1 Reinforced Embankments

Geosynthetic Reinforced Embankment (GRE) is a system that incorporates planar geosynthetic reinforcement within a slope (Figure 1) for slope inclinations less than 70 degrees from horizontal. A GRE is also referred to as a Reinforced Soil Slope.

Situations where GRE may be used include:

- Limited right of way
- Shortage of fill quantity for slope construction
- Excess of excavated materials
- Distressed or deteriorated slopes need to be restored.

The components of a geosynthetic reinforced embankment include: geosynthetic reinforcements, reinforced soil, drainage system, and erosion control. The foundation below the GRE (foundation soil) and slope behind the GRE (retained soil) also affect the design of the GRE.

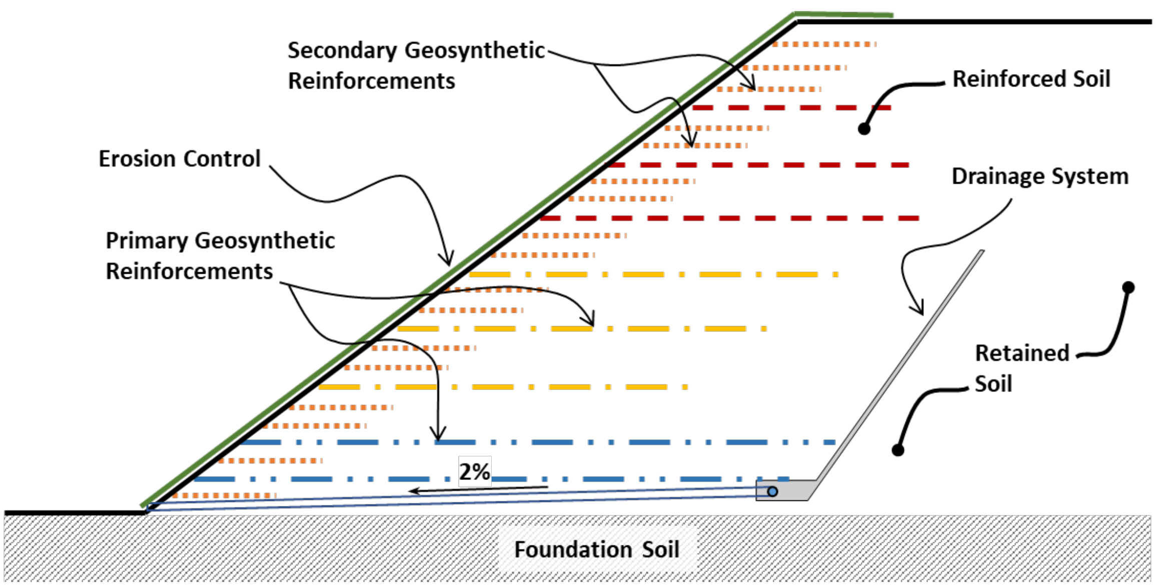


Figure 1: Components of Geosynthetic Reinforced Embankment

1.1 Common Applications of GRE

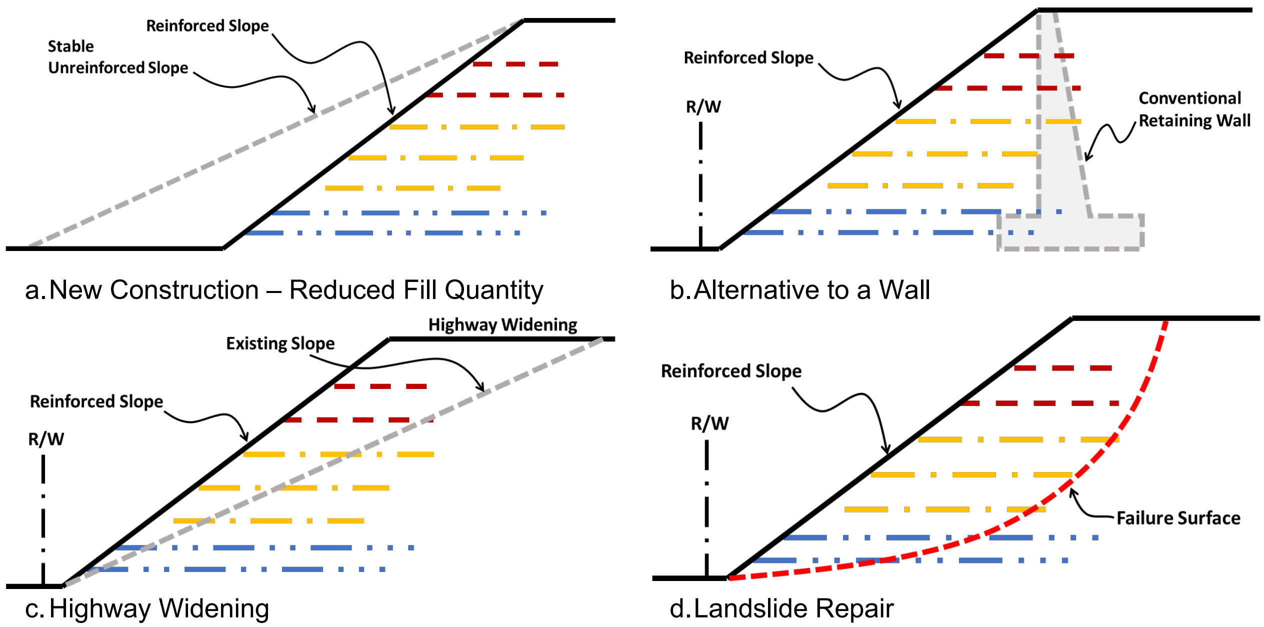


Figure 2: Common Applications of Geosynthetic Reinforced Embankment

1.2 Advantages and Potential Disadvantages of GRE

Advantages:

- Improved slope stability
- A slope inclination steeper than natural grade can be built, which may reduce the need for right-of-way
- Much cheaper than MSE walls
- Lower quality backfill materials may be used – compensated by more geosynthetic reinforcement
- Most on-site borrow can be used, except for the materials that may cause creep
- Most general contractors can perform the work and there is no need for specialty contractors
- Construction materials, both the geosynthetics and backfill, are relatively available

Potential disadvantages:

- Require a relatively large space behind the slope face to install geosynthetic reinforcement
- Relatively steep temporary excavation
- The need for traffic control during construction
- Potential issues of access for maintenance crews on the steepened slope
- Guardrails are often necessary for highway above the steep slopes built with GRE

2 Geotechnical Design Practice

The geotechnical tasks for the design of GRE include:

- Work with Project Development Team (PDT) members on evaluating whether the GRE is a preferred option
- Review available project, design, and geotechnical information
- Perform geotechnical investigation
- Perform analyses and design
- Issue the geotechnical report
- Assist in developing and reviewing the PS&E package
- Provide construction support

3 Investigation

The scope of geotechnical investigation for the design of GREs should be similar to the scope of geotechnical investigation for the design of highway embankments. The focus of geotechnical investigation for GREs should be on engineering properties that may affect global stability, long-term settlement, and how to use available on-site borrow as the reinforced soil. Interpreting engineering properties of in-situ soils using correlations is acceptable.

Perform a geotechnical investigation to determine the engineering properties of:

- Retained soils (i.e., native soils or existing embankment that will be retained behind the reinforced soil) including unit weight, and shear strength and the potential for groundwater seepage.
- Reinforced soil to be used, including gradation, and shear strength, and compaction characteristics, such as dry unit weight and optimum moisture content.
- Foundation soils, including unit weight, groundwater conditions and elevation, and shear strength.

4 Analysis and Design

To analyze and design GRE, the geotechnical designer must understand two essential design components: geosynthetic reinforcements and reinforced soil. The first subsection provides detailed discussion of the two design components, followed by sections covering analysis and design practices.

4.1 Design Components

4.1.1 Geosynthetic Reinforcements

Geosynthetic reinforcements used for Caltrans projects must be included in the *AASHTO NTPEP DataMine product list* per Caltrans Standard Specifications.

Geosynthetic reinforcements can be either geotextile or geogrid as long as they provide required Nominal Long-Term Strength (LTS).

Use the term LTS, instead of Long-Term Design Strength (LTDS), to comply with AASHTO standards referred to in the [AASHTO NTPEP DataMine](). The values for LTS and LTDS are the same. The main reason for retiring the term, LTDS, is that the term is inherently inconsistent with the value it represents, which is the nominal long-term PAgestrength of the material and does not include design factors.

The LTS, as shown in the following equation, is a function of

$$LTS = \frac{T_{Ultimate}}{RF_{Creep} \times RF_{Installation\ Damage} \times RF_{Durability}}$$

The gradation requirement in the Standard Specifications for GRE spans from gravels, sands, to clays to encompass most possible reinforced soil gradations. During design, the gradation and composition of the reinforced soil to be used are typically unknown. But the gradation and angularity of the reinforced soil dictate the reduction factor for installation damage of geosynthetic reinforcements. All three reduction factors vary significantly depending on the source materials, such as high-density polyethylene (HDPE), polypropylene (PP), or polyester (PET), of the geosynthetic reinforcement.

Prescribing sets of reduction factors and ultimate tensile strengths of geosynthetic reinforcements to be used during design suggests the vendor and the vendor’s products have been selected for the project. This practice is not allowed for projects contracted by a public agency. Therefore, GRE needs to be designed based on LTS of geosynthetic reinforcements.

As part of construction submittal, the contractors must submit test results of each geosynthetic reinforcement to prove that the LTS of geosynthetic reinforcements to be used for the job meet the requirements for the reinforced soil.

The test data that support the LTS of geosynthetic reinforcements for typical reinforced soil, such as sands, clays, should be available in the AASHTO NTPEP DataMine website and readily available by the vendors. However, most geosynthetics may not have been tested for installation damage with gravels larger than 1.5” and the variation of angularity of the gravels. Tests for installation damage are expensive and time consuming, and only a few test facilities in the U.S. are conducting these tests. Therefore, avoid using reinforced soil with gradation larger than specified in the Standard Specifications. When no tests for the geosynthetic reinforcement and the reinforced soil are available, defaulted reduction factors must be applied according to AASTHTO R69.

Note that the LTS of geosynthetic reinforcements are for the design of GRE with 75-year design life (i.e., the strength at the end of 75 years). For GRE used for temporary applications, the LTS may be adjusted with lower reduction factors for creep and durability according to the duration of the temporary applications, such as temporary access roads and temporary embankment for falsework.

4.1.2 Reinforced Soil

Most on-site borrow, including clays and silts, may be used as reinforced soil, if the materials do not cause creep, such as fat clay. The costs of geosynthetic reinforcements, both materials and placement, in typical GRE projects are less than 20 percent of total construction cost. Therefore, the cost increases due to the increased demand for strength and quantity of geosynthetic reinforcements needed to accommodate low-shear strength reinforced soil materials is typically relatively small compared to the cost of import borrow. This is especially true in regions where hauling for import borrow and disposal of on-site materials is difficult and expensive.

4.2 Configurations and Design Details

Typical GRE design configurations are as follows:

- Use generic and functioning terms, primary reinforcement and secondary reinforcement during design and reporting. Do not use specific material terms such as uniaxial geogrid and biaxial geogrid.
- Place geosynthetic reinforcements horizontally.
- Select a set of LTS from the table of primary geosynthetic reinforcements in the Standard Specifications section 96-1.02D(2) as shown below:

Primary Geosynthetic Reinforcement

Quality Characteristic	Requirement						
	PR1000	PR1400	PR2000	PR2600	PR3200	PR4000	PR4800
Nominal long-term strength, (min, lb/ft)	1000	1400	2000	2600	3200	4000	4800
Color Marking (On both edges of each product roll)	White	Red	Orange	Yellow	Green	Blue	Purple

- For slope heights less than 25 feet, use a set of at least 2 different geosynthetic reinforcements that allows for selection of 2 LTS during analysis and design. For slopes higher than 25 feet, use a set of at least 3 different geosynthetic reinforcements, with a set of 3 or more LTS can be selected for analysis and design.
- Adjust geosynthetic reinforcement lengths according to stability demand. Reduce the reinforcement lengths toward the top of the slope as the demand reduces.
- The reinforcement lengths must be at least 8 feet.

- The vertical spacing of geosynthetic reinforcements should be the multiplier of the compacted thickness of reinforced soil layer. For example, if typical compacted thickness of reinforced soil is 6 inches, during design place geosynthetic reinforcements at 6, 12, or 24 inches, etc., instead of at 8, 10, 16, or 20 inches, which will require additional reinforced soil placement and compaction work.

  Note: Section 19-6.03C of Standard Specifications stipulates, "… Construct embankment in layers. The loose thickness of each layer must not exceed 8 inches."

- The typical vertical spacing between primary geosynthetic reinforcements is 4 feet.
- The vertical spacing for the top layer near the top of the slope may be increased to 6 feet.
- The vertical spacing at the bottom of the slope may be 2 feet or smaller depending on load demand.
- For primary reinforcements with vertical spacing greater than 2 feet, include secondary reinforcements with a maximum vertical spacing of 2 feet to provide surficial stability.
- Select secondary geosynthetic reinforcements in the Standard Specifications section 96-1.02D(3) as shown below:

Secondary Geosynthetic Reinforcement

Quality Characteristic	Test method	Requirement	
		SR0800	SR1200
Tensile strength at ultimate, (min, lb/ft)	ASTM D6637	800	1200
Aperture size, (min and max, inch)	Calipered	0.8 – 3.0	
UV resistance, retained tensile strength, 500 hours, (min, %)	ASTM D4355	70	

  The Standard Specifications table includes three more secondary geosynthetic reinforcement products with higher tensile strength requirements than the two in the above table. Do not use those products for GRE. Those products are for applications such as foundation load transfer, and access roads. The products shown in the above table can satisfy all design needs for slope surface treatments.

- The embedment length of secondary reinforcements should be at least 4 feet.
- For slopes steeper than 1.5H:1V, use wrap-around or welded-wire mesh faced slope to prevent erosion.
- For wrap-around slope face, the embedment lengths of the wrapped-back must be at least 3 feet. The wrapped-back secondary reinforcement layer may be placed on top of the previously placed layer without separation by a soil layer.
- In the design detail, provide at least 3-inch soil layer between the last two-third of the wrapped-back and the reinforcement layer above for effective mobilization of the pull-

out resistance of the reinforcement layers.

4.3 Stability Analysis

4.3.1 Software

The analysis and design of GRE is based on Limit Equilibrium Analysis and includes rotational, and translational stability analysis. When using software, refer to the user guide for details of modeling the geosynthetic reinforcements in the software. Ensure the software can model the materials and mechanism of geosynthetic reinforcements.

4.3.2 Criteria and Procedure

Design based on LTS, instead of ultimate tensile strengths. Refer to section 5.1.1 Geosynthetic Reinforcements for details. To use LTS for analysis and design, in the input of the software set the reduction factors = 1 and substitute the selected LTS value as the ultimate tensile strength.

To design a GRE with varying slope heights, develop at least 3 representative cross sections. Arrive at the designs that provide slightly higher FoS than required. The required FoS for GRE are the same as those applied to highway embankments and slopes. With a slightly higher FoS, the design or portion of the design for each representative cross section may be applied to the slopes near the cross section but with different heights or with different slope top and toe elevations.

Ensure the most critical surface is bracketed by the search limits, so that no search surfaces outside of the search limit have lower FOS than the most critical surface found within the set search limits.

For seismic analysis, use 1/3 PGA for horizontal seismic coefficient. Obtain PGA using Caltrans ARS Online.

Include live and dead loads, such as traffic load.

Perform both circular failure and translational failure analyses.

Optimize the design of geosynthetic reinforcements as follows:

- Step 1: Set the lower search limits to be in front of the toe of slope.

  Adjust the types (with different LTS) and lengths of geosynthetic reinforcements at the bottom geosynthetic reinforcement layers, to satisfy the required FoS.

  The design of bottom geosynthetic reinforcement layers can be determined in this step.

- Step 2: Move or extend the search limits to encompass lower portion of the slope.

Adjust the types (with different LTS) and lengths of geosynthetic reinforcements, especially the geosynthetic reinforcement layers at mid-height of the slope, to satisfy the required FoS.

- Step 3: Progressively move or extend the search limits to the top of the slope.

  Adjust the types (with different LTS) and lengths of geosynthetic reinforcements, especially the geosynthetic reinforcement layers at mid-height and near the top of the slope, to satisfy the required FoS.

4.4 Drainage System

Water that infiltrates through deteriorated pavement or the retained slope may compromise the stability of the GRE. To drain water in the soils, provide a drainage system between the reinforced soil and the retained soil (Figure 1) especially when design for highway widening or slope restoration. A typical drainage system for GRE includes:

- Subdrain placed behind and near the bottom of the reinforced soil and along the alignment of the GRE. The subdrain includes 4-inch diameter slotted PVC or corrugated pipe surrounded by the Permeable Material as described in section 68 of Standard Specifications and in turn wrapped by the Filter Fabric as described in Section 96.
- Twelve-inch wide geocomposite strip drains extending from the subdrain to 2/3 height of the slope at the interface of the retained soil and reinforced soil. Strip drains are typically spaced at every 25 feet along the alignment.

  To accommodate the required bench cut of an existing slope, geocomposite strip drains may be installed with short segments that allow folding and manipulation during reinforced soil and compaction. Ensure continuity of drainage path with sufficient overlap of the strip drains.
- Solid 4-inch diameter PVC drainpipe installed at a 2% grade and perpendicular to the GRE alignment to drain the collected water to the toe of the GRE. The drainpipes are typically spaced at every 75 feet along the alignment.

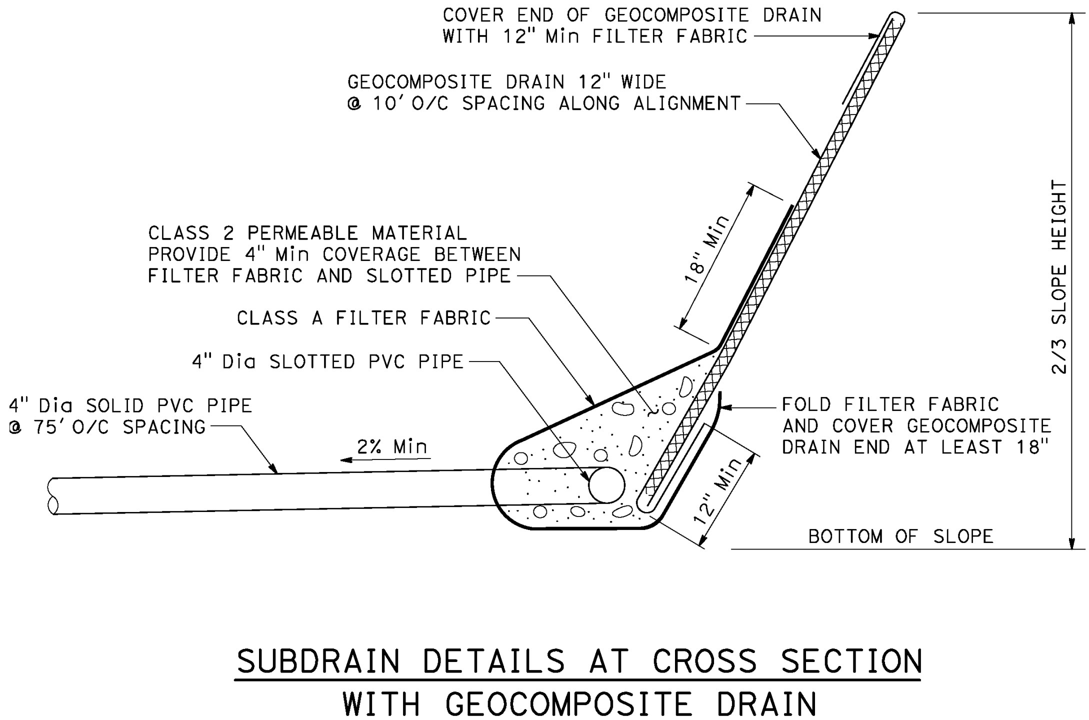


Figure 3: GRE Drain Detail

4.5 Slope Facing and Erosion Control

The treatment of GRE facing can be divided into four categories:

1. Self-retained facing using geosynthetic reinforcement wrapped face with soil-retaining geotextile inside
2. Erosion control blanket or mat
3. pre-cast/prefabricated modular facing, such as gabion baskets, half baskets, and concrete blocks
4. GRE facing waterway

Self-retained facing can be used for GRE with all slope inclinations. The geosynthetic reinforcement is extended to wrap the face with sufficient embedment length, typically at least 4 feet. Include a layer of non-woven geotextile behind the geosynthetic reinforcements to retain reinforced soil. The non-woven geotextile must have enough embedment length at both the top and bottom of the wrap.

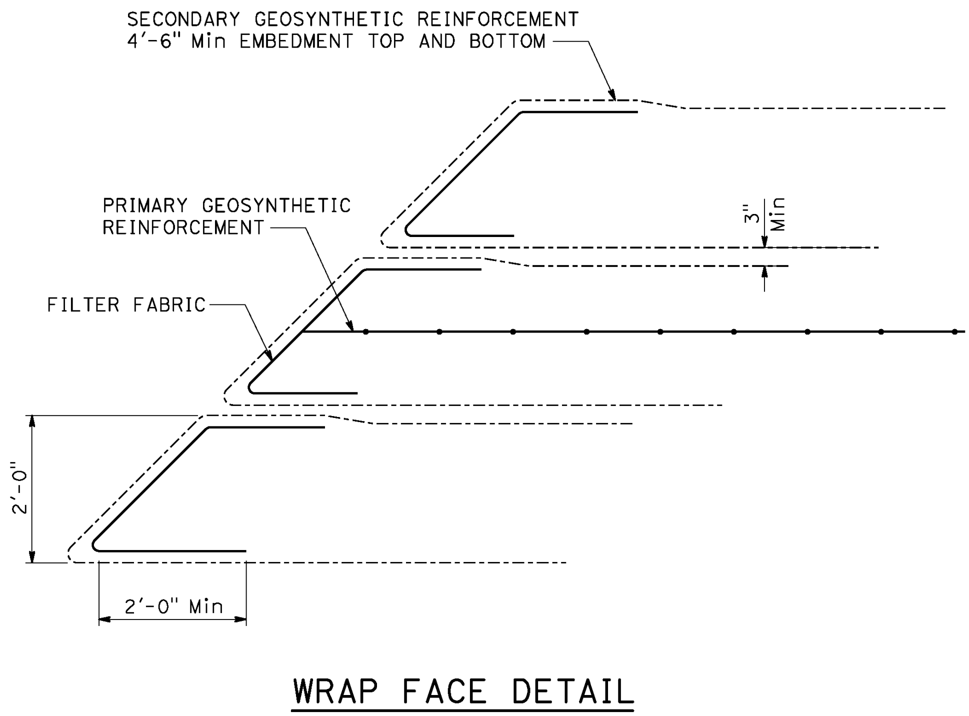


Figure 4: GRE Wrap Face Detail

Erosion control blanket *or mat* is generally used for slope grades less than 1.5H:1V. Erosion control blanket or mat may be biodegradable or non-biodegradable. The design and selection of erosion control blanket or mat should be provided by District Landscape Architect.

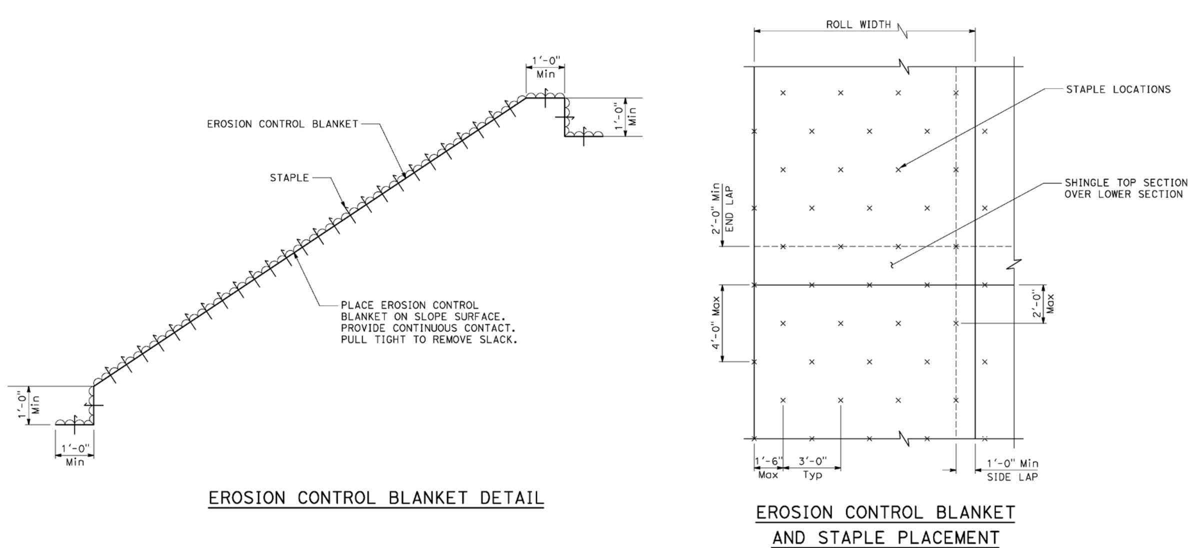


Figure 5: GRE Erosion Control Blanket Details

Welded-wire mesh/Pre-cast/prefabricated modular facing is generally used for slopes steeper than 1H:1V. The pre-cast modular facing must have positive connection with the primary geosynthetic reinforcements. Typical gabions are at least 3 feet deep, which provide sufficient frictional resistance to integrate with the geosynthetic reinforcements placed between gabions without positive connection.

The facing provides open drainage for the GRE.

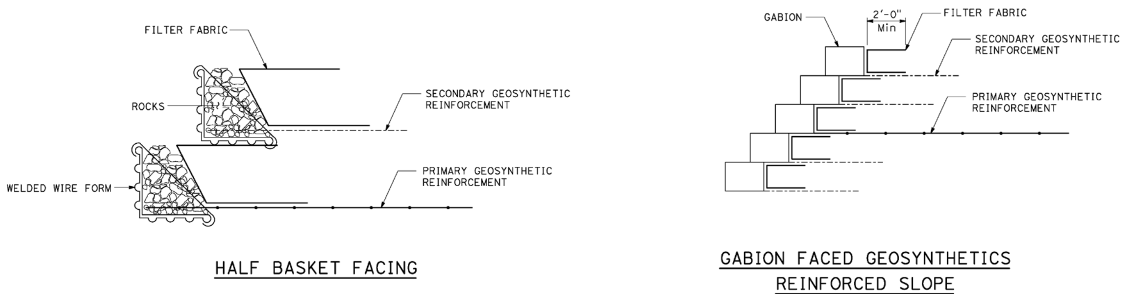


Figure 6: GRE Facing Details for Slope Steeper than 1H:1V

- ***GRE facing a waterway*** should be designed with armored scour and slope erosion protection using rock slope protection or gabion. For such application, an additional layer of geotextile is required between GRE and rock slope protection or gabion to retain soils.

  Consult with Structure Hydraulics or District Hydraulics for additional design requirements, such as scour mitigation.

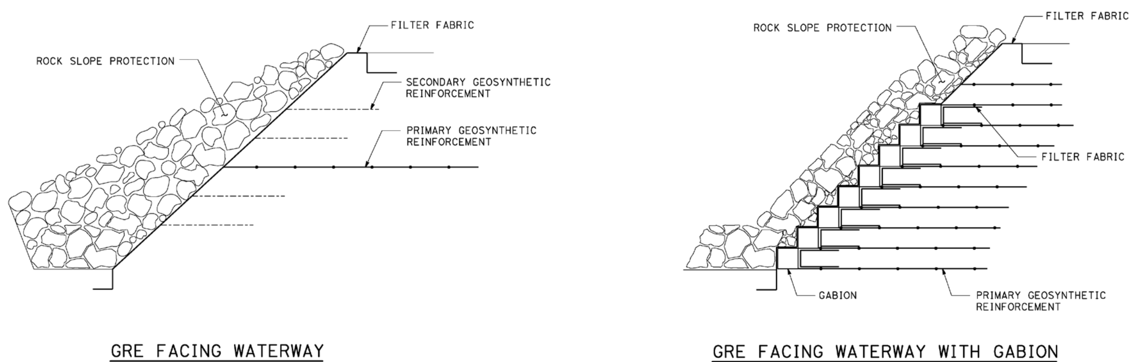


Figure 7: GRE Facing Details for Slopes Facing Waterway

4.6 Settlement and Bearing Capacity Evaluation

Perform settlement and bearing capacity evaluation as needed. Refer to the *Embankment* module.

4.7 Design for Slope Restoration

GRE may be an effective option for restoring failed slopes.

For this application, remove landslide debris by excavating below and beyond the failure surface. The excavation may be constrained at the landslide scarp due to the need to keep the highway open. Establish sufficient space, at least 10 feet horizontally near the top of the slope for the installation of geosynthetic reinforcements. If necessary, one traffic lane may need to be closed during construction.

Processed landslide debris may be used as reinforced soil if sufficient geosynthetic reinforcements are used, the reinforced soil materials do not cause creep, and proper subdrain is designed.

To keep the slope dry, prefabricated vertical drains may be placed horizontally in conjunction with the geosynthetic reinforcements.

5 Execution and Communication During Design

During design, close communication among the PDT is needed to produce an efficient and easy to construct design, and clear and easy to understand plans. Follow the procedure outlined below during design.

1) Obtain from District Design plan sheets, elevation view plans of the slope, and cross sections of the slopes, both original grade (OG) and final grade (FG), at 25-feet spacing.

2) Obtain design constraints, such as plans showing right-of-way line, nearby culverts and utilities, feasibility or needs for traffic control, temporary roadway realignment.

3) Select representative cross sections for GRE analysis and design based on the elevation view plans, cross sections, and subsurface conditions.

4) Perform analysis and design.

5) Based on the layout of geosynthetic reinforcements of representative slopes, draft, manually or electronically, on the elevation view plans to show:

    - the geosynthetic reinforcement types using different line types
    - elevations of each geosynthetic reinforcements
    - embedment lengths of each geosynthetic reinforcement

- begin and end stations of the reinforcements using termination marks.

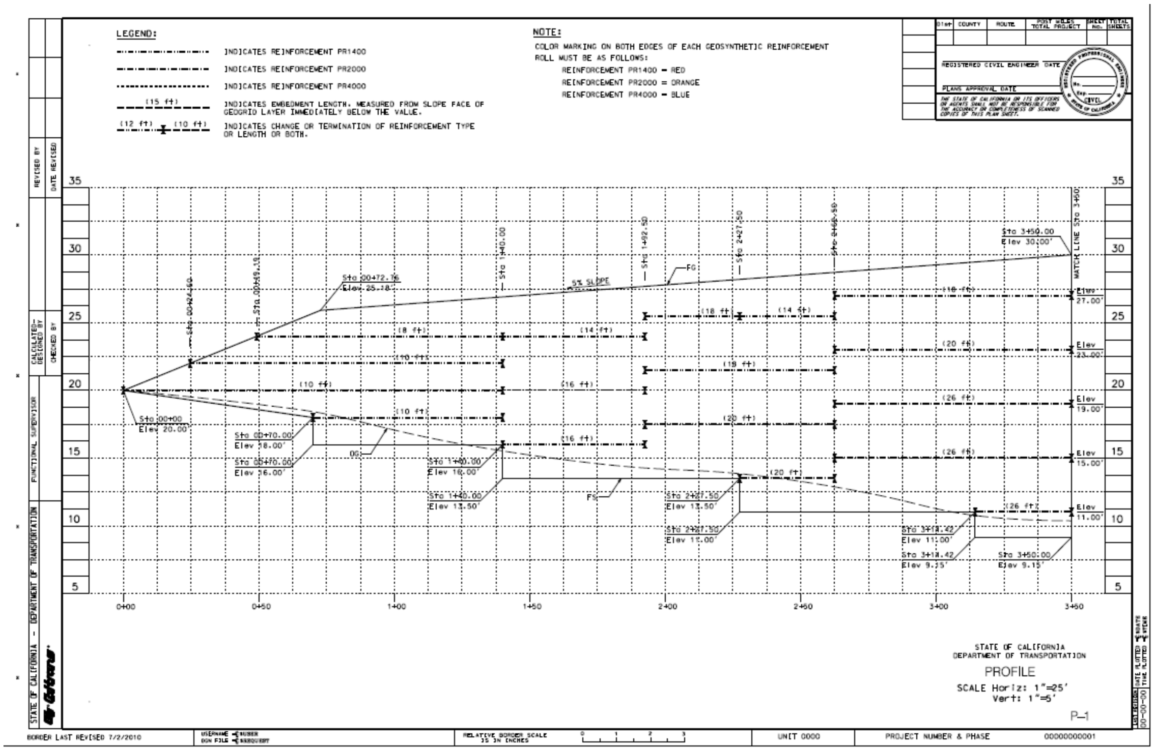


Figure 8: GRE Elevation View

6) Coordinate with District Design on stepping of the toe of slope for ease of construction and installation.

7) Identify on the plan sheets the horizontal limits of the GRE.

8) Develop a typical cross section of GRE including typical spacings of primary reinforcements and secondary reinforcements, and the length of secondary reinforcements, location of subdrain, and limits of excavation.

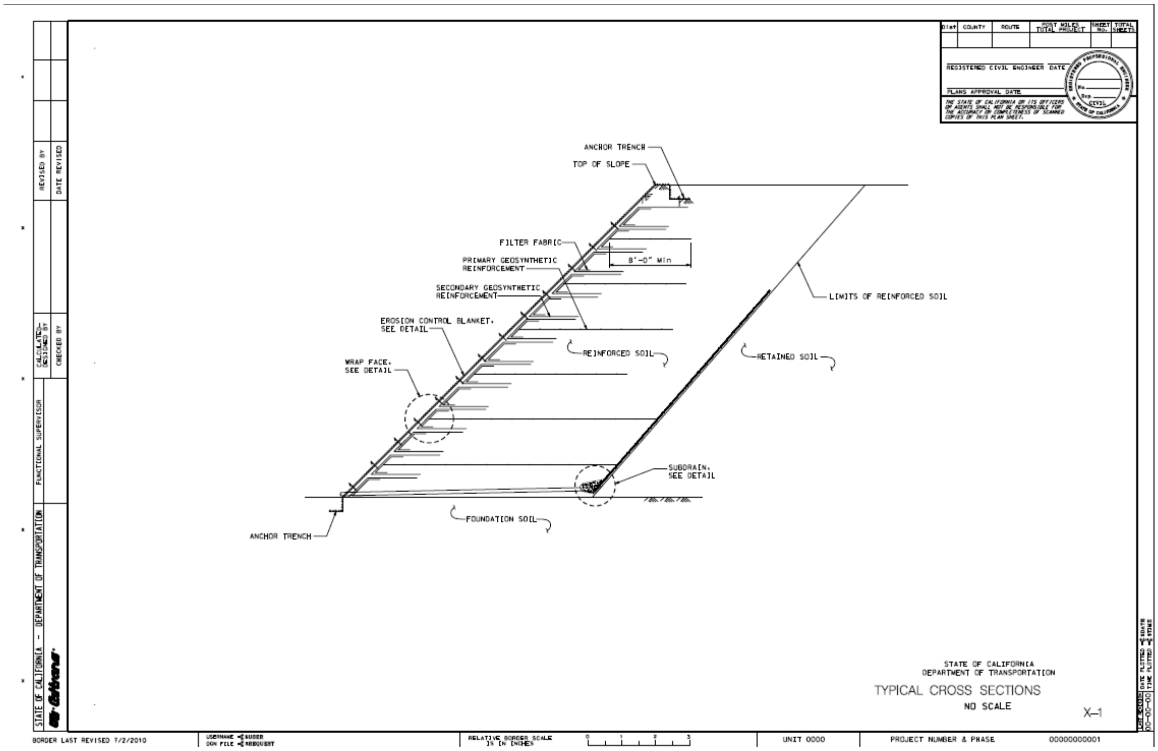


Figure 9: GRE Cross-section View

9) Develop details for subdrain.

10) Develop details for erosion protection and slope facing.

The GREs mostly consist of a steepened slope that requires an erosion control measure. Even though there are several typical facing design details readily available to geotechnical designers to address erosion control issues. The aesthetics of the slope facing and selection of vegetation on the slope is also an important factor, which in turn affected by whether the GRE is in an urban or rural area, local climate, and whether the slope face is visible to the travelling public and the residents.

These above factors should be evaluated and addressed by District Landscape Architect, with assistance from the geotechnical designer, who is responsible for long-term integrity of the slope, including the slope face.

Coordinate with District Landscape Architect and request for the design and selection of erosion control measures, such as erosion control blanket or mat and vegetation.

For potential need of maintenance access on the slope, District Landscape Architect may in-turn invite District Maintenance for input on slope facing selection and design.

11) Provide District Design:

- Elevation view plans produced in step 5.
- Plan sheets produced in step 7.
- A typical cross section of the GRE produced in step 8
- Subdrain produced in step 9.
- Slope facing details produced in step 10.

The templates for the plans described in the above list are presented in Appendix 1 and the corresponding MicroStation (.dgn) files can be download from the Geotechnical Design Aids webpage.

The MicroStation (.dgn) template plan files have been processed by HQ/OE to comply with Caltrans CAD and Plans standards. These plans are ready to be incorporated into project plans after project-specific revisions are made.

6 Reporting

Document GRE recommendations in a Geotechnical Design Report.

Provide the following in the Recommendations section:

- List of geosynthetic reinforcement types, with corresponding long-term strength (LTS).
- Engineering properties of other geosynthetics used for the design.
- Engineering properties of backfill as the reinforced soil used for the design. If the properties of backfill do not meet the requirements described in the Standard Specifications, revise the requirements using the Standard Special Provisions and provide the editing instruction in the “Notes for Specifications” section of the report.
- The typical cross section.
- Slope facing details.
- Drainage system details.

7 Geotechnical Review of PS&E Package

Request for the review of PS&E package.

Review the PS&E package to verify that Plans and Special Provisions have implemented the recommendations provided in the geotechnical report and during design.

8 Construction Support

Typical construction support that may be needed from the geotechnical designers are:

- Review contractor's submittal of geosynthetics material data sheets, including test results for the LTS.
- Review submittal for alternative reinforced soil. Ensure the installation damage reduction factor of geosynthetics is consistent with the reinforced soil material to be used.
- Revise the design due to unexpected obstructions, groundwater, or limitations.

9 References and Guidelines

- AASHTO Designation R69. "Determination of Long-Term Strength for Geosynthetic Reinforcement"
- FHWA (1998). "Geosynthetic Design and Construction Guidelines." Publication No. FHWA-HI-95-038.
- FHWA (2009). FHWA GEC 011 "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes - Volume I." Publication No. FHWA-NHI-10-024.
- FHWA (2009). FHWA GEC 011 "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes - Volume II." Publication No. FHWA-NHI-10-025.
- TxDOT (2016). "Geosynthetic Reinforced Steep Slopes." Report No. FHWA/TX-14/0-6792-1.

Appendix 1

Geosynthetic Reinforced Embankment Plan Templates

LEGEND:

- - - - - - - - INDICATES REINFORCEMENT PR1400

— - — - — - — INDICATES REINFORCEMENT PR2000

.... INDICATES REINFORCEMENT PR4000

(15 ft) INDICATES EMBEDMENT LENGTH, MEASURED FROM SLOPE FACE OF GEOGRID LAYER IMMEDIATELY BELOW THE VALUE.

(12 ft) (10 ft) INDICATES CHANGE OR TERMINATION OF REINFORCEMENT TYPE OR LENGTH OR BOTH.

NOTE:

COLOR MARKING ON BOTH EDGES OF EACH GEOSYNTHETIC REINFORCEMENT ROLL MUST BE AS FOLLOWS:

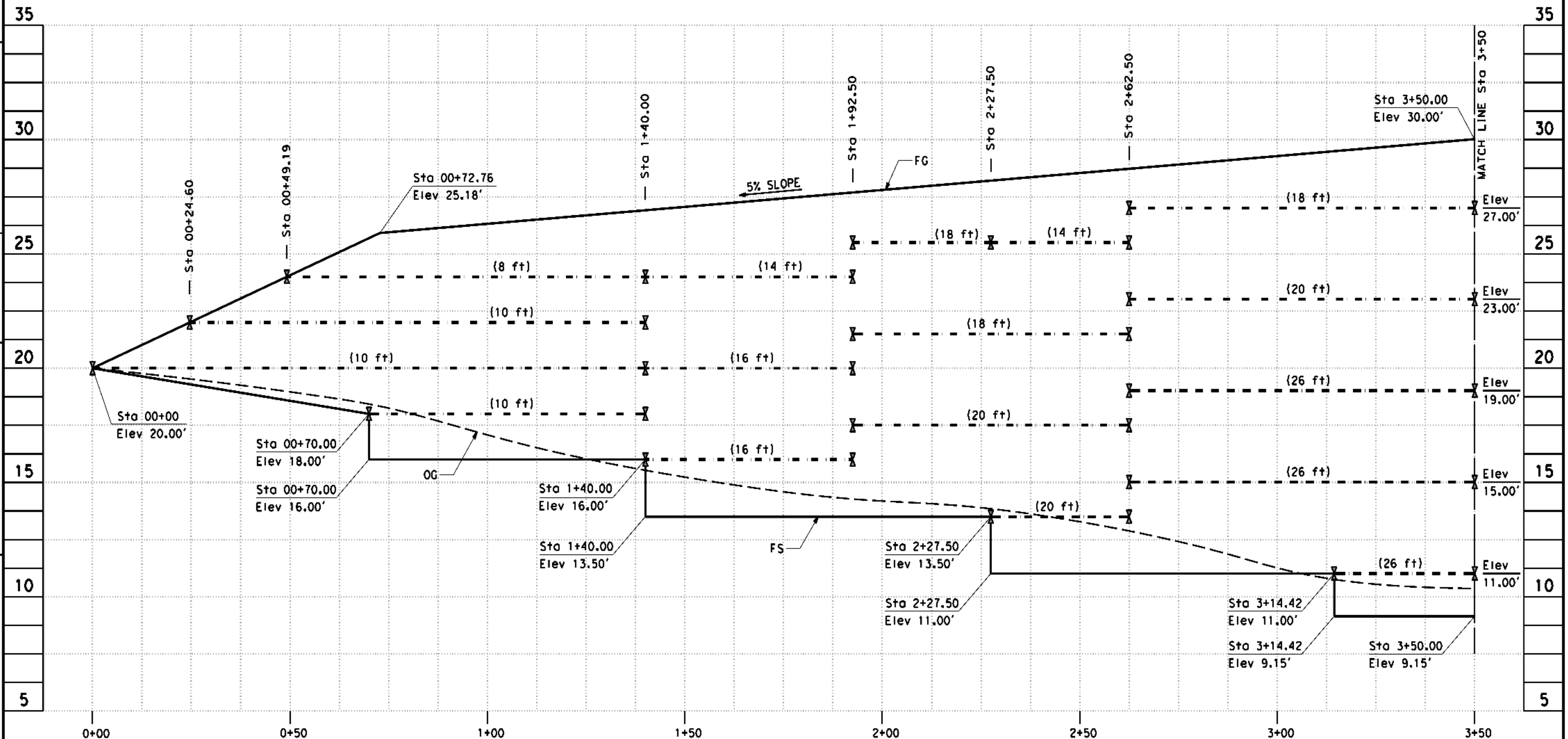
REINFORCEMENT PR1400 = RED
REINFORCEMENT PR2000 = ORANGE
REINFORCEMENT PR4000 = BLUE

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

PROFILE

SCALE Horiz: 1"=25'
Vert: 1"=5'

P-1

REVISED BY | DATE REVISED | CALCULATED-DESIGNED BY | CHECKED BY | FUNCTIONAL SUPERVISOR

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

DATE PLOTTED => 6/6/2023
TIME PLOTTED => 8:23:20 AM

LAST REVISION 00-00-00

LEGEND:

INDICATES REINFORCEMENT PR1400

INDICATES REINFORCEMENT PR2000

INDICATES REINFORCEMENT PR4000

(15 ft) INDICATES EMBEDMENT LENGTH, MEASURED FROM SLOPE FACE OF GEOGRID LAYER IMMEDIATELY BELOW THE VALUE.

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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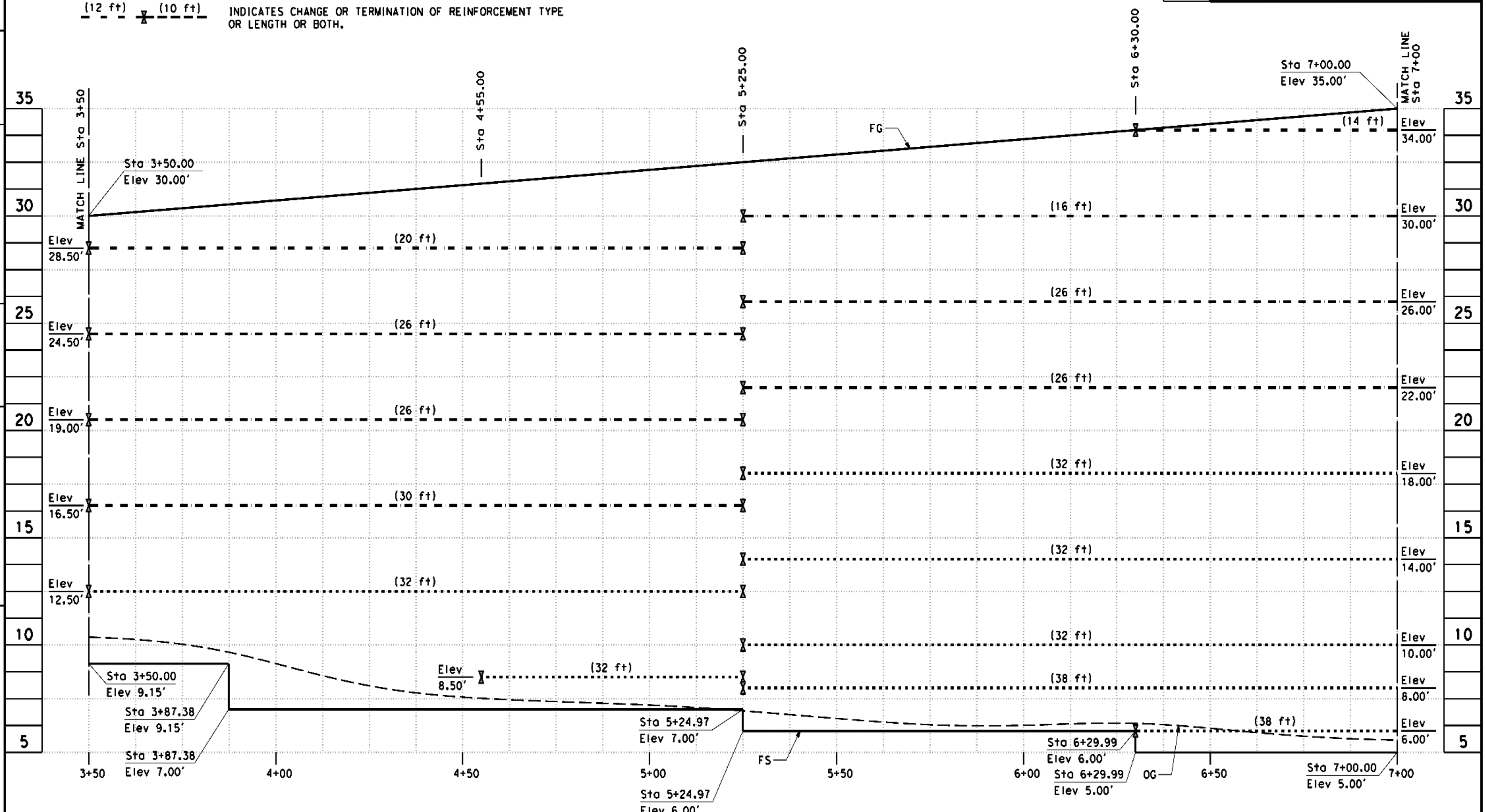

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- - - - - - - - INDICATES REINFORCEMENT PR2000

.... INDICATES REINFORCEMENT PR4000

(15 ft) INDICATES EMBEDMENT LENGTH, MEASURED FROM SLOPE FACE OF GEOGRID LAYER IMMEDIATELY BELOW THE VALUE.

(12 ft) (10 ft) INDICATES CHANGE OR TERMINATION OF REINFORCEMENT TYPE OR LENGTH OR BOTH.

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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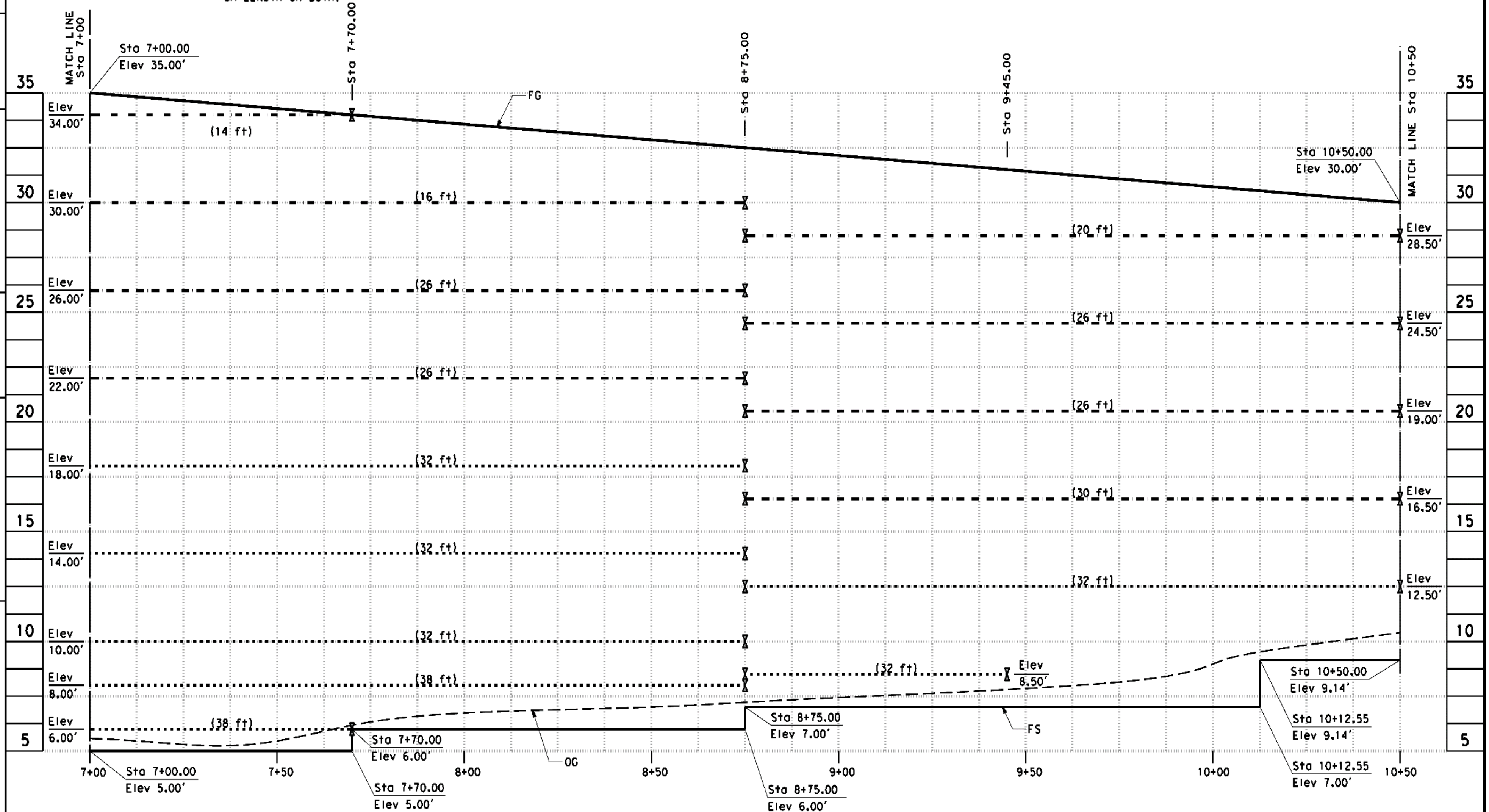

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

PROFILE

SCALE Horiz: 1"=25'
Vert: 1"=5'

P-3

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— · — · — · —	INDICATES REINFORCEMENT PR1400
— — — — —	INDICATES REINFORCEMENT PR2000
· · · · · · · · · ·	INDICATES REINFORCEMENT PR4000
(15 ft)	INDICATES EMBEDMENT LENGTH, MEASURED FROM SLOPE FACE OF GEOGRID LAYER IMMEDIATELY BELOW THE VALUE.
(12 ft) (10 ft)	INDICATES CHANGE OR TERMINATION OF REINFORCEMENT TYPE OR LENGTH OR BOTH.

NOTE:

COLOR MARKING ON BOTH EDGES OF EACH GEOSYNTHETIC REINFORCEMENT ROLL MUST BE AS FOLLOWS:

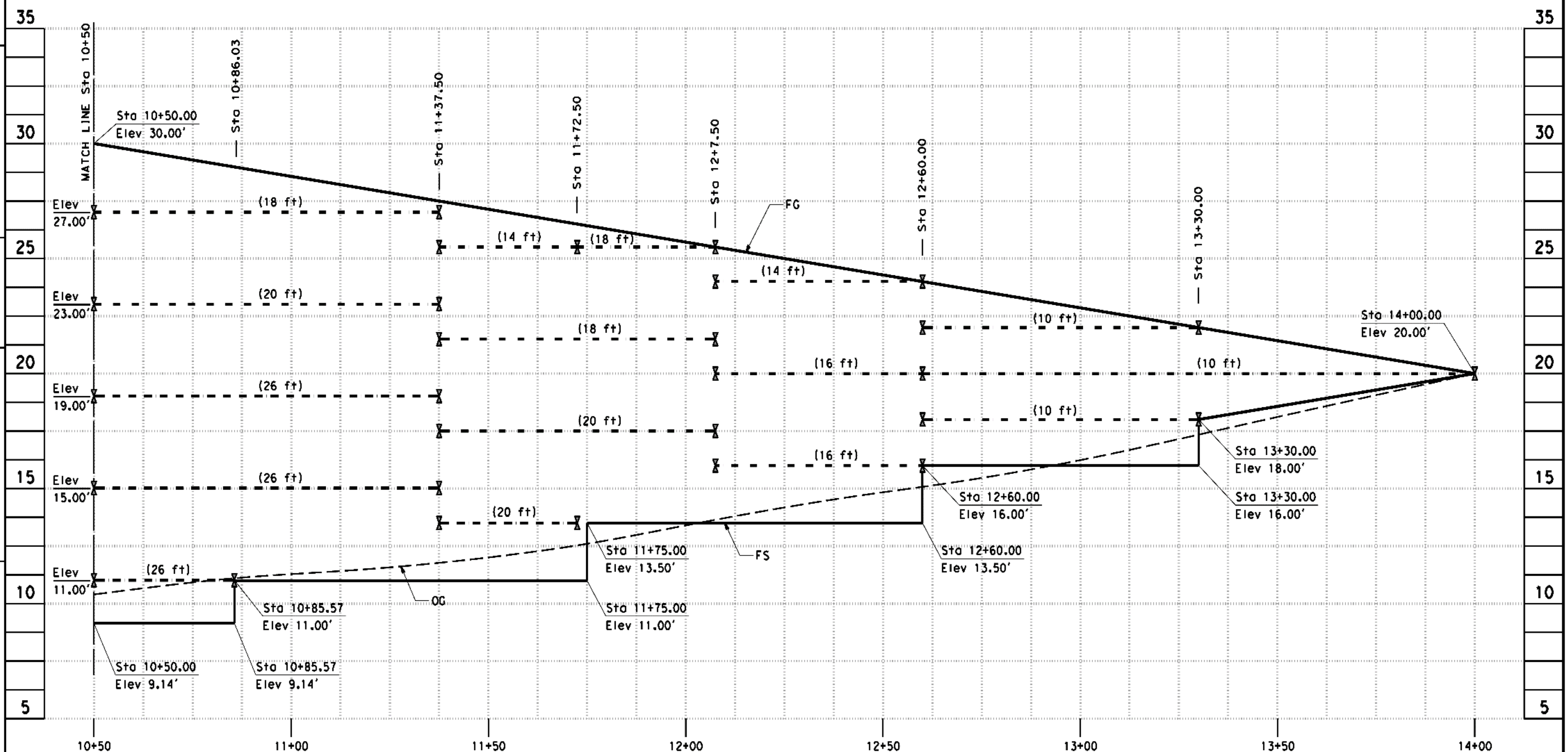
REINFORCEMENT PR1400 = RED
REINFORCEMENT PR2000 = ORANGE
REINFORCEMENT PR4000 = BLUE

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

PROFILE

SCALE Horiz: 1"=25'
Vert: 1"=5'

P-4

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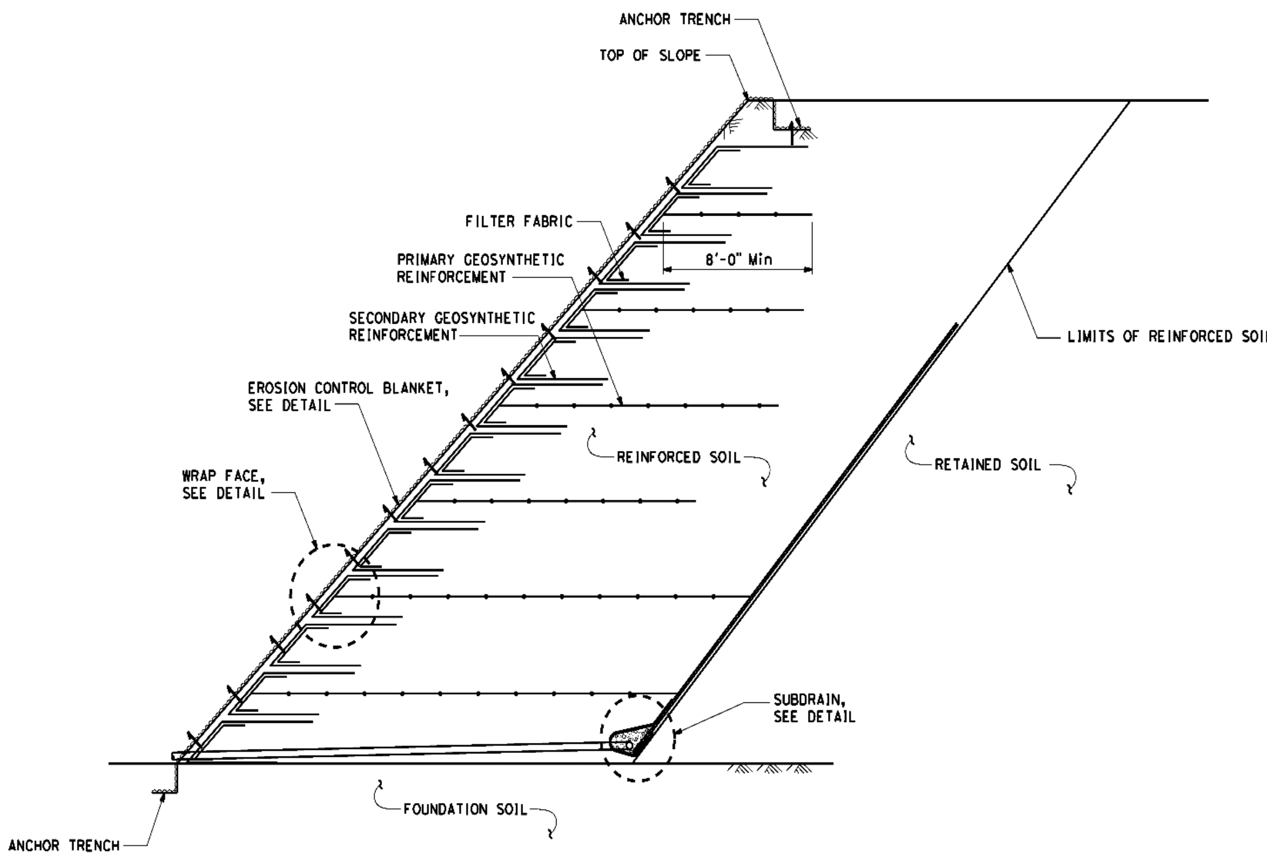
Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA



STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

TYPICAL CROSS SECTIONS

NO SCALE

X-1

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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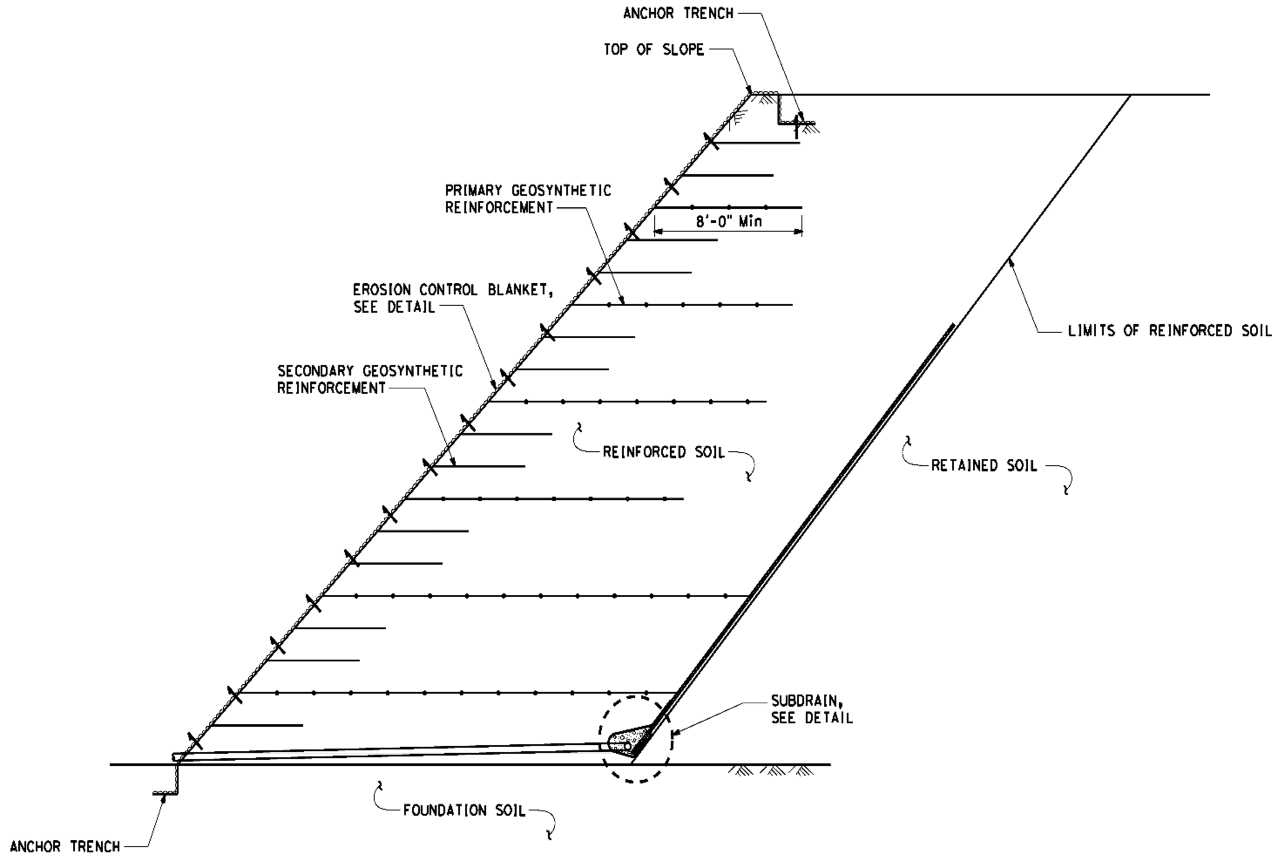
REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA



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DATE REVISED
CALCULATED-DESIGNED BY
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FUNCTIONAL SUPERVISOR
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

TYPICAL CROSS SECTION

NO SCALE

X-2

LAST REVISION 00-00-00 | DATE PLOTTED => 6/6/2023 | TIME PLOTTED => 8:31:00 AM

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

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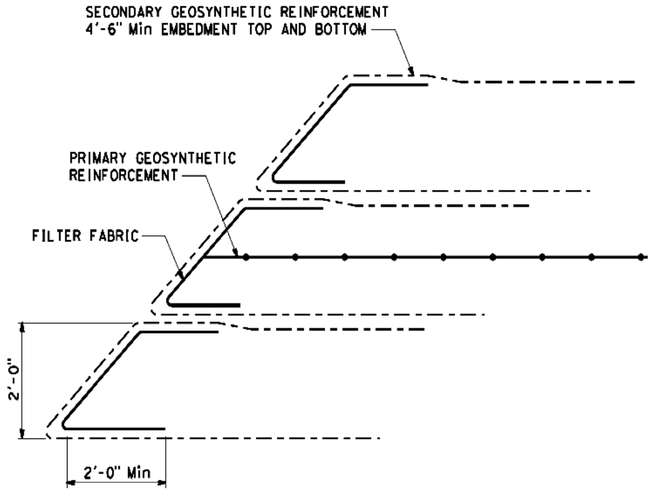
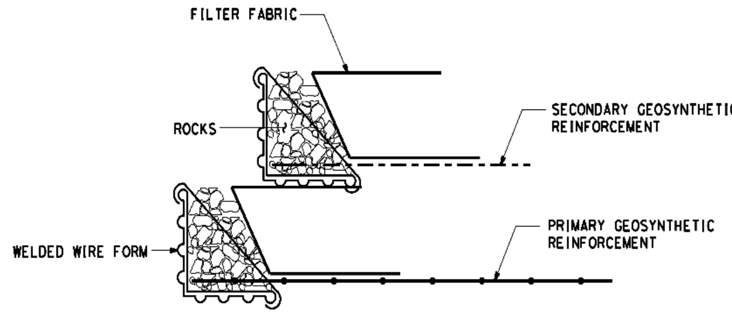
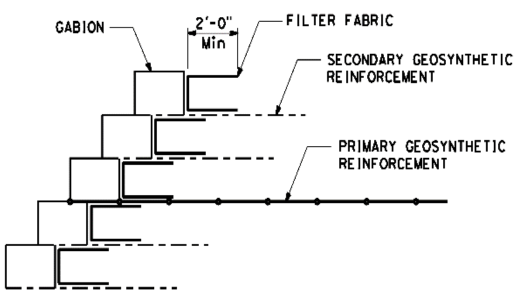


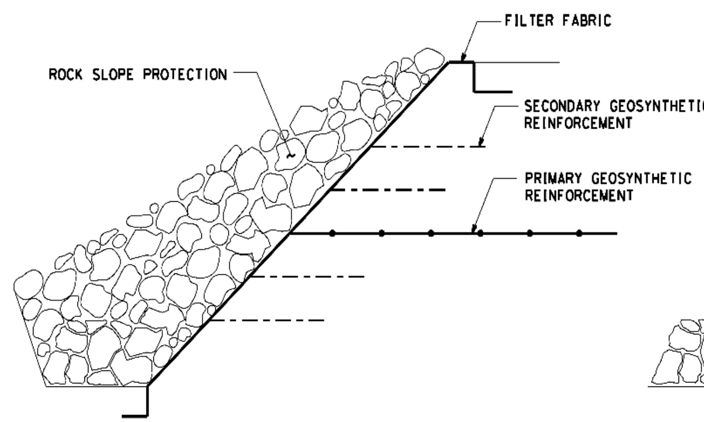
WRAP FACE DETAIL



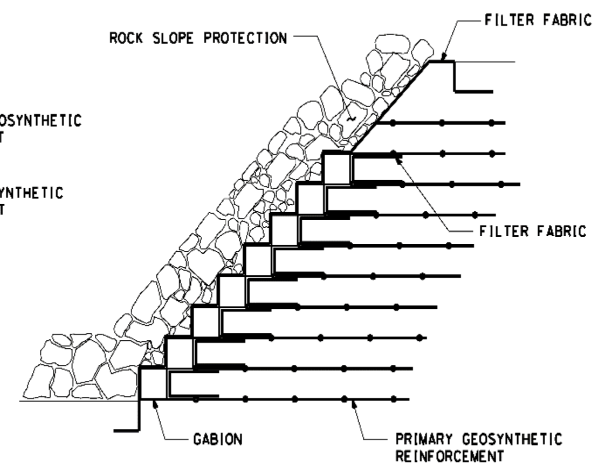
HALF BASKET FACING



GABION FACED GEOSYNTHETICS REINFORCED SLOPE



GRE FACING WATERWAY



GRE FACING WATERWAY WITH GABION

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

CONSTRUCTION DETAILS
FACING DETAILS
NO SCALE

C-X

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

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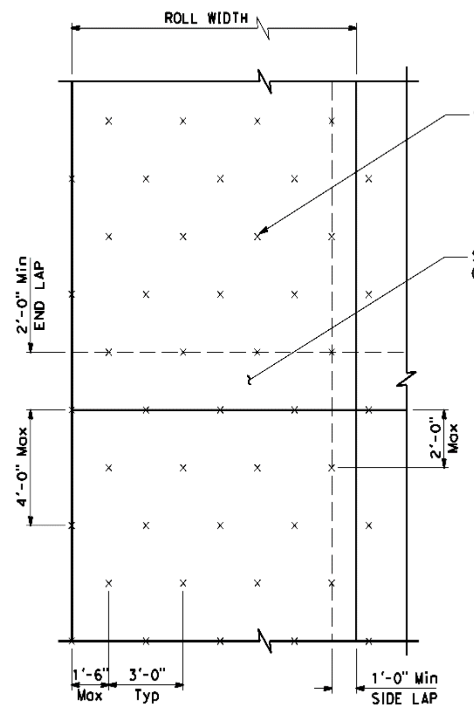
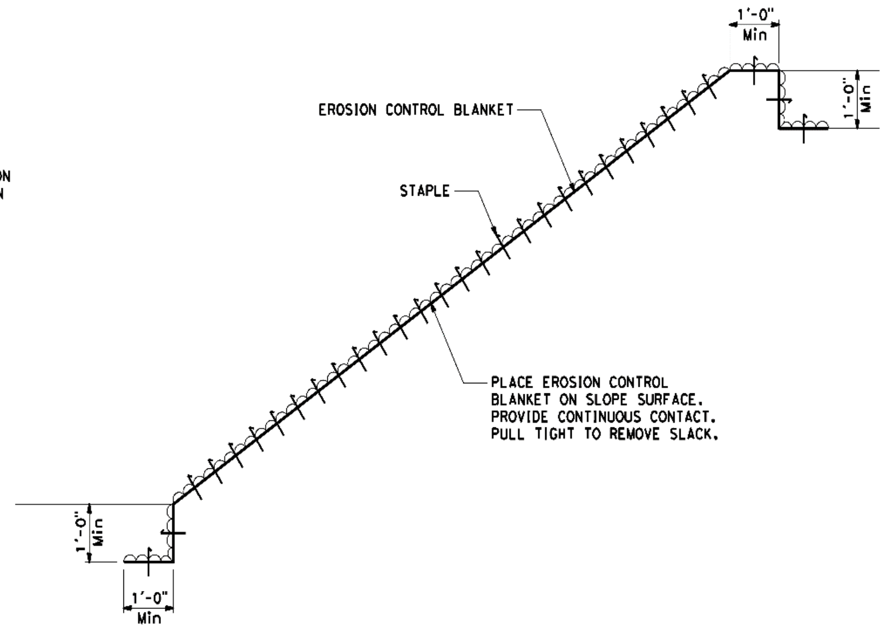
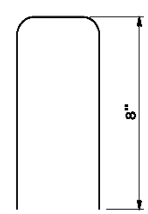


EROSION CONTROL BLANKET AND STAPLE PLACEMENT



EROSION CONTROL BLANKET DETAIL



STAPLE DETAIL

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

CONSTRUCTION DETAILS
EROSION CONTROL BLANKET

NO SCALE

C-X

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

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BORDER LAST REVISED 7/2/2010

USERNAME =>
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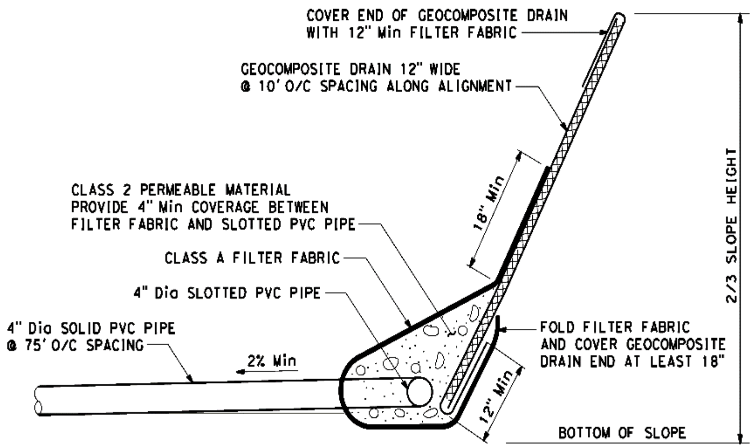
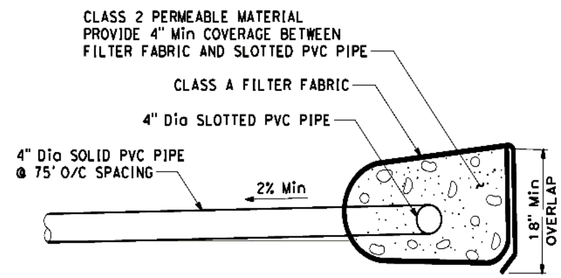
RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 00000000001



SUBDRAIN DETAILS AT CROSS SECTION WITH GEOCOMPOSITE DRAIN



SUBDRAIN DETAILS AT CROSS SECTION WITHOUT GEOCOMPOSITE DRAIN

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

CONSTRUCTION DETAILS

SUBDRAIN DETAILS

NO SCALE

C-X