bearing Capacity

The U.S. EPR FSAR includes the following COL Item in Section 2.5.4.10.1:

> A COL applicant that references the U.S. EPR design certification will verify that site-specific foundation soils beneath the foundation basemats of Seismic Category I structures have the capacity to support the bearing pressure with a factor of safety of 3.0 under static conditions.

This COL Item is addressed as follows:

{Sections 2.5.4.10.1.1 and 2.5.4.10.1.2 are added as a supplement to the U.S. EPR FSAR.

2.5.4.10.1.1 Bearing Condition of Units 1 and 2 Soils

CCNPP Units 1 and ~~1~~2 UFSAR (BGE, 1982) provides an evaluation of the site soils for bearing purposes for CCNPP Units 1 and 2. It indicates that the upper (Pleistocene Age) soils are capable of supporting light loads, on the order of 2 to 3 kips per square foot (ksf) for a small amount of settlement. The lower (Miocene Age) soils are described as being capable of supporting heavy loads, on the order of 15 ksf to 20 ksf with slight consolidation.

The CCNPP Units 1 and 2 Turbine Building, Nuclear Auxiliary Building, Containments, Turbine Generators, and Circulating Water Systems are supported on mat foundations on the Miocene soils. Site grading prior to foundation construction resulted in significant ground unloading. The following is a summary of pertinent information (BGE, 1982).

Structure	Contact Pressure (ksf)	Foundation Elevation (ft)	Average Ground Elevation (ft)	Average Excavation Unloading (ksf)
Nuclear Containment Structure Mat	8	-1	60 to 75	6.6 to 8.4
Auxiliary Building Mat	8	-14 to -19	70	8.3 to 8.85
Turbine Pedestal Mat	5	---	---	---
Turbine Building Column Footings	5	-11	40 to 60	4.9 to 7.3
Intake & Discharge Structure Mat	2.5	-27 to -30	20 to 80	4.05 to 10.8

It is also reported in CCNPP Units 1 and ~~1~~2 UFSAR (BGE, 1982) that elastic expansion of the soils occurred as a result of the excavations, producing "slight upward movement." No magnitude, however, is given. Reference is also made to downward movement of the soils as the foundation load was applied, resulting in a "small" movement and "was complete when construction was completed." ~~No~~Again, no magnitude~~, however,~~ is given.

2.5.4.10.1.2 Bearing Capacity of CCNPP Unit 3 Structures

The ultimate (gross) bearing capacity of a footing, q_{ult}, supported on homogeneous soils can be estimated by (Vesic, 1975):

$$q_{ult} = cN_c\zeta_c + \gamma' D_f N_q \zeta_q + 0.5\gamma B N_\gamma \zeta_\gamma \qquad \text{Eq. 2.5.4-16}$$

where, c = undrained shear strength for clay material (c_u) or cohesion intercept for (c, ϕ) material,

$\gamma' D_f$ = effective overburden pressure at base of foundation,

γ' = effective unit weight of soil,

D_f = depth from ground surface to base of foundation,

B = width of foundation,

N_c, N_q, and N_γ are bearing capacity factors (defined in Vesic, 1975), and

ζ_c, ζ_q, and ζ_γ are shape factors (defined in Vesic, 1975).

The ultimate bearing capacity, q_u, of a footing supported on a strong sandy layer underlain by weaker soil (a 2-layer system) can be estimated by Meyerhof (Meyerhof, 1978):

$$q_u = q_b + \gamma_1 H^2\left(1+\frac{B}{L}\right)\left(1+\frac{2D_f}{H}\right)\left(\frac{K_s \tan\phi_1}{B}\right) - \gamma_1 H \le q_t \quad \text{Eq. 2.5.4-17}$$

where, $q_b = c_2 N_{c2}\zeta_{c2} + \gamma_1(D_f + H)N_{q2}\zeta_{q2} + 0.5\gamma_2 B N_{\gamma 2}\zeta_{\gamma 2}$ Eq. 2.5.4-18A

$q_t = c_1 N_{c1}\zeta_{c1} + \gamma_1 D_f N_{q1}\zeta_{q1} + 0.5\gamma_1 B N_{\gamma 1}\zeta_{\gamma 1}$ Eq. 2.5.4-18B

K_s = punching shear coefficient, defined in Meyerhof (Meyerhof, 1978)

H = depth to the lower layer

The factors in Eqs. 2.5.4-18A and 2.5.4-18B, are defined as follows:

Layer	Effective Unit Weight	Soil Friction	Shear Strength	Bearing Capacity Factors	Shape Factors
Top (strong layer)	γ_1	ϕ_1	c_1	$N_{c1}, N_{q1}, N_{\gamma 1}$	$\zeta_{c1}, \zeta_{q1}, \zeta_{\gamma 1}$
Bottom (weak layer)	γ_2	ϕ_2	c_2	$N_{c2}, N_{q2}, N_{\gamma 2}$	$\zeta_{c2}, \zeta_{q2}, \zeta_{\gamma 2}$

For each of the Category I structures under consideration, where applicable, the bearing capacity of the foundations wasis estimated using two methods, i.e., (1) considering a layered system (Meyerhof, 1978), assuming a strong layer (Stratum IIb Chesapeake Cemented Sand) over a "weak" layer (Stratum IIc Chesapeake Clay/Silt), and (2) considering homogenous soils (Vesic, 1975), assuming Stratum IIc Chesapeake Clay/Silt soils are present under the foundation in entirety. This assumption provides a lower-bound estimate of the bearing capacity.

It is noted that the Reactor, Safeguard, and Fuel Buildings, which are on a common basemat, will essentially derive support from Stratum IIb Chesapeake Cemented Sand. All other structures, except the Ultimate Heat Sink Makeup Water Intake Structure, are supported on compacted structural fill resting on Stratum IIb Chesapeake Cemented Sand. The Ultimate Heat Sink Makeup Water Intake Structure derives support from Stratum IIc Chesapeake Clay/Silt soils. The UHS Electrical Building derives support from Stratum IIb Chesapeake Cemented Sand, or from compacted fill supported on Stratum IIc Chesapeake Clay/Silt soils, depending on final excavation plans. For this bearing capacity and settlement evaluation, it is conservatively assumed that the UHS Electrical Building foundation is supported on Stratum IIc Chesapeake Clay/Silt soils. No Category I structure is supported on Stratum I Terrace Sand or Stratum IIa Chesapeake Clay/Silt.

The subsurface conditions and material properties wereare described in Section 2.5.4.2. Material properties, conservatively designated for the various strata, wereare used for foundation evaluation, as shown in Table 2.5-36. The specific parameter values used in the bearing capacity evaluations are provided in Table 2.5-54. The following bounding property values for compacted fill wereare used in the analyses: a unit weight of 120 pcf, an angle of internal friction of 32 degrees, and a modulus of elasticity of 500 tsf. These are estimated values based on typical engineering properties for similar materials. Compacted fill is verified to meet the design requirements during construction. Locations of structures, relative to the subsurface conditions, are shown in Figure 2.5-130 through Figure 2.5-134. An average ground water level at elevation 80 ft wasis used for foundation evaluation. For the case of the UHS Makeup Water Intake Structure and the UHS Electrical Building, where the ground surface wasis below elevation 80 ft, the ground water elevation wasis considered to be at the ground surface.

A summary of the estimatedcalculated allowable bearing pressures, using both the layered and the homogeneous soils assumptions, including recommended values, are as follows. A factor of safety of 3.0 was applied to obtain the allowable values. The estimated allowable values below are based on adopted foundation size, foundation elevation, foundation pressure, site grade elevation, groundwater level, and structural fill properties which are preliminary.

Category I Structure	Calculated Allowable Bearing Pressure (Layered System) (ksf)	Calculated Lower-Bound Allowable Bearing Pressure (ksf)	Recommended Allowable Max. Bearing Pressure (ksf)
~~Essential Service Water System (~~ESWS~~)~~ Cooling Towers (~~Ultimate Heat Sink~~UHS)	~~13 - 14~~13	8.0	13
Emergency Power Generating Building (EDGB)	~~14 - 15~~16	~~7.8~~7.9	13
Common Basemat	24	8.3	22
~~Ultimate Heat Sink~~UHS Makeup Water Intake Structure	---	~~8.0~~8.5	~~8~~7
UHS Electrical Building	10	7.8	7

~~Design values of~~Estimated design foundation pressures (in ksf) for the Category I structures, based on available project information, are as follows:~~were estimated based on project knowledge and typical loading for similar structures. The design values were adopted for comparison with the allowable values above and are as follows.~~

Estimated Design Foundation Pressures (ksf)

ESWS Cooling Towers (~~Ultimate Heat Sink~~UHS)	~~7~~4.3
E~~D~~PGBs	~~5~~3.3
Common Basemat (average value)	~~15~~15.0
~~Ultimate Heat Sink~~UHS Makeup Water Intake Structure	~~6~~5.1
UHS Electrical Building	1.7

The recommended ~~maximum~~allowable bearing pressures exceed the estimated design foundation pressures. Traditionally, a factor of safety of 3.0 has been found acceptable for foundation design, although lower factors of safety (1.7 to 2.5) have been suggested for mat foundations (Bowles, 1996). A factor of safety of 3.0 ~~was~~is used in the bearing capacity evaluations. However, a~~A~~ comparison of the ~~recommended maximum~~calculated allowable bearing pressures with the estimated design foundation pressures suggests that the final factors of safety ~~is~~are even higher than 3.0. The approximate final factor of safety values are:

Approximate Factors of Safety

ESWS Cooling Towers (UHS)	9
EPGBs	14
Common Basemat (average value)	5
UHS Makeup Water Intake Structure	5
UHS Electrical Building	17

Additionally, the recommended allowable bearing pressures are comparable with estimates of bearing capacity identified in the CCNPP Units 1 and 2 UFSAR (BGE, 1982) (i.e., site soils identified as being capable of supporting heavy loads on the order of 15 ksf to 20 ksf)~~;~~. ~~the~~The notable difference is between the ~~estimate of~~average design foundation pressure of 15 ksf for the Common Basemat and the "contact pressure" of 8 ksf for the Containment Structure Mat of CCNPP Units 1 and 2.

Table 5.0-12.1-1 of the U.S. EPR FSAR identifies the soil bearing capacity as a required parameter to be enveloped, defined as "Minimuma minimum static bearing capacity (static)of "22 ksf in localized areas at the bottom of the Nuclear Island basemat and 15 ksf on average across the total area of the bottom of the Nuclear Island basemat."

For static loading conditions, and based on a factor of safety of 3.0, the calculated allowable bearing pressure for the NI basemat is 24 ksf (as shown above). On this basis, the available bearing capacity for the actual site specific condition meets the minimum 22 ksf and the average 15 ksf values identified in the U.S. EPR FSAR.}

A sensitivity evaluation was performed to investigate the difference in bearing capacity by also modeling the common basemat as a rectangular foundation 345 ft x 232 ft (80,040 ft^2). The calculated bearing capacity for the 345 ft x 232 ft (80,040 ft^2) foundation is 25 ksf, as compared to the 24 ksf calculated for the adoptive foundation of 322 ft x 200 ft. Such a small difference in the calculated bearing capacity is considered inconsequential with respect to the site soil stability, particularly in light of the factor of safety exceeding 3.0.

2.5.4.10.2 Settlement

The U.S. EPR FSAR includes the following COL Item in Section 2.5.4.10.2:

> A COL applicant that references the U.S. EPR design certification will verify that the differential settlement value of ½ inch per 50 ft in any direction across the foundation basemat of a Seismic Category I structure is not exceeded. Settlement values larger than this may be demonstrated acceptable by performing additional site--specific evaluations.

This COL Item is addressed in the following section {and in Section 3.8.5.}

{The pseudo-elastic method of analysis wasis used for settlement estimates. This approach is suitable for the overconsolidated soils at the site. The analysis is based on a stress-strain model that computes settlement of discrete layers:

$$\delta = \Sigma(\Delta p_i \times \Delta h_i)/E_i \qquad \text{Eq. 2.5.4-19}$$

where,

δ = settlement

i = 1 to n, where n is the number of soil layers

p_i = vertical applied pressure at center of layer i

h_i = thickness of layer i

Ei = elastic modulus of layer i

The stress distribution below the rectangular foundations is based on a Boussinesq-type distribution for flexible foundations (Poulos, 1974). The computation extends to a depth where the increase in vertical stress (Δp) due to the applied load is equal to or less than 10 percent of the applied foundation pressure. The Boussinesq-type vertical pressure under a rectangular footing, σ_z, is as follows (Poulos, 1974):

$$\sigma_z = (p/2\pi)(\tan^{-1}(lb/(zR_3)) + (lbz/R_3)(1/R_1^2 + 1/R_2^2)) \qquad \text{Eq. 2.5.4-20}$$

where,

l = length of footing
b = width of footing
z = depth below footing at which pressure is computed
$R_1 = (l^2 + z^2)^{0.5}$
$R_2 = (b^2 + z^2)^{0.5}$
$R_3 = (l^2 + b^2 + z^2)^{0.5}$

Settlement estimates ~~were~~are made following the preceding relationships and using available soils properties given in Table 2.5-36. To estimate settlement values, a subsurface profile in the foundation area of interest ~~was~~is adopted, as shown in Figure 2.5-130 through Figure 2.5-134. The soil layers ~~were~~are further subdivided into sublayers for refined estimates. From the stress distribution defined by~~in~~ Eq. 2.5.4-20, the sublayer thickness, and the elastic modulus for the particular soil, values for settlement ~~were~~are estimated using Eq. 2.5.4-19. The final settlement is the summation of the estimated values for all of the sublayers combined. Significant to estimating settlement values is the value of elastic modulus, E. This parameter ~~was~~is selected from the available summary of soil engineering properties, as shown in Table 2.5-36, complimented with estimates of elastic moduli, reduced for strain magnitude, based on the average shear wave velocity values shown in Table 2.5-36. Elastic modulus estimated from the average shear wave velocity values and reduced for strain magnitude is used for the common basemat settlement estimate because of its large foundation size and loading. Settlement estimates ~~were~~are made for all Category I structures, for the estimated design foundation pressures given in this subsection. They are as follows.

Category I Structure	Est. Design Foundation Pressure (ksf)	Est. Foundation Settlement (in.) Center	Edge	Average
ESWS Cooling Towers (~~Ultimate Heat Sink~~UHS)	~~7~~4.3	~~5~~3.9	~~3~~2.4	~~4~~3.2
~~EDGB~~EPGBs	~~5~~3.3	~~4~~2.7	~~2~~1.7	~~3~~2.2
Common Basemat (average value)[1]	~~15~~15.0	~~10~~10.0	~~6~~6.0	~~8~~8.0
~~Ultimate Heat Sink~~ UHSMakeup Water Intake Structure	~~6~~5.1	~~2~~1.8	~~1~~1.1	~~1.5~~1.4
UHS Electrical Building	1.7	0.5	0.3	0.4

(1) The settlement values shown for the common basemat are based on the 322 ft x 200 ft adopted foundation size.

The settlement magnitudes are discussed later.

The ~~planned~~available site grading plan indicates~~results in~~ removing as much as 23 ft of soil (El. 105 to El. 82) from the area of the Emergency Power Generating Building-South (1UBP and 2UBP, shown in Figure 2.5-104) and in adding as much as 17 ft of fill (El. 65 to El. 82) to the Emergency Power Generating Building-North (3 UBP and 4 UBP shown in Figure 2.5-104). Additionally, foundations rest ~~as much as 3 ft to 41~~from a minimum of 6 ft to a maximum of 41.5 ft below the final site grade for the Emergency Power Generating Buildings and the ~~C~~common ~~B~~basemat, respectively, resulting in further changes in the net foundation loading. Net foundation pressures ~~were~~are estimated, based on available grading information, as follows.

Category I Structure[(1)]	~~Average~~ Existing Site Grade Elevation, ft (Average) ~~(ft)~~	~~Final~~ Grade Elevation[(2)] (ft)	Foundation Elevation (ft)	Est. Design Foundation Pressure (ksf)	Est. Net Foundation Pressure[(3)] (ksf)
ESWS Cooling Tower North(URB3&4)	60 - 95 (80)	81	~~63~~59.5	~~7~~4.3	~~6~~3
ESWS Cooling Tower-South(URB1&2)	90 - 120 (100)	82	~~63~~59.5	~~7~~4.3	~~4~~1
~~EDGB~~EPGB-North(UBP3&4)	55 - 70 (65)	82	~~79~~76	~~5~~3.3	~~7~~5
~~EDGB~~EPGB-South(UBP1&2)	105 – 115 (105)	82	~~79~~76	~~5~~3.3	~~2~~1
Common Basemat	70 – 110 (90)	~~85~~83	~~44~~41.5	~~15~~15.0	11
~~Ultimate Heat Sink~~UHS Makeup Water Intake Structure~~.~~	10 (10)	10	~~-25~~-24.5	~~6~~5.1	~~4~~3
UHS Electrical Building	10 (10)	10	-10.5	1.7	1

(1) Refer to Figure 2.5-104 for locations

(2) Available information preliminary. Foundation depth estimate varies slightly, depending on final grade elevation.

(3)Est. Net Foundation Pressure = Est. Design Foundation Pressure – Effective Overburden Stress at the Foundation Level.

Estimated settlements corresponding to the net foundation pressures are given below. It is noted, however, that for most foundations the magnitude of estimated settlements ~~are~~is generally not significantly changed, given the typically small change in foundation pressures due to grading and excavations.

Category I Structure	Est. Net Foundation Pressure (ksf)	Est. Foundation Settlement (in)		
		Center	Edge	Average
ESWS Cooling Tower-North	~~6~~3	~~5~~2.7	~~3~~1.7	~~4~~2.2
ESWS Cooling Tower-South	~~4~~1	~~3~~0.9	~~2~~0.6	~~2~~0.8
~~EDGB~~EPGB-North	~~7~~5	~~5~~4.1	~~3~~2.6	~~4~~3.4
~~EDGB~~EPGB-South	~~2~~1	~~2~~0.8	~~1~~0.5	~~1~~0.7
Common Basemat	11	~~7~~7.0	~~5~~5.0	~~6~~6.0
~~Ultimate Heat Sink~~ UHSMakeup Water Intake Structure~~.~~	~~4~~3	~~1~~1.1	~~1~~0.7	~~1~~0.9
UHS Electrical Building	1	0.4	0.2	0.3

The average total settlement estimates above are in the range of about 1 to ~~4~~3 in except for the ~~C~~common ~~B~~basemat which is about 6 in for the 11 ksf loading case and about 8 in for the 15 ksf loading case. The maximum total settlement (at center of common basemat) is estimated to be about 10 in resulting from the 15 ksf loading. It would be anticipated that the calculated settlements for the common basemat with dimensions of 345 ft x 232 ft (80,040 ft^2) would only be slightly larger. The larger foundation size would affect an increased depth of soil, but the deeper soils are significantly harder and denser than the soils directly below the foundation and therefore contribute little to the overall total calculated settlement.

Generally acceptable total and differential settlements for mat foundations supported on clays are typically in the range of 2.5 in and 1.5 in, respectively, although tolerable total settlements as high as 4 in have been suggested for mat foundations (Bowles, 1966). Higher total settlements are accommodated by delaying critical connections to adjacent structures, utilities, and pavements until as late in the construction schedule as practicable. Differential settlement, however, is more critical than total settlement. Acceptable tilt for foundations is on the order of 1/300 (Bowles, 1966), although values as low as 1/750 have been stated for foundations that support machinery sensitive to settlement (Das, 1990).

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From the above estimates, average foundation settlement for the Ultimate Heat Sink Makeup Water Intake Structure ~~is~~and the UHS Electrical Building are within the acceptable range of 2.5 in to 4 in Similarly average settlement estimates for the Emergency Power Generating Building and the ESWS Cooling Towers are within the acceptable range of 2.5 in to 4 in For the ~~C~~common ~~B~~basemat, an average settlement of about 8 in was estimated for the 15 ksf loading. This estimated total settlement is largely the result of the extreme foundation size and loading as well as the depth of influence of the large mat.

Differential settlements ~~were~~are estimated as the difference in settlement values at the center and edge of foundations. The estimated values are as follows: about 1 in ~~to 2 in~~or less for the ESWS Cooling Towers, about 1.5 in or less~~1 in to 2 in~~ for the Emergency Power Generating Building, about 2 in to 4 in for the Common Basemat, and ~~practically zero~~less than 0.5 in for the Ultimate Heat Sink Makeup Water Intake Structure and UHS Electrical Building. From these values, maximum tilt ~~was~~is estimated as the ratio of the differential settlement and the distance over which it is calculated, at about ~~1/600~~1/760 for the ESWS Cooling Towers, ~~1/550~~1/350 for the ~~EDGB~~EPGBs, ~~and in the range of 1/600~~1/300 to ~~1/1,200~~1/600 for the ~~C~~common ~~B~~basemat ~~foundations~~, and 1/900 for the UHS Makeup Water Intake Structure and UHS Electrical Building. ~~Estimates of tilt for all structures, including the Common Basemat, are well within the acceptable limit of 1/300, however, they exceed the 1/750 for the special case of sensitive machinery, although the difference is not substantial.~~ It is noted that the tabulated settlement estimates are based on the assumption of a flexible foundation; they do not take into account the effects of a thick, highly reinforced foundation mat which tends to mitigate differential settlements.

~~F~~Also, foundation settlements largely take place concurrent with construction; therefore, a majority (i.e., more than half) of the settlements will have taken place prior to placing the equipment, piping, and the final finishes. Hence, post-construction total and differential settlements are expected to be lower than the values noted herein, particularly after accounting for foundation mat rigidity. The settlement estimates are the subject of further studies during the detailed design phase of the project. A supplemental geotechnical investigation is currently underway to support this. The final settlement values will be verified so that they are consistent with the foundation design requirements.

The U.S. EPR FSAR Section 2.5.4.10.2 identifies differential settlement as a required parameter to be enveloped, and is defined as "½ inch per 50 ft in any direction across the foundation basemat of a Seismic Category I structure" and that "values larger than this may be demonstrated acceptable by performing additional site specific evaluations."

The estimated differential settlements do not meet the U.S. EPR FSAR requirement of ½ inch per 50 ft (or 1/1,200); however, additional site specific evaluations will be performed to demonstrate their acceptability, as follows.

To verify that foundations perform according to estimates, and to provide an ability to make corrections, if needed, major structure foundations are monitored for rate of movement during and after construction.

In general, the estimated foundation settlements are larger than those indicated for CCNPP Units 1 and 2, although no estimates or measured values are available for Units 1 and 2, as discussed in Section 2.5.4.10.1. The difference in settlement between the two areas is not due to differing soil conditions, as the soils are comparable. Rather, they are largely due to the difference in magnitude of net loading imposed by these structures on the soils, and foundation size. The influence of the larger and heavier Common base mat for Unit 3 extends deeper, thereby influencing a larger volume of soils.

~~However, a~~All foundations are designed to safely tolerate the anticipated total and differential settlements. Additionally, engineering measures are incorporated into design for control of differential movements between adjacent structures, piping, and appurtenances sensitive to movement, consistent with settlement estimates. This includes the development and implementation of a monitoring plan that supplies and requires evaluation of information throughout construction and post-construction on ground heave, settlement, pore water pressure, foundation pressure, building tilt, and other necessary data. This information provides a basis for comparison with design conditions and for projections of future performance.

These estimated differential settlements~~, except for those associated with the Ultimate Heat Sink Makeup Water Intake Structure~~ represent departures from the U.S. EPR FSAR requirements. Additional discussion of the acceptability of these estimated differential settlements is provided in Section 3.8.5.

Sections 2.5.4.10.2.1 through 2.5.4.10.2.2 are added as a supplement to the U.S. EPR FSAR.

2.5.4.10.2.1 Earth Pressures

Static and seismic lateral earth pressures are addressed for plant below-ground walls. Seismic earth pressure diagrams are structure-specific and are, therefore, only addressed generically herein. Specific earth pressure diagrams are developed for specific structures based upon each structure's final configuration. Passive earth pressures are not addressed; they are ignored for conservatism for general purpose applications. The following soil properties were assumed for the backfill; an angle of shearing resistance of 30 degrees and a total unit weight of 120 pcf. Structural backfill material is verified to meet the design requirements prior to use during construction. A surcharge pressure of 500 psf was assumed as well. The validity of this assumption will be confirmed during detailed design. Lateral pressures due to compaction are not included; these pressures are controlled by compacting backfill with light equipment near structures.

Earthquake-induced horizontal ground accelerations are addressed by the application of $k_h \cdot g$. Vertical ground accelerations ($k_v \cdot g$) are considered negligible and were ignored (Lambe, 1969). A seismic acceleration of 0.125g was adopted for developing the generic earth pressure diagrams. Backgrounds on seismic accelerations are discussed in Section 2.5.4.8.2.

2.5.4.10.2.1.1 Static Lateral Earth Pressures

The static active earth pressure, pAS, is estimated using (Lambe, 1969):

$$p_{AS} = K_{AS} \cdot \gamma \cdot z \qquad \text{Eq. 2.5.4-21}$$

where K_{AS} = Rankine coefficient of static active lateral earth pressure

γ = unit weight of backfill

Table 2.5-54—{Bearing Capacity Evaluation Parameters}

Structure	Embedment, D ~~(ft)~~ (m)	Length, L ~~(ft)~~ (m)	Width, B ~~(ft)~~ (m)	B/L	Soil Layer	c (ksf)	ϕ (deg)	N_c	N_q	N_γ	ζ_c	ζ_q	z_q
ESWS Cooling Towers (UHS)	~~13.7–22.7~~22 (6.7)	~~147~~173 (52.7)	~~96~~128 (39)	~~0.65~~0.74	Compacted Fill, Stratum II-b	0	34	42.16	29.44	41.06	~~1.46~~1.52	~~1.44~~1.50	~~0.74~~0.70
					Stratum II-c	4	0	5.14	1	0	~~1.13~~1.14	1	~~0.74~~0.70
~~Emergency Power Generating Buildings~~EPGBs	~~3–6~~6 (1.8)	~~131~~134 (40.8)	~~93~~94 (28.7)	~~0.71~~0.70	Compacted Fill, Stratum II-b	0	32	35.49	23.18	30.22	1.46	1.44	0.72
					Stratum II-c	4	0	5.14	1	0	1.14	1	0.72
~~Reactor (~~Common Basemat*~~)~~	~~41~~41.5 (12.6)	322 (98.1)	200 (61)	0.62	Stratum II-b	0	34	42.16	29.44	41.06	~~1.43~~1.47	~~1.42~~1.45	~~0.75~~0.73
					Stratum II-c, III	2.3	16	11.63	4.34	3.06	~~1.23~~1.25	~~1.18~~1.19	~~0.75~~0.73
UHS Makeup Water Intake Structure	~~30.5~~34.5 (10.5)	~~78~~68 (20.7)	~~47~~63 (19.2)	~~0.60~~0.93	Stratum II-c	4	0	5.14	1	0	~~1.12~~1.18	1	---
UHS Electrical Building	20.5 (6.2)	76 (23.2)	35 (10.7)	0.46	Stratum II-b	0	34	42.16	29.44	41.06	1.32	1.31	0.82
					Stratum II-c	4	0	5.14	1	0	1.09	1	0.82

* Bearing capacity factors are for the adopted foundation size shown, not for alternate sizes discussed elsewhere

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Figure 2.5-103—(REVISED) {Subsurface Investigation Location Plan}

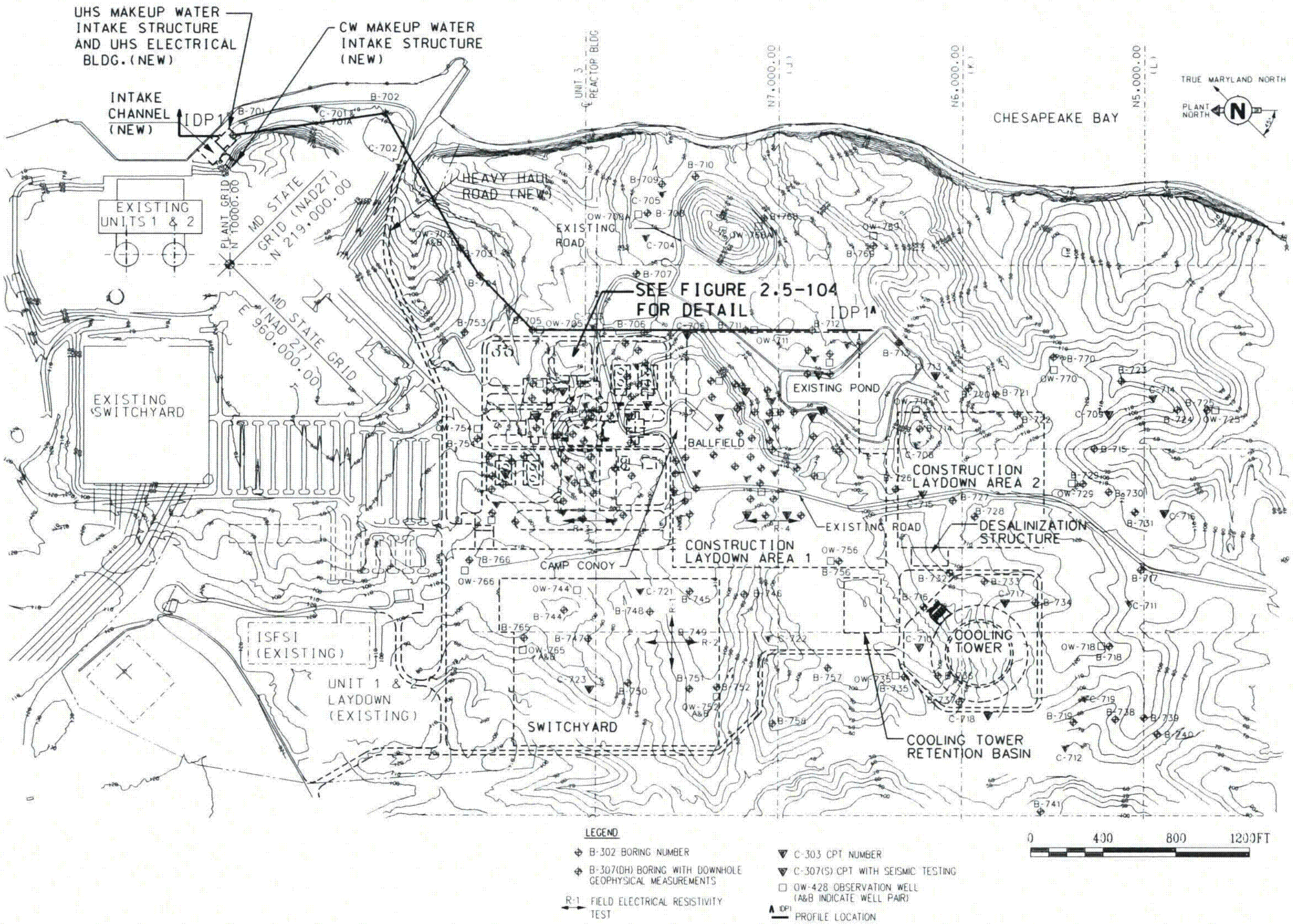

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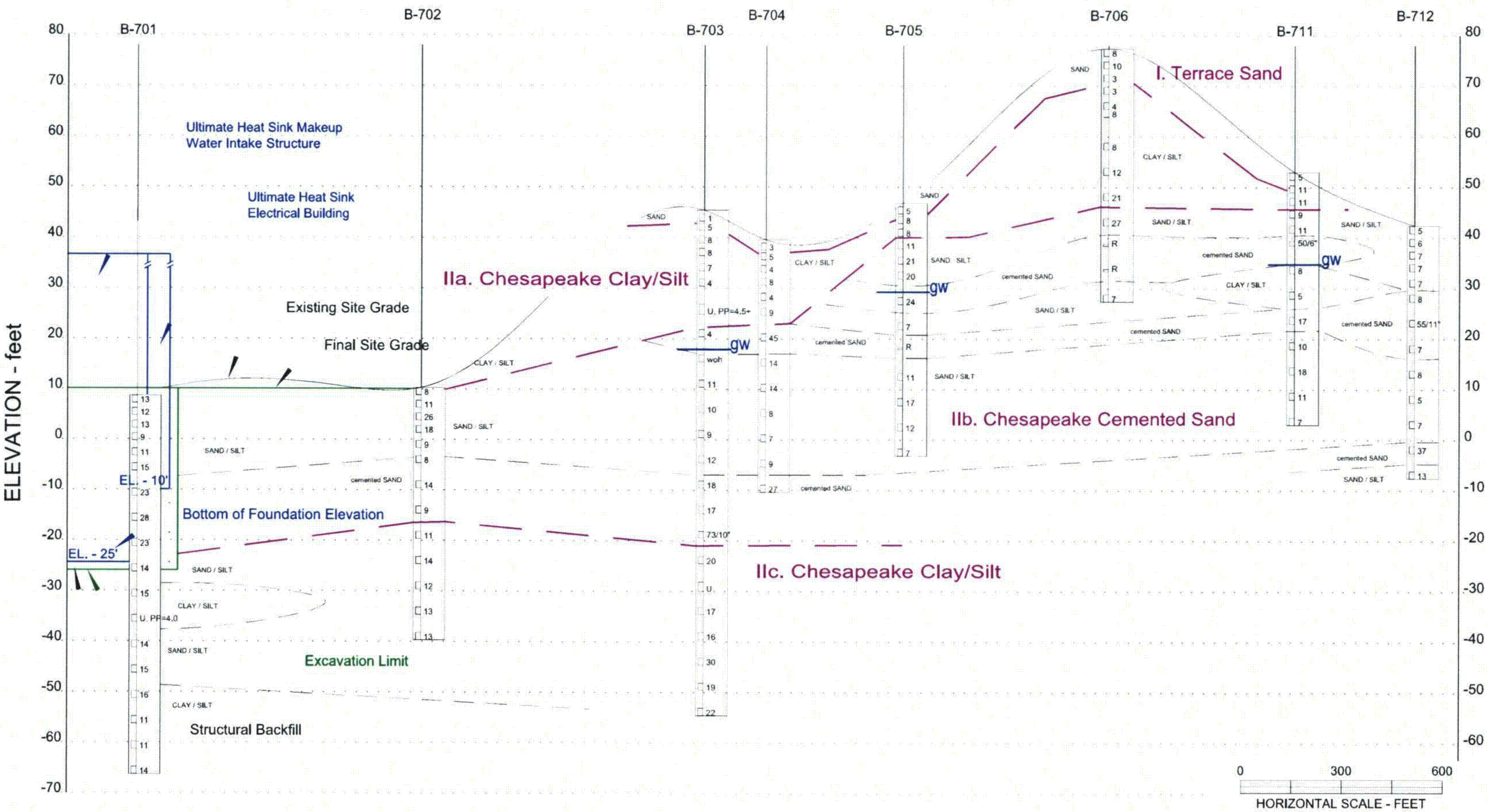
Figure 2.5-134—(REVISED) {Excavation Profile IDP1}



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