

October 31, 2008

Ms. Joan L. Hughes
Oak Bluffs Conservation Commission
56 School Street
P.O. Box 1327
Oak Bluffs, MA 02557

Re: East Chop Bluff (CLE No. 08.057.100, D&A Job No. 0193.022.00)

Dear Ms. Hughes:

From September 8 to September 9, 2008, Geo-Logic and CLE/D&A conducted a subsurface exploration program for the East Chop Bluff Project on Martha's Vineyard, Massachusetts. The exploration program utilized Standard Penetration Testing (SPT) to help determine the strength properties and behavior of the in-situ soils. The SPT findings were used to analyze the stability of a 1,500' foot section of coastal bank (slope), and make recommendation on how to stabilize the slope. This letter summarizes the following:

1. Subsurface Exploration Program
2. Site and Subsurface Conditions
3. Soil Properties
4. Slope Stability Analysis & Considerations
5. Slope Stabilization Options
6. Conclusions

1. SUBSURFACE EXPLORATION PROGRAM

The drilling program consisted of three 60 foot deep test borings: SPT-1, SPT-2 and SPT-3. The borings were taken in the center of the northern most travel lane of East Chop Drive. Each boring was advanced using 4-inch casing, a tricone roller bit, and drilling mud. Standard Penetration Testing (SPT) and sampling was conducted at five-foot intervals. Soil samples were classified and the boring logs are attached to this letter.

It should be noted when reviewing the boring logs that the drill rig used a wire line and winch release mechanism for raising and releasing the 140-pound donut hammer. Energy measurements taken for this specific hammer indicate the average transferred energy is only 28.1% efficient. To put this in perspective a traditional cathead/donut hammer system is typically 45% efficient, while the safety/automatic trip hammer is 70% to 80% efficient. Thus, the field blow counts appear to be high, but after energy and overburden corrections are

accounted for the blow counts used for design are significantly lower than what is recorded on the field logs.

2. SITE AND SUBSURFACE CONDITIONS

Site Conditions

The coastal bank in question runs parallel to East Chop Drive and consists of a 20 to 40 foot high (upper) slopes that dip downward to the north at a 36 to 37 degree angle. The majority of the slope is covered in vegetation (beach grass, *Rosa rugosa*, brush, etc.) and asphalt/concrete debris. At the toe of the slope is 13.5 to 20 foot wide bench made of light riprap. The east half of the bench ends at an old wooden seawall that has been partially buried by a wave break made of heavy riprap. The old seawall was not observed on the western half of the bench. The wave break dips downward to the north at 18 to 41 degrees. See the following photographs for examples of these features.



The bench and wave break appear to be in fair condition. The upper vegetated slope of the bank is in poor condition. Numerous scarps, sloughs, and eroded gullies were observed along the length of the slope. Numerous locations of the slope are bare of vegetation. Example photos of distressed areas are shown below.



Local residents informed D&A that much of the natural brushy vegetation and trees had been removed within the last few years, and replaced with beach grass in order to improve the view. D&A was also informed that several generations ago playing fields existed to the east of the existing slope, but were washed away during various storms. To prevent further erosion the bank was protected by the current benched riprap. According to Mr. John Breckenridge, the original design required riprap being placed on the upper slope as well, but this work was not completed.

Subsurface Conditions

The existing roadway consists of 8 to 9 inches of asphalt. Below the asphalt is generally fine to medium grain sand with trace amounts of coarse sand, trace amounts of gravel, and trace amounts of fines. Based on the drilling returns, very thin to thick gravelly layers are interbedded with the sand. After making correction for overburden pressure and hammer efficiency, the sand deposit is generally medium dense. The soil retrieved in the sampler generally has a Unified Soil Classification Designation of SP (poorly graded sand), and Massachusetts State Building Code (see 780 CMR Table 1804.3) material classification of 8/9. The subsurface soils have been reported by others as being glacial outwash material overlying glacial moraine deposits. The soils encountered in the borings are consistent with outwash material. Glacial moraine material was not encountered in the holes, but mostly likely exists at deeper depths.

The groundwater table depth could not be measured in the borings due to the use of drilling mud. However, the water elevation is probably close to the mean tide elevation. No springs were observed on the face of the slope, bench, and lower riprap wave break.

3. SOIL PROPERTIES

Based on the corrected SPT results, the following in-situ soil properties are considered appropriate for determining the stability of the slopes and the loads on earth retaining structures.

- Unit Weight of Soil = 125 pcf
- Friction Angle of Soil, $\phi = 32-34$ degrees

4. SLOPE STABILITY ANALYSIS & CONSIDERATION

Based on the type of soils encountered in the borings, and information on the soil in the area, deep seated failures are not expected at this site. The slope failure mechanism at this site is expected to be a series of shallow sloughs. Thus an infinite slope analysis can be used to determine the stability of the existing slopes. The results of the infinite slope analysis for the East Chop Bluff are provided on Table 1.

Table 1: Slope Stability (based on $\phi = 34$ degrees)

Station	Pitch of Slope	Factor of Safety (Note 1)
2+50	36 Degrees	0.93
7+50	36 Degrees	0.93
12+50	35 Degrees	0.96

Note 1: Surcharges associated with traffic loads on East Chop Drive were considered, but they were determined to be insignificant. The load caused by a tire quickly reduces with depth and lateral distance. The nearest portion of the slope is 7 feet from where tire travel is expected, and quickly increases as the road slopes away from East Chop Drive.

Stable slopes are typically designed with a factor of safety of 1.25 or higher. As seen in Table 1 the current slope is not considered stable even when using the highest practical friction angle of 34 degrees for the in-situ soils.

Currently the deterioration of the slope is being slowed down by the presence of vegetation. Rapid deterioration with significant erosion may occur if waves start to overtop the heavy riprap wave break and contact the bottom of the upper slope. Periods of heavy rain (i.e. 25 year storm) may also destabilize local areas of the slope.

Currently the roadway is sufficiently far enough away from the slope that tire loads do not impact the slope stability. If the slope further deteriorates, the influence of tire loads may cause destabilization. Thus during weather events, such as heavy rain or waves breaking on to the upper slope, trucks carrying heavy loads (i.e. concrete, soil/rock, and tractor trailers) should not be allowed on East Chop Drive. Local traffic (i.e. residents of East Chop Drive) consisting of cars, SUV's and small trucks should be limited during said storm events to the west bound lane as long as the east bound lane shows no signs of distress (i.e. cracking). The roadway should be closed if the east bound lane starts to show signs of distress.

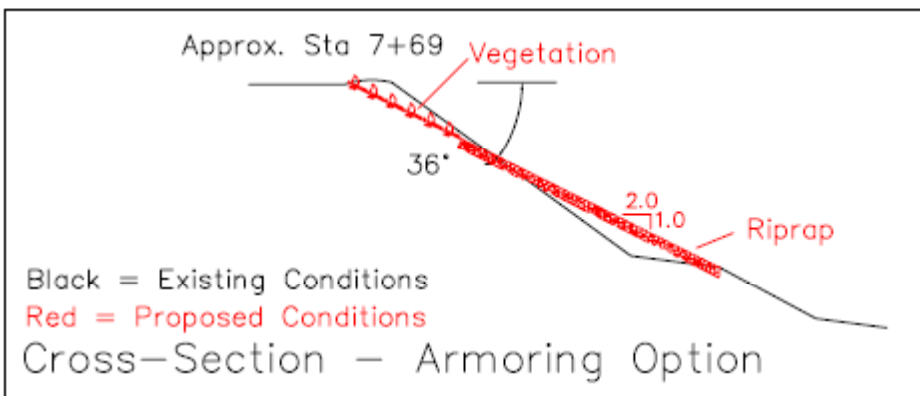
5. SLOPE STABILIZATION OPTIONS

The East Chop Bluff must be flattened and protected against wave action in order to protect East Chop Drive from being compromised. The following are several options that are available for reducing the slope and providing erosion protection:

- Armoring
- Rockfill
- Mechanically Stabilized Earth Wall
- Sheetpiling (2 Options)

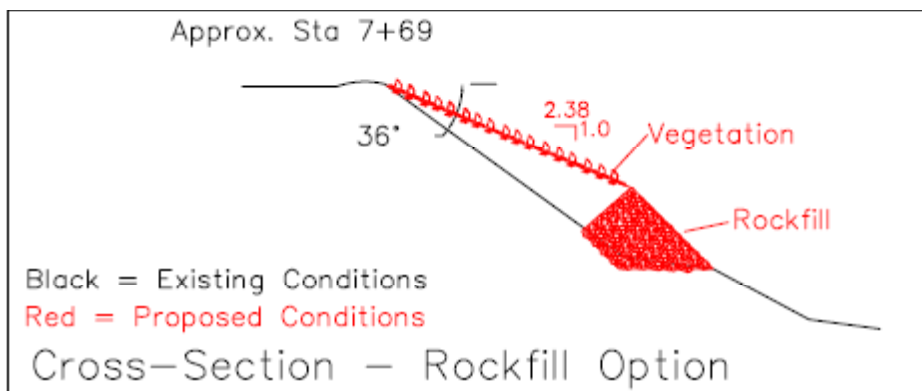
Each option has its positives and negatives, and the ideal solution may involve using a combination of these various options.

Armoring Option



Armoring the slope with heavy riprap or an articulated pre-cast concrete block system requires reshaping the slope to a naturally stable angle. This option is shown above (Armoring Option). The Armoring Option involves reshaping the slope to a 2H:1V pitch, armoring the wave run-up zone, and developing vegetation on the remainder of the slope in order to provide a stable section. However, to fit a 2H:1V slope will require cutting into the top of the slope. At numerous locations the slope will be near to the edge of the East Chop Drive. The alternative is to run the riprap at a 2H:1V to where it encounters the slope, but this leaves an unstable slope above the riprap. In both cases the existing vegetation will be disturbed, thus leaving the slope in a precarious condition during construction and until vegetation is re-established.

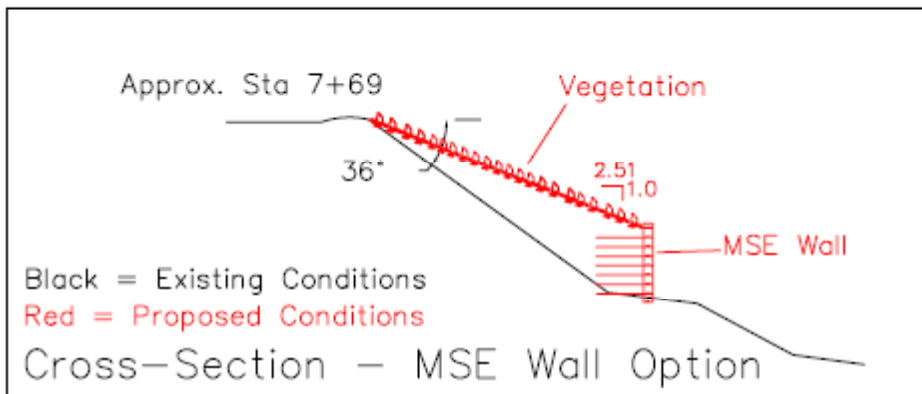
Rockfill Option



Adding rockfill on top of the current bench to a significant height would allow the pitch of the slope to be reduced to a stable angle. This option is shown above (Rockfill Option). The drawback of this method is the added dead weight on top of the bench. The dead weight of the rockfill

adds a destabilizing effect on the soils beneath the lower riprap slope, and a detailed analysis would be required to insure its viability.

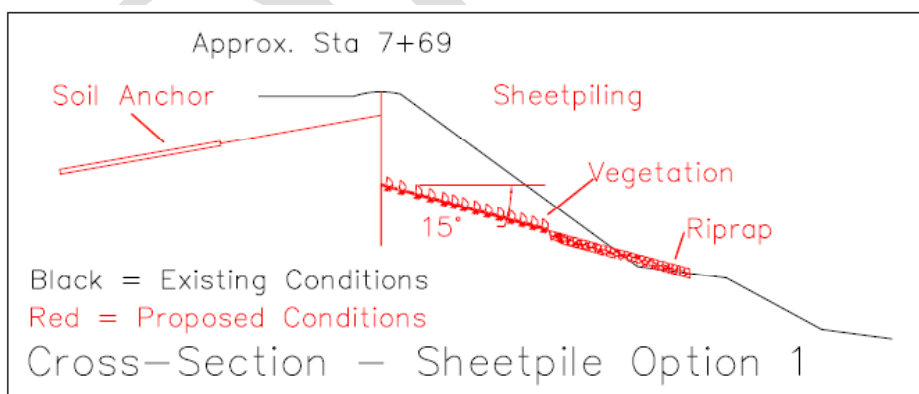
Mechanically Stabilized Earth (MSE) Wall Option



MSE walls are a very popular option due to their cost. MSE walls are made of precast concrete blocks and geogrid reinforcement that extend into the backfill behind the blocks. The blocks and geogrid form a reinforced soil mass. The reinforced soil mass acts as a gravity wall whose dead weight supports the slope. This option is shown above (MSE Wall Option). The MSE wall has two draw backs:

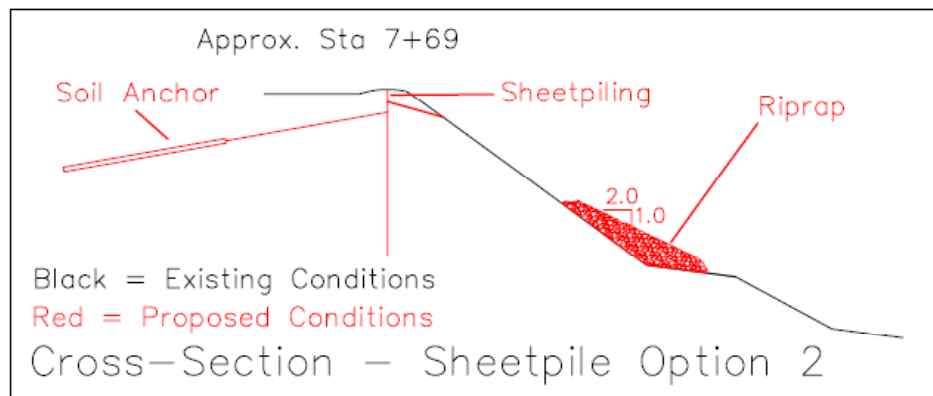
- The dead weight of the MSE wall adds a destabilizing effect on the soils beneath the lower riprap slope, and a detailed analysis would be required to insure its viability.
- Depending on the severity of the wave action, the blocks of the MSE wall may become destabilized.

Anchored Sheetpiling at the Top of the Slope with Slope Modification & Armoring (1)



Installing a 20 foot high anchored sheetpile wall at top of the bluff will allow the existing slope to be excavated down to a flatter angle. The reduced slope can be armored with riprap within the wave run-up zone and the remainder of the slope can be re-vegetated. This is shown above as Sheetpile Option 1 (SO1).

Anchored Sheetpiling at the Top of the Slope with Toe Armoring (2)



An alternative to SO1 is to keep the slope as-is and drive sheetpiling similar to SO1. However, in this case the upper slope it is left as-is, and only riprap is added to the bottom of the upper slope. See Sheetpile Option 2 (below). This option reduces the amount of construction excavation, and may have an aesthetic value by potentially maintaining the current vegetation but still protecting against catastrophic erosion. On the negative side this option may develop maintenance issues which are harder to address because of the steep pitch of the upper slope.

6. CONCLUSIONS

The conclusions of this report are listed below:

1. The subsurface materials are outwash sands with interbedded gravelly layers.
2. The current slope is showing signs of distress and localized failures.
3. The current slope does not meet minimum stability factors of safety.
4. The slope may erode quickly if exposed to wave action.
5. Slope stabilization is required, and may include one or more (i.e. combinations) of the following: Sheetpiling, Mechanically Stabilized Earth (MSE) wall, and Armoring.
6. Local traffic (i.e. residents of East Chop Drive) consisting of cars, SUV's and light trucks should be limited to the west bound lane of East Chop Drive during heavy storm events. Heavy storm events include 25 year rain storm events and/or waves breaking at the base of the upper slope. Trucks carrying heavy loads should not use East Chop Drive during heavy storm events. If the east bound lane of East Chop Drive starts to show signs of distress (i.e. cracking), the road should be closed and the condition of the road/slope re-evaluated.

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If you have any questions please contact me at (978) 886 - 4550.

Sincerely,

DEERE & AULT CONSULTANTS, INC.

CLE ENGINEERING, INC.



Joel Q. Kantola, P.E.
Principal



Carlos G. Peña, P.E.
Vice President

Attachments - Boring Logs

DRAFT