FIGURE 6. Loose diorite boulders are common throughout the site.

FIGURE 7. Picture showing composition of diorite.

FIGURE 8. Spheroidal weathering

FIGURE 9. Weathered rock with resulting residual soils.

FIGURE 10. Colluvium deposits on the eastern side of the hill.

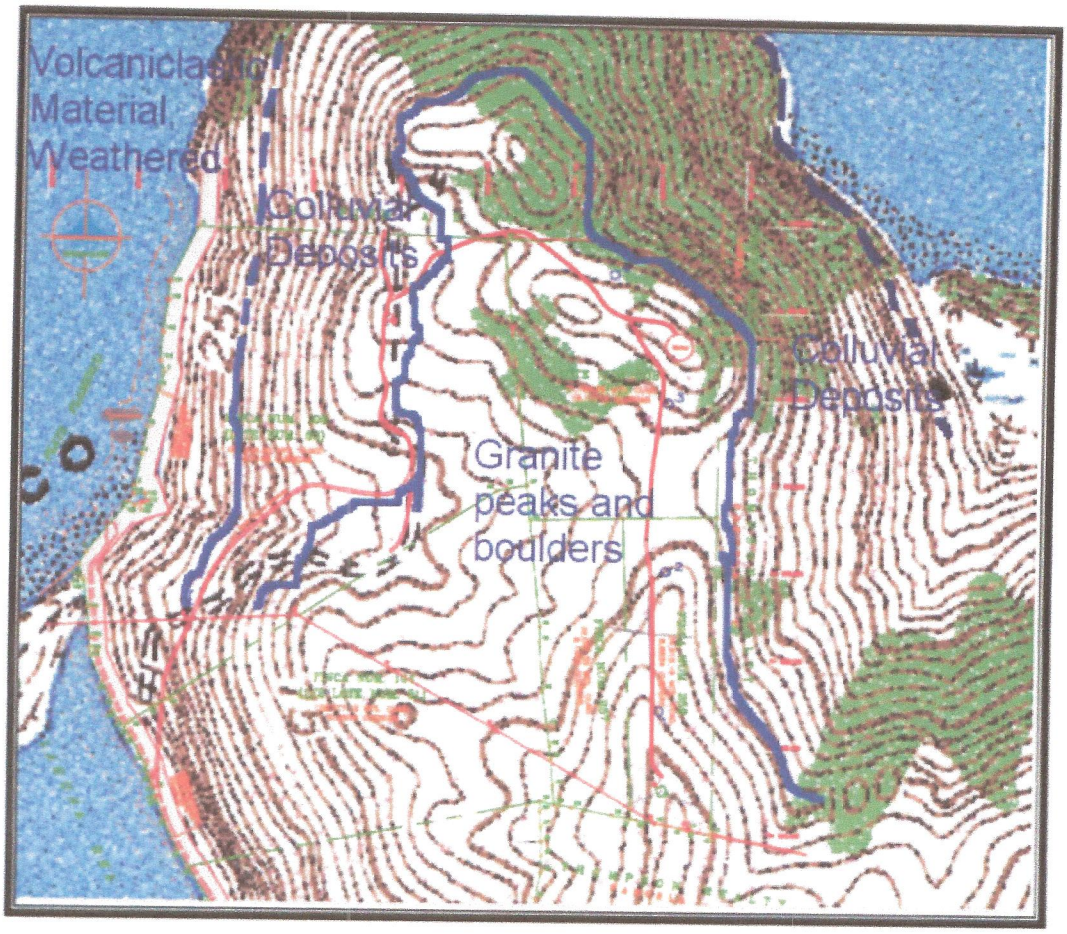


**FIGURE 11. General geologic map of the site.**

## ►GROUNDWATER

Due to the high relief topography, and soil and rocky composition of the hill, no shallow groundwater levels are expected at the site, however, some water might be found in fractures and joints in the plutonic body.

The USGS Atlas of Ground-Water Resources in Puerto Rico and the U.S.Virgin Islands states that: "The depth to the water table beneath the hills may be 100 feet or more, but in the lower part of the valleys may be less than 10 feet." Being the project site at ground elevations between 95 to 105 meters above sea level, the occurrence of shallow groundwater is not anticipated..

## ►LANDSLIDE POTENTIAL

The four wind turbines will be located at the highland, in relatively flat areas, and away from hill side slopes. The highland is underlaid by very competent rock formations, which do not suggest landslide-related problems. No potential for landslides is expected at wind turbine locations.

## ►ASSESSMENT OF LIQUEFACTION SUSCEPTIBILITY

One of the most dramatic causes of damage to engineering structures during an earthquake has been the development of liquefaction in saturated soil deposits. The factors affecting liquefaction of sands have been extensively investigated in the past three decades. The understanding of the phenomenon has advanced to a degree that analytical procedures have been formulated to predict if liquefaction would occur at a site. More recently, Boulanger and Idriss (2006, 2007), as well as Bray and Sancio (2006), have incorporated new concepts and refinements to the standard practices of liquefaction analysis.

The latest liquefaction susceptibility criteria for saturated silts and clays provided guidance for selecting engineering procedures for estimating potential strains, and strength loss during seismic loading. For the case of clays and silts, monotonic and cyclic undrained loading test data shows that they transition, over a fairly narrow range of plasticity indices (PI), from soil that behave more fundamentally like sands (sand-like behavior) to soils that behave more fundamentally like clays (clay-like behavior).

Considering the behavior of fine-grained soils under seismic loading, it is recommended that the term "liquefaction" be reserved for describing the development of significant strains or strength loss in soils exhibiting a sand-like behavior, whereas the term cyclic softening be used to describe similar phenomena in soils exhibiting a clay-like behavior. Clay-like behavior can be expected for fine grained soils that have PI>5 or 7 (Boulanger and Idriss, 2006).

The plasticity index (PI) has been described as a robust indicator of liquefaction susceptibility. According to Bray and Sancio (2006), loose soils with PI<12 and w>0.85LL are susceptible to liquefaction while cyclic mobility should be expected in fine-grained soils with PI<20 and w>0.85LL. Seed et al. (2003) found that sand-like soils are potentially liquefiable if their PI<12, LL<37 and w>0.80LL. In a similar way, clay-like soils may be susceptible to cyclic softening if their PI<20, LL<47 and w>0.85LL.

Considering the geology of the area, the competence and type o the soil profile, and the location of the water table, the site can be classified as not having potential for liquefaction.

## ►SEISMIC GROUND MOTION VALUES

### Mapped Acceleration Parameters

According to IBC 2006, the 0.2 sec spectral response acceleration (Ss) for the Island of Culebra corresponds to 0.99. The 1.0 sec spectral response acceleration (S1) corresponds to 0.30.

### Site Class Definition

Based on the IBC site class definitions, a Class B type can be assigned to the project site.

### Estimate of Peak Ground Acceleration

It is the current standard of practice to consider seismic events corresponding to a 10% probability of exceedance within a 50 year design life (i.e. an annual risk level of 0.21% or a 475-year return period) as the Design Basis Earthquake.

Prediction of peak horizontal ground accelerations (PHGA) on bedrock in the study area were obtained from the USGS Seismic Hazard Maps for Puerto Rico (2003). According to the USGS maps, a peak bedrock acceleration of 0.25g is applicable to the 475-year return period.

Based on the shallow depth to bedrock in the project site, it is expected that the intensity of ground shaking would not be significantly amplified during upward propagation (overlying soft soils are not expected). Therefore, the corresponding peak horizontal acceleration at the site is approximately 0.25g.

## ►EXPECTED FOUNDATIONS

Many foundation types are used to support wind turbines with substantial hub height (>300 ft), vertical loads (400 to 600 kips) and moments (18,500 kip-ft to 60,000 kip-ft). Shallow turbine foundations are typically made of reinforced concrete, octagonal in shape. The minimum diameter is usually dictated by foundation stiffness or maximum allowable pressure.

For wind turbine foundation sizing and design checks, rotational stiffness is generally the first design check conducted to confirm that the nominal stiffness requirement contained in the manufacturer's load document is met or exceed. Factors of design include design life, material strength, serviceability and fatigue analysis. Design loads are provided by the turbine manufacturer and consist of wind, service, fatigue and seismic loads.

Bearing capacity can be the controlling factor in the design of wing turbines supported on shallow foundations, especially for the high edge pressures resulting from the large moments applied to the foundation. Corrections for eccentricity and foundation effective area must be applied in this analysis. For settlement, given the magnitude of the vertical loads from the wind turbines and the typical size of the spread footings, the contact pressure from vertical loads is low, typically in the range of 2,500 to 3,000 psf. Considering the findings of the geologic assessment, the soil profile expected at the Culebra site should have adequate bearing capacity and stiffness such that settlements would be less than 1 inch.

For this particular project, the use of shallow spread footings are expected. Because shallow spread footings are typically embedded about 6 to 8 feet below grade, foundation design would not be impacted by groundwater. A shallow water table is not expected at this site.

Respectfully submitted.

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**mgn**

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