PEER REVIEW REPORT
OCEAN BOULEVARD EROSION AND ENHANCEMENT PHASE 2 PROJECT
CITY OF LONG BEACH, CALIFORNIA

Prepared for:

CITY OF LONG BEACH

Tidelands Capital Improvement Division

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1.0 INTRODUCTION

1.1 Site and Project Background

The Ocean Boulevard Erosion and Enhancement Project, Phase 2 involves improvements to the existing slope south of Bluff Park, from the southerly projection of Loma Avenue to the southerly projection of Lindero Avenue. The slope is approximately 4,300 feet long, with an uneven slope face and inclination varying from 4½:1 (horizontal:vertical) to near vertical due to previous shallow failures, accumulations of slump debris, ongoing erosion, and past grading in localized areas to install beach access and utility improvements. Generally, the lower one third of the bluff face has a gentler gradient than the upper two thirds.

The top of the bluff is essentially flat with elevations ranging from 43 to 49 feet above mean sea level (msl). Concrete sidewalks, approximately 5 to 7 feet wide, some of which have been undermined due to erosion, and a historic handrail extend the entire length of the top of the bluff. A partially buried wall exists at the toe of the slope that extends approximately 1 to 2½ above the beach sand. Elevations at the toe of the slope range from 7 to 10.5 feet msl. Portions of the slope had been improved with gabion walls that were constructed on the slope with heights of approximately 9 to 11 feet. Landscaping on the slope face was relatively sparse except where the gabion walls were present and some form of grading had occurred.

In 2000, the City of Long Beach (City) hired Tetra Tech, with Geotechnical Professionals Inc., as a subconsultant, to prepare a Bluff Master Plan for the purpose of beautifying the slope, slowing down the erosion process, and improving slope stability. Additional studies were later performed by Kleinfelder in 2009 and 2010. The final recommendations included slope planting and irrigation, posts and timbers boards to repair undermined areas, and soil nailing and shotcrete in selected areas where the slope inclination is relatively steep. Construction plans prepared by Kleinfelder and RJM Design Group were prepared in 2012.

We understand that the City began construction of Phase 2 in October 2013 and that the construction has been temporarily halted since April 2014. At the direction of the City Council, the City has formed a peer review committee to assess if the selected slope improvements are the preferred method and evaluate available alternatives.

1.2 Peer Review Committee

This peer review is a collaboration of three independent geotechnical consulting firms. The peer review committee (Committee) consists of the following members:

- Djan Chandra, PE, GE; Leighton Consulting, Inc.
- Dr. Arul K. Arulmoli, PE, GE; DGE, Earth Mechanics, Inc.
- Dr. Daniel Pradel, PE, GE, DGE; Group Delta Consultants, Inc.

1.3 Purpose and Scope of Services

The purpose of the peer review is to evaluate if recommendations in the project geotechnical reports are appropriate and if there are other viable options for the subject slope improvements. The scope of services included the following tasks:

- Review of documents provided by the City listed in Section 1.4;
- Site reconnaissance to observe current site conditions and exposed soils; and
- Preparation of this report presenting our findings, conclusion and recommendations.

The Committee will attend a City Council meeting scheduled for July 1, 2014 to answer questions that the City Council may have on this report.

Independent evaluation of the geotechnical analyses performed by Kleinfelder (including selection of soil properties, slope stability analyses, design ground motion characteristics, and other calculations) was specifically outside the scope of services of the Committee.

1.4 Reviewed Documents

The subject of this review was the reports prepared by Kleinfelder in 2009 and 2010, which included as an appendix a report prepared in 2003 by Geotechnical Professionals Inc. These reports are listed below:

- Geotechnical Professionals Inc. (GPI), 2003, *Preliminary Geotechnical Investigation Proposed Belmont Shore Bluff Restoration, Long Beach, California*, dated September 3, 2003.

- Kleinfelder, 2009, DRAFT, *Possible Slope Improvement Options for Project Cost Estimating Bluff Park, East Ocean Boulevard between Loma Avenue and Lindero Avenue, Long Beach, California*, dated December 28, 2009.

- Kleinfelder, 2010, *Geotechnical Study, Proposed Slope Improvements Bluff Park, East Ocean Avenue between Loma Avenue and Lindero Avenue, Long Beach, California*, dated April 30, 2010.

Following the kickoff meeting, the Committee was provided with a memorandum prepared by the City Manager dated May 13, 2014, a memorandum titled "*Long Beach Bluff Stabilization Alternatives*" prepared by ESA PWA dated May 14, 2014, and the approved Construction Plans prepared by Kleinfelder and RJM Design Group. These documents were also reviewed in conjunction with the reports listed above for preparation of this report.

2.0 REVIEW FINDINGS

2.1 Project Parameters

The project site is located in a coastal environment and constrained by an existing sidewalk and handrail immediately on top of the bluff. City's memorandum and Kleinfelder report (2010) indicated that the mitigation measure involving grading to flatten the slope should not be considered. Such measure would involve filling the beach area or reducing the size and configuration of Bluff Park. The option of constructing a concrete retaining wall at the toe or in the middle of the slope was not acceptable either for cost and aesthetic reasons. Additionally, the selected slope improvement measures should be designed to resist ground shaking due to the design earthquake. A design earthquake is a site-specific ground motion that the improvements are required to safely withstand and, as defined in the Kleinfelder report (2010), has a 10 percent probability of occurrence in 50 years.

The slope improvement measures were understood to be developed within the parameters mentioned above. Accordingly, the peer review was conducted within the same parameters, which are specifically summarized below:

1) Proposed improvements to the slope should not extend into the park (at the top) or the beach (at the bottom);

2) Concrete retaining wall is not an acceptable option; and

3) Slope improvement measures should meet seismic requirements that were available at the time the Kleinfelder reports were prepared.

2.2 Field Exploration

Kleinfelder drilled 11 borings to depths of 16.5 to 51.5 feet below the existing grade. Five borings were located at top of the bluff and six borings were located on the beach by the toe of the bluff. GPI (2003) previously advanced three borings and three Cone Penetration Tests (CPT's) at top of the bluff within the Phase 2 project limits.

The soils on the slope were determined to be Pleistocene Old Paralic Deposits consisting of interbedded layers of silty sand and silty clay. The soils in the beach were found to consist of import beach fill underlain by recent beach deposits and the Pleistocene Old Paralic Deposits. Surficial and/or erosional failures were mapped but no deep-seated failure was observed along the slope.

Based on the relative consistency of the soils and the extent of the project, the field exploration program is considered adequate.

2.3 Subsurface Soils and Groundwater Modeling

Shear strength parameters used for the slope stability analysis were generally developed based on laboratory test results, published correlations of blow count during sampling and shear strength parameters, and published literature on geotechnical parameters of cemented sand on steep slopes (Kleinfelder, 2010). The parameters are presented in Table 1 below.

Table 1 – Summary of Shear Strength Parameters

Deposit	Material Type	Cohesion (psf)	Friction Angle
Slope Fill	Sand and Silty Sand	50 – 125	29
Beach Fill	Sand/Sand with Silt	0	32
Beach Deposit	Sand/Sand with Silt	0	34
Colluvium	Sand, Silty Sand and Silt	50 - 125	27 – 28
Paralic Deposits	Clay and Silt	200 - 350	25 -27
Paralic Deposits	Sand and Silty Sand	50 - 125	35 – 36
Import Fill	Sand and Silty Sand	0 - 50	32

Groundwater was encountered in the borings at elevations of +3 to +7 msl. These groundwater levels were used in the slope stability analysis.

The shear strength parameters appear to be reasonable for the onsite soils.

2.4 Seismic Design

The project requires that the proposed mitigations be designed to be stable during the design earthquake. For seismic slope deformation evaluations, Kleinfelder (2010) used an allowable slope deformation of approximately 6 inches. Their seismic slope stability evaluations were performed in accordance with "*Special Publication 117A, Guidelines for Evaluating and Mitigating Seismic Hazards in California*" (California Geological Survey, 2008) and "*Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Landside Hazards in California*" (Southern California Earthquake Center, 2002). This approach is considered reasonable and is also consistent with the current practice by the County of Los Angeles.

Kleinfelder (2010) recommended a peak horizontal ground acceleration of 0.39g and a corresponding earthquake magnitude of 7.1 in their slope deformation evaluations, which is reasonable in our opinion. The site has experienced the 1933 Long Beach Earthquake without any reported major damage or collapse of the bluff. The magnitude of the 1933 earthquake was reported as 6.4 and a peak horizontal ground acceleration of 0.29g was measured approximately 2 miles away in downtown Long Beach. The apparent successful performance of the bluff during the 1933 earthquake should not be considered as an indication that it will perform adequately during the design earthquake. Although the shaking was significant, it was smaller than what would be expected from the current design earthquake magnitude of 7.1, which has an anticipated energy release about 11 times larger than the energy released from the 1933 earthquake.

Based on the design considerations presented in section 2.1 above, Kleinfelder concluded that portions of the existing slopes did not meet the seismic requirements without improvements. We agree with this conclusion.

2.5 Slope Stability Analyses

Slope stability analysis was performed using commercially available computer programs PCStabl 5, GStabl 7, SNAIL and Slide 5.0. The limit equilibrium methods employed for the analysis included the Janbu corrected method, simplified Bishop method, and Spencer method. The approach to the slope stability analysis appears to be reasonable.

The slope stability analyses indicated factors of safety less than the code requirements for portions of the slope under static conditions and during the seismic design event. For the portions of the slope that are deficient, Kleinfelder used soil nails and shotcrete to improve them. It is our judgment that static and seismic improvement of the slope will have to utilize either soil nails, tie-backs or other forms of deep anchoring into the slope. Therefore, the soil nail system used on the project is an appropriate solution. Shotcrete is a common method to mitigate surficial slope instability in conjunction with soil nails; however, other options, as discussed later in this report, are also available.

2.6 Recommended Slope Improvements

2.6.1 Erosion Control

To reduce surface erosion, Kleinfelder recommended slope planting with deep-rooted, drought-resistant vegetation and permanent erosion fabrics. The slope planting was recommended to consist of shrubs for portions of the slope no steeper than 1½:1 and ground cover (light-weight vegetation) for steeper portions of the slope. Permanent erosion fabrics, anchored at the top of the slope and stapled to the slope face, were recommended for portions of the slope at 2:1 or steeper. Such measures for erosion control appear to be reasonable.

2.6.2 Soil Nailing

Locally where slope inclinations are steep, the repair method proposed by Kleinfelder involves:

- Soil nails that enhance the deep-seated stability of the bluff under static and dynamic conditions (Figure 1) and locally support portions of the sidewalk; and

- A shotcrete facing (Figure 1) that protects the slope surface from weathering and erosion caused by surface water, and enhances the surficial stability.

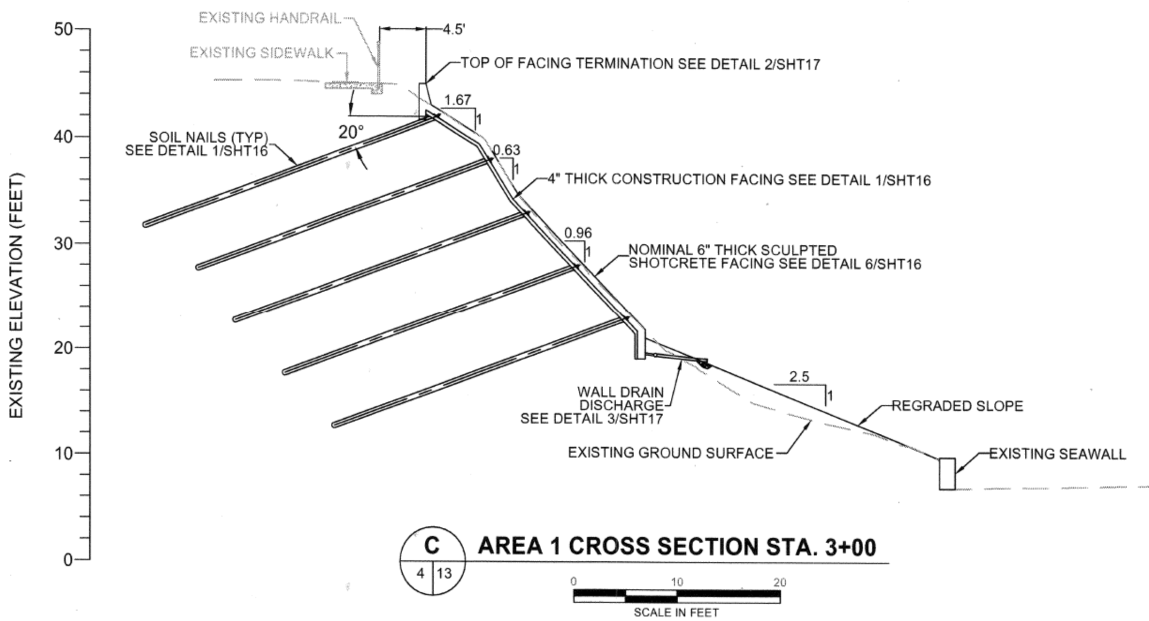
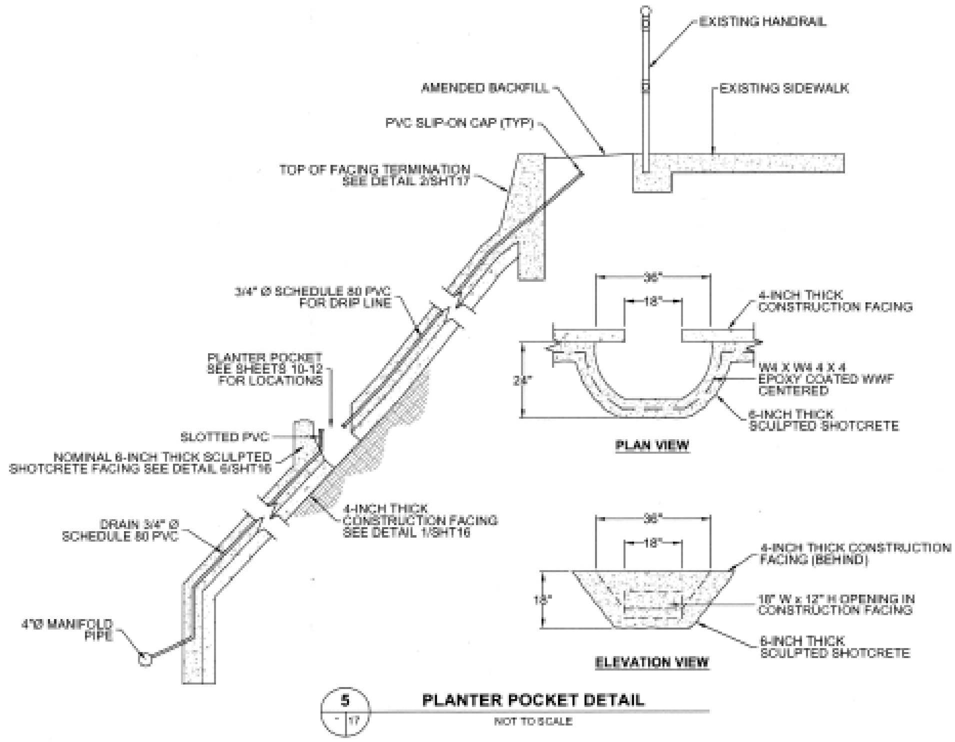


Figure 1 - Design Cross-Section of Soil Nailing

The shotcrete facing will be sculpted to blend in with the surrounding landscape. At specific locations, the shotcrete facing has planter pockets that allow vegetation to grow on the slope and with time will partially cover the shotcrete surface, as exemplified in Figure 2. The design contemplates having open-bottom planters that allow infiltration into the slope. Failure of sprinklers and/or the irrigation pipes may result in a concentrated influx of water directly into the slope which is undesirable. The design includes irrigation PVC pipes embedded into the shotcrete to drain excess irrigation water.

Soil nailing with shotcrete facing is commonly used in southern California for bluff stabilization. Examples of successful bluff stabilization projects include the Del Mar Bluffs Stabilization and Pacific Coast Highway Bluff Stabilization in Dana Point and San Clemente.

It is the Committee's opinion that the recommendations on using soil nailing with shotcrete facing is reasonable considering the project parameters discussed in Section 2.1. An available alternative to shotcrete for slope face protection is using biotechnical techniques as discussed later in Section 3.0.



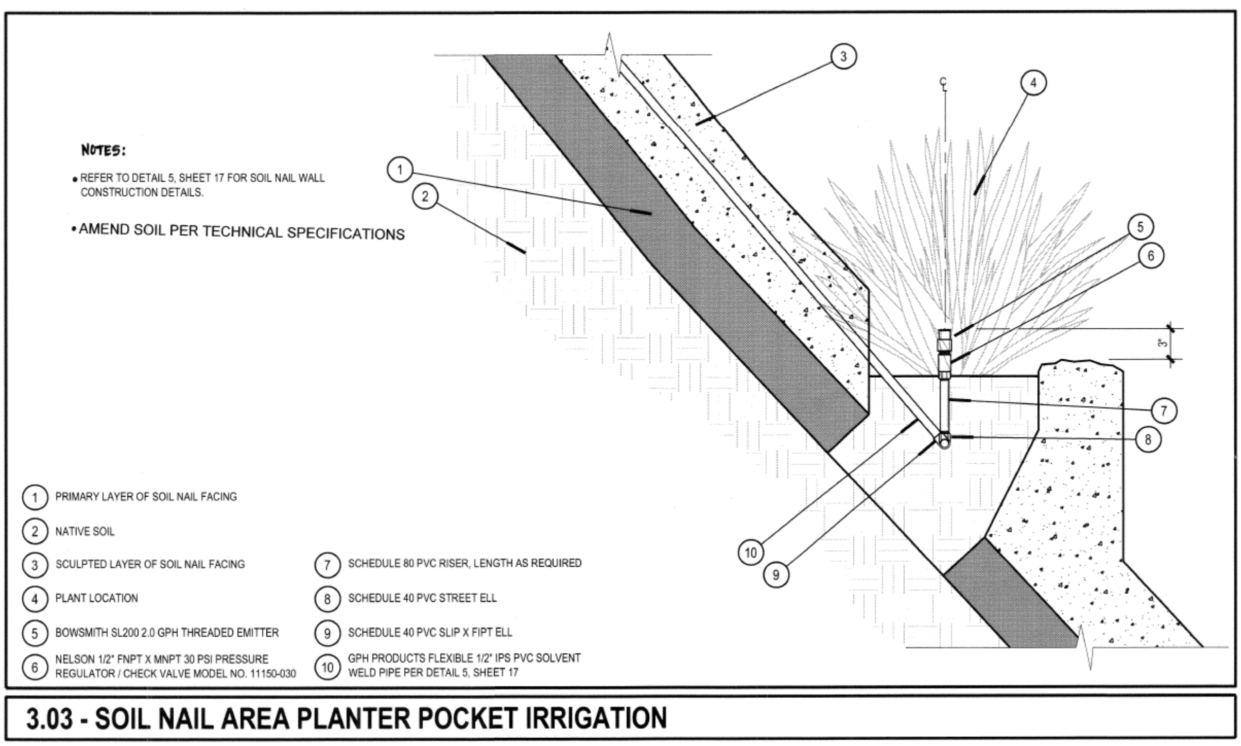


Figure 2 - Planter Details

2.7 ESA PWA Memorandum

The memorandum titled "*Long Beach Bluff Stabilization Alternatives*" dated May 14, 2014, prepared by ESA PWA included nine options for slope stabilization treatment that ranged from vegetation to grading, retaining wall, and soil nailing. The options of vegetation and erosion control fabric are feasible for flatter slopes and were already recommended by Kleinfelder as discussed in Section 2.6.1. The options of grading the slope and construction of retaining walls are not acceptable due to the project constraints discussed in Section 2.1.

Options 8 and 9 suggested in the ESA PWA memorandum are two possible ways to improve the slope stability and meet the City's design requirements and project constraints. Option 8 is soil nail walls with geogrid material to assist vegetation growth, which is one of the biotechnical techniques feasible for the site as mentioned later in Section 3.0. This option, however, is only feasible in slope areas where shotcrete has not been constructed. In areas where shotcrete has been installed, this option will require removal of the existing shotcrete which could be potentially detrimental to the soil nails and/or slope face that are already in place and slope face. The challenges of removing existing shotcrete are described in Section 3.0. Option 9 includes soil nail walls fitted with planter pockets which are already implemented for this project (see Section 2.6.2).

3.0 ALTERNATIVES FOR SLOPE FACING

Shotcrete was selected to improve surficial stability of the slope where soil nailing was recommended. Shotcrete acts as a barrier against weathering of the slope face from direct sunshine and saturation during rainstorms; hence reduces the likelihood of shallow slope failures. In recent years, biotechnical techniques have been used to improve slope faces instead of using shotcrete. The main appeal of biotechnical techniques is that they can be more aesthetically pleasing than walls or shotcrete.

Biotechnical techniques typically involve anchoring the near-surface soils using plant roots, often in combination with structural elements. There is a wide variety of available biotechnical techniques, some of which that may be applicable for the site include:

- Deep rooted vegetation as depicted in Figure 3;
- Deep rooted vegetation in combination with geogrid or timber grid used to hold topsoil and slope plantings as shown in Figure 4; and
- Live slope grating where a lattice-like array of vertical and horizontal timbers are fastened or anchored to a steep slope and the openings in the structure are filled with suitable backfill material and layers of live branch cuttings (see Figure 5).

These biotechnical techniques could be considered for the subject slope instead of shotcrete, especially for slope inclinations of 1:1 or flatter. Although biotechnical techniques generally provide excellent erosion protection, the resulting vegetation requires significant maintenance. Biotechnical techniques only improve the stability of the near-surface soils and provide a very limited benefit for deep-seated instabilities; thus, they are not a substitute to soil nails as their depth of influence is limited.

These techniques can be used in the western portion of the project, designated as Area 1 and the western portion of Area 2 on the Construction Plans, where the slope has been stabilized with soil nails but shotcrete has not been installed. Area 1 has slope inclinations varying from 0.63:1 to 1.63:1 (horizontal:vertical) from top to bottom of the slope, which would make the installation of a geogrid or steel mesh facing easier to implement than timber grid or timber grating. Deep-rooted vegetation may be used for the flatter inclination, perhaps in combination with shotcrete or geogrid/steel mesh for the steeper slopes. The western portion of Area 2 has a fairly uniform inclination of 0.85:1 to 1:1 (horizontal:vertical) that can facilitate the biotechnical options mentioned above. Minor grading may be required to create a bench to support the timber grids or grating. Due to steepness and variety of inclinations of the slope, biotechnical techniques must be evaluated and designed by an experienced engineer and landscape architect.

The biotechnical techniques are not recommended on portions of the slope where soil nails and shotcrete have been installed because they require removal of the shotcrete. Since the shotcrete is reinforced with rebar and integrated with the soil nails, removal of the shotcrete may impact the integrity of the soil nails. The removal will require extreme care and is expected to be a labor intensive effort. Additionally, the shotcrete was placed directly on the slope face; removal of the shotcrete will inevitably remove some of the soils on the slope face that adhere to the shotcrete, which will reduce stability of the slope.

An inquiry was brought up in one of the City Council meetings about adding soil nails to the existing design in lieu of shotcrete. More soil nails will certainly improve the stability of the slope but will not eliminate the need for protection of the slope face.

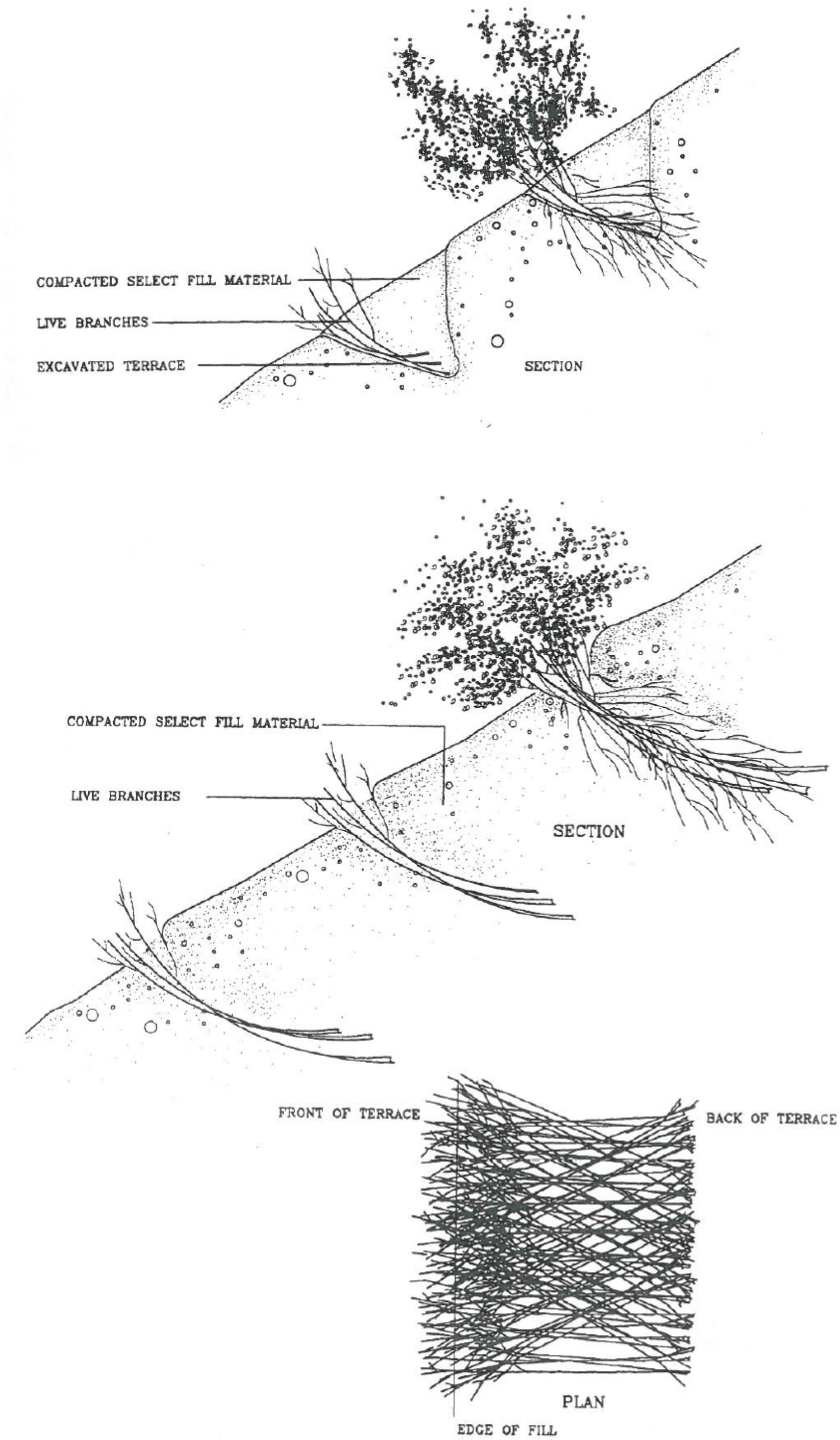


Figure 7-21. Schematic diagram of an established growing *fill slope* brushlayer installation showing alternating layers of live cut brush inserted between lifts of soil.

Figure 3 – Example of Deep-Rooted Vegetation

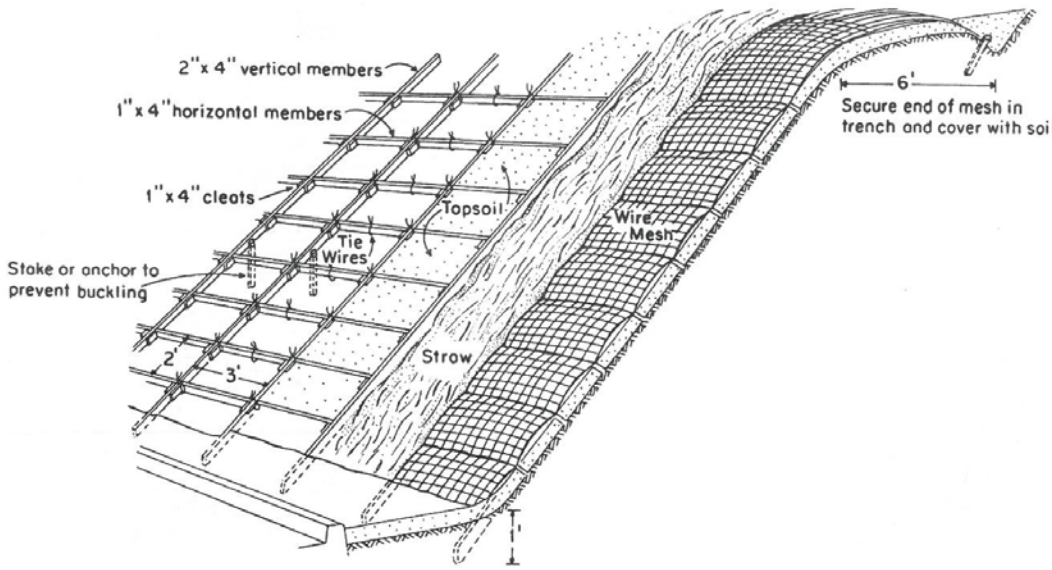


Figure 8-18. Anchored timber grid used to hold topsoil and slope plantings.

Figure 4 – Example of Deep-Rooted Vegetation with Timber Grid

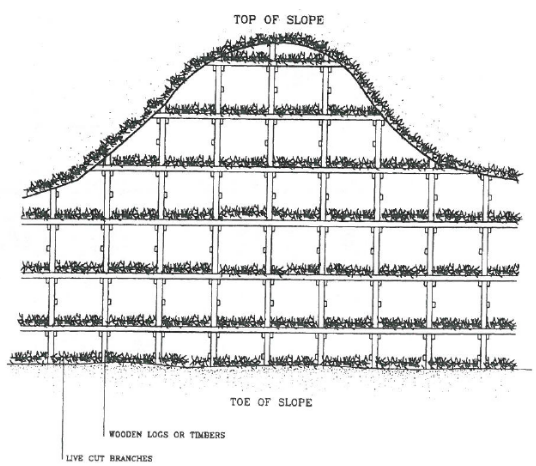


Figure 7-36. Schematic illustration, frontal view, of live slope grating consisting of lattice-like array or grid of horizontal and vertical timbers that are anchored to a steep slope.

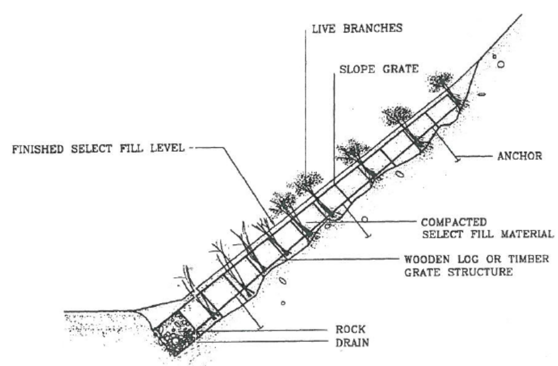


Figure 7-37. Profile view of an established growth slope grating system showing placement of live cuttings or branches in box-like compartments in the grating.

Figure 5 – Example of Live Slope Grating

4.0 CONCLUSIONS AND RECOMMENDATIONS

As documented in the reviewed reports listed in Section 1.4, the original unimproved slope has experienced numerous shallow failures in recent times and is highly vulnerable to surficial instabilities due to their steepness. The calculated factors of safety for portions of the slope were below the code requirements under both static and seismic conditions. It is our opinion that the recommended soil nail system and the surface treatment for portions of the slope with relatively steep inclination is an appropriate solution to improve static and seismic stability of the slope and preserve the existing terrains.

The Committee concluded that the soil nail system and shotcrete are an appropriate solution for the project; however, there are feasible biotechnical alternatives for the soil nailed areas that have not received shotcrete. If biotechnical techniques are considered for those areas where there is no shotcrete, they should be further evaluated and designed by an experienced engineer and landscape architect. The Committee does not recommend the removal of shotcrete to implement these biotechnical alternatives. Removing shotcrete would require extreme care and be a labor intensive activity. The installed shotcrete is reinforced with rebar and integrated with the soil nail system, so its removal may impact the integrity of the installed soil nails.

5.0 LIMITATIONS

This peer review was performed using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical consultants practicing in this or similar localities. We reviewed the approach, methology, and results presented in the geotechnical reports to verify that they meet the standard of care; however, independent evaluation of the geotechnical analyses performed by Kleinfelder (including selection of soil properties, slope stability analyses, design ground motion characteristics, and other calculations) was specifically outside the scope of services of the Committee. The findings, conclusion, and recommendations included in this report are considered preliminary and are subject to verification. We do not make any warranty, either expressed or implied.