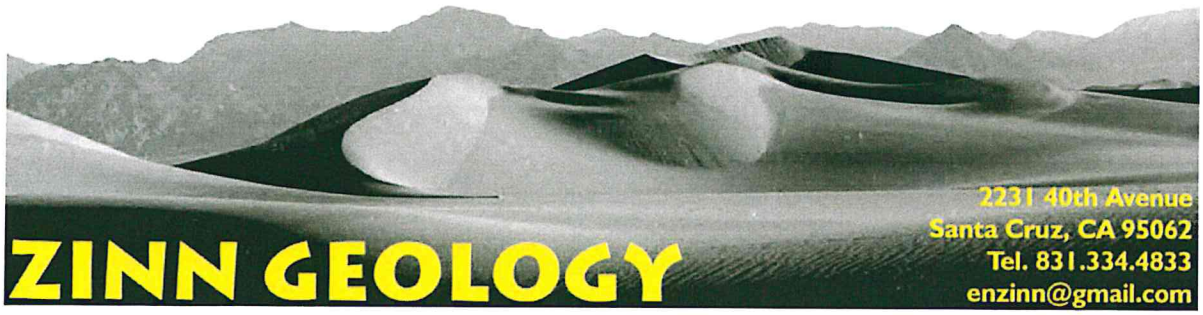


Revised 15 May 2017 Job #2017013-G-SC

City of Capitola, Public Works
Attention: Steve Jesberg, Public Works Director
420 Capitola Ave
Capitola, California 95010
Phone: (831) 475-7300
sjesberg@ci.capitola.ca.us

Re: Limited geological investigation of coastal bluff failure
Grand Avenue near intersection with Oakland Avenue and Hollister Avenue
Capitola, California 95010

Dear Mr. Jesberg:

This letter presents the results of our limited geological investigation of the bluff failure that has undermined the footpath along Grand Avenue between its intersection with Oakland Avenue and Hollister Avenue (see Plate 1).

The bluff below the footpath has been episodically retreating as the the soil and bedrock exposed on the bluff face erodes and fails in the form of shallow landslides, debris flows and rock falls, mostly in response to intense storms, wave erosion and earthquakes. The most recent shallow landslides that have caused the top of the bluff to retreat and undermine the footpath this winter appear to have been mostly driven by saturation of the marine terrace deposits soil that caps the underlying Purisima Formation bedrock.

The overall failure process for the coastal bluff at this location is a two-part process. The Purisima Formation bedrock exposed in the lower bluff is eroded and notched by waves until the notch intersects a nearly vertical bluff-parallel joint set, at which point a slab of bedrock topples. The bedrock topple process also takes the overlying marine terrace deposits along with it. This typically leaves behind a very steeply dipping to nearly vertical scar in the bluff face that exposes both the bedrock and marine terrace deposits. At that point, the wave scour process begins anew at the base of the bluff, eventually carving another notch into the bedrock. The marine terrace deposits simultaneously begin to erode and fail in a piecemeal fashion as they seek the angle of repose of about 38 degrees for the sand and gravels that compose that formation. This process continues unabated until the bedrock topples again in the future, resetting the retreat process clock.

We mapped the position of the bluff and the exposed formations using the base map by Bowman and Williams provided to us by the City of Capitola. We relocated the top of the bluff on that map because the bluff has apparently receded since the last time that portion of the map was modified.

The portion of the bluff studied for this investigation can be broken into three distinct zones based upon the stage of failure of the bedrock at the base (see Figure 1). The portion of the bluff nearest to the Oakland Avenue, designated "Block A", involved a toppling failure this past winter of the undercut bedrock and the marine terrace deposits. Additional failure of just the marine terrace deposits also occurred with Block A due to intense storms that saturated the slope of the upper bluff.

The portion of the bluff designated "Block B" on Figure 1 did not failure this winter. This block is marked by a vegetated upper bluff and a significantly undercut bedrock bluff face mid- and lower-bluff. This block is primed and ready to fail in a fashion similar to Block A.

The portion of the bluff designated "Block C" on Figure 1 failed only within the marine terrace deposits on the upper portion of the bluff. The bedrock exposed in the bluff face for this portion is undercut in a fashion similar to Block B and will likely fail in the near future.

We also reviewed a geological report for the Depot Hill Geological Hazard Abatement District, prepared on 12 April 2000 by Rogers Johnson and Associates. The report documents a past calculated long term bluff retreat rate of about 1.0 feet per year at that time which seems reasonable based upon our experience with past geological investigations in this area. The authors also cautioned the reader that the bluff had been severely undercut at that point, implying that a large failure of the bluff was imminent.

As noted at the beginning of this letter, the fate of the bluff and the retreat is always tied to what is happening at the base of the bluff with respect to notching and formation of sea caves. We noted two distinct conditions with respect to that observation for the area studied:

1. The landslide that occurred this winter closest to Oakland Avenue within Block A appears to have been triggered by toppling of undercut bedrock. Although we could not observe the base of the bluff in this area, since it is still obscured by landslide debris, the volume of large sandstone blocks in the debris indicates that bedrock portion of the bluff failed, perhaps as much as five to eight feet of the undercut bluff face.

2. The landslide that occurred this winter closest to Hollister Avenue in Block C, appears to have been within the marine terrace deposits only. The bedrock bluff face in this area appears to be undercut by at least ten feet and is primed to topple.

3. Although no landsliding occurred within Block B, between the end blocks A and C, the bedrock is primed to topple at this location due to being notched at the base and overhung above the base (see Figure 1).

The marine terrace deposits within Blocks A and C are over steepened and will likely lay back to an average angle of about 38 degrees. This may come about in one to three rainy seasons. Since this region is subject to wet and dry cycles that can last for years, we need to assign a range of years to the concept of one to three rainy seasons. The conservative analysis would assume that we will have back-to-back wet seasons for the next several years, which will lay back the marine terrace deposits to the angle of repose. A more liberal analysis would assume that we will enter a drought period of three to five years, followed by wet year. Using those ranges implies that the top of the bluff within Blocks A and C may retreat significantly within one to six years.

A review of the most recent El Nino status by NOAA (which can be accessed here: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf) indicates that El Nino neutral conditions are present, with increasing chances for El Nino development by late summer and fall. If we have a repeat of this past storm season next year, the top of the bluff may retreat significantly by the end of next winter.

We have projected where the top of the bluff will retreat if the marine terrace deposits lay back to the angle of repose of about 38 degrees on two cross sections and the site map (see Plate 1). Using just this analysis pushes the top of the bluff back from the its current 20 to 22 feet. This line represents the retreat that could happen in one to six years.

We have not factored in the collapse of the undercut portion of the bluff or the landsliding and subsequent retreat that would occur in the event of a large magnitude earthquake. If either of those processes are factored in and occur within that time period of one to six years, the amount of bluff retreat may be even greater.

Turning to Block B, we note that the marine terrace deposits are over steepened AND the bedrock is significantly undercut. Although there a is little bit more of a buffer between the top of the bluff and the current foot path for this block as compared to the other two blocks, the buffer is not enough push an expected time to undermining of the foot path beyond one to six years. Seismic shaking from a nearby earthquake (which can happen at any time) or another winter with large damaging waves will trigger a toppling failure of the bedrock, that will trim Block B and bring it in line with Block A.

On a final note, we understand that if the footpath is to be reopened, it will need to be repositioned further landward from its current position. Any work toward that end should be completed in a manner that will not exacerbate the tenuous stability of the marine terrace deposits exposed in the bluff face.

FINDINGS

Turning to Plate 1, the reader may note that our projected one to six year bluff retreat line impinges upon the seaward end of the residential properties. This implies that even if the footpath is pushed landward and snugged up against those properties, it may be undermined and threatened in less than a decade.

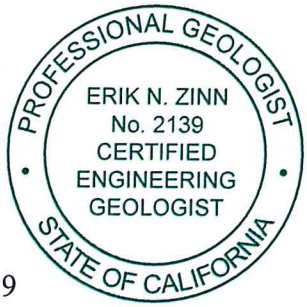
The marine terrace deposits exposed in the upper bluff are in a very fragile state with respect to landsliding. The usage of heavy equipment within 15 feet of the top of the bluff, particularly if the soils are wet, may trigger further landsliding of the marine terrace deposits.

RECOMMENDATIONS

1. The City should consider the effective life of the footpath when contemplating short term and long term expenditures for keeping the footpath open. In the long term, the City will need to protect the entire bluff from further erosion and landsliding with relatively expensive armoring methods if they want to keep the footpath open.

2. Any work performed on the footpath between Oakland Avenue and Hollister Avenue should be done by hand within 15 feet of the top of the bluff. The use of heavy vibratory equipment should be avoided if possible to lessen the possibility of triggering further landsliding of the bluff. If heavy equipment is used, the work should only be performed when the marine terrace deposits are dry, typically late spring (May) through fall (October).

Sincerely,
ZINN GEOLOGY



Erik N. Zinn
Principal Geologist
P.G. #6854, C.E.G. #2139

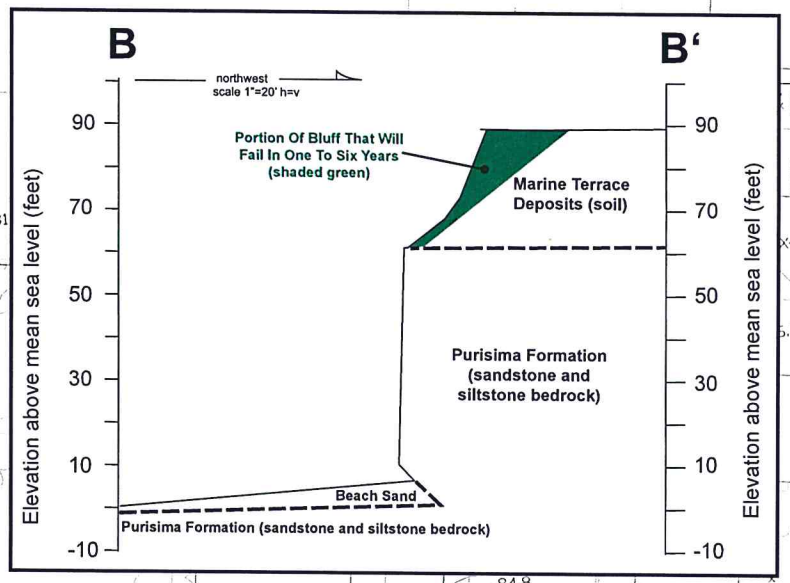
Attachment: Figure 1 - Oblique Photo Of Study Area On 19 April 2017
Plate 1 - Geologic Site Map And Cross Sections

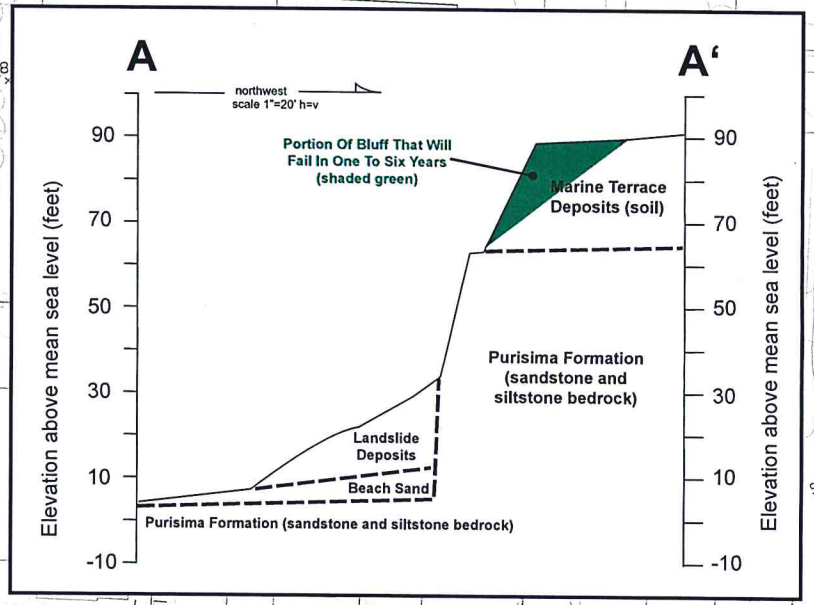
Photo Credit : Snapshot taken from video shot on 19 April 2017, provided by Misha Burich. Original video can be seen on Youtube at https://youtu.be/YltqbzIJPhk

ZINN GEOLOGY

Oblique Photo Of Study Area On 19 April 2017
City of Capitola
Grand Avenue Coastal Bluff Footpath
Capitola, California

FIGURE #
1
JOB #
2017013-G-SC





PROJECTED TOP OF BLUFF ONE TO SIX YEARS FROM NOW

CURRENT TOP OF BLUFF

BLOCK A

BLOCK B

BLOCK C

2017 LANDSLIDE SCARS
(shaded red)

A'

A

B'

B

WATER LINE

0 10 20 40
Feet

PROFESSIONAL GEOLOGIST
ERIK N. ZINN
PG 2139
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

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Geological Site Map & Cross Sections
City of Capitola
Grand Avenue Footpath
Between Oakland Ave. & Hollister Ave.

Date: 5 May 2017	Revised: 15 May 2017
Job #2014018-G-SC	
Scale: Map 1"=20'; Sections 1"=20', h=v	**Plate 1**
Drawn by: ENZ/enz	