Propex®
GEOSOLUTIONS

Engineered Earth Solutions

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Applications Engineer

Outline

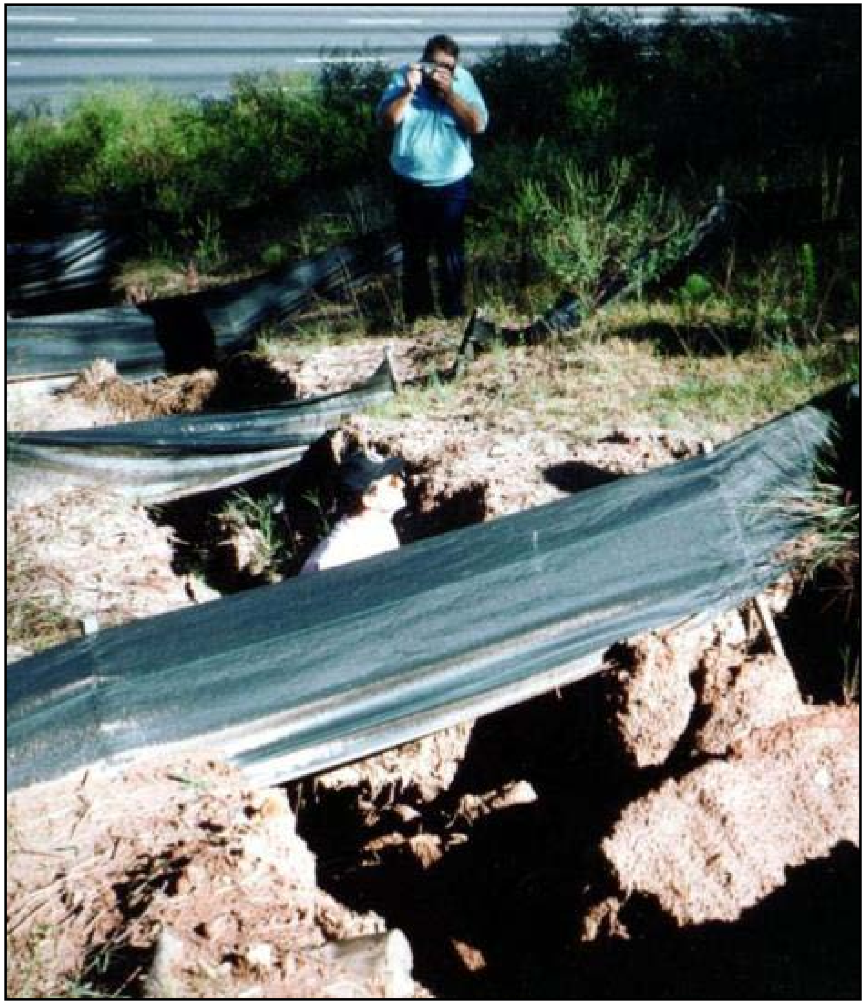
- Erosion Control
  - Conventional Solutions
  - Benefits of Vegetation
- Turf Reinforcement Mat (TRM)
- High Performance Turf Reinforcement Mat (HPTRM)
- Engineered Earth Armoring Solution
- Surficial Slope Stability
- Case Studies

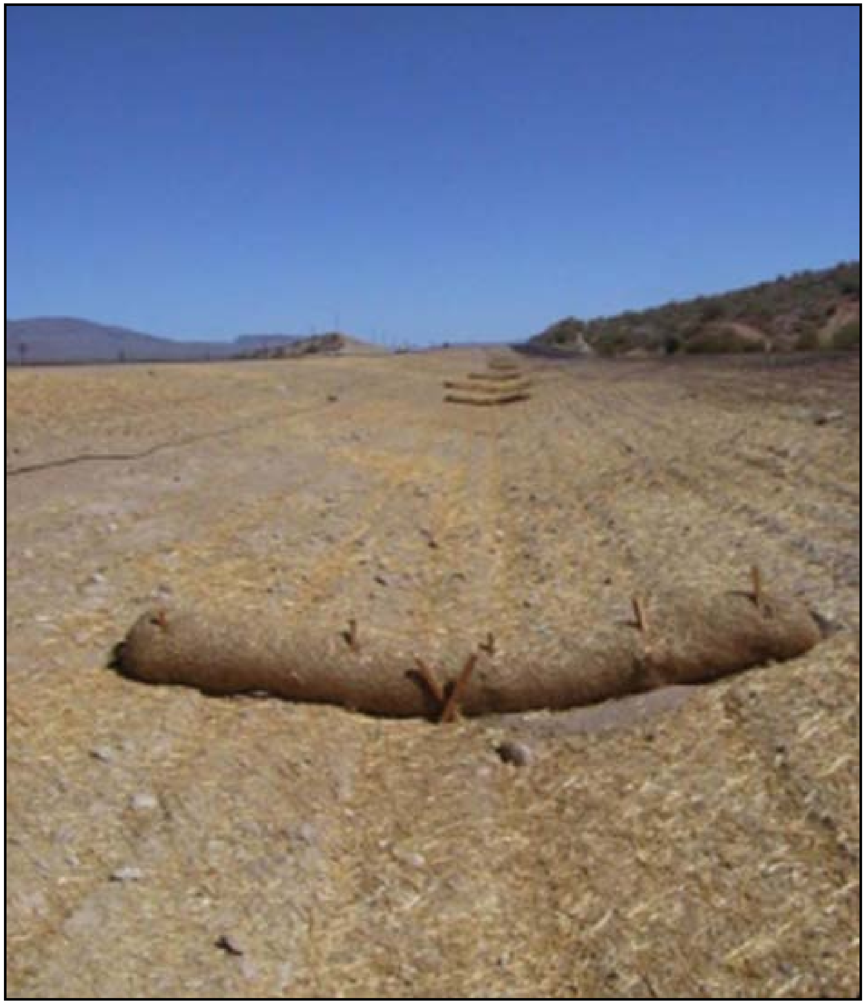
Problem: Earth Moves

Conventional Solution

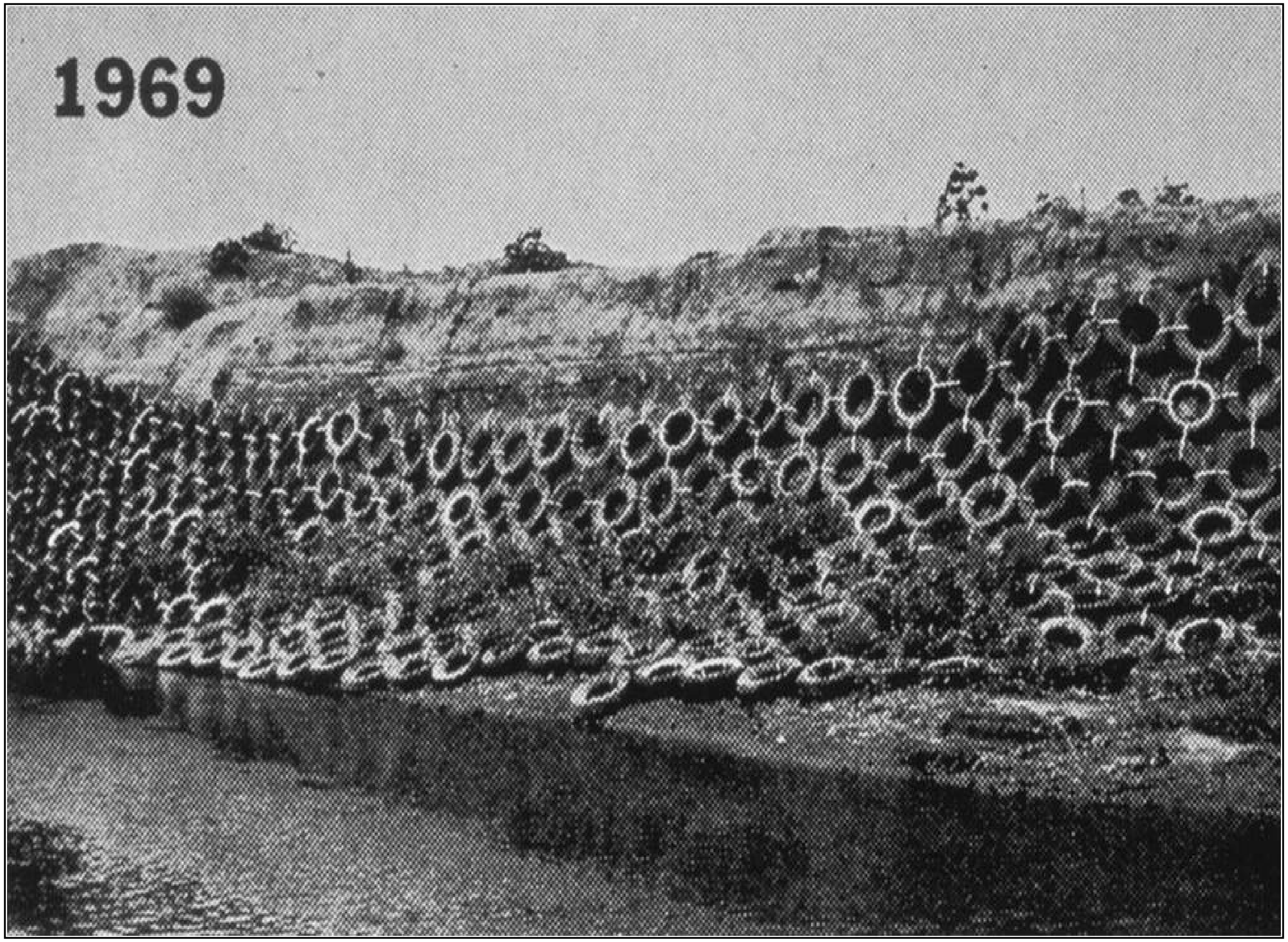
DEFENSIVE STRATEGY:
Be *Reactive* and Control the Movement of Sediments Downhill

Conventional Solution





Conventional Solution



Conventional Solution

US Clean Water Act Regulation Facts

- US$13 Billion Cost Annually
- Over US $1 Billion removing sediment from waterways annually
- EPA estimates sediment removal from reservoirs costs US $500 million annually.
- Annual water storage replacement costs from sediment range from US $2 to US$6 billon

The Driving Force:

- EPA Environmental Protection Agency – Via Clean Water Act (CWA)

NPDES – National Pollutant Discharge Elimination System:

- Use of Best Management Practices for NPDES Compliance (EPA TRM Fact Sheet)

EPA BMP Fact Sheets

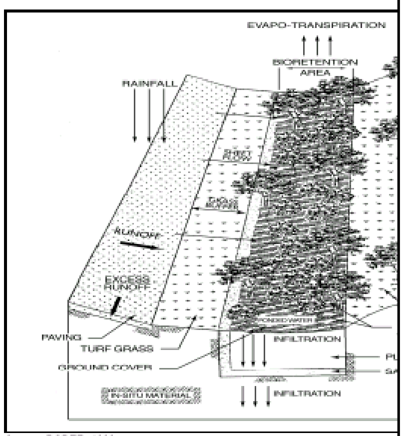
United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-012 September 1999

EPA

Storm Water Technology Fact Sheet
Bioretention

DESCRIPTION

Bioretention is a best management practice (BMP) developed in the early 1990's by the Prince George's County, MD, Department of Environmental Resources (PGDER). Bioretention utilizes soils and both woody and herbaceous plants to remove pollutants from storm water runoff. As shown in Figure 1, runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. Runoff passes first over or through a sand bed, which slows the runoff's velocity, distributes it evenly along the length of the ponding area, which consists of a surface organic layer and/or ground cover and the underlying planting soil. The ponding area is graded, its center depressed. Water is ponded to a depth of 15 centimeters (6 inches) and gradually infiltrates the bioretention area or is



Source: PGDER, 1993.

FIGURE 1 BIORETENTION ARE

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-027 September 1999

EPA

Storm Water Technology Fact Sheet
Vegetative Covers

DESCRIPTION

Soil erosion and sedimentation caused by vegetation removal, soil disturbances, changes to natural drainage patterns, or increases in impermeable ground cover are two of the primary problems associated with storm water runoff. One of the most effective ways to prevent erosion and sedimentation is to stabilize disturbed land through the addition of vegetation. This practice is referred ... egetative covers can ... vegetation and/or ... ey can provide both ... erosion potential by ... apping sediment, ... ating the energy of

... vegetative covers is ... r permanent new ... can include applying ... ermanently seeding ... manent grass cover ... ea to provide an ... that both stabilizes ... tes sediment loss. ... planting grass seed ... ling to provide soil ... ver is established. ... perennial vegetation

... vegetative covering ... ation. This allows a ... isting trees, vines, ... n as a natural buffer ... ctivities.

APPLICABILITY

Vegetative covers can be applied at any site and are not restricted by the size of the site or local land uses. The type of soil, topography, and climate at the site determine the appropriate tree, shrub, and ground cover species for that particular management practice. Local climatic conditions help determine the appropriate time of year for planting. Temporary seeding is most suitable in areas disturbed by construction where the ground is left exposed for several weeks or more. Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is desired. Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks.

ADVANTAGES AND DISADVANTAGES

Vegetative covering can be a relatively low-cost and low-maintenance practice for controlling dust and preventing erosion. It also adds to the aesthetics of a storm water control area.

Limitations of vegetative covers as a management practice include:

- Vegetative covering must be coordinated with climatic conditions for proper establishment. For example, cold climate areas have limited growing seasons and arid regions require careful selection of plant species.
- An appropriate maintenance program must be implemented to ensure the optimum performance.

United States Environmental Protection Agency | Office of Water Washington, D.C. | 832-F-99-006 September 1999

EPA

Storm Water Technology Fact Sheet
Vegetated Swales

DESCRIPTION

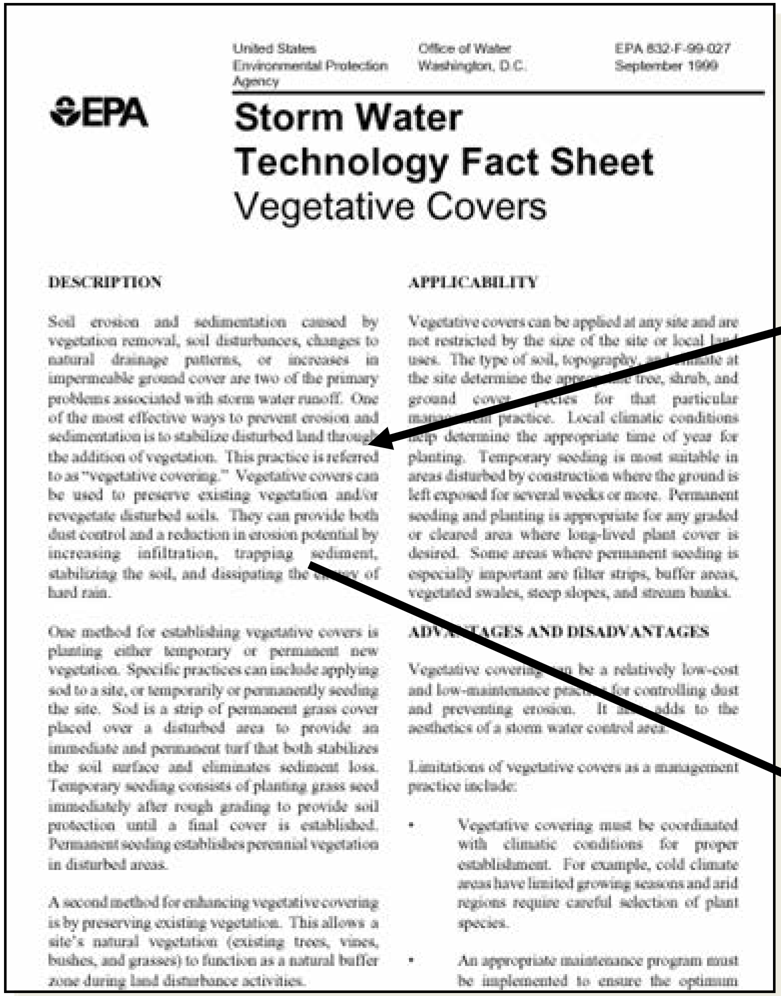
A vegetated swale is a broad, shallow channel with a dense stand of vegetation covering the side slopes and bottom. Swales can be natural or manmade, and are designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of storm water runoff. A typical design is shown in Figure 1.

Vegetated swales can serve as part of a storm water drainage system and can replace curbs, gutters and storm sewer systems. Therefore, swales are best suited for residential, industrial, and commercial areas with low flow and smaller populations.

APPLICABILITY

Vegetated swales can be used wherever the local climate and soils permit the establishment and maintenance of a dense vegetative cover. The feasibility of installing a vegetated swale at a

The Benefits of Vegetation



United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-027 September 1999

EPA

Storm Water Technology Fact Sheet
Vegetative Covers

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One method for establishing vegetative covers is planting either temporary or permanent new vegetation. Specific practices can include applying sod to a site, or temporarily or permanently seeding the site. Sod is a strip of permanent grass cover placed over a disturbed area to provide an immediate and permanent turf that both stabilizes the soil surface and eliminates sediment loss. Temporary seeding consists of planting grass seed immediately after rough grading to provide soil protection until a final cover is established. Permanent seeding establishes perennial vegetation in disturbed areas.

A second method for enhancing vegetative covering is by preserving existing vegetation. This allows a site's natural vegetation (existing trees, vines, bushes, and grasses) to function as a natural buffer zone during land disturbance activities.

APPLICABILITY

Vegetative covers can be applied at any site and are not restricted by the size of the site or local land uses. The type of soil, topography, and climate at the site determine the appropriate tree, shrub, and ground cover species for that particular management practice. Local climatic conditions help determine the appropriate time of year for planting. Temporary seeding is most suitable in areas disturbed by construction where the ground is left exposed for several weeks or more. Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is desired. Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks.

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"One of the most effective ways to prevent erosion and sedimentation is to stabilize disturbed land through the addition of vegetation."

"…provide both dust control and a reduction in erosion potential by increasing filtration, trapping sediment, stabilizing the soil, and dissipating the energy of hard rain."

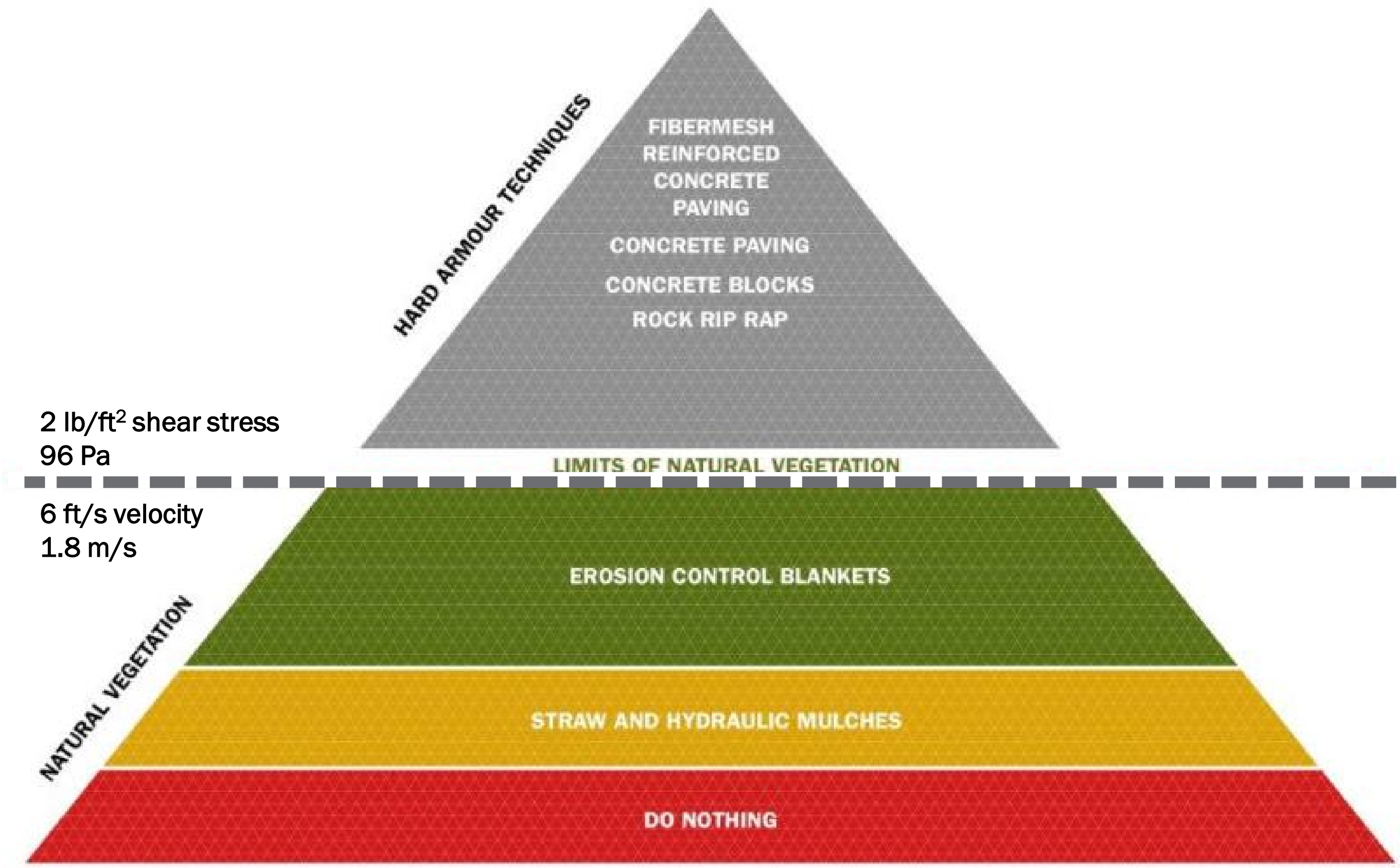
Environmental Benefits of Grassed Swales

TABLE 1 EFFECTIVENESS OF DESIGN SWALES

Pollutant	Median % Removal
Total Suspended Solids	81
Oxygen Demanding Substances	67
Nitrate	38
Total Phosphorus	9
Hydrocarbons	62
Cadmium	42
Copper	51
Lead	67
Zinc	71

- Per the EPA Fact Sheet, vegetated swales are most effective at removing particulate pollutants (TSS).
- A conservative estimate is 25-50% removal, but 70-95% has been achieved on most sites.

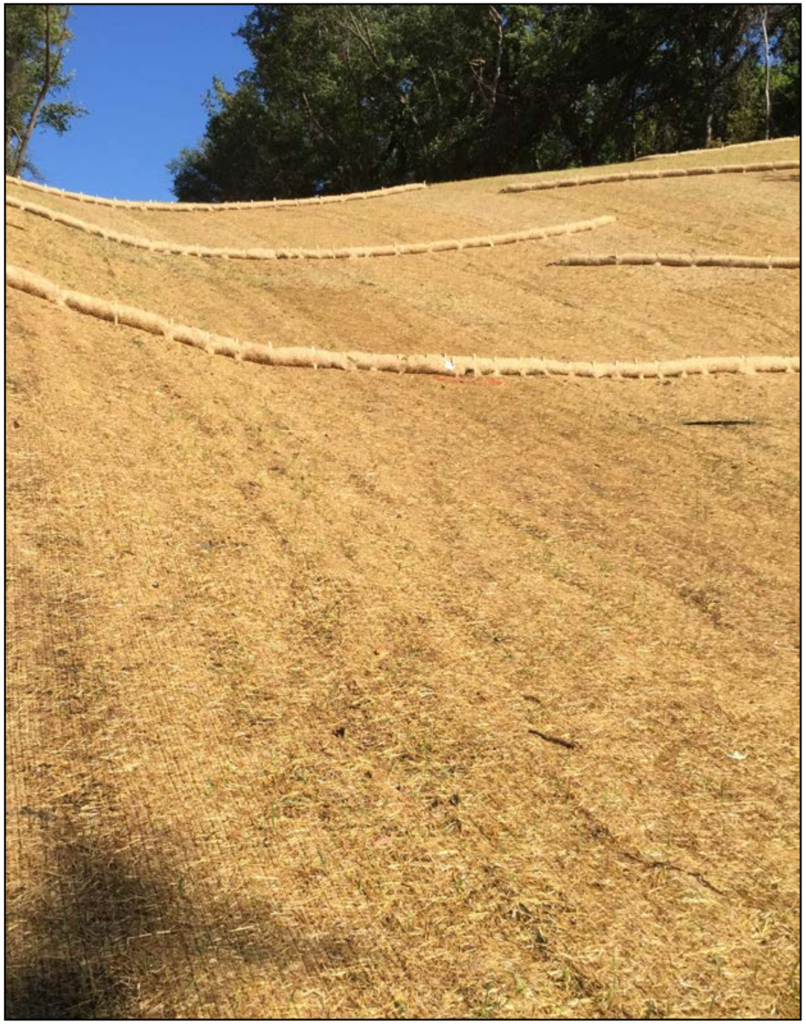
Limitations of Vegetation



Erosion Control Blankets

- Straw
- Coconut
- Wood Excelsior
- Coir

Establish Vegetation



Rock Riprap Performance

Rock Riprap Size (D_{50})	Permissible Velocity [1]	Permissible Shear Stress [2]	
		Channel Bottom	2.0H:1V
in	ft/s	lb/ft^2	lb/ft^2
3	6.2	1.2	0.9
6	8.7	2.4	1.7
9	10.7	3.6	2.6
12	12.3	4.8	3.5
18	15.1	7.2	5.2
24	17.5	9.6	6.9

1. Velocity based on Isbash Method
2. Shear Stress based on HEC-15

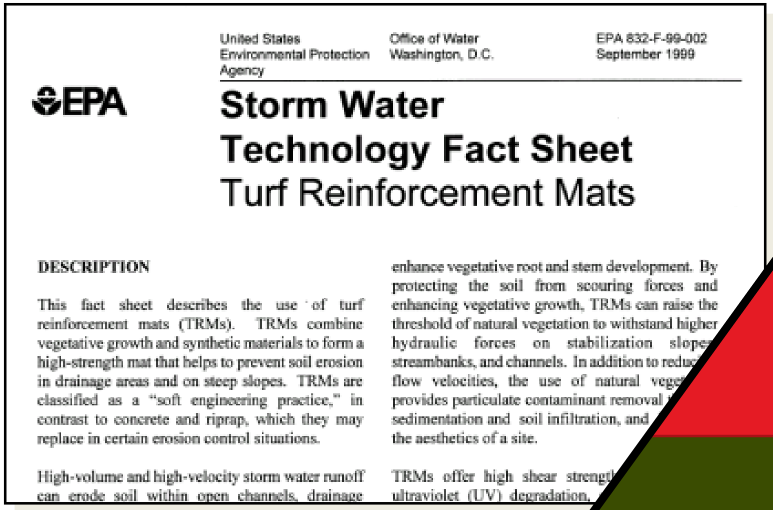
Rock Riprap

Rock Riprap

Paved Concrete Channel

Paved Concrete Channel

Turf Reinforcement Mat (TRM)



United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-002 September 1999

EPA

Storm Water Technology Fact Sheet
Turf Reinforcement Mats

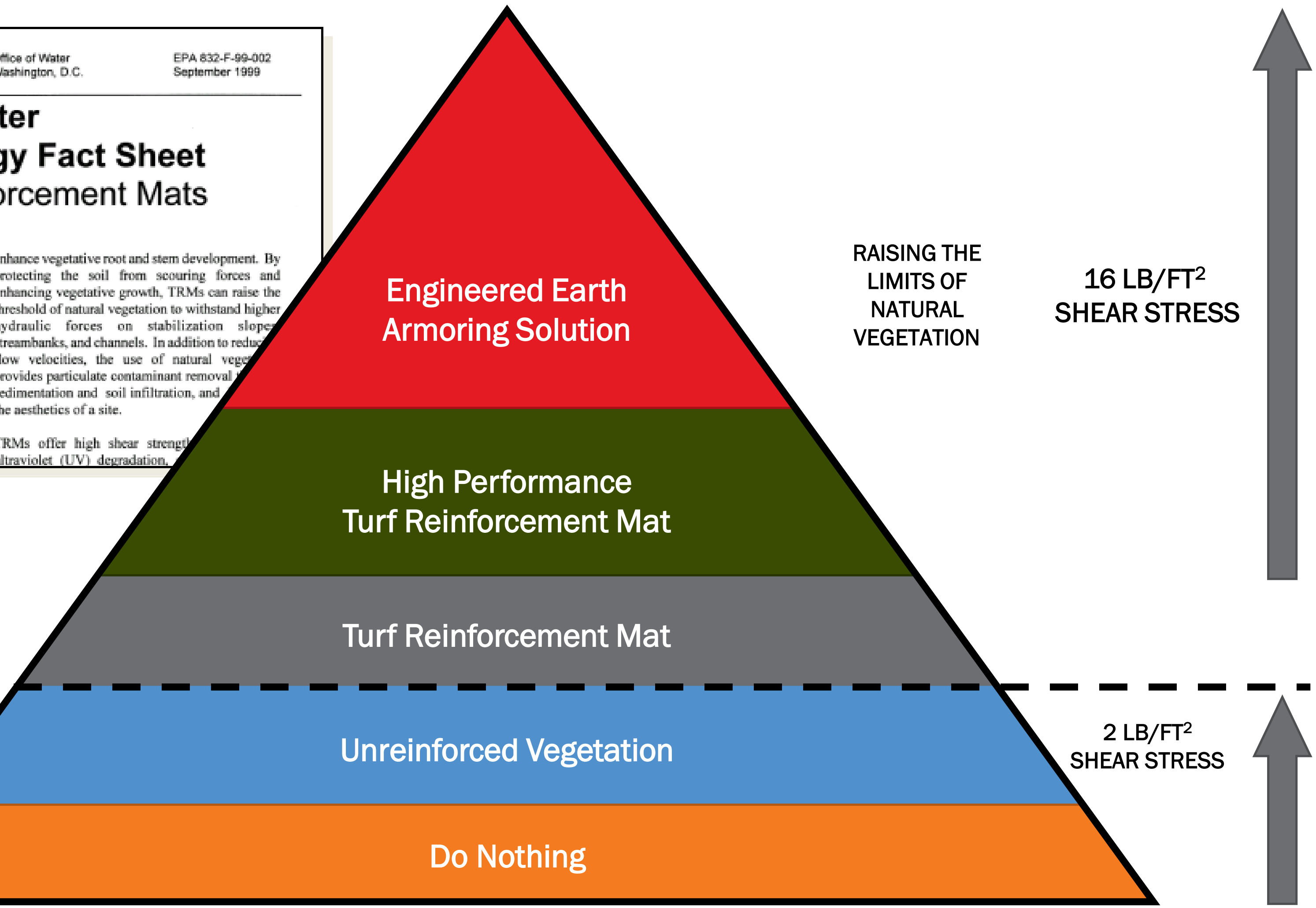
DESCRIPTION

This fact sheet describes the use of turf reinforcement mats (TRMs). TRMs combine vegetative growth and synthetic materials to form a high-strength mat that helps to prevent soil erosion in drainage areas and on steep slopes. TRMs are classified as a "soft engineering practice," in contrast to concrete and riprap, which they may replace in certain erosion control situations.

High-volume and high-velocity storm water runoff can erode soil within open channels, drainage

enhance vegetative root and stem development. By protecting the soil from scouring forces and enhancing vegetative growth, TRMs can raise the threshold of natural vegetation to withstand higher hydraulic forces on stabilization slope streambanks, and channels. In addition to reduc flow velocities, the use of natural vege provides particulate contaminant removal sedimentation and soil infiltration, and the aesthetics of a site.

TRMs offer high shear strengt ultraviolet (UV) degradation,



Reinforced Vegetation

Vegetated Drainage Channel

Vegetated Drainage Channel with Turf Reinforcement Mats
Ground Water Recharge & Improved Water Quality

1st Generation Stitch-Bonded TRM

Three Layers

- Two Nets on the Outside
- Stitch-Bonded Polypropylene Composite

Tensile Strength

- 400 x 300 lb/ft
- 5.8 x 4.4 kN/m

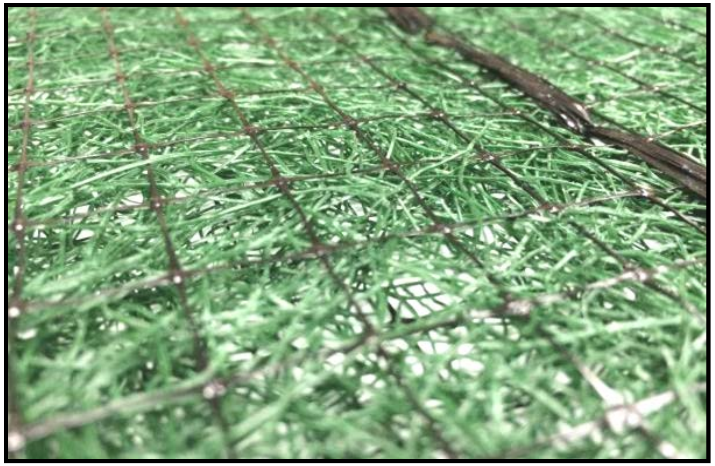
Moderate UV Stabilization

- Up to 10 year life if exposed
- 80% at 1,000 hours (ASTM D 4355)

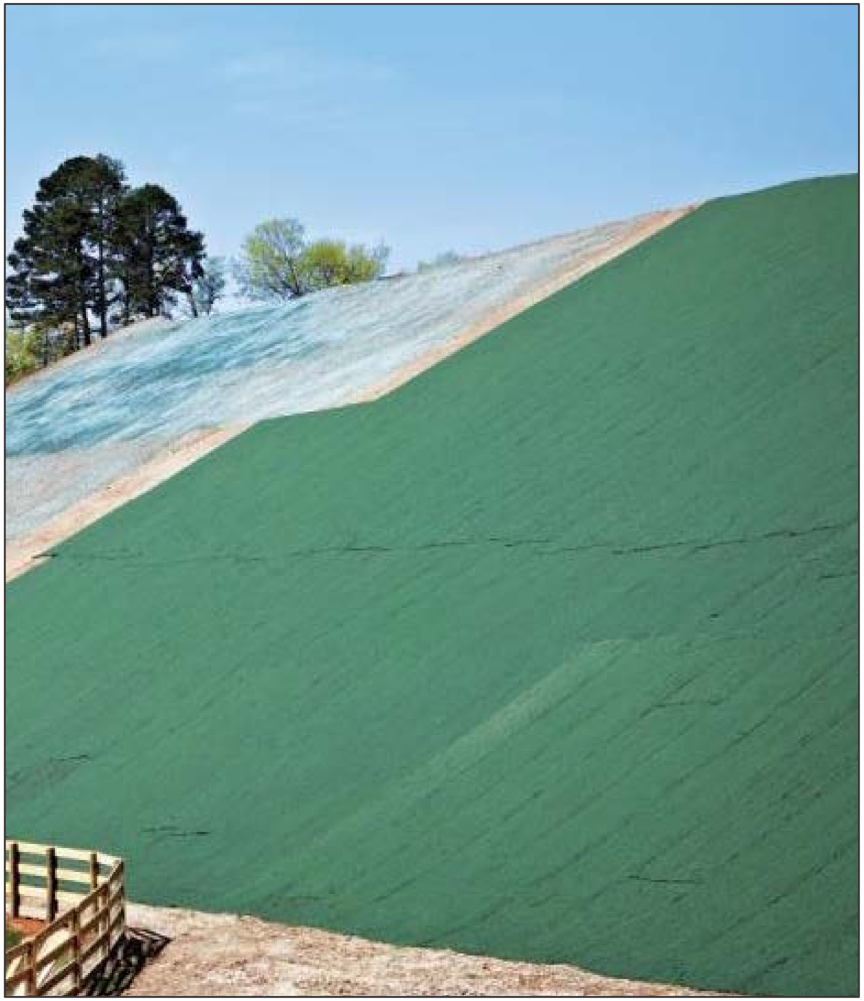
Appropriate Applications

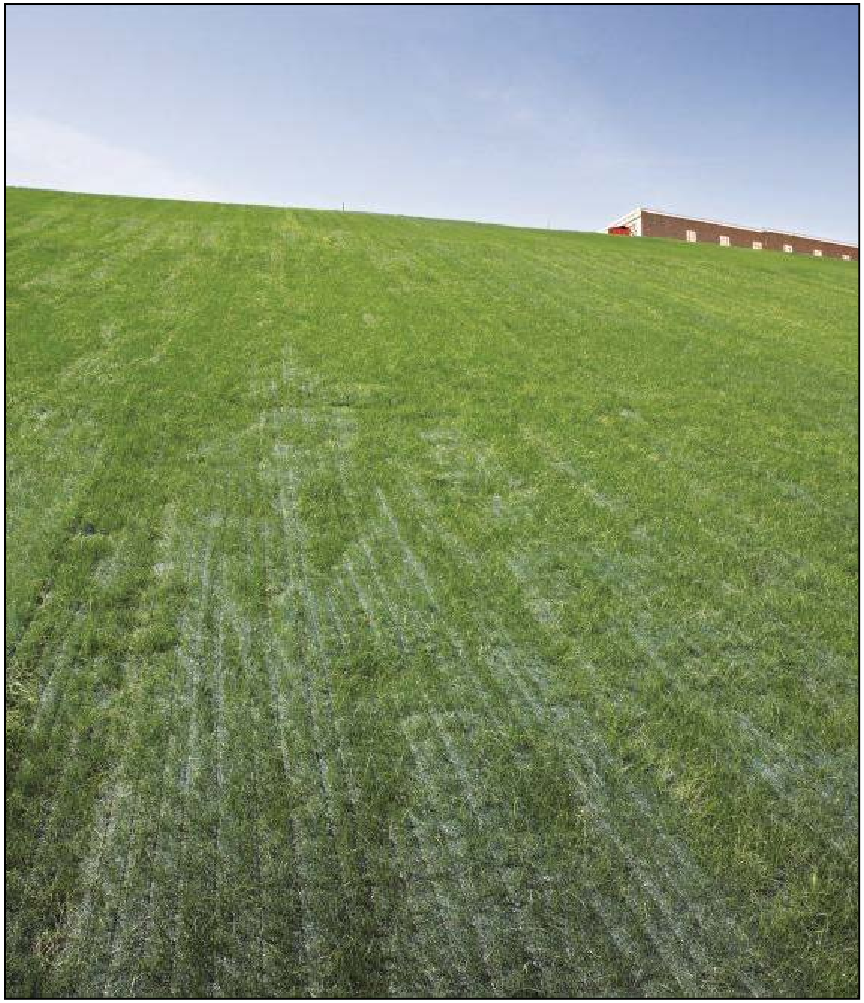
- Low Flow Channels
- Minor Slopes
- Low stress conditions

LANDLOK®



1st Generation Stitch-Bonded TRM





Key Lessons from 1st Generation TRMs

Improper Application

- Hydraulic conditions exceeded TRM's Performance thresholds
- Non-Hydraulic Stresses not considered
- Limited Design Life

Inadequate TRM specification

- Must be comprehensive to the application
- Alternate materials must meet all requirements

Installation Quality Control

- Specification needs to stipulate installation guidance
- On site installation meeting with the contractor, engineer & manufacturer

Key Lessons from 1st Generation TRMs

TRMs must also be designed for Applicable Non-Hydraulic Stresses

Durability:

- Non-hydraulic Stresses
  - Heavy Mowing Activity
  - Maintenance Loading
  - Debris Loading
  - Animal Loading
  - Ice Flows
- Design Life
  - Ultraviolet (UV) Resistance
  - Tensile Strength

2nd Generation Woven TRMs

Construction:

- Three-dimensional, woven polypropylene geosynthetic mat

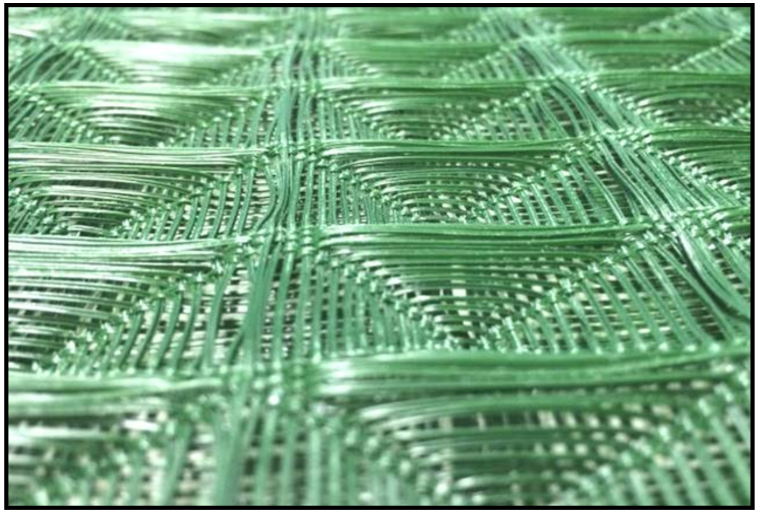
Material Construction:

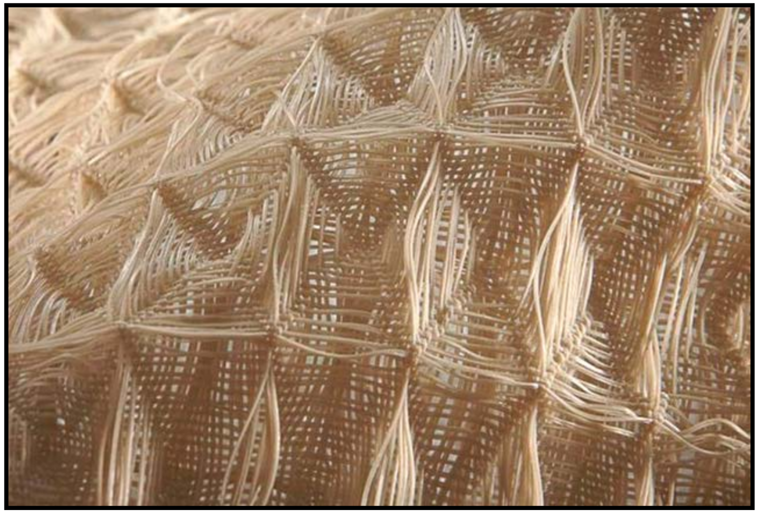
- X3® Fiber Technology
- Woven into a uniform configuration
- Homogeneous Structure

Created to specifically address the Limitations of 1st Generation TRMs:

- Non-hydraulic Stresses
- Design Life

PYRAMAT®



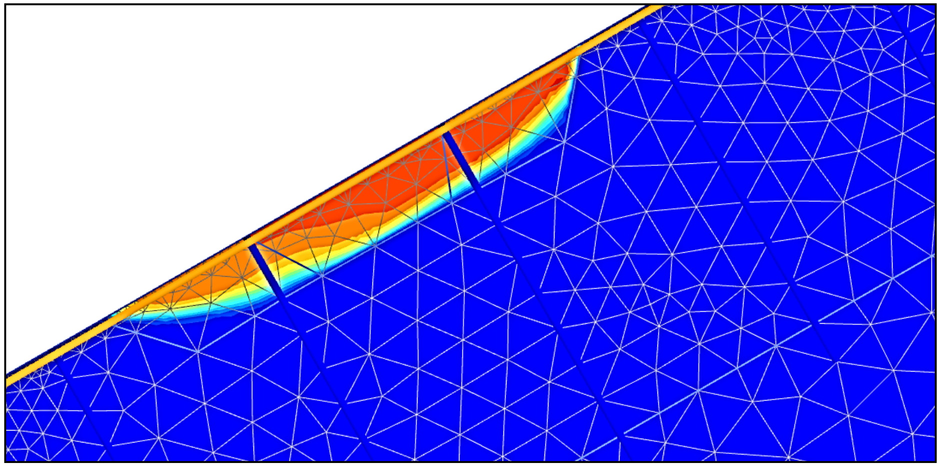


Design Criteria

- Must design for both hydraulic and non-hydraulic stresses
- Resistance to Hydraulic Forces (Velocity & Shear Stress)
- Resistance to Non-Hydraulic Stresses

Non-Hydraulic Stresses

- Heavy Mowing Activity
- Maintenance Loading
- Debris Loading
- Animal Loading
- Ice Flows
- Higher Factors of Safety



Design Life

Determined based on:

- Durability
  - Ultraviolet (UV) Resistance
  - Field Correlation

- Ultimate Tensile Strength

- Non-Hydraulic Stresses
  - Maintenance Loading
  - Debris Loading

Design Life

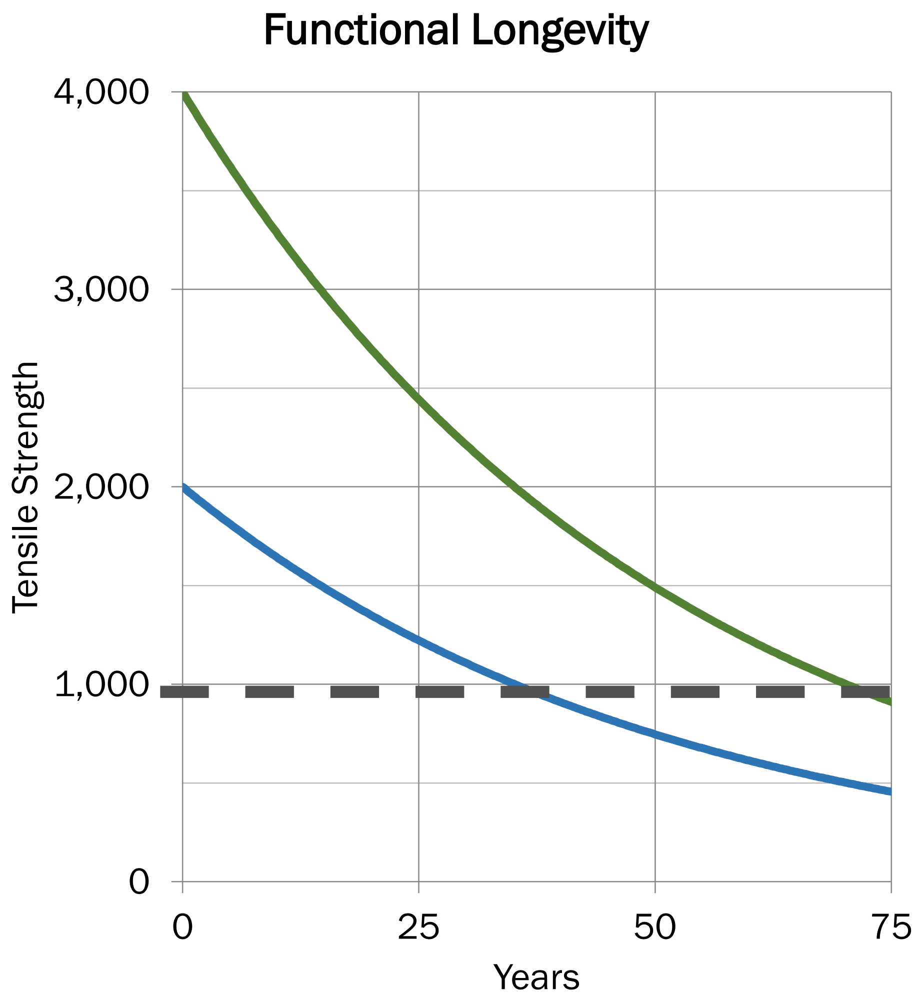
UV Resistance:

- Antioxidants are incorporated to increase stability
- Xenon Arc testing: ASTM D-4355
  - Accelerated exposure
  - Changes in temperature and moisture
  - up to and over 10,000 hours
- Retained Tensile Strength
- Test results must be correlated to field performance

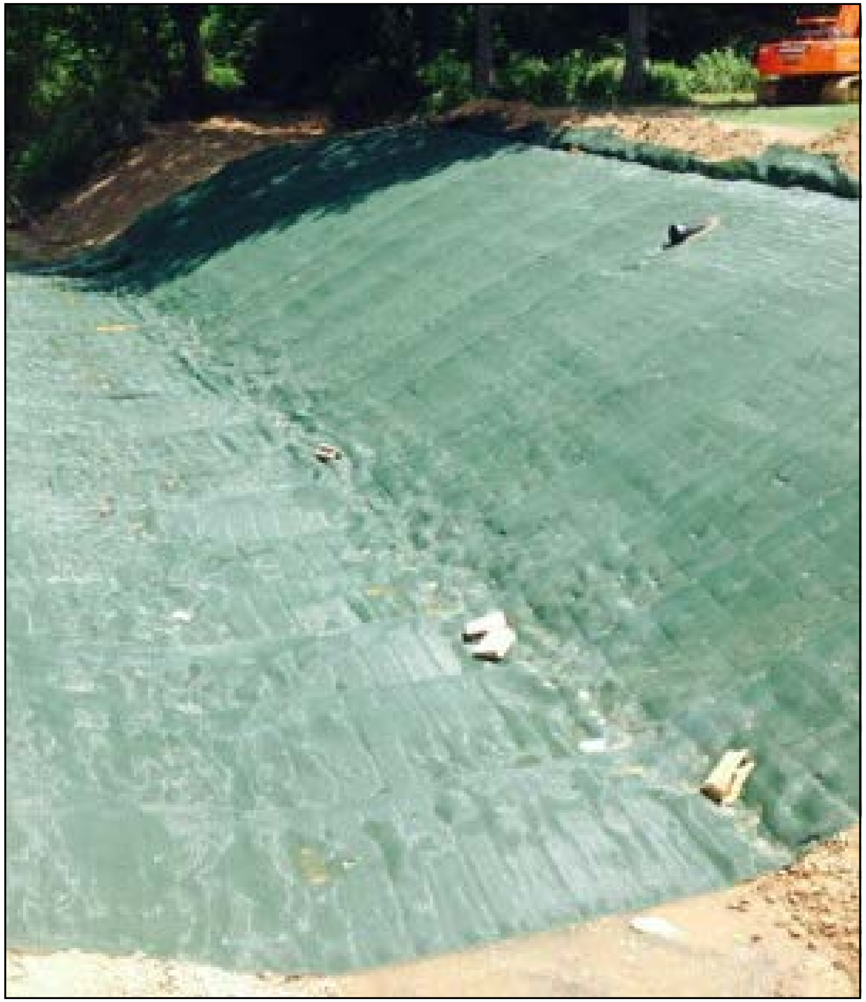
Design Life

Tensile Strength:

- Material will degrade over time based on environmental stresses
- Retained tensile strength at end of design life of 1,000 lb/ft, 14.6 kN/m required
- Initial Tensile Strength is critical to define the functional longevity
    - 4,000 lb/ft, 58.4kN/m up to 75 year design life
    - 2,000 lb/ft, 29.2 kN/m up to 25 year design life

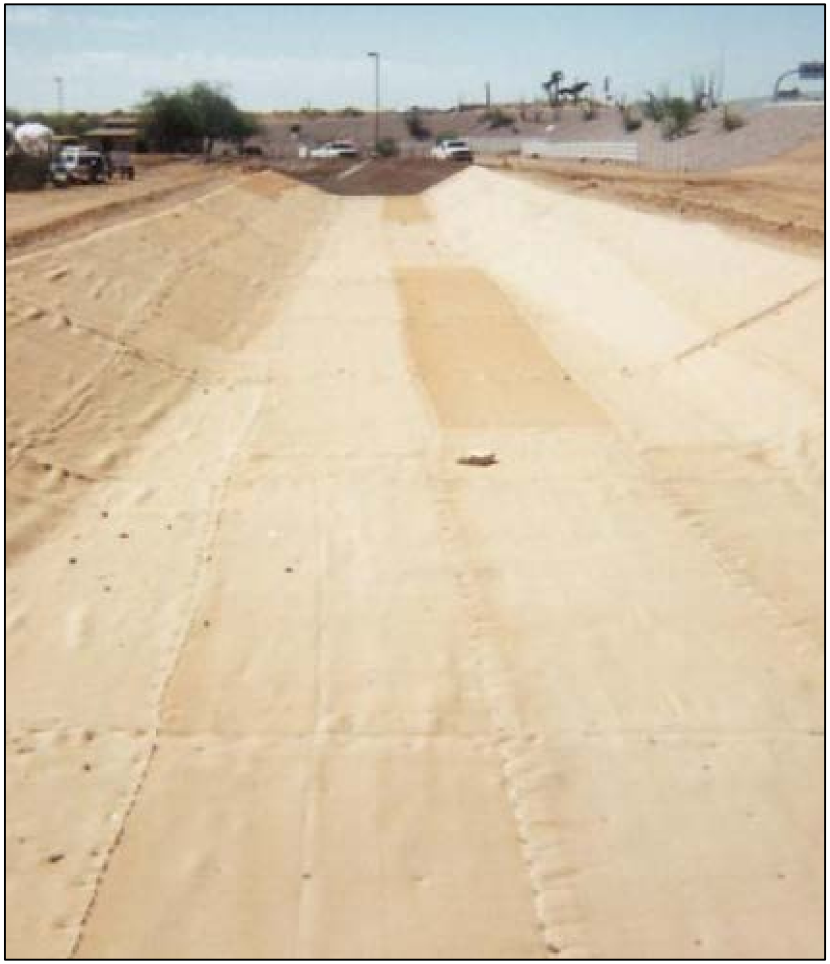


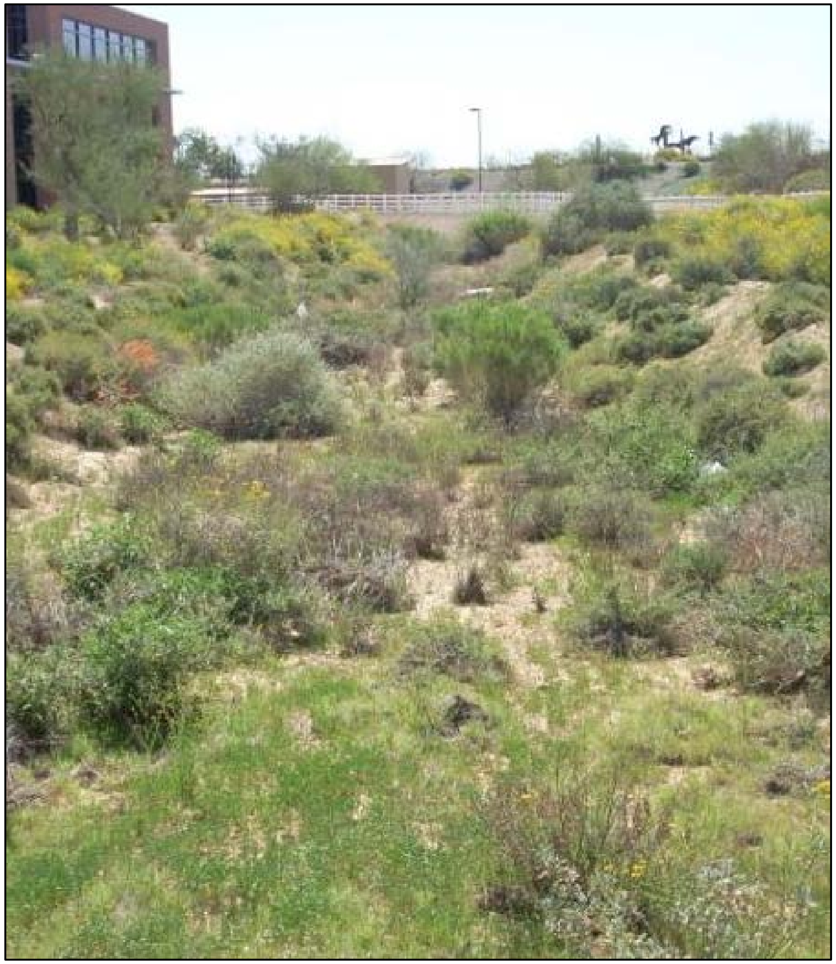
Woven TRM



Woven HPTRM

Woven HPTRM





Engineered Earth Armoring Solution

Composed of:

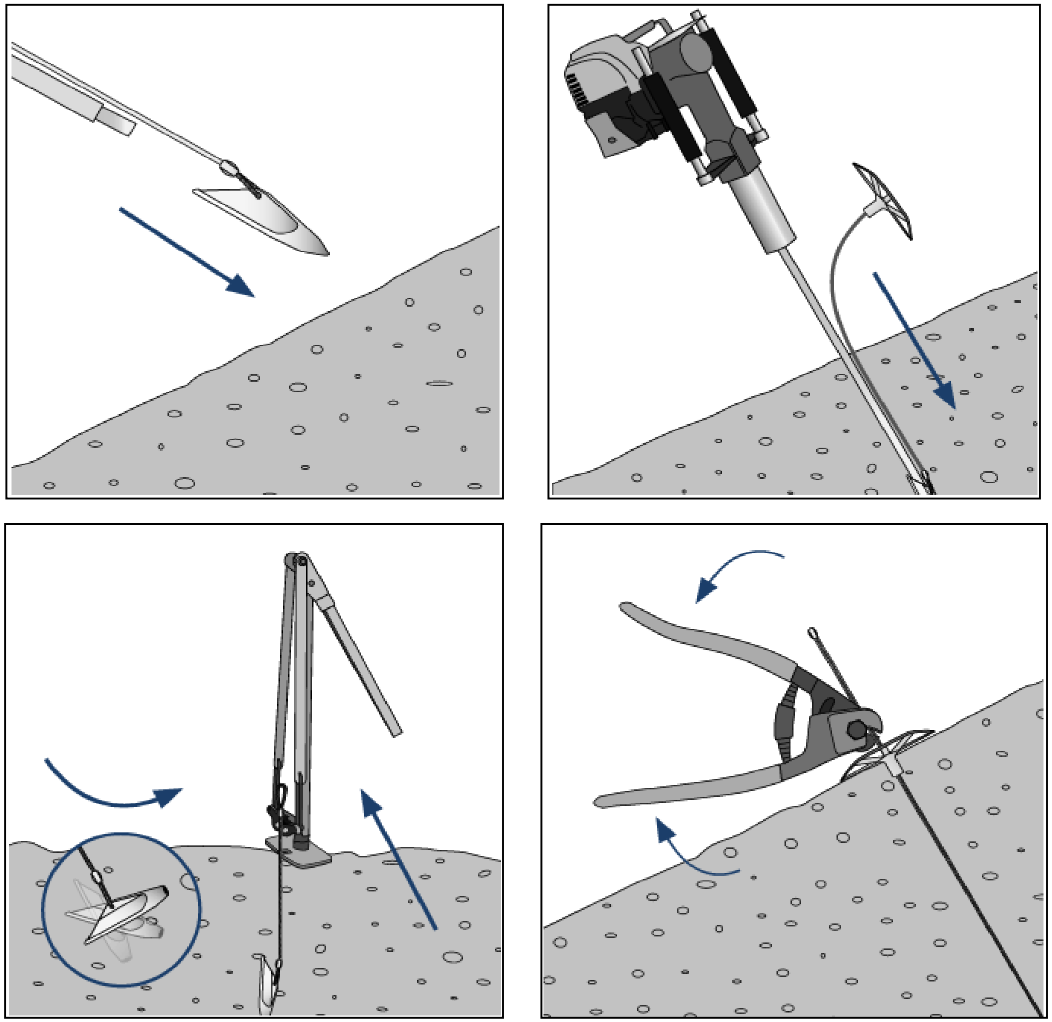
- High Performance Turf Reinforcement Mat (HPTRM)
- Engineered Earth Anchor

Expanded applications:

- Critical Structures
- Wave overtopping
- Shallow Plane Slope Stabilization
- Underwater protection
- Wave run-up
- Higher Factor of Safety

ARMORMAX®

Engineered Earth Armoring Solution



Engineered Earth Armoring Solution

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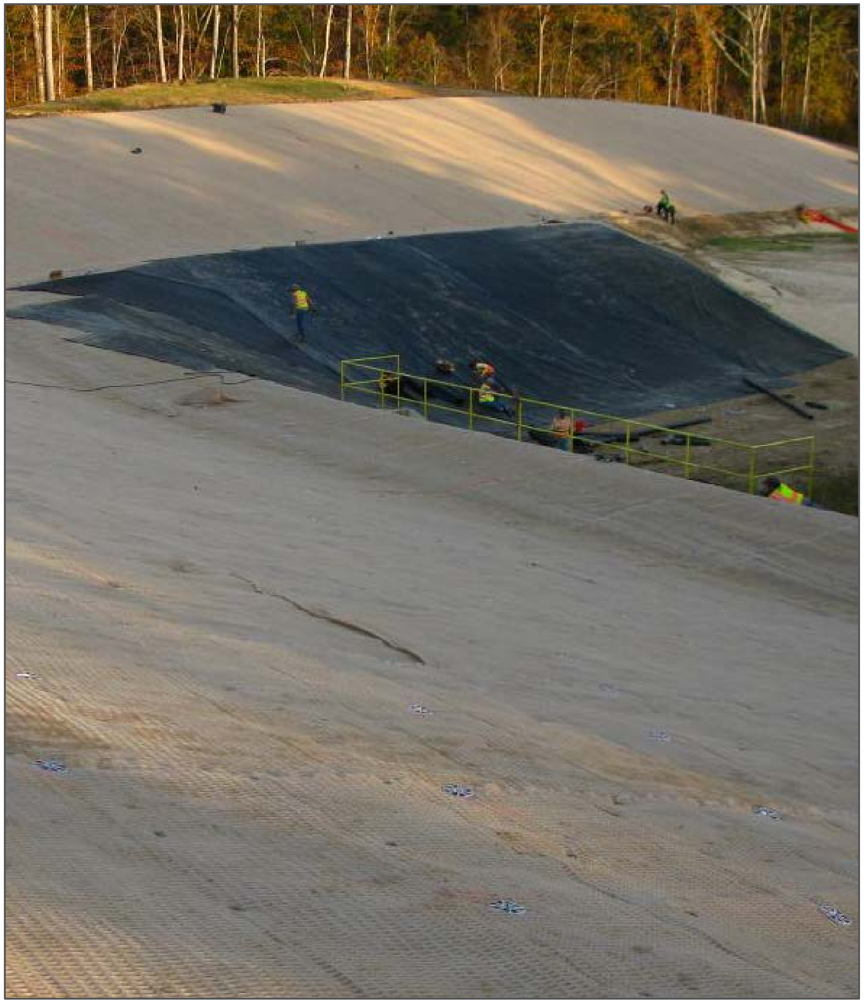
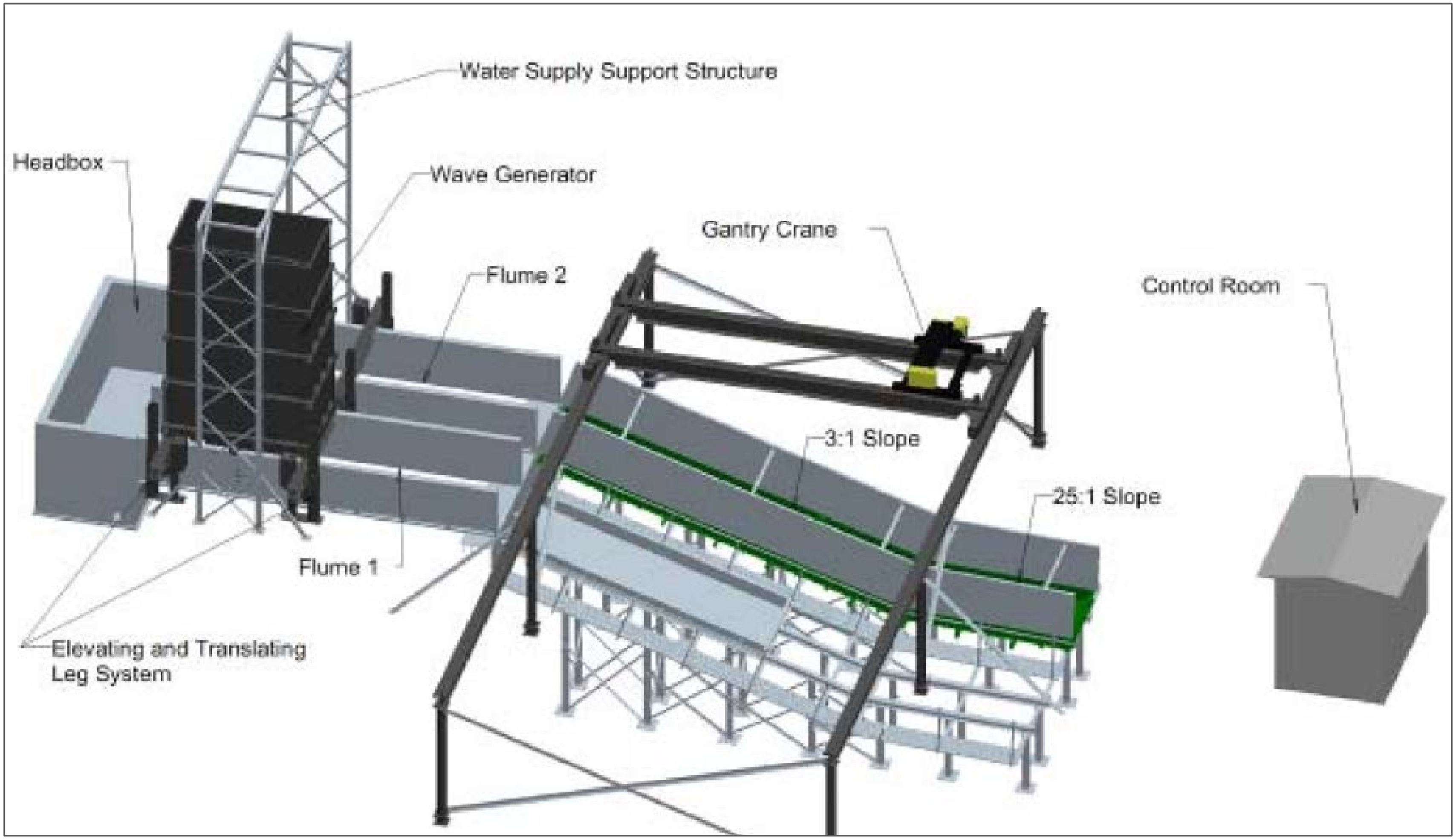


Wave Overtopping R&D



Wave Overtopping R&D

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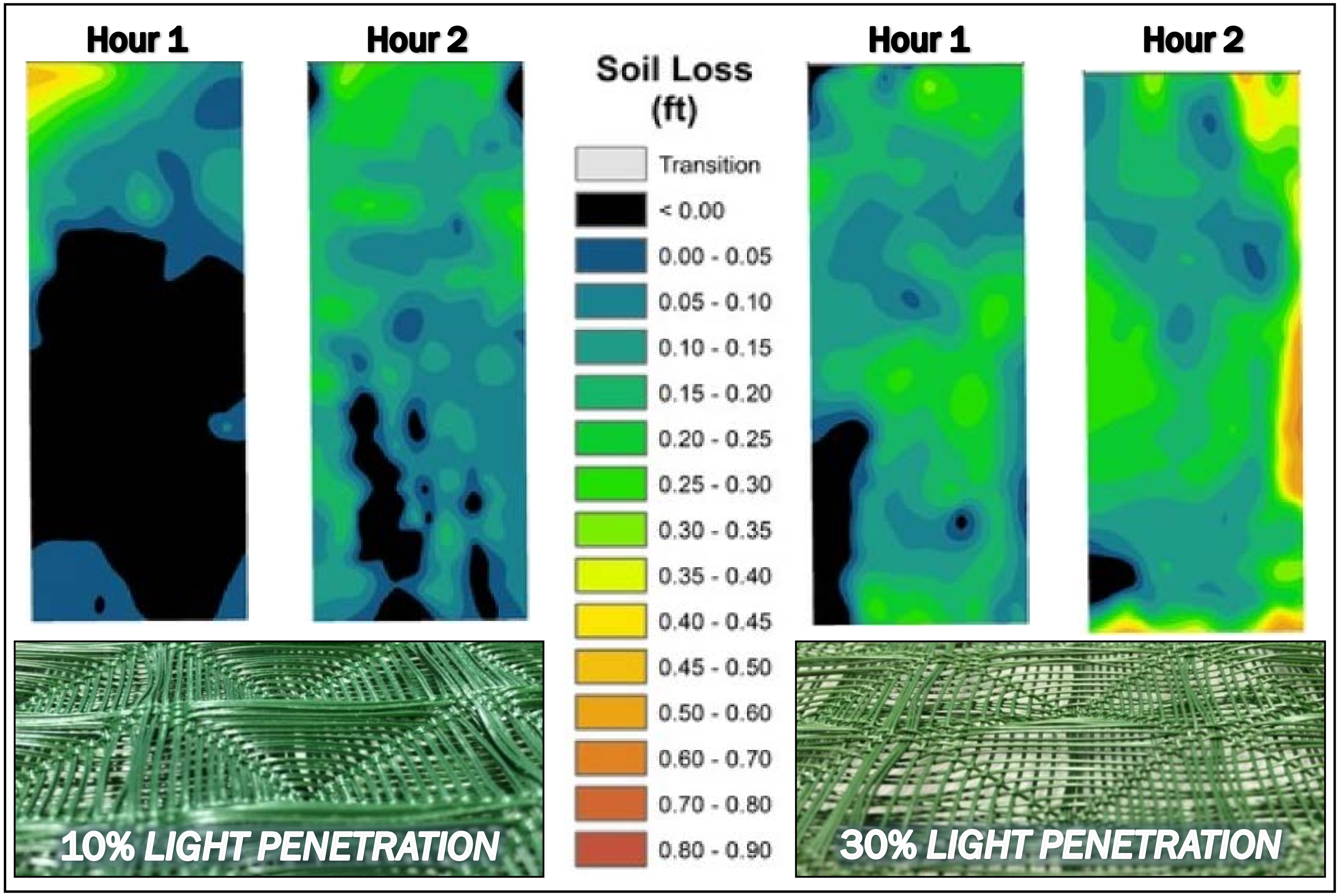
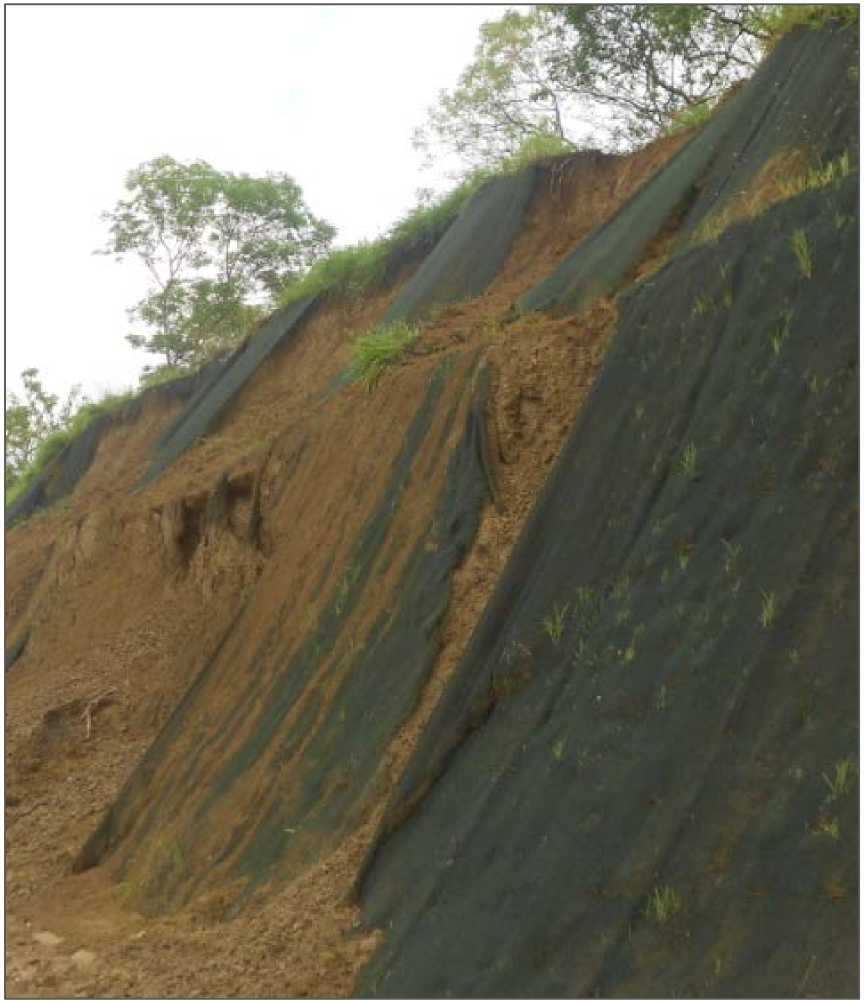
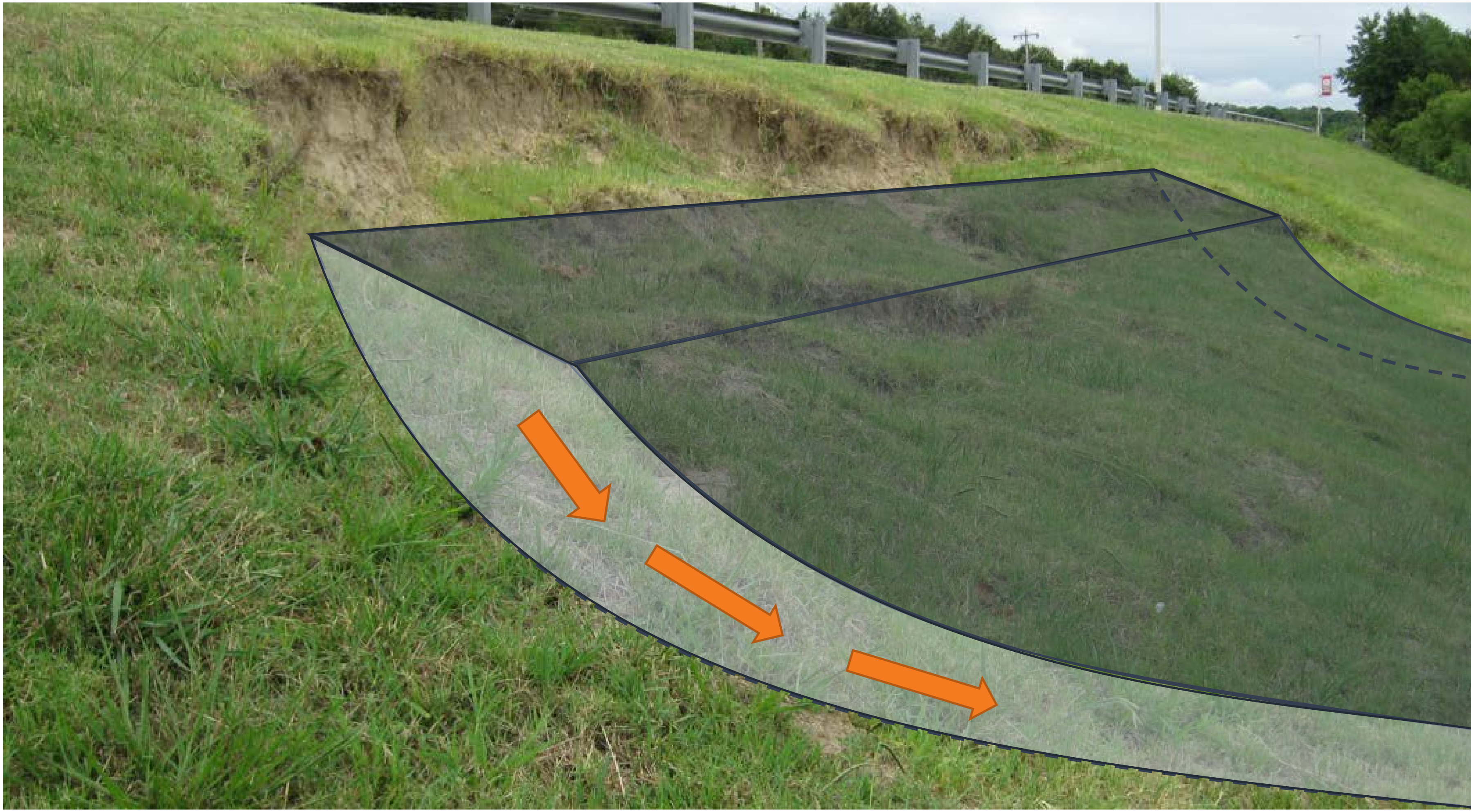


Engineered Earth Armoring Solution

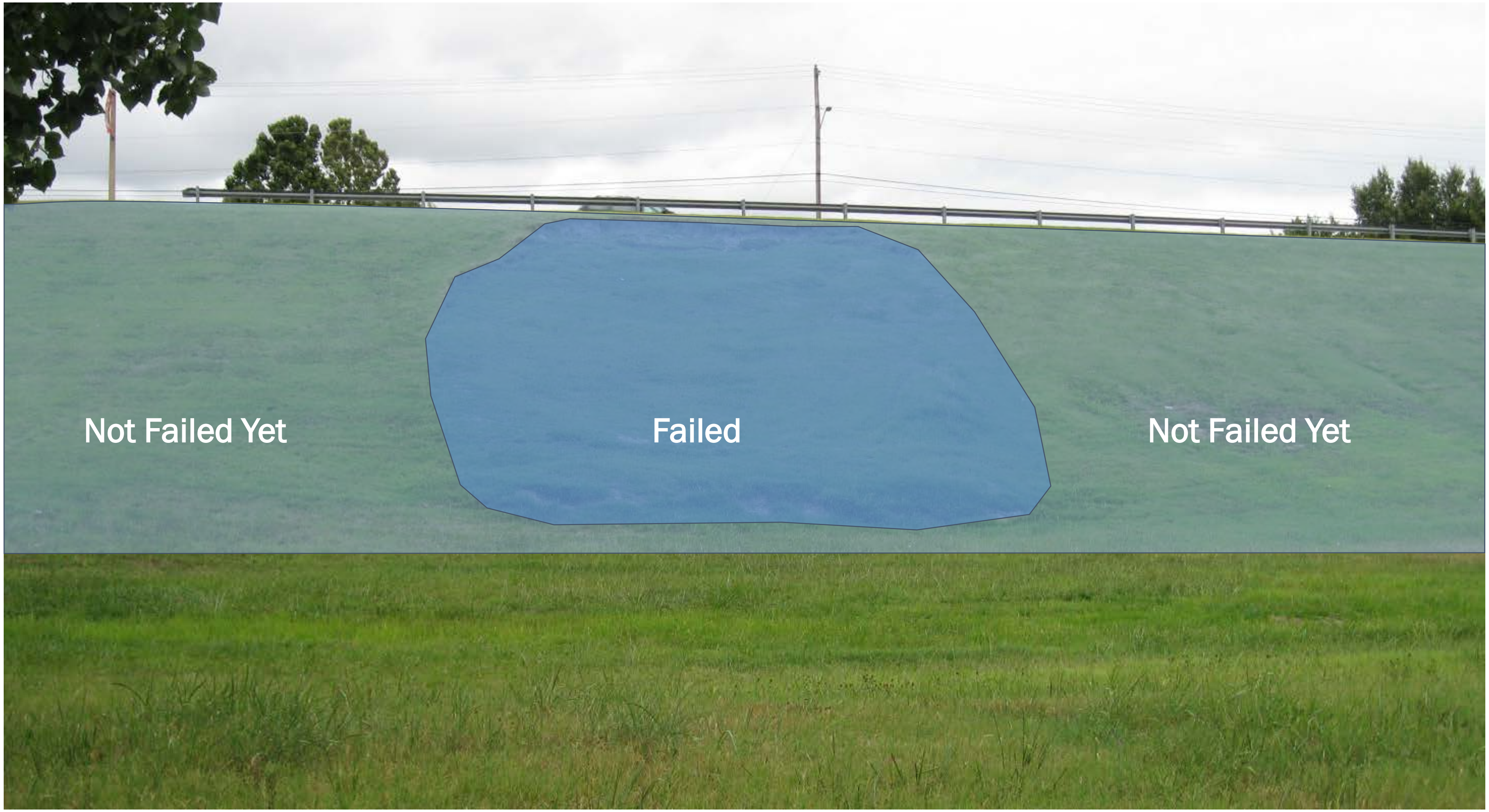
Erosion vs. Slope Instability



Mobilization of a large mass of soil



Soils are dynamic and complex



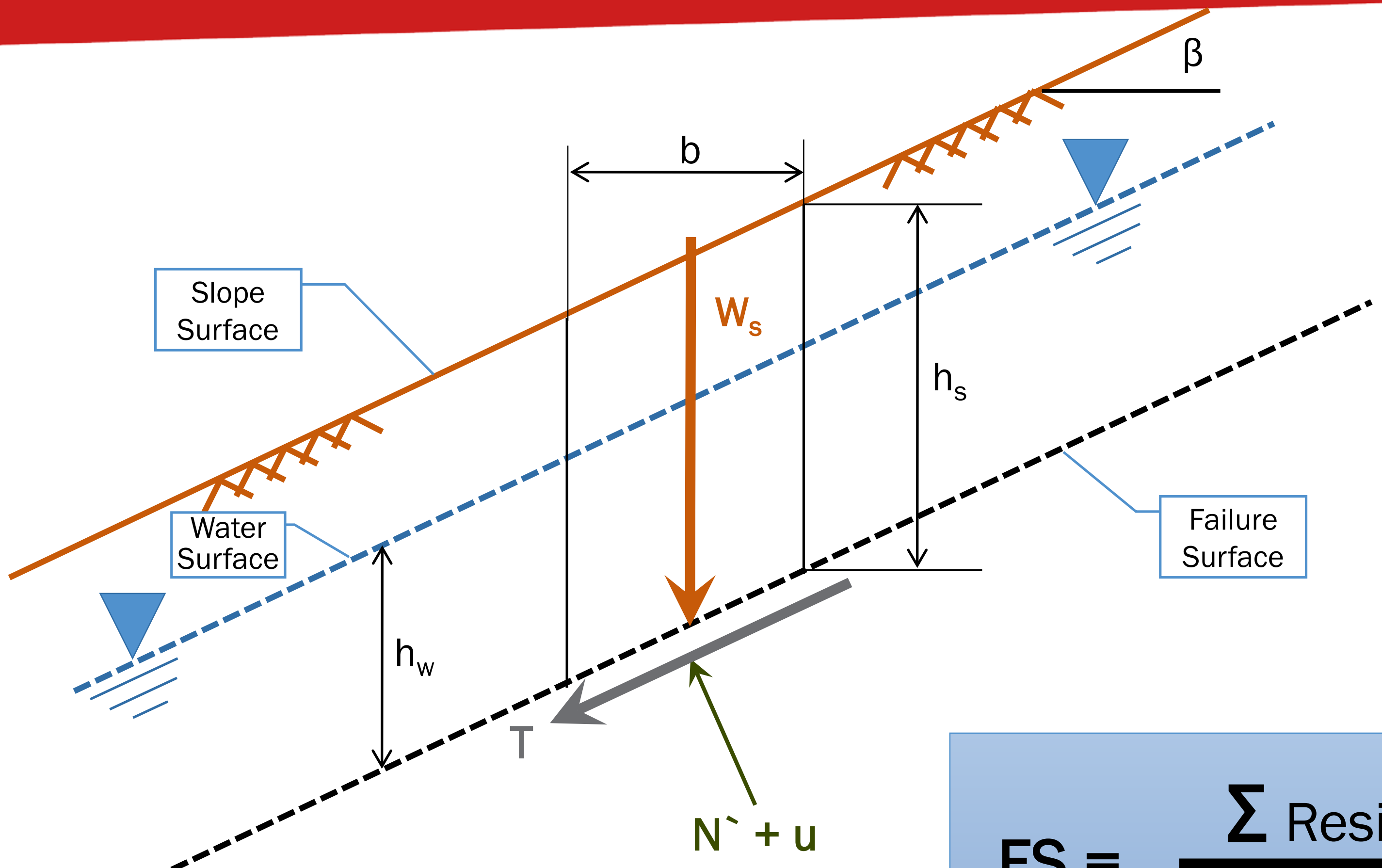
Slopes can easily become unstable

2004 2006 2008 2010 2011 – Severe Flooding 2013 2014 2015 2016

Causes of Slope Instability

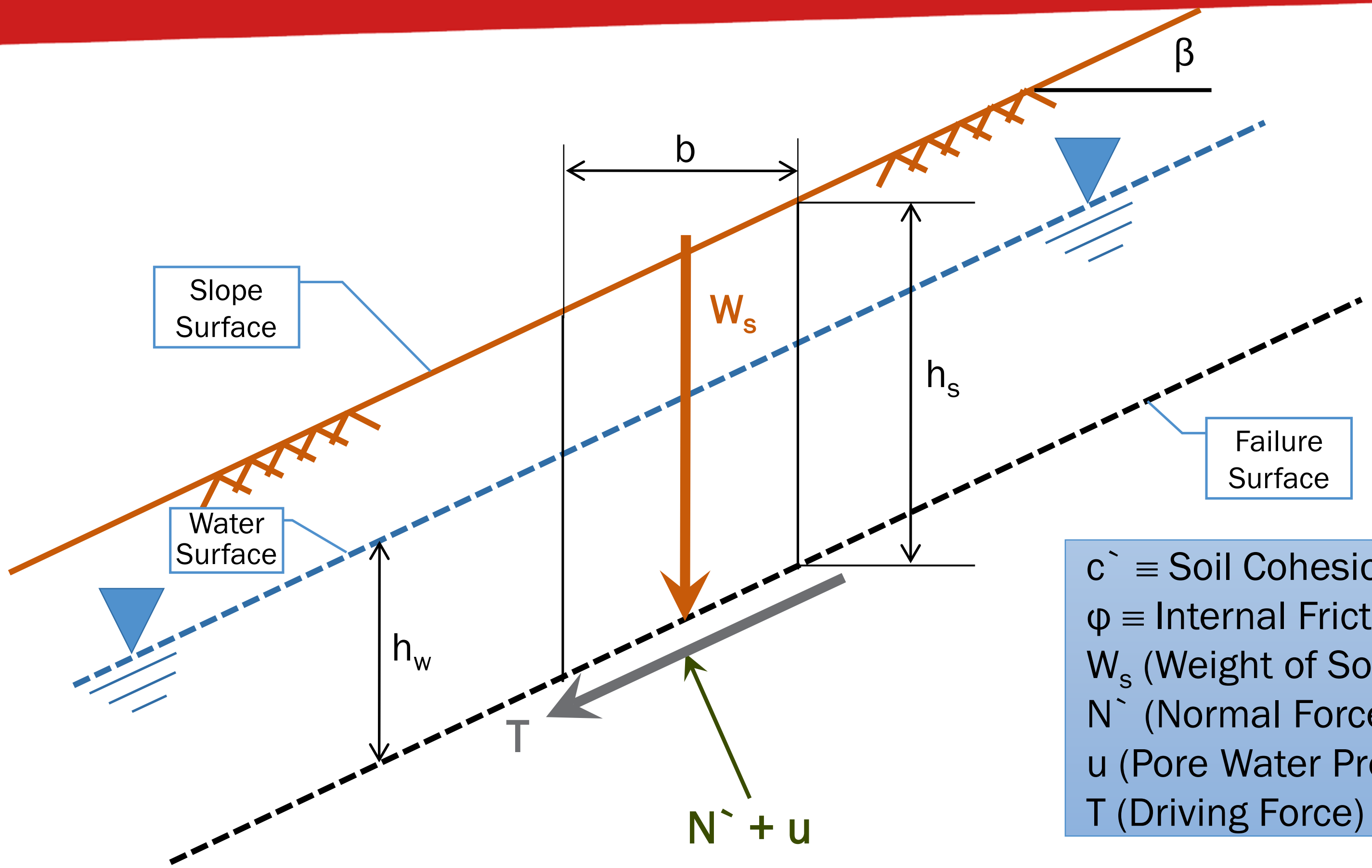
- Increased Shear Stress vs. Decreased Shear Strength
- Over steepening and Removal of Stabilizing Mass
- Increased External Loading
- Seepage Erosion
- Saturation of Soils and Loss of Matric Suction (i.e., the “wet sand castle” effect)
- Dramatic Changes to Pore Water Pressure from Rapid Drawdown
- Vibratory Action
- Tension Cracking

Fundamentals of Slope Stability



$$FS = \frac{\Sigma \text{ Resisting Forces}}{\Sigma \text{ Driving Forces}}$$

Fundamentals of Slope Stability

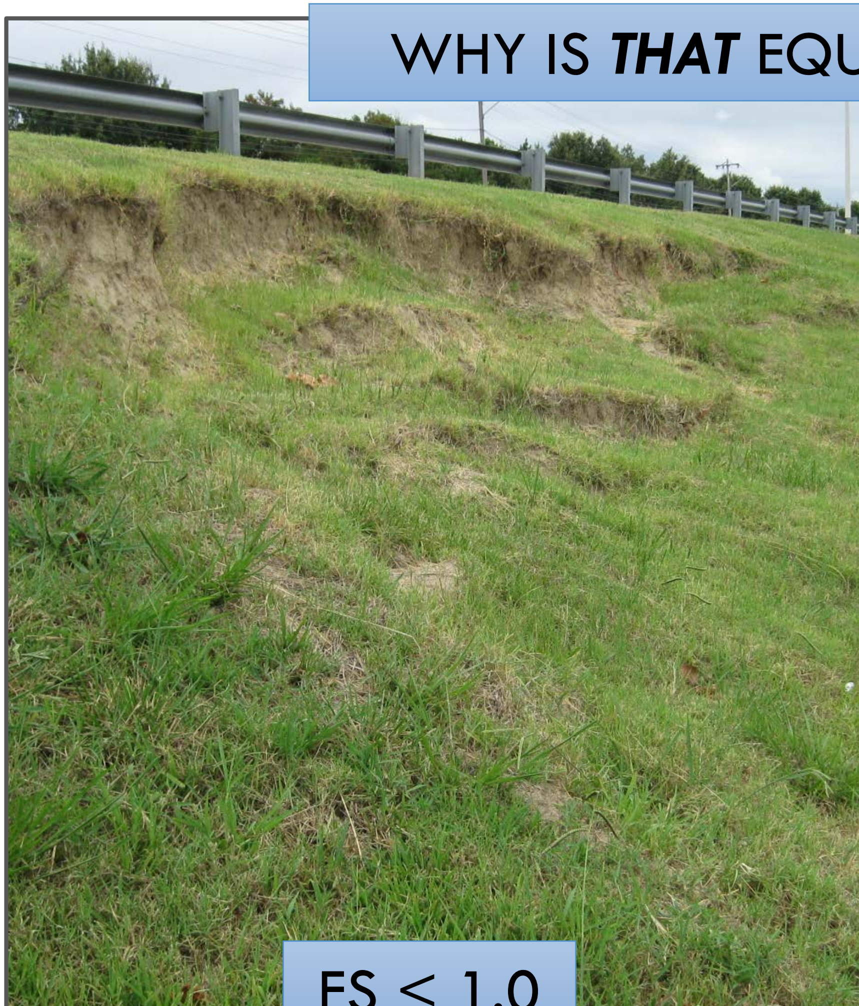


c` ≡ Soil Cohesion
φ ≡ Internal Friction Angle
W_s (Weight of Soil) = $\gamma_s b^2 h$
N` (Normal Force) = $W_s \cos\beta$
u (Pore Water Pressure) = $\gamma_w h \cos\beta$
T (Driving Force) = $W_s \sin\beta$

$$\mathbf{FS} = \frac{c`b\sec\beta + (W_s\cos\beta + \gamma_w h\cos\beta)\tan\phi}{W_s\sin\beta}$$

Fundamentals of Slope Stability

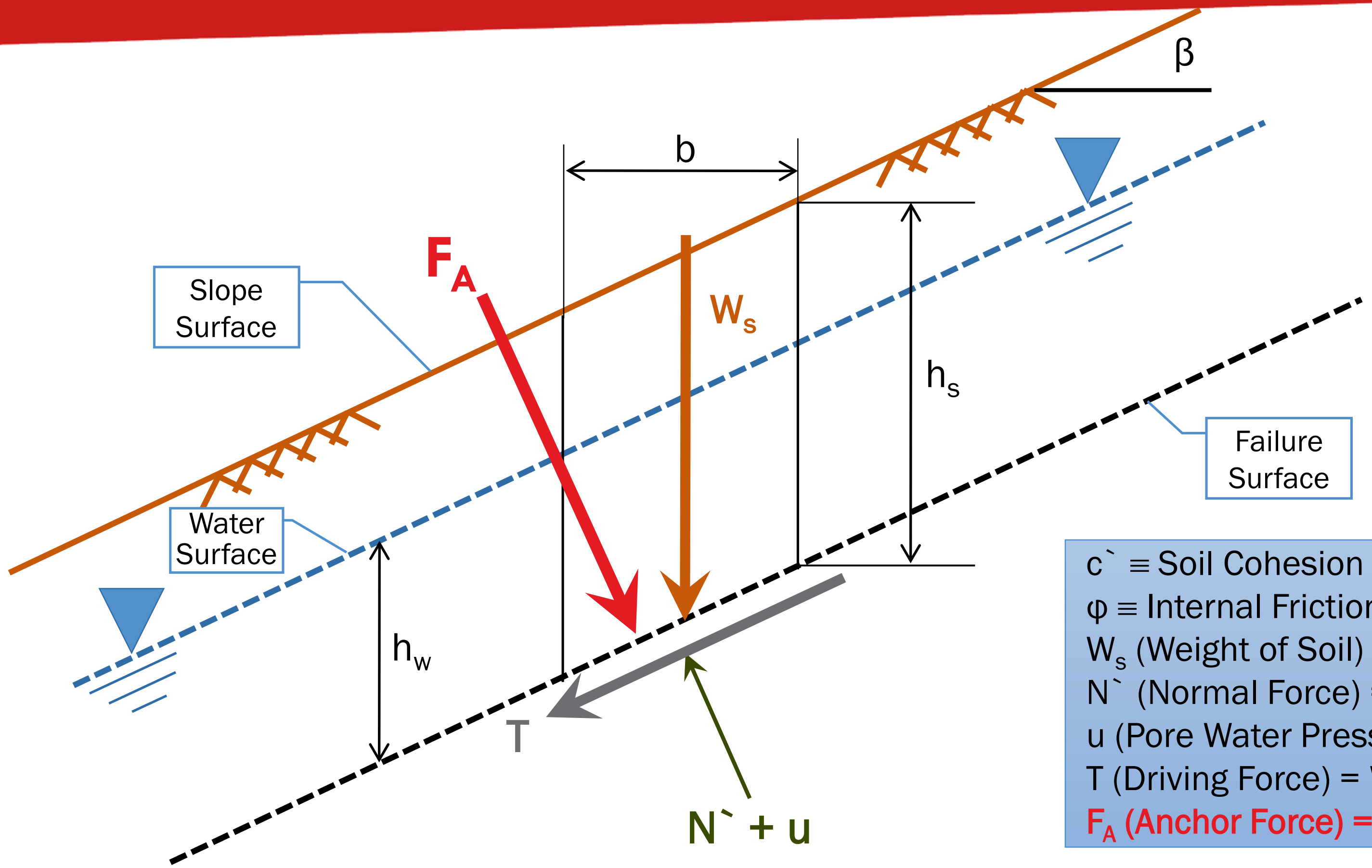
WHY IS ***THAT*** EQUATION IMPORTANT?



FS < 1.0

FS > 1.0

Fundamentals of Slope Stability



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u (Pore Water Pressure) = $\gamma_w h \cos\beta$

T (Driving Force) = $W_s \sin\beta$

F_A (Anchor Force) = (Anchor Pullout) $\cos\beta$

$$FS = \frac{c`\, b \sec\beta + (F_A + W_s \cos\beta + \gamma_w h \cos\beta)\tan\varphi}{W_s \sin\beta}$$

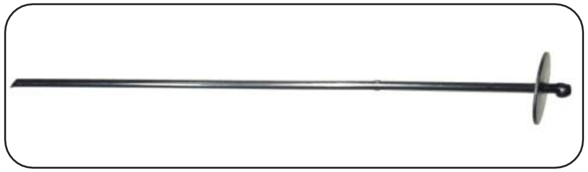
Engineered Earth Armoring Solution

- Flexible/Soft Armoring Solution
- Engineered to resist erosive forces and shallow plane slope instability
- Vegetation provides Environmental and Aesthetic benefits

Engineered Earth Armoring Solution

HPTRM

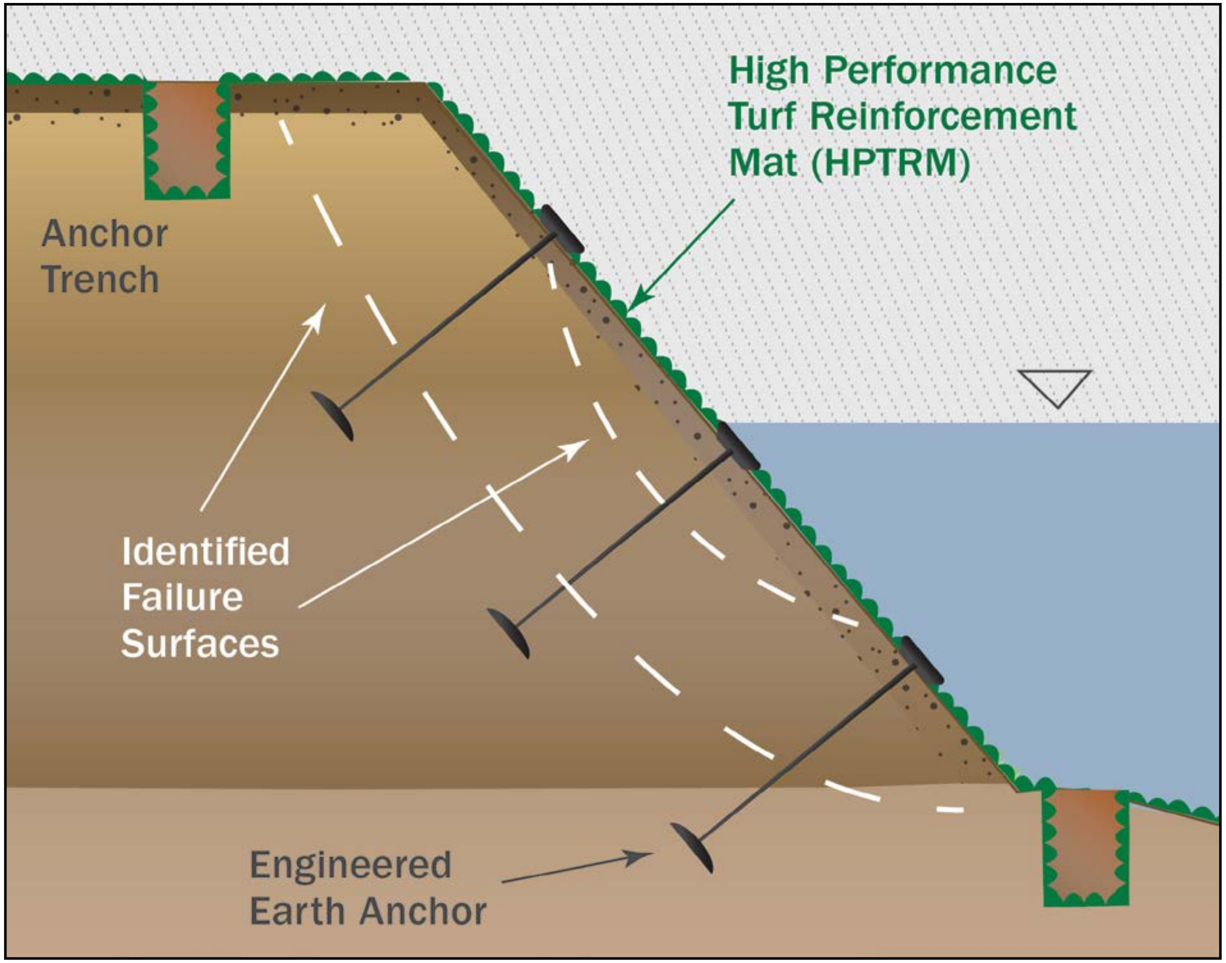
Securing Pins



Engineered Earth Anchor

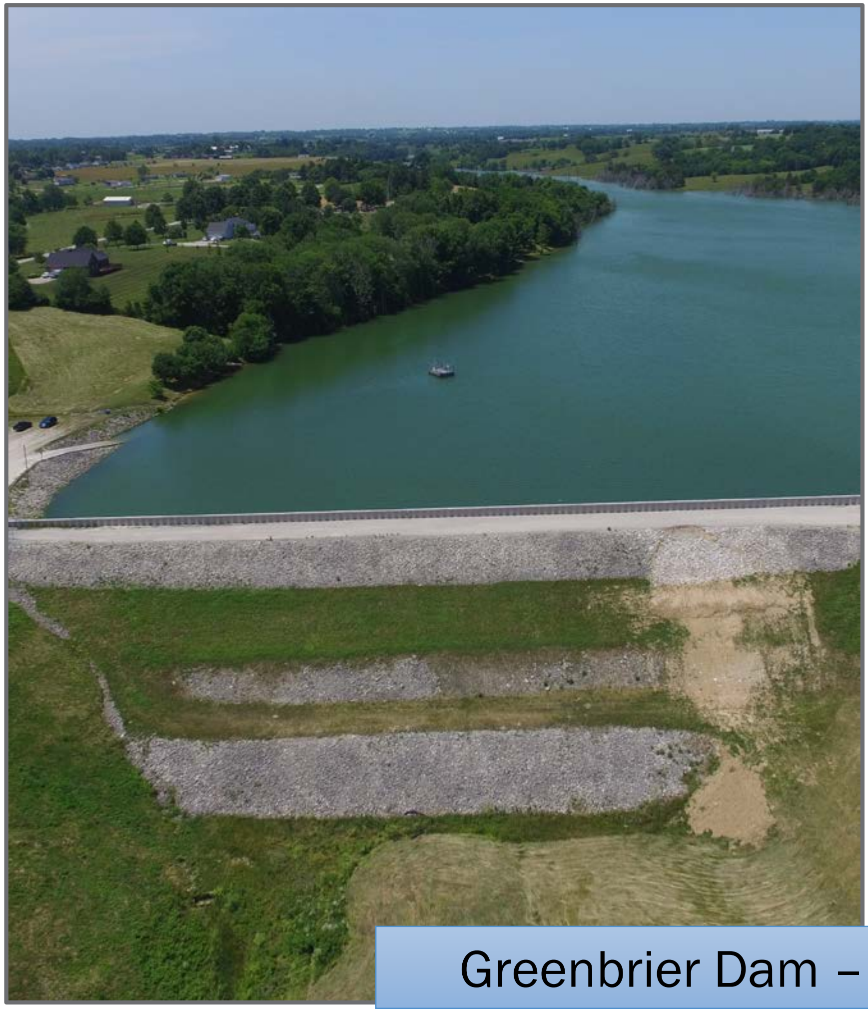
Vegetation

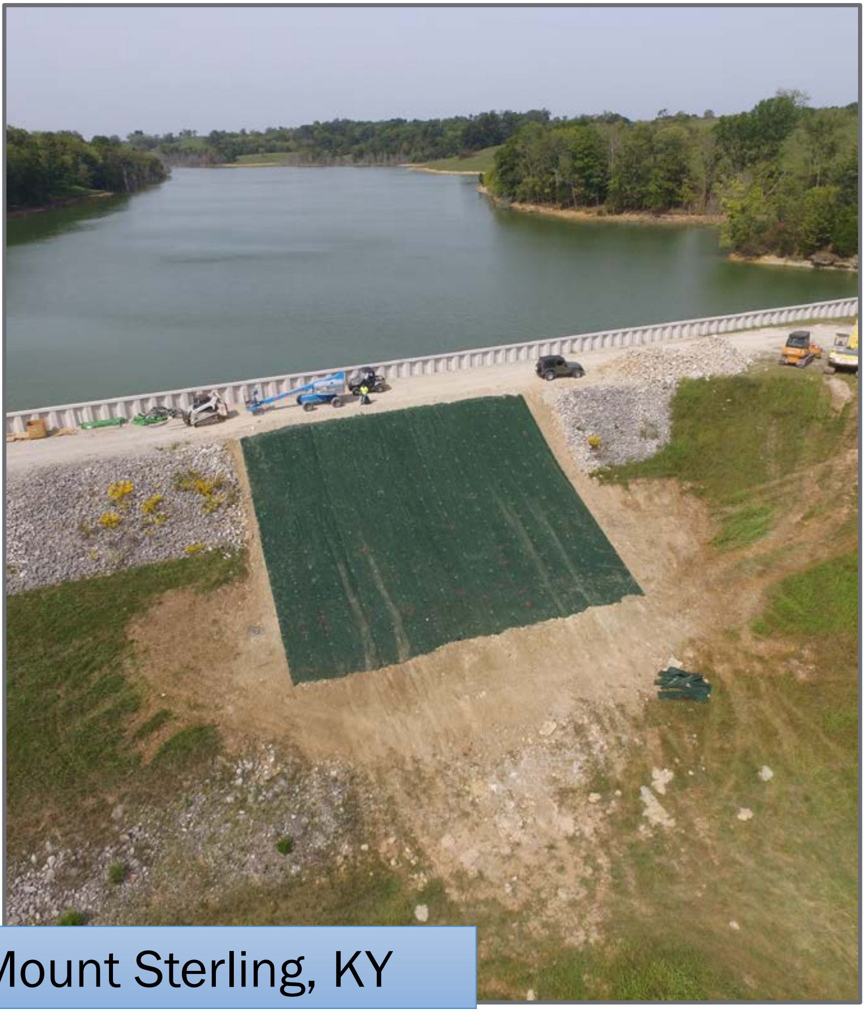
Slope Stabilization



- Engineered Earth Anchors are designed to provide resistance to shear and lateral forces, and embedded beyond the predicted plane of failure
- HPTRM distributes loads amongst anchors while providing a continuous compressive cover
- HPTRM is also permeable for pore pressure relief and promotes vegetative establishment

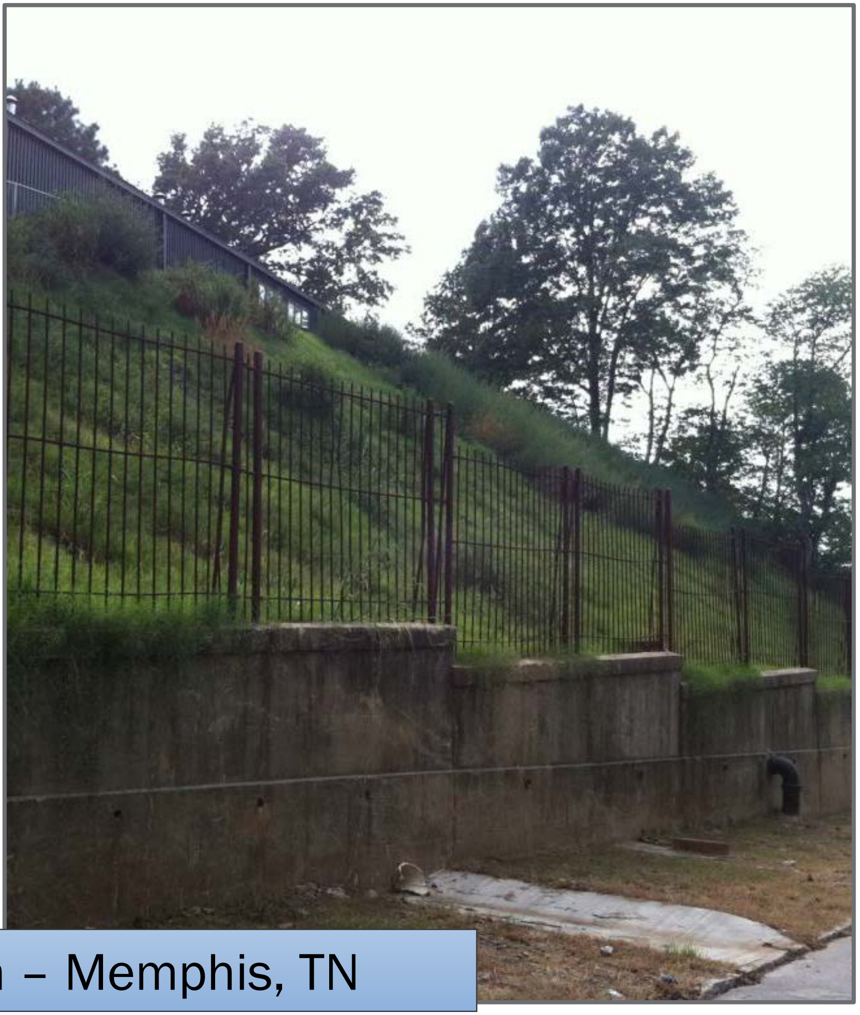
Engineered Earth Armoring Solution





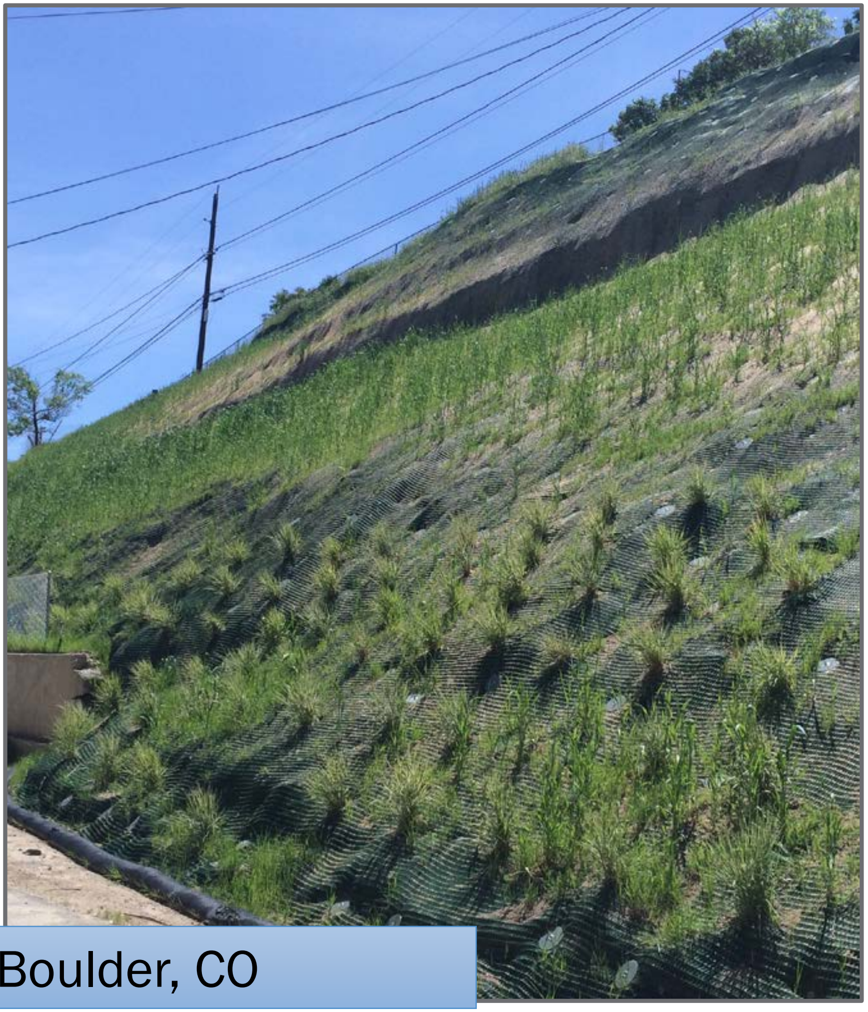
Greenbrier Dam – Mount Sterling, KY

Engineered Earth Armoring Solution



Metal Art Museum – Memphis, TN

Engineered Earth Armoring Solution



MHP Slope – Boulder, CO

Case Studies

West City Ditch Repairs

Application: Channel Slope Stabilization

Client: City of Kissimmee, FL

Designer: TY Lin International

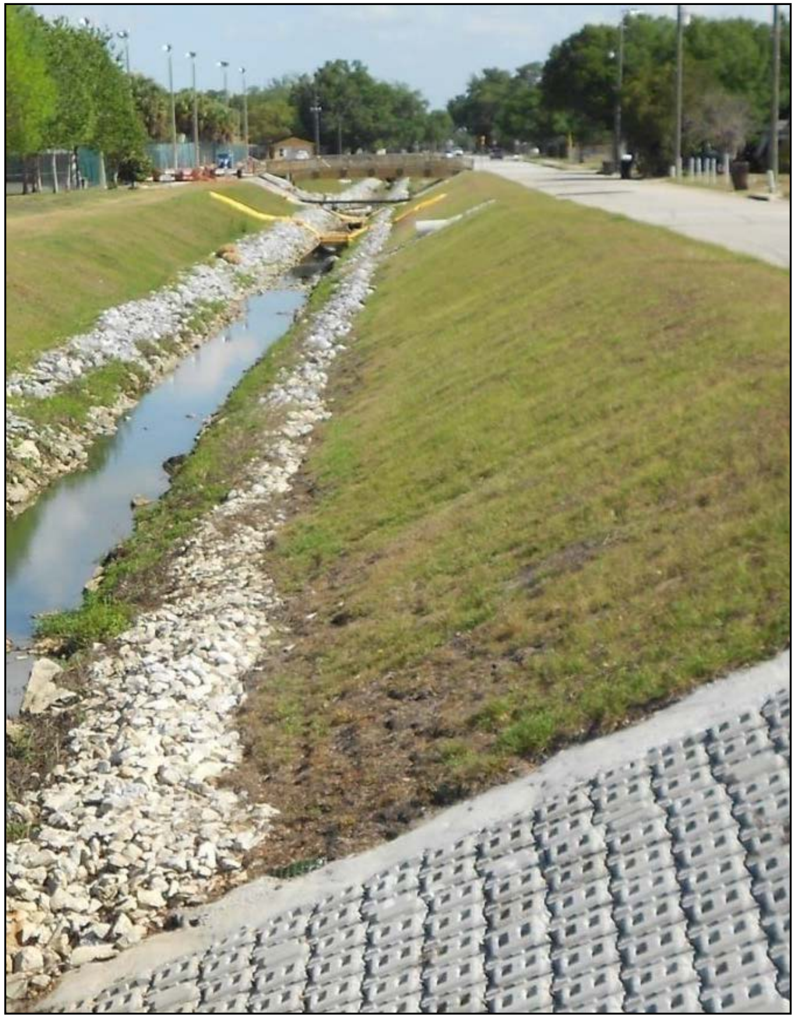
Contractor: Underwater Engineering Services, Inc.

Installed: 2010

Product: ARMORMAX®
6-12’ Type B2 Anchors
0.5 anchors per square yard
0.6 anchors per square meter

Quantity: 20,000 SY
16,700 SM

ARMORMAX®



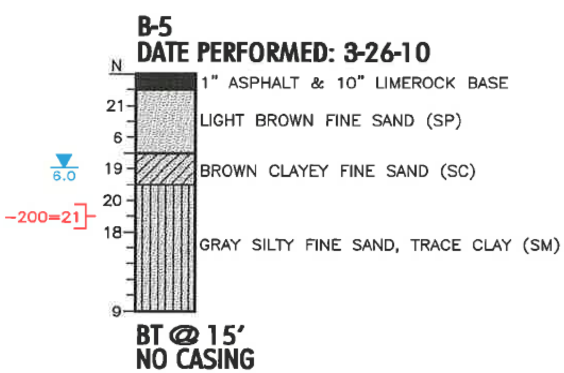
West City Ditch Repairs

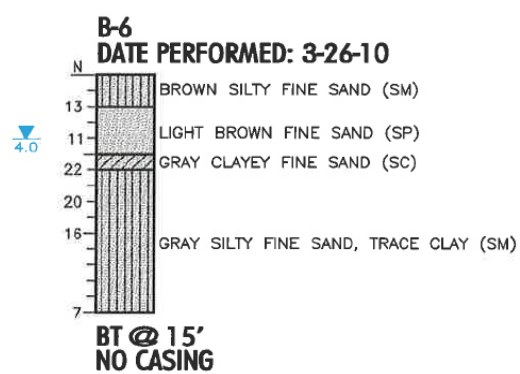
West City Ditch Repairs

STANDARD PENETRATION TEST BORING RESULTS

Table 5
West City Ditch Soil Profile

Average Soil Layer Depth (ft)	Soil Description	Observed "N" Values (bpf)
0 – 7	Very loose to medium dense fine sand (SP) and fine sand with silt (SP-SM) with occasional layers of clayey sand (SC)	3 – 23
7 – 15	Loose to medium dense silty fine sand (SM) with layers of clayey sand (SC)	6 – 22





SPT Boring Summary

- Soils encountered consist of fine sand, silty fine sand, and clayey fine sand to a depth of 15'
- Blow counts ranged from 3 to 23, with most above 10 (and categorized as medium dense sand)
- Groundwater encountered between 4-7 feet

West City Ditch Repairs

Table 1. Summary of Material Properties Used in Slope Stability Analysis

Soil	Moist Soil Unit Weight (pcf)	Saturated Soil Unit Weight (pcf)	Friction Angle (degrees)
Loose Sand[1]	110	115	30
Medium Dense Sand[1]	115	120	32
Riprap[2]	130	130	40

Table 2. Summary of Slope Stability Analysis Results (without anchor system)

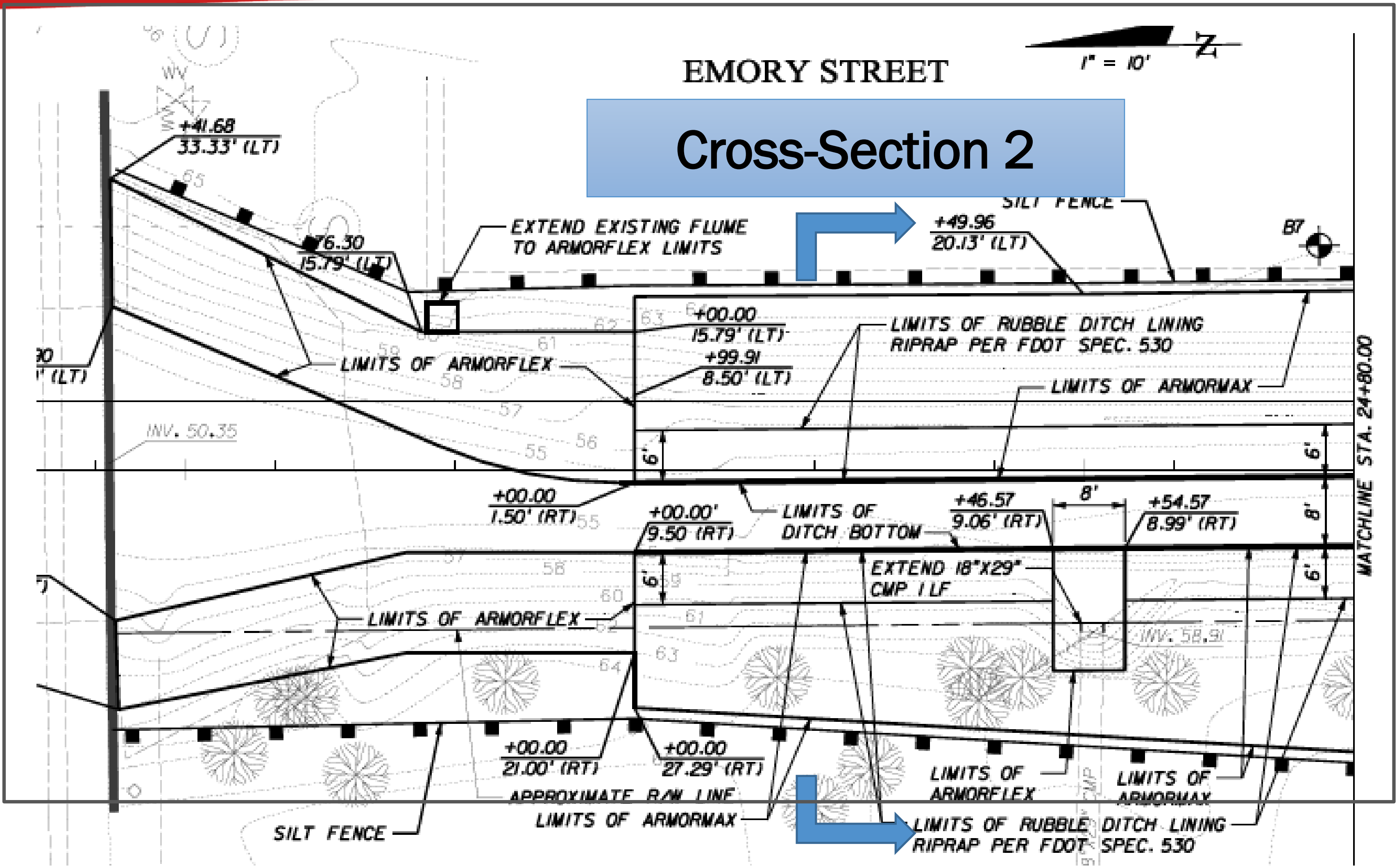
Cross Section	Side Slope[1]	Long-term Normal Condition[2]			Rapid Drawdown Condition		
		Calculated FS	Target FS	Is FS OK?	Calculated FS	Target FS	Is FS OK?
1	Left Slope	1.2	1.5	No	0.4	1.1	No
	Right Slope	1.2	1.5	No	0.4	1.1	No
2	Left Slope	1.2	1.5	No	0.4	1.1	No
	Right Slope	1.2	1.5	No	0.4	1.1	No
3	Left Slope	1.1	1.5	No	0.4	1.1	No
	Right Slope	0.4	1.5	No	0.2	1.1	No
4	Left Slope	1.2	1.5	No	0.4	1.1	No
	Right Slope	0.9	1.5	No	0.3	1.1	No
5[3]	Left Slope	1.1	1.5	No	0.4	1.1	No
6[4]	Right Slope	1.1	1.5	No	0.4	1.1	No

Slope Stability Analysis:

Material Properties and Existing Conditions Results

- Separate unit weights and φ angles designated using SPT results
- Water table considered in unit weights and rapid drawdown conditions
- Six cross sections analyzed, none met minimum FS values without reinforcement

West City Ditch Repairs



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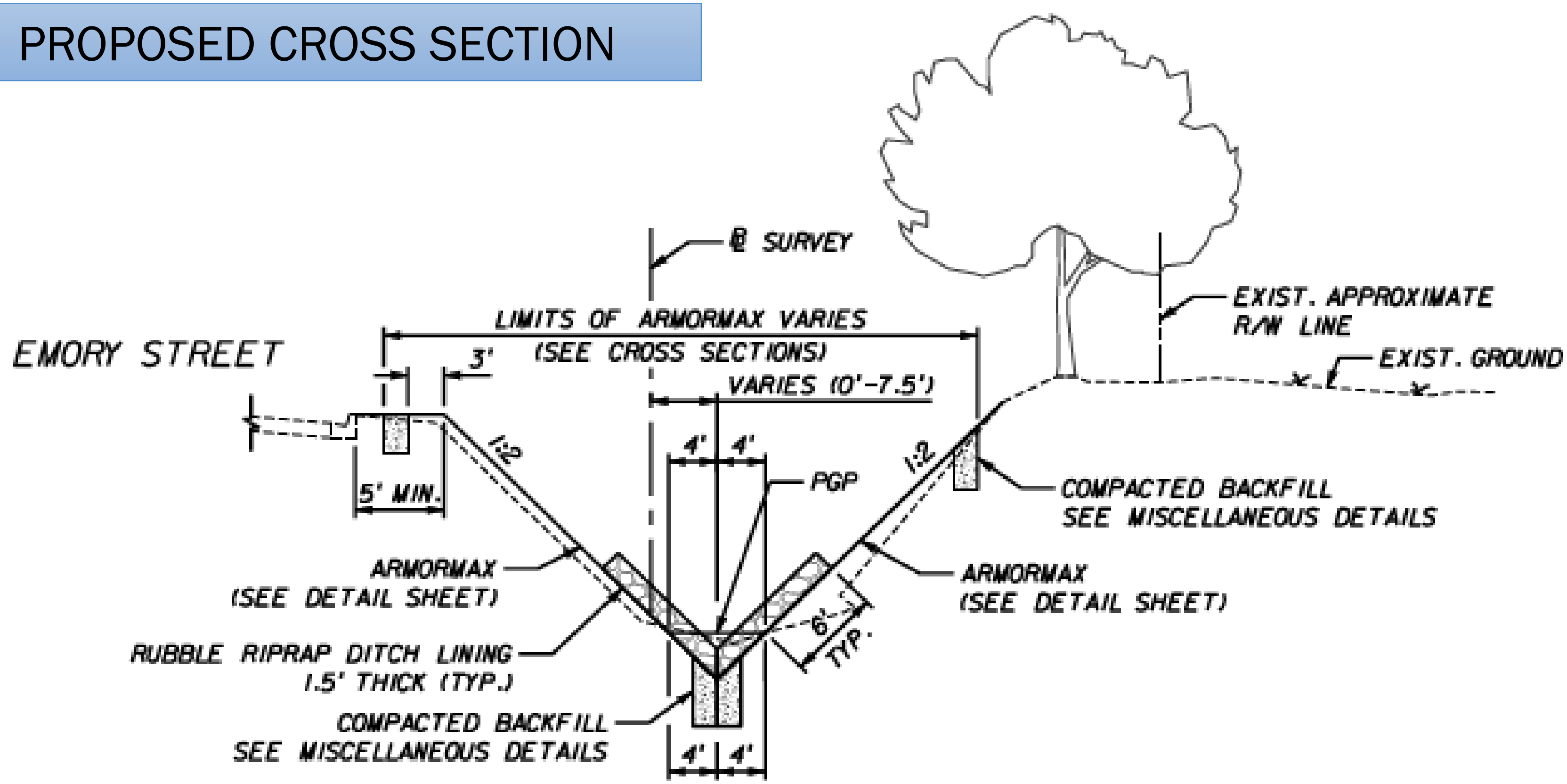
PROPOSED CROSS SECTION

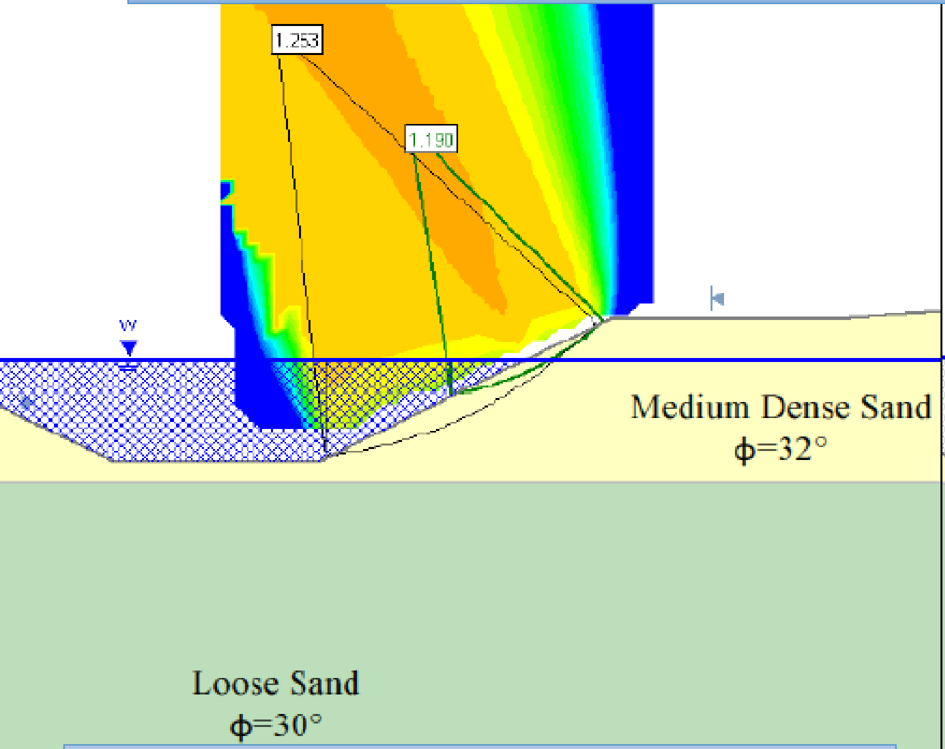


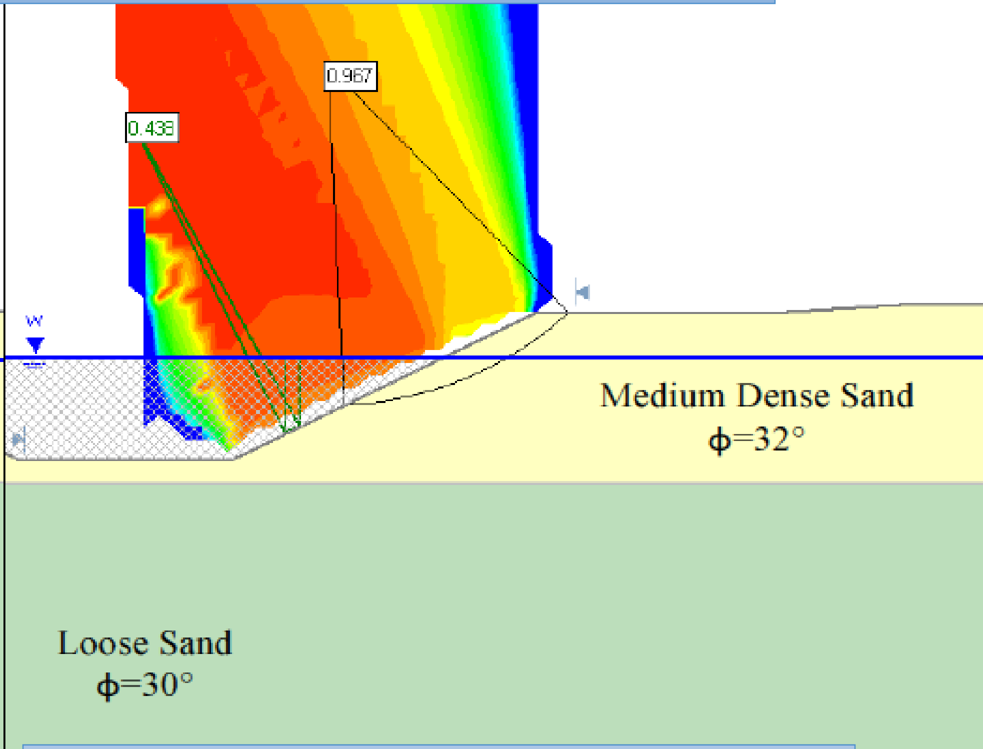
ARMORMAX® was proposed for the channel lining,

but how were the slopes stabilized?

West City Ditch Repairs

SLOPE STABILITY ANALYSIS – CROSS SECTION 2





Long-Term Normal Condition
No Reinforcement
Calculated FS = 1.2
Minimum Acceptable FS = 1.5

Rapid Drawdown Condition
No Reinforcement
Calculated FS = 0.4
Minimum Acceptable FS = 1.1

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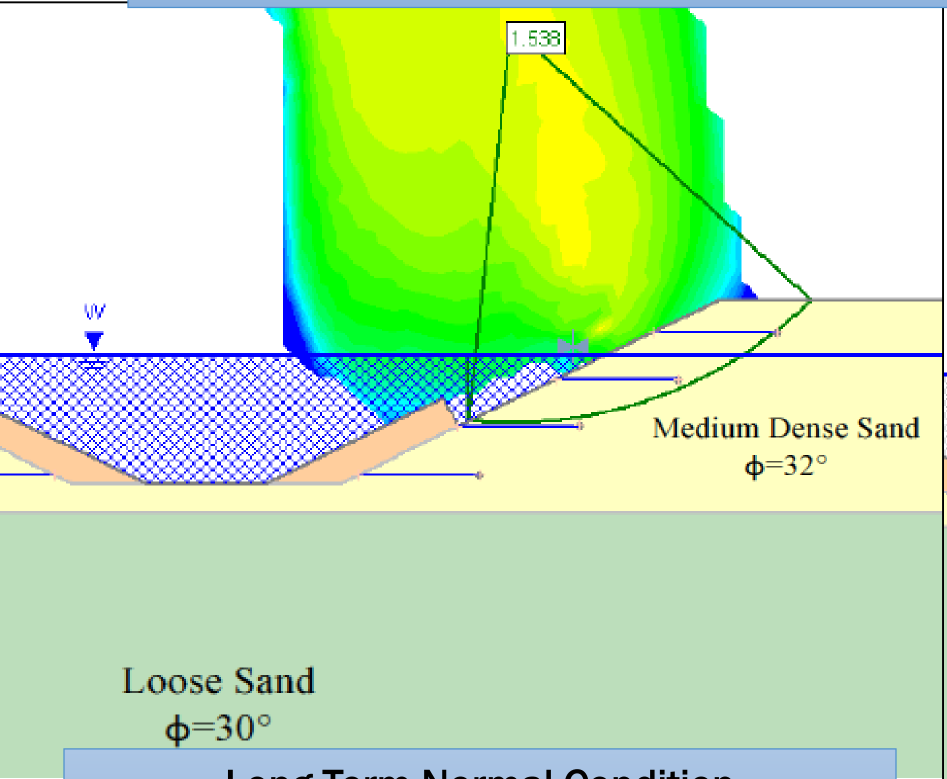
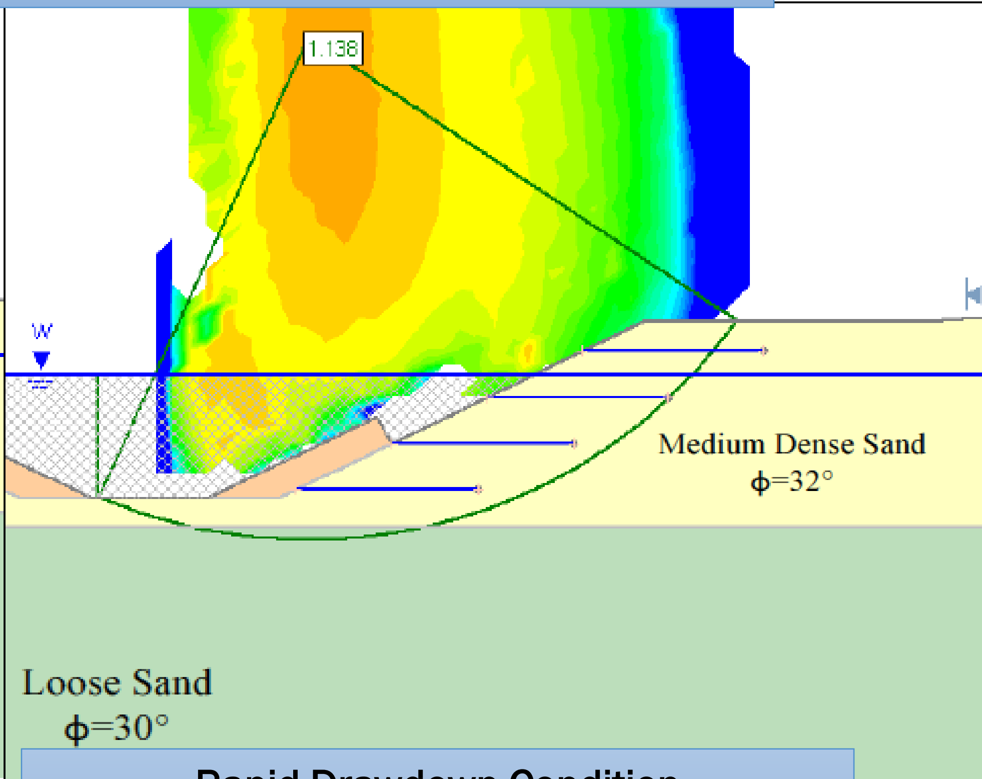
SLOPE STABILITY ANALYSIS – CROSS SECTION 2



Long-Term Normal Condition
5.5’ Anchor (850 lb.)
Calculated FS = **1.5**
Minimum Acceptable FS = 1.5



Rapid Drawdown Condition
8.5’ Anchor (850 lb.)
Calculated FS = **1.1**
Minimum Acceptable FS = 1.1

West City Ditch Repairs

ARMORMAX® SELECTED INSTALLATION DETAILS

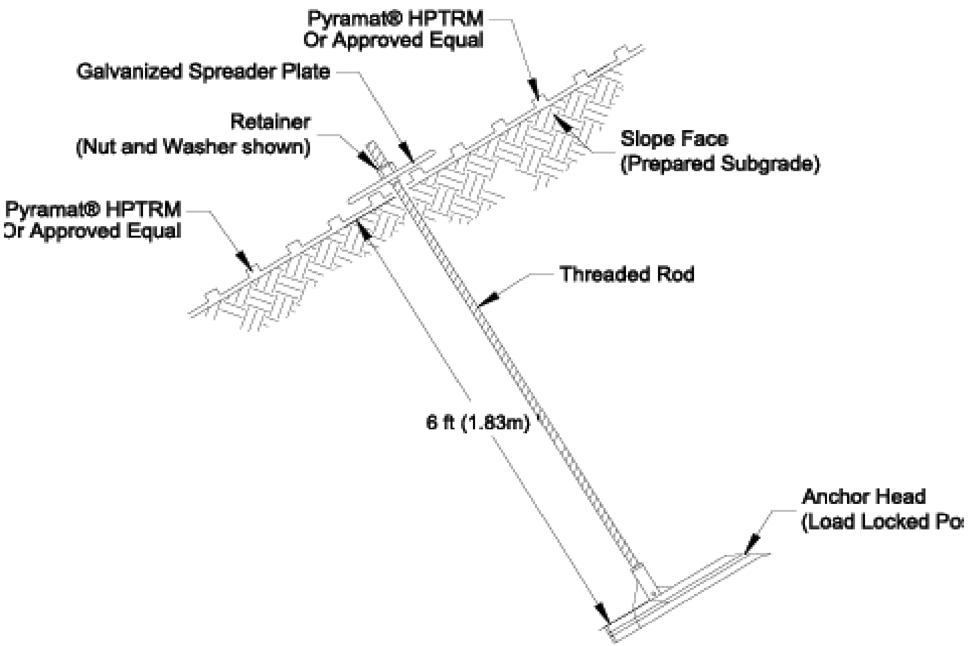


FIGURE 10B: SLOPE ANCHOR, TYPE B2 DETAIL

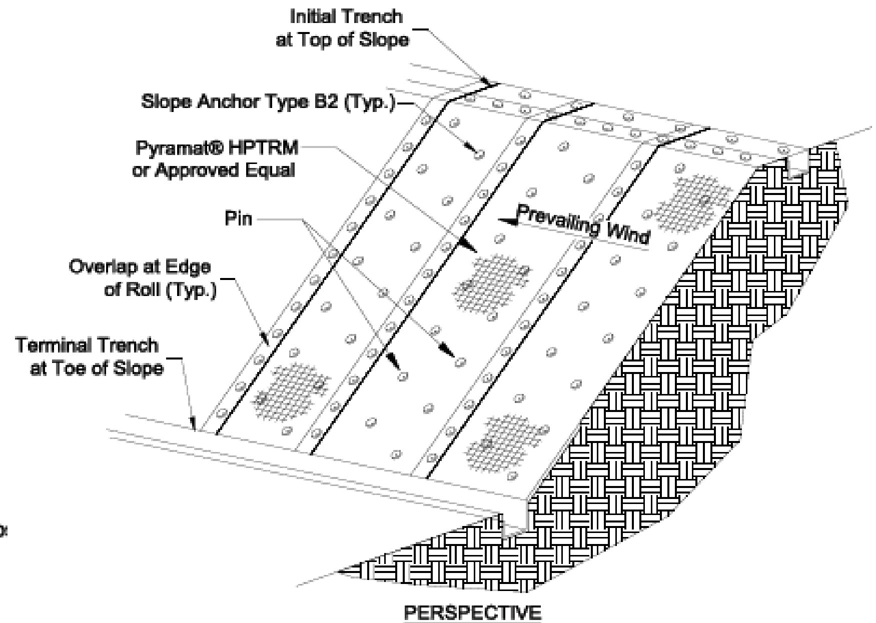


FIGURE 1: OVERVIEW OF ARMORMAX® SYSTEM ON SLOPE

*Note: For Clarity, Perspective View does not show all pins and anchors.

Specified "B-2"
Engineered Earth Anchor
Length varies per section
Size selected to meet pull-out requirement.

Slope Face
Installation Detail
HPTRM panels shingled downslope
Anchor trenches at top and toe of slope

West City Ditch Repairs

ARMORMAX® SELECTED INSTALLATION DETAILS

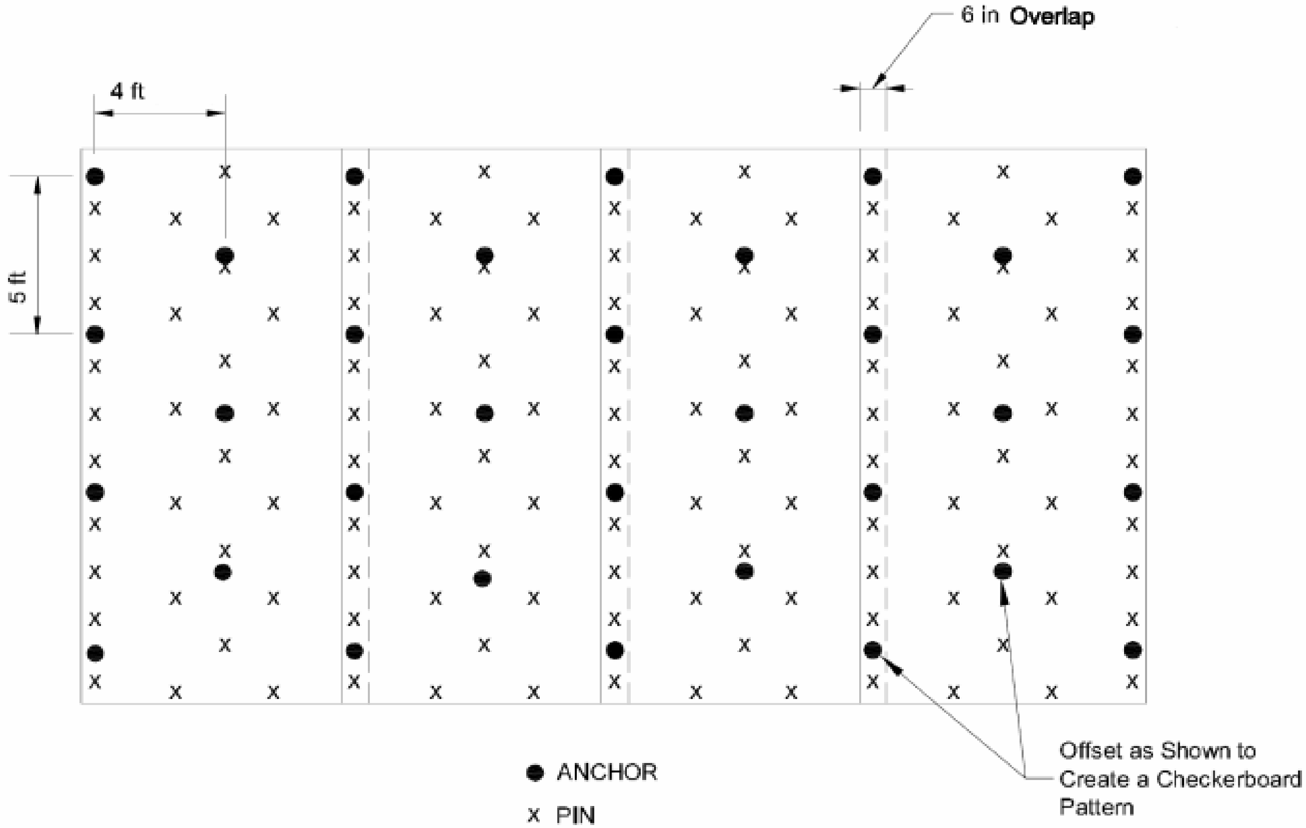


FIGURE 4:TYPE B2 ANCHOR / PIN PATTERN DETAIL FOR SLOPE FACE

Specified Anchoring Pattern

- Spacing of 4 ft in the 'X' direction, 5 ft in the "Y" direction
- 6-inch overlap for HPTRM panels
- Pattern staggered to secure HPTRM efficiently
- Spacing and density modeled in slope stability software

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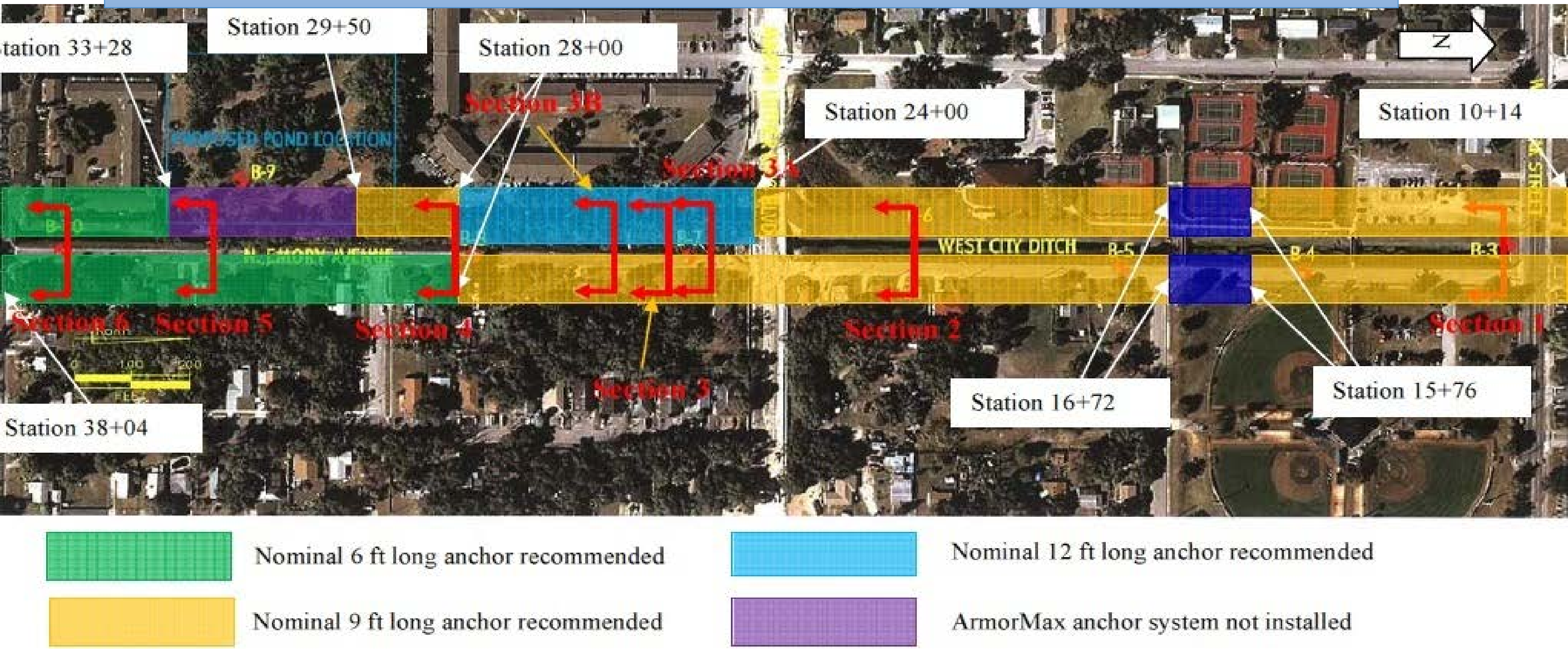
ANCHOR DESIGN LENGTHS PER PLAN VIEW SECTION



6-FT, 9-FT, & 12-FT (Nominal) Anchor Lengths Designated in Various Sections, per Factor of Safety Determinations

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Construction Begins!
Smoothing side slopes, near Cross Section 2
August 25, 2009

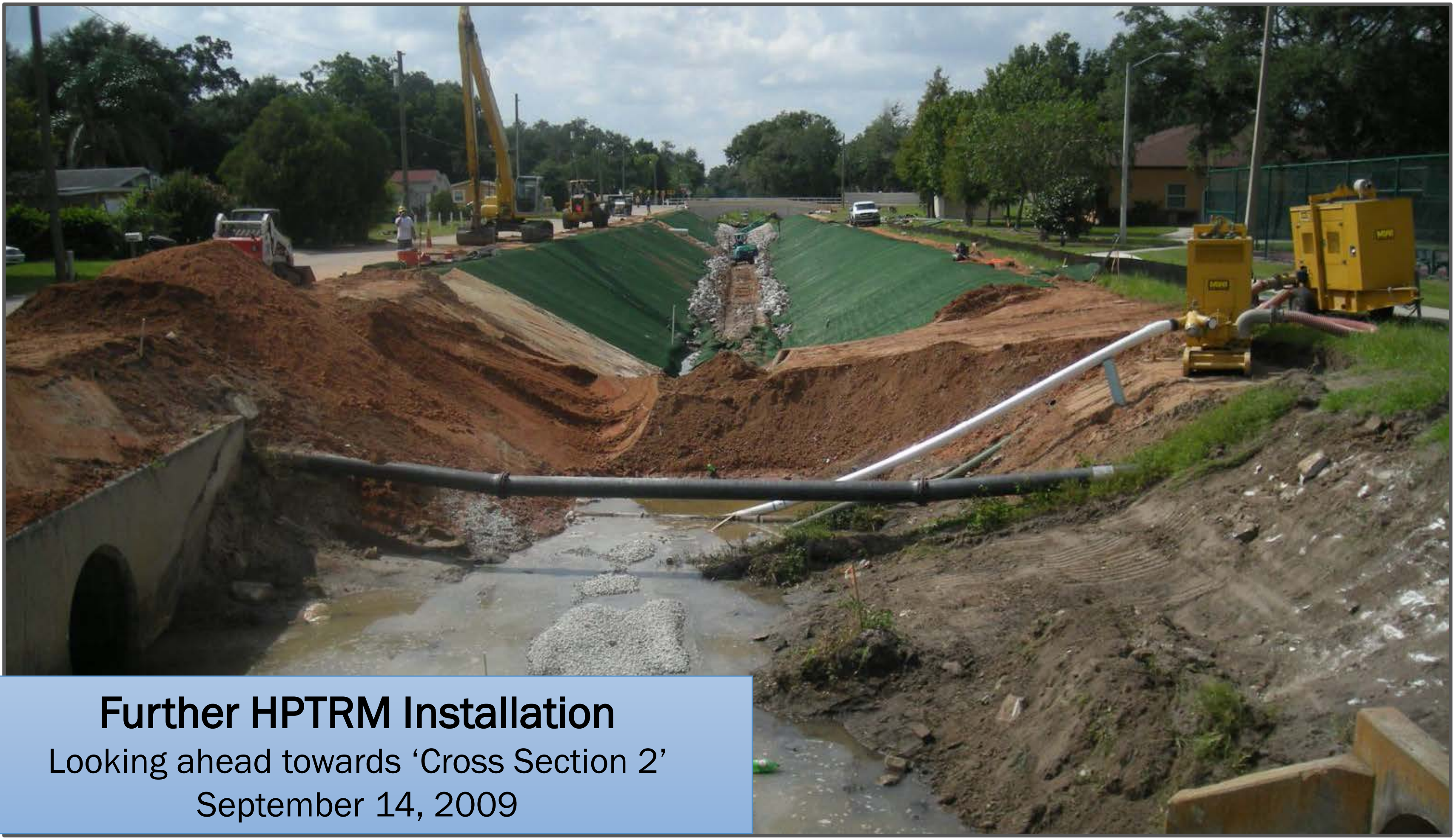
West City Ditch Repairs

Earthwork Complete – Installing HPTRM
Inserting into lower trench for pulling up slope
September 5, 2009

West City Ditch Repairs

Stabilization Continues
Installed HPTRM near 'Cross Section 2'
September 5, 2009

West City Ditch Repairs



Further HPTRM Installation
Looking ahead towards 'Cross Section 2'
September 14, 2009

West City Ditch Repairs

Installing Engineered Earth Anchors
Using a 65-lb Percussion Hammer
September 14, 2009

West City Ditch Repairs

Quality Control Load Testing

Spot checks of random anchors to verify load spec

September 29, 2009

West City Ditch Repairs

Completed ARMORMAX® Installation
Looking south towards 'Cross Section 2'
October 8, 2009

West City Ditch Repairs

Storm Hits!
ARMORMAX® provides protection prior to vegetation
October 11, 2009

West City Ditch Repairs

Initial Placement of Sod
Bahia sod pinned to slopes at ‘Cross Section 2’
October 20, 2009

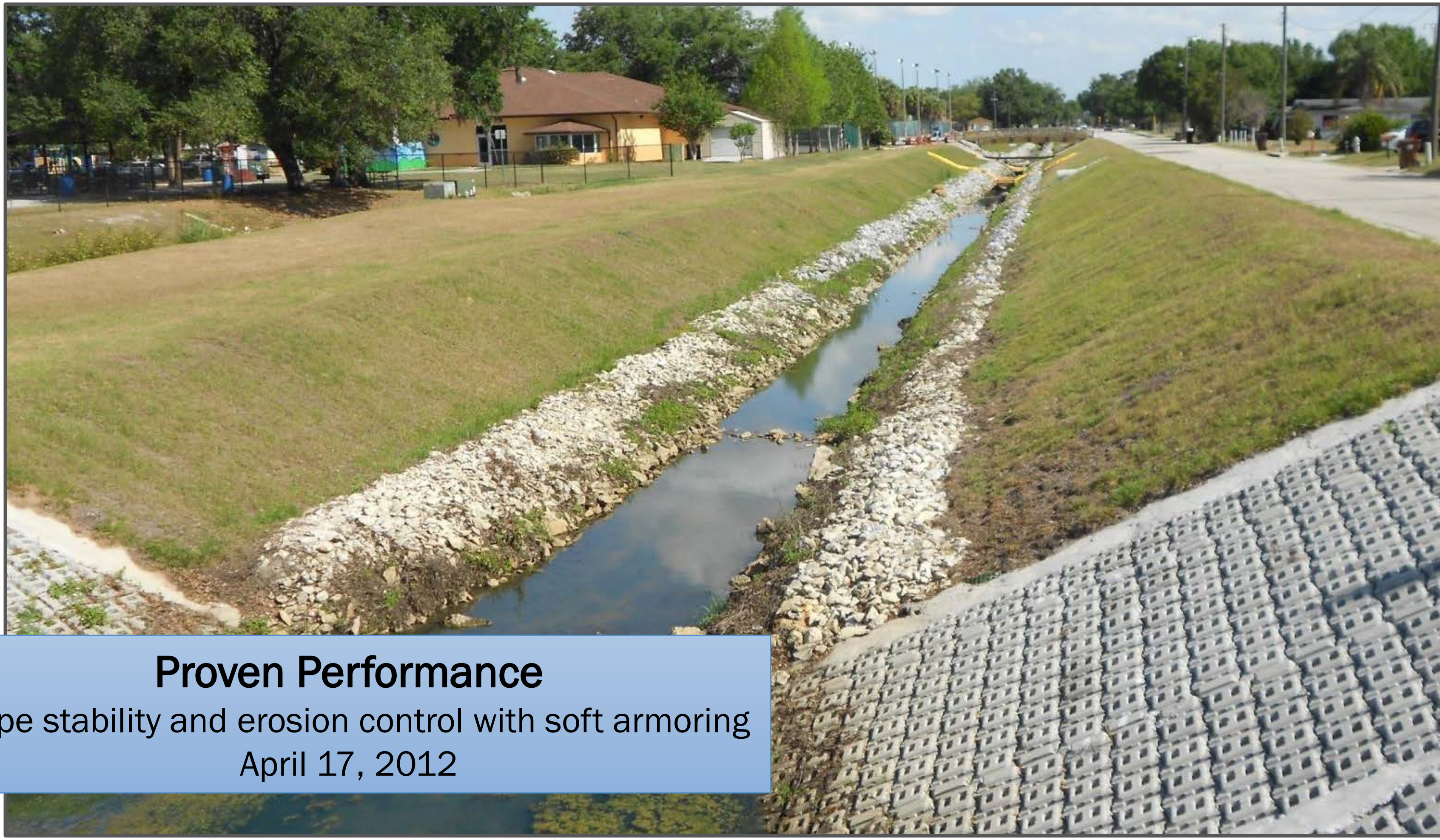
West City Ditch Repairs

Proven Performance

Slope stability and erosion control with soft armoring

April 17, 2012

West City Ditch Repairs



Proven Performance
Slope stability and erosion control with soft armoring
April 17, 2012

Vensel Creek Flood Relief

Application: Structural Streambank Slope Stabilization

Client: City of Tulsa, OK

Contractor: Tri Star Construction

Installed: 2013

Product: ARMORMAX®
6' Type B2 Anchors
0.5 anchors per square yard
0.6 anchors per square meter

Quantity: 5,000 SY
4,200 SM

ARMORMAX®

Vensel Creek Flood Relief

Vensel Creek Flood Relief

Vensel Creek Flood Relief

Geotechnical Engineering Report
Flood Control, Vensel Creek ■ Tulsa, Oklahoma
May 6, 2011 ■ Terracon Project No. 04115025

Terracon

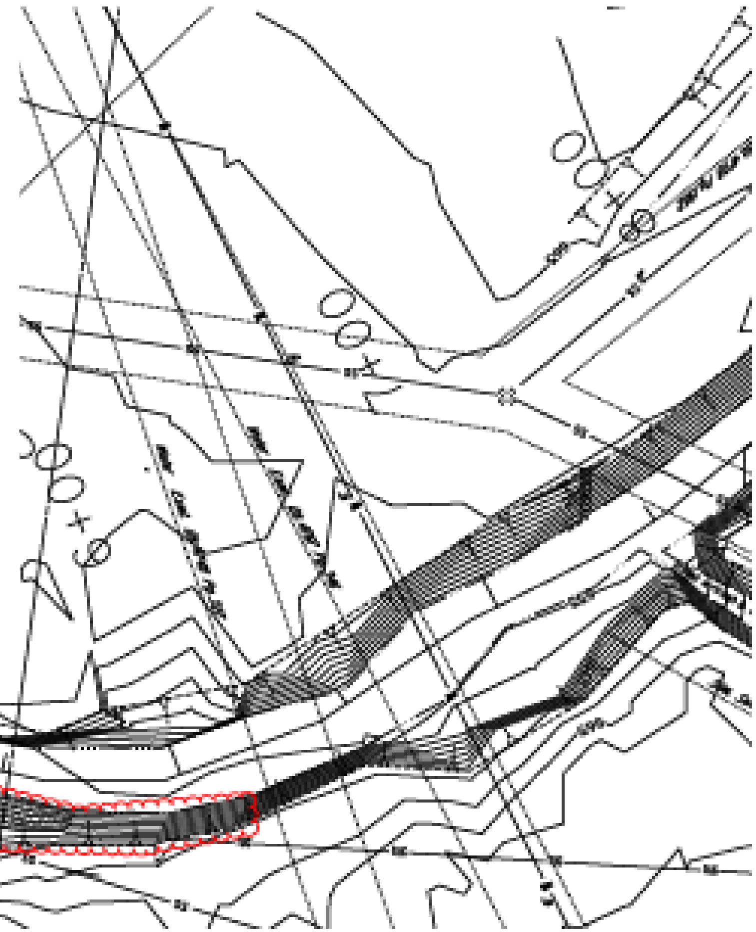
The fill material should be placed on a relatively level surface. Subgrade slopes greater than about 4H:1V should be continuously benched to avoid placing fill on a sloped surface. The benches should be of sufficient width for easy access to dumping and compaction equipment. We recommend that channel side slopes be overbuilt and cut back to the proposed finish grade.

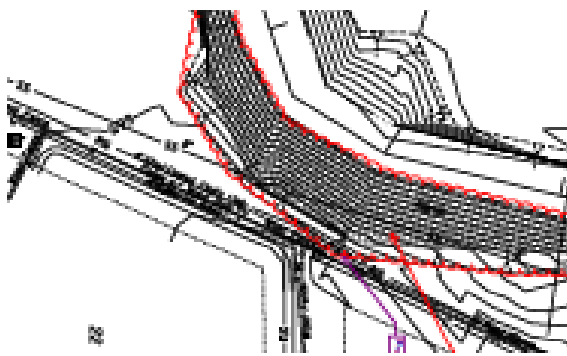
4.3 Gravity Block Retaining Wall

We understand that block walls up to a maximum height of 20 feet are planned on both sides of the creek between Stations 116+00 and 122+00. Wall design considerations are presented in the following sections.

4.3.1 Gravity Block Retaining Wall Global Stability Analyses

We used the STABL program to estimate the global factor of safety against slope failure. For this study, we performed analyses using the Spencer method for circular failure surfaces and the Morgenstern-Price method for block failure surfaces for normal, sudden drawdown, and critical flood stage conditions for an 8, 12, and 20-foot tall block wall and the corresponding base block sizes.





Vensel Creek Flood Relief

General Information:

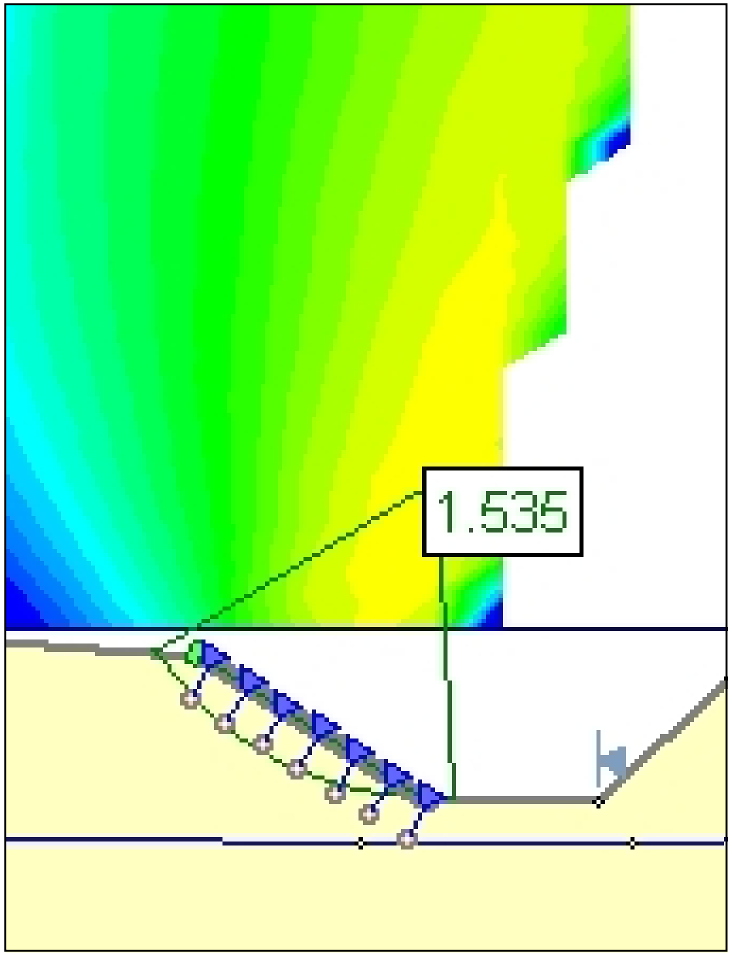
- 5 to 15 feet deep channel
- Maximum 100 year velocity of 11.85 ft/sec
- New channel to have 4:1 side slopes
- Between stations 116+00 and 122+00 to have gravity block retaining walls
- Clayey sands and low plasticity clays.

Soil properties:

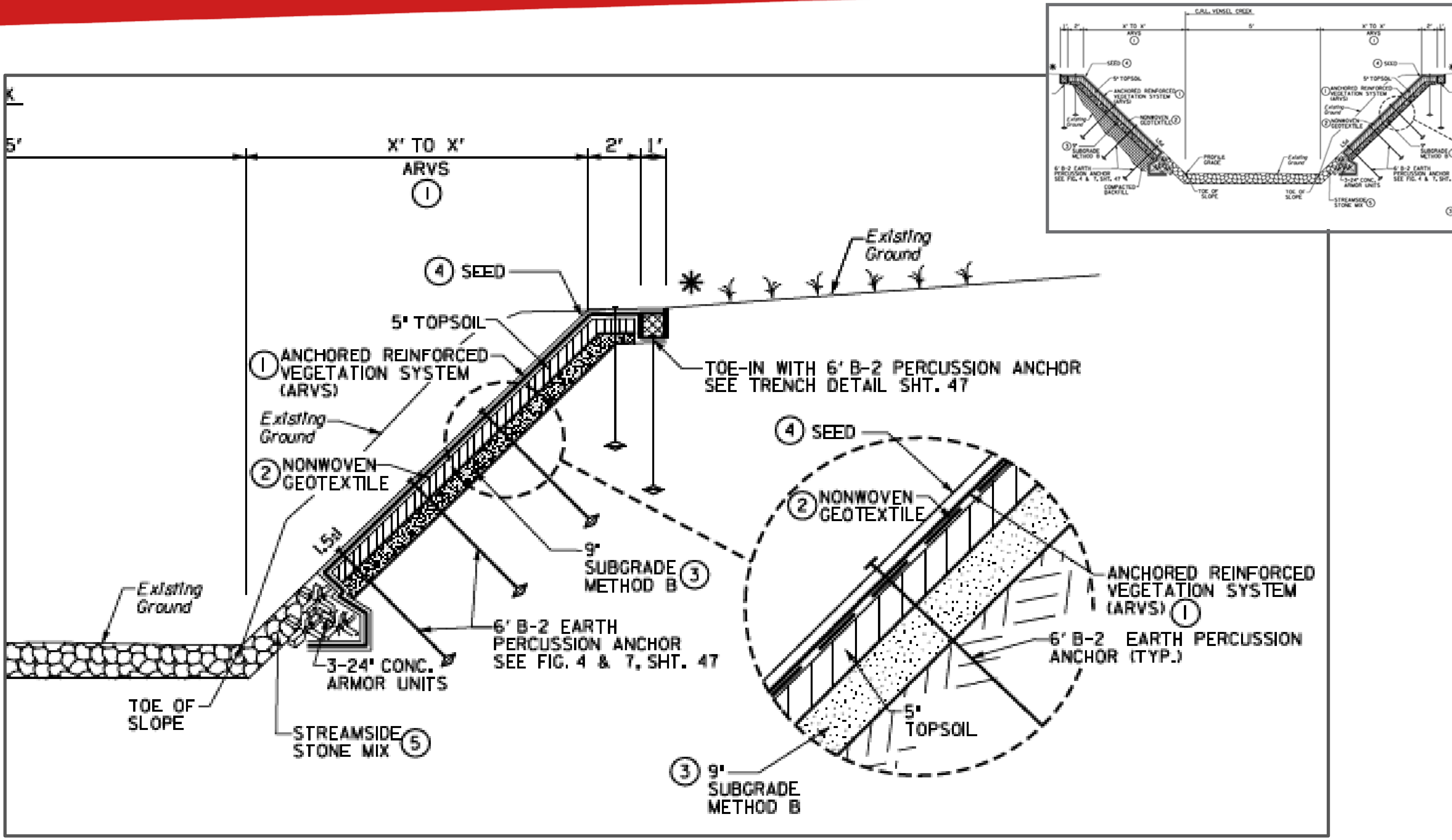
- Unit weight = 120 lb/ft^3 unsaturated, 125 lb/ft^3 saturated
- Cohesion=50 lb/ft^2
- Phi angle = 31º

Design Scenarios:

- Normal condition:
  - Water table 17' below top of channel
  - Required Factor of Safety=1.3-1.5
- Steady state seepage
  - Water level a few feet deep
  - Required Factor of Safety=1.3
- Rapid draw down condition
  - Water level drops from about 15' deep to 3' deep
  - Required Factor of Safety=1.1



Vensel Creek Flood Relief



Vensel Creek Flood Relief

Installed ARMORMAX® – October 2013

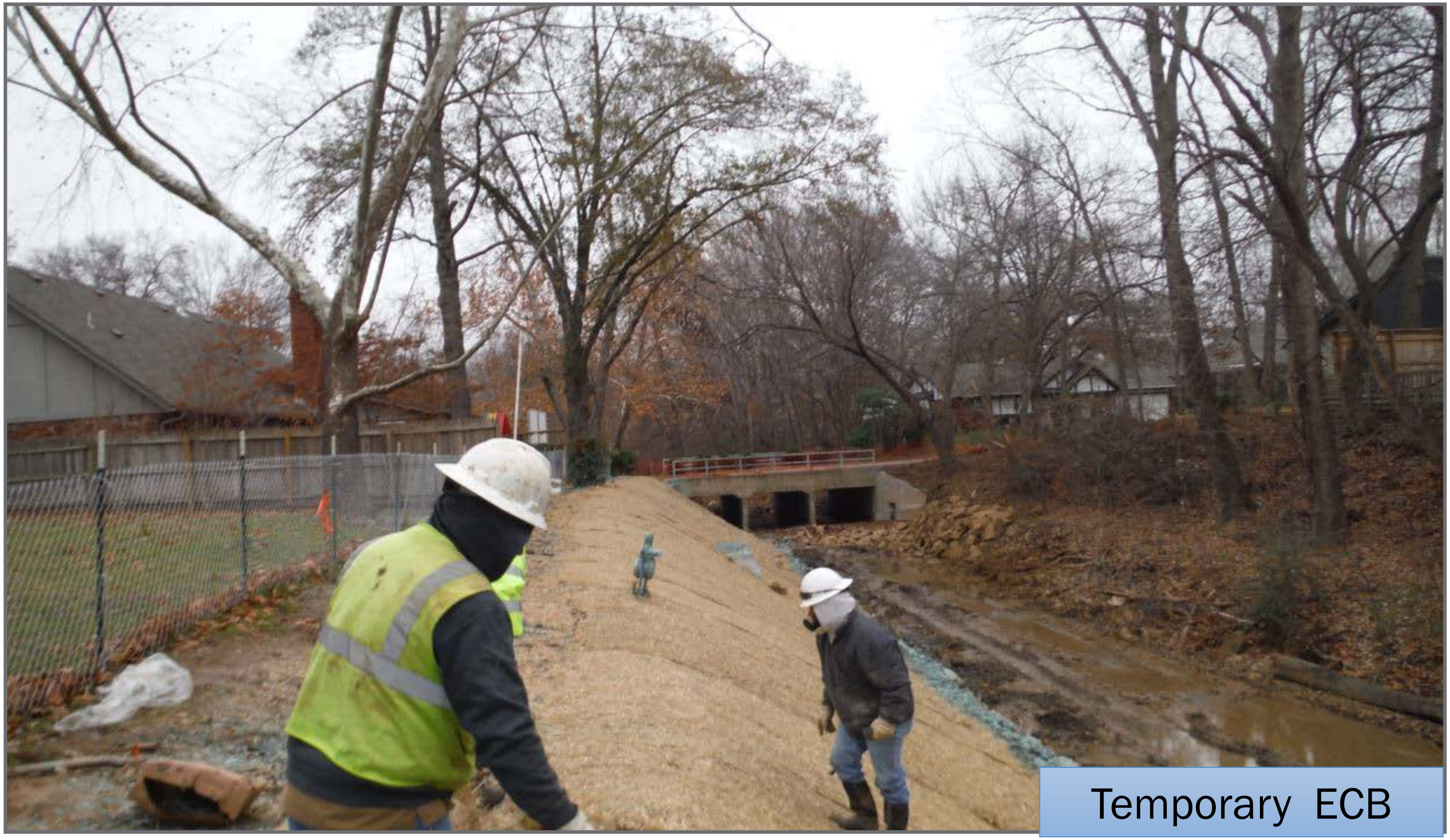
Vensel Creek Flood Relief

Installed ARMORMAX® – October 2013

Vensel Creek Flood Relief

Hydroseeded ARMORMAX®

Vensel Creek Flood Relief



Temporary ECB

Vensel Creek Flood Relief

Vegetation Establishment – April 2014

Vensel Creek Flood Relief

Vegetated ARMORMAX® – May 2014

Vensel Creek Flood Relief

Vegetated ARMORMAX® – May 2015

Vensel Creek Flood Relief

Vegetated ARMORMAX® – May 2015

Vensel Creek Flood Relief

Vegetated ARMORMAX® – May 2015

Vensel Creek Flood Relief

Vegetated ARMORMAX® – May 2015

5^{th} Runway Slope Stabilization

Application: Slope Stabilization

Client: Hartsfield-Jackson Atlanta International Airport

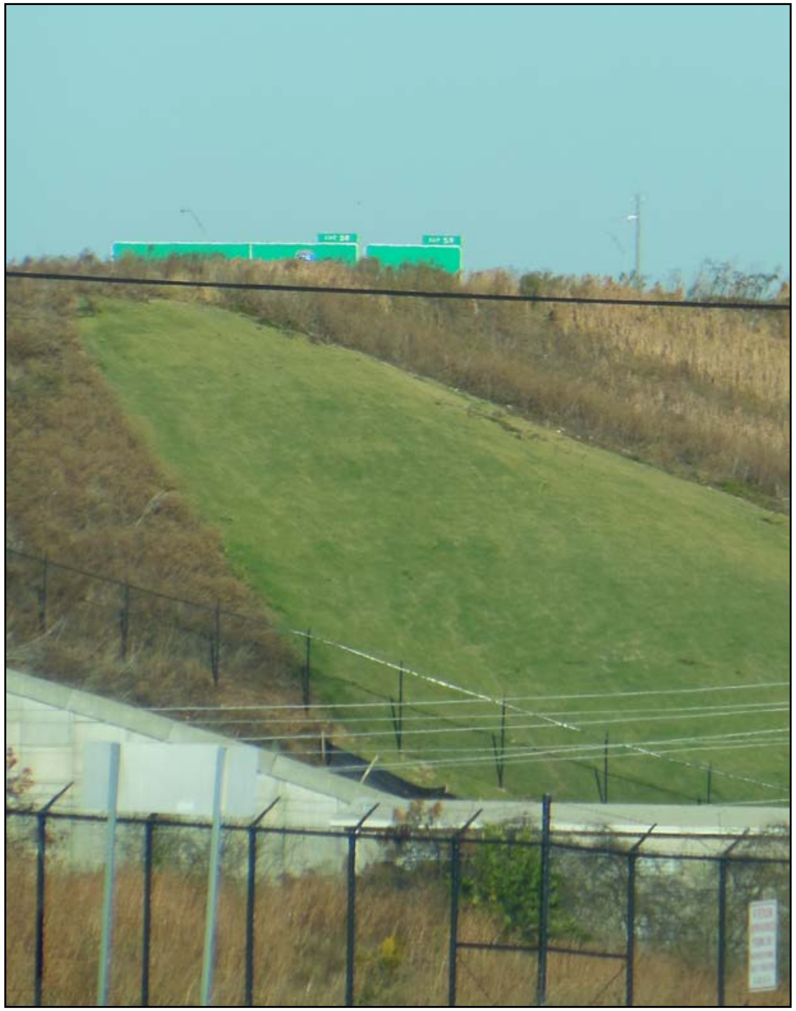
Contractor: Athena Construction Group
CW Matthews Contracting

Installed: 2016

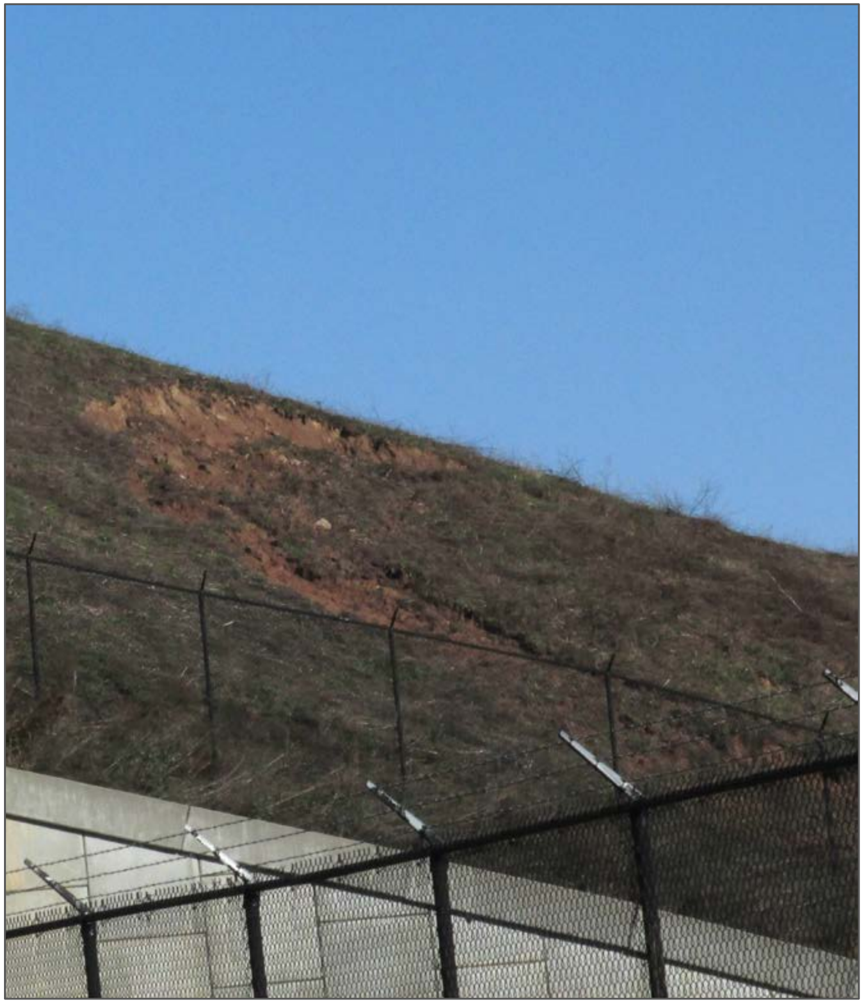
Product: ARMORMAX®
9' Type B2 Anchors
0.62 anchors per square yard
0.75 anchors per square meter

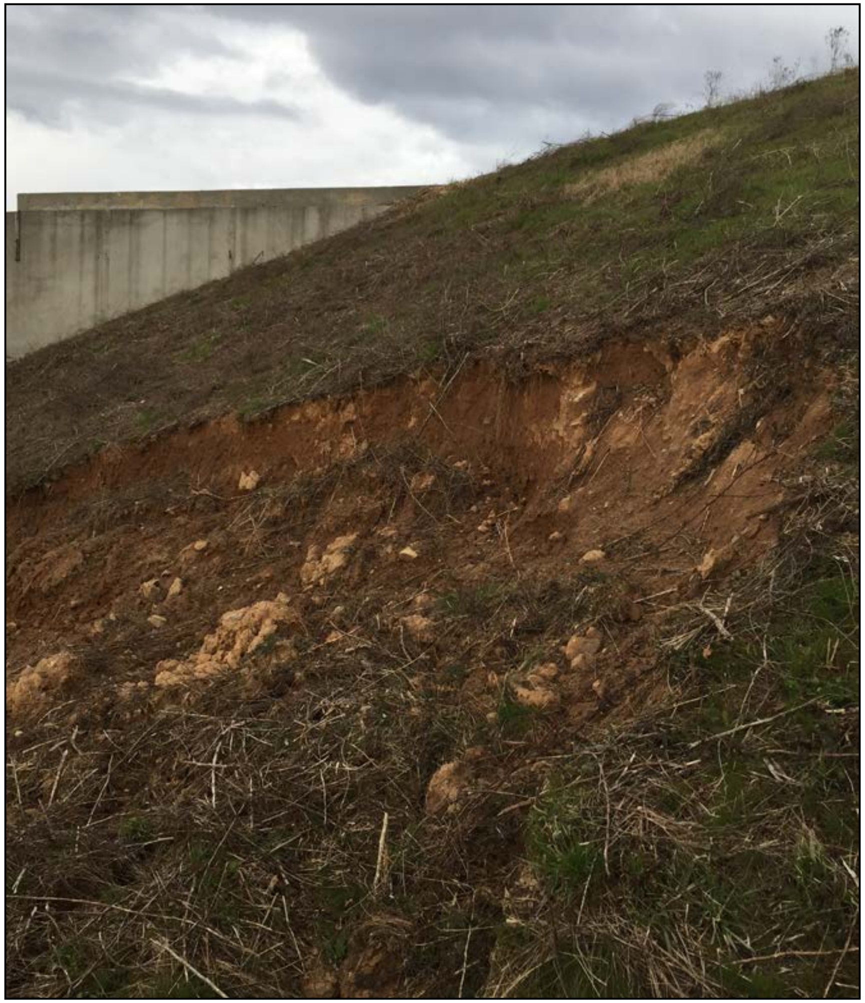
Quantity: 1,000 SY
800 SM

ARMORMAX®

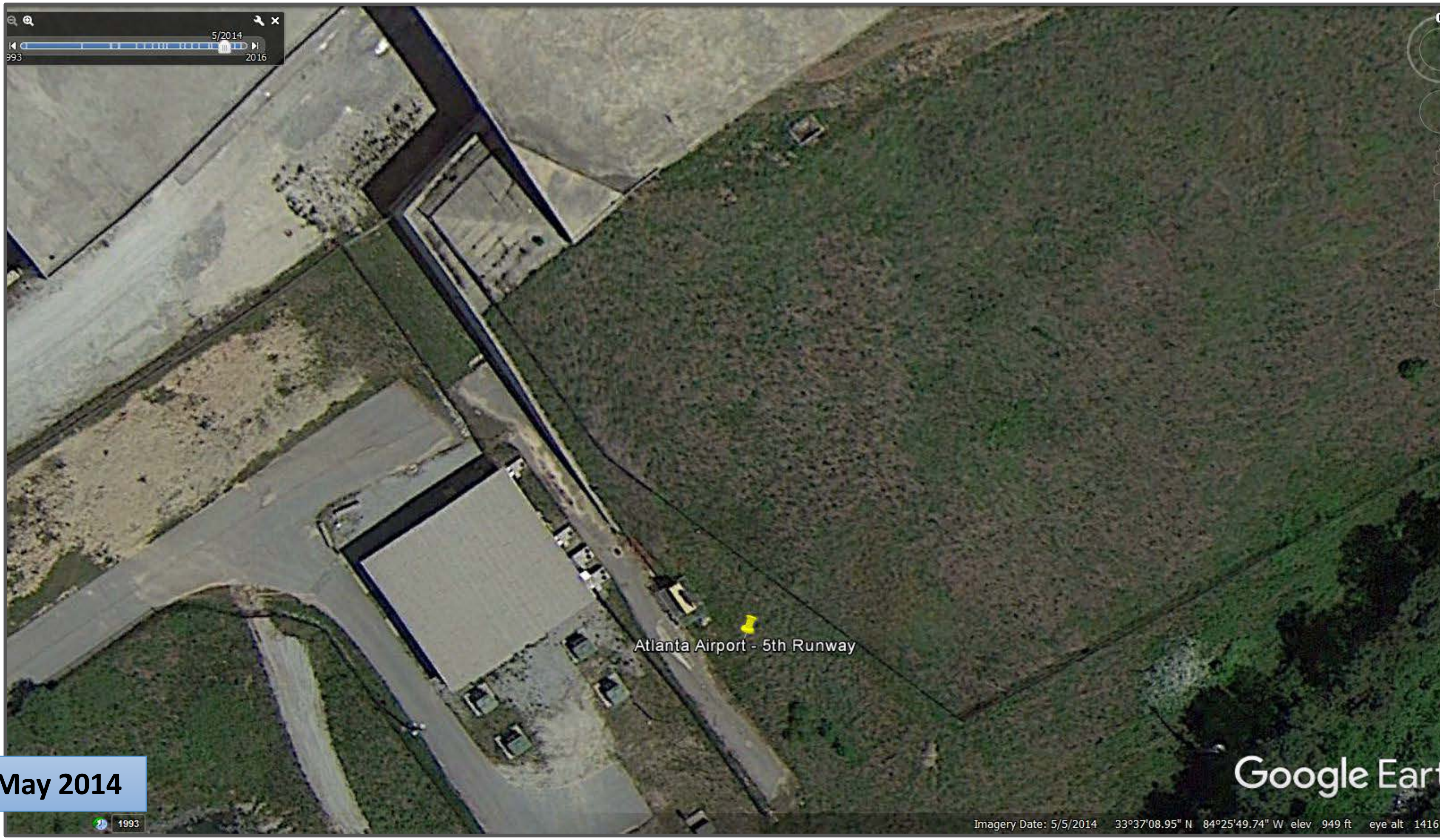


5^{th} Runway Slope Stabilization





5th Runway Slope Stabilization



May 2014

5th Runway Slope Stabilization

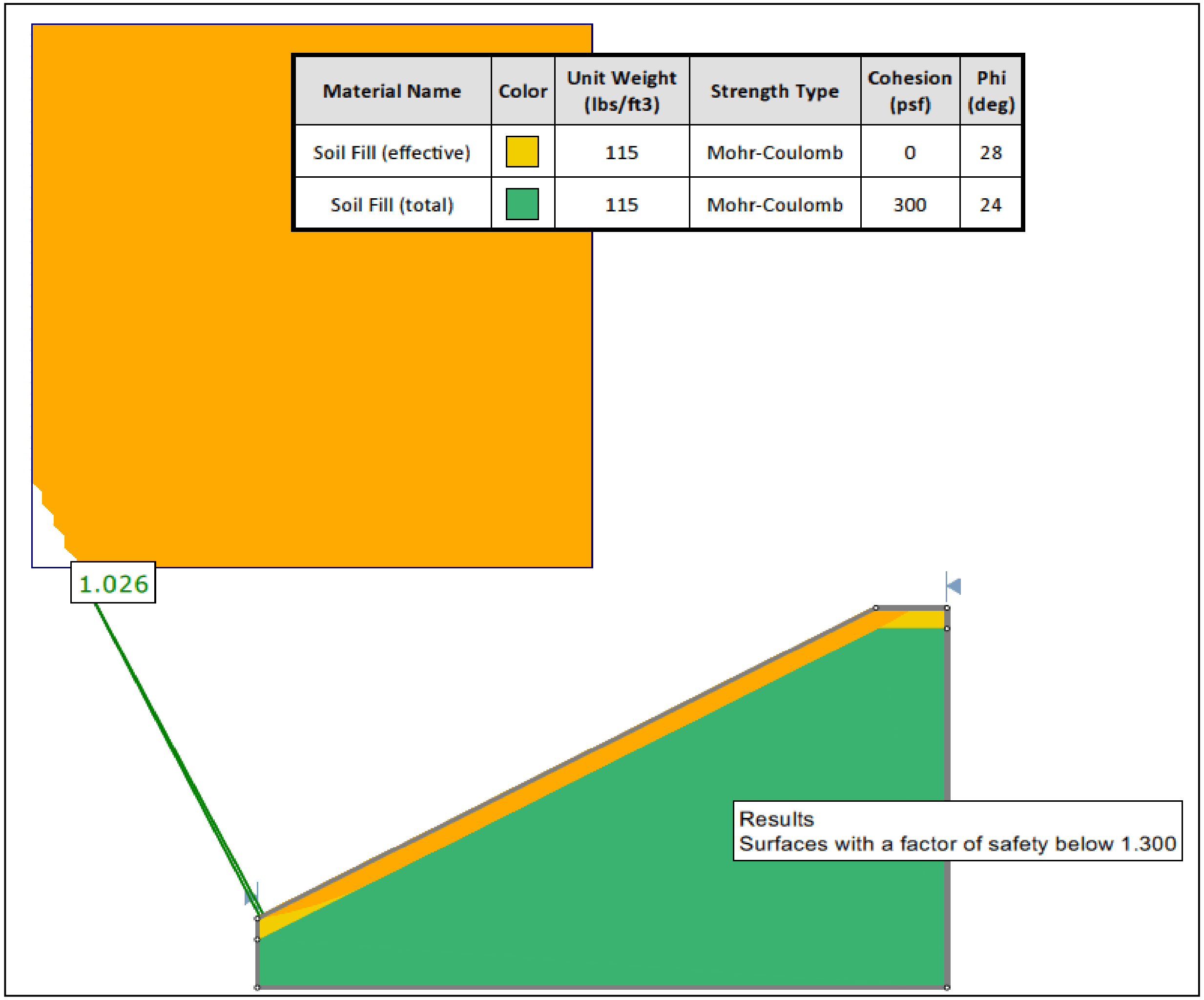
August 2015

5th Runway Slope Stabilization

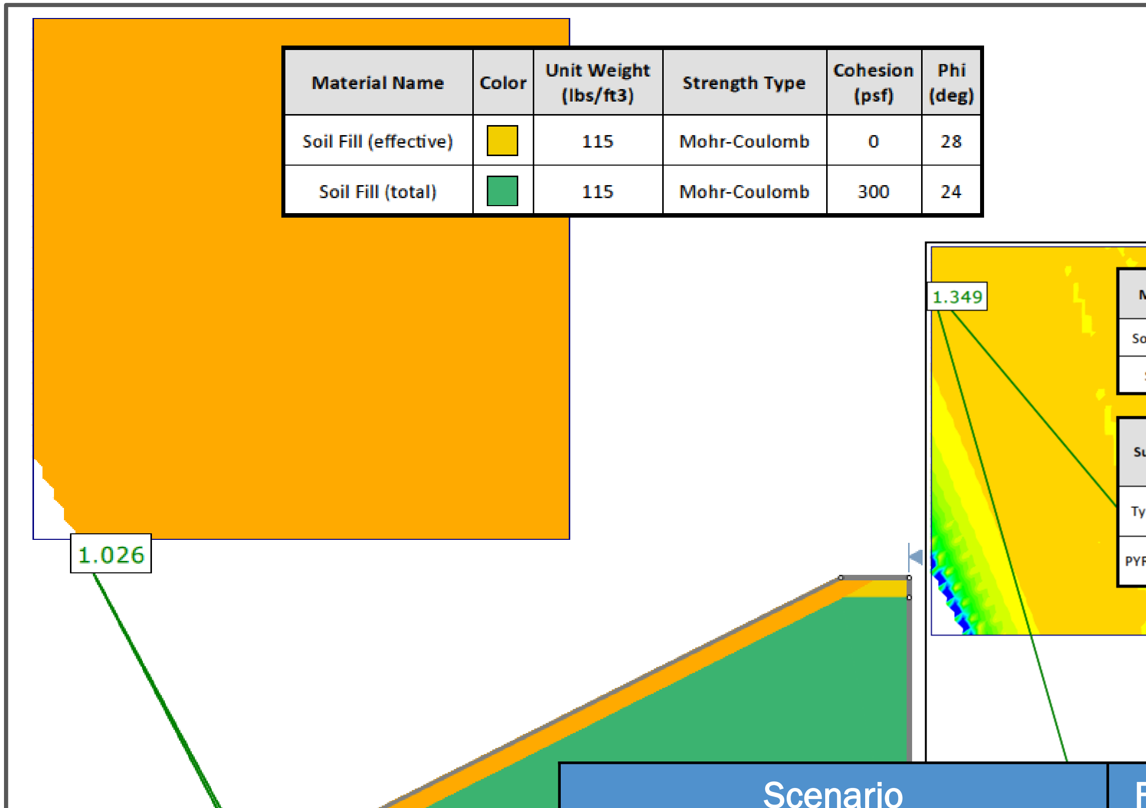
May 2016

5th Runway Slope Stabilization

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Soil Fill (effective)		115	Mohr-Coulomb	0	28
Soil Fill (total)		115	Mohr-Coulomb	300	24



5th Runway Slope Stabilization



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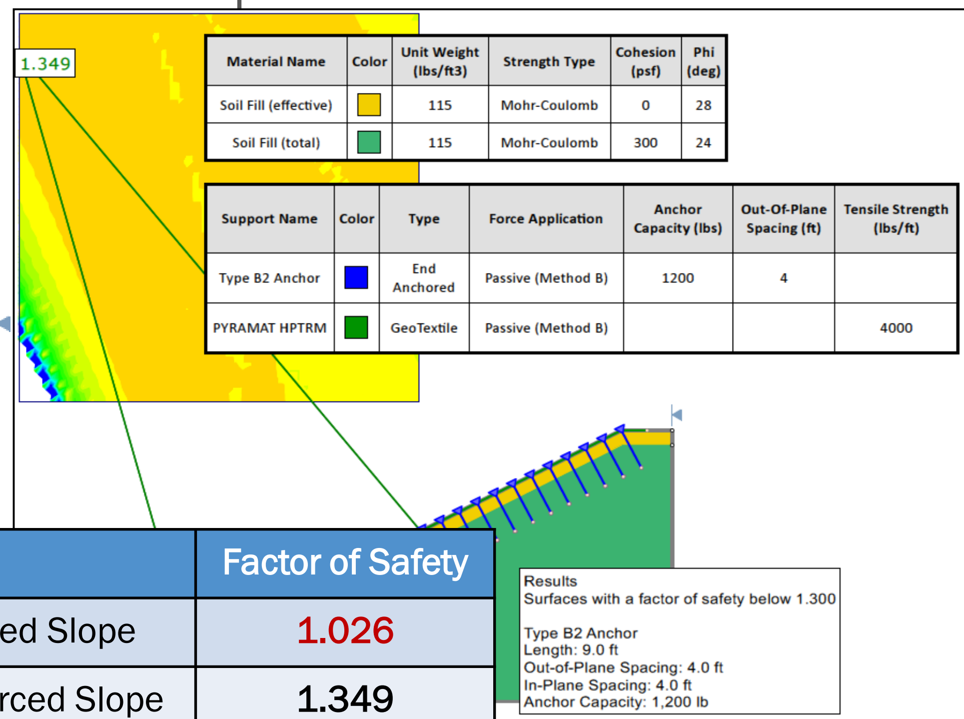
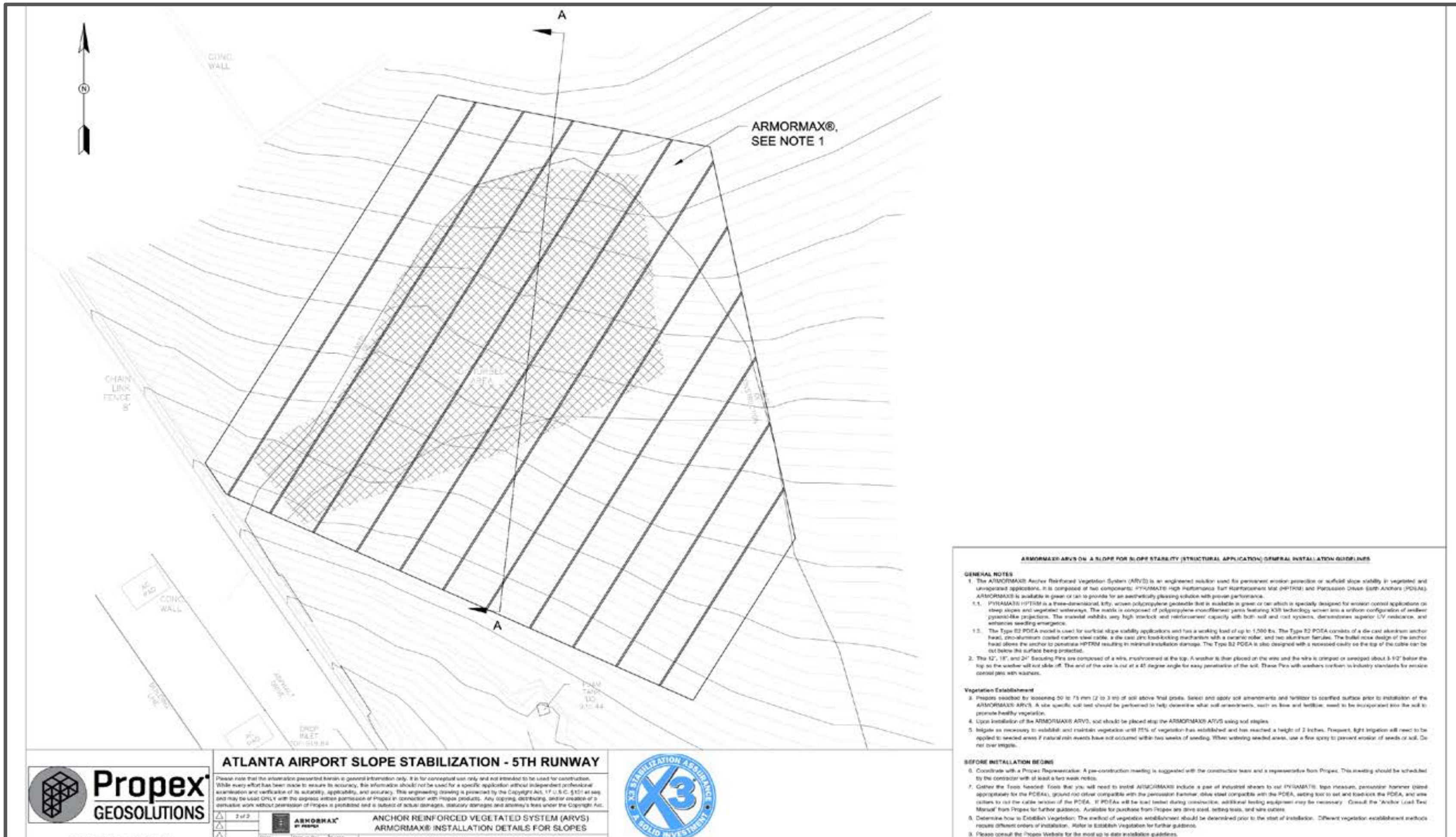


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Soil Fill (effective)		115	Mohr-Coulomb	0	28
Soil Fill (total)		115	Mohr-Coulomb	300	24

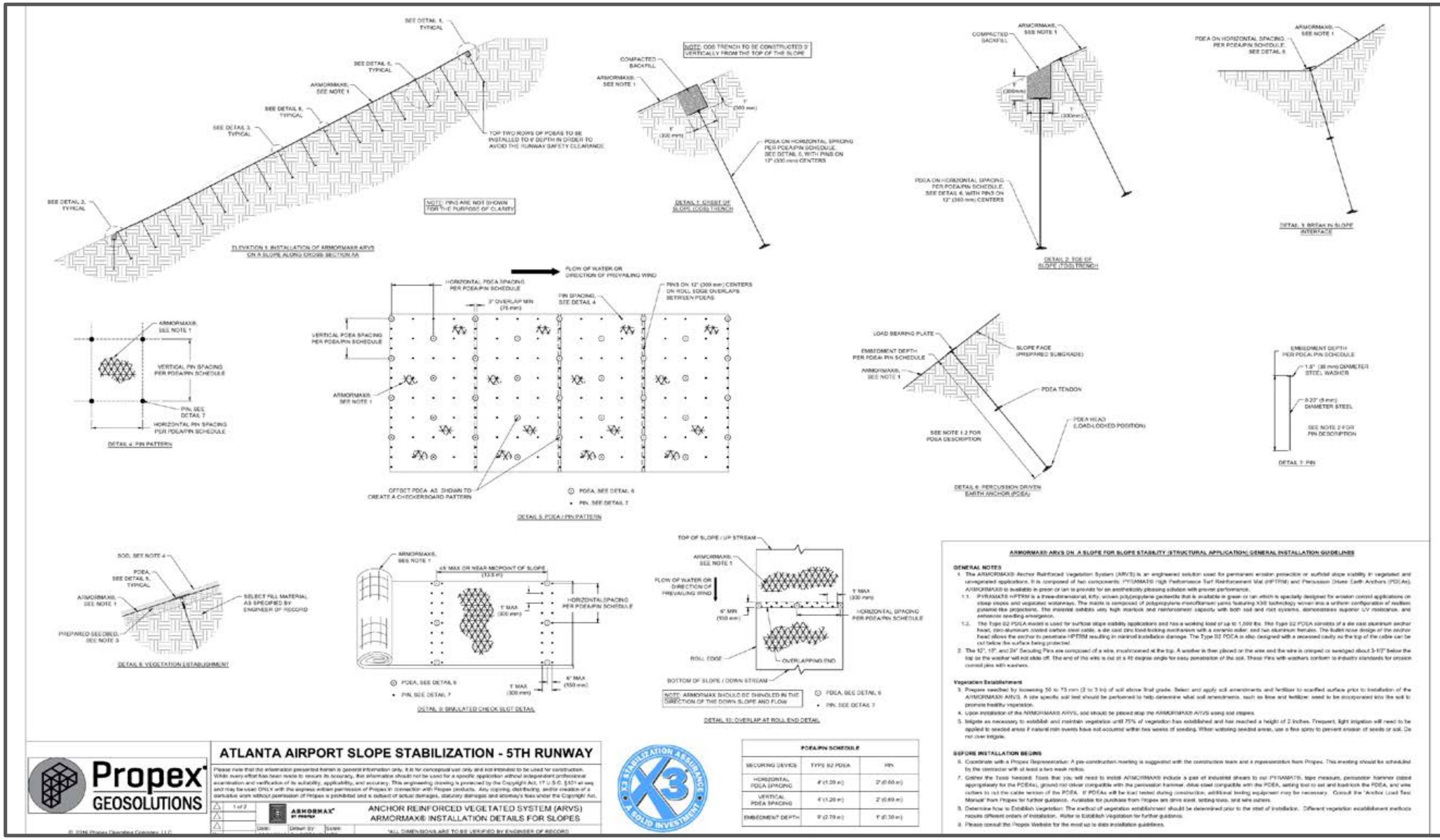
Support Name	Color	Type	Force Application	Anchor Capacity (lbs)	Out-Of-Plane Spacing (ft)	Tensile Strength (lbs/ft)
Type B2 Anchor		End Anchored	Passive (Method B)	1200	4	
PYRAMAT HPTRM		GeoTextile	Passive (Method B)			4000

Scenario	Factor of Safety
Original Unreinforced Slope	1.026
ARMORMAX® Reinforced Slope	1.349

5th Runway Slope Stabilization



5th Runway Slope Stabilization



5th Runway Slope Stabilization

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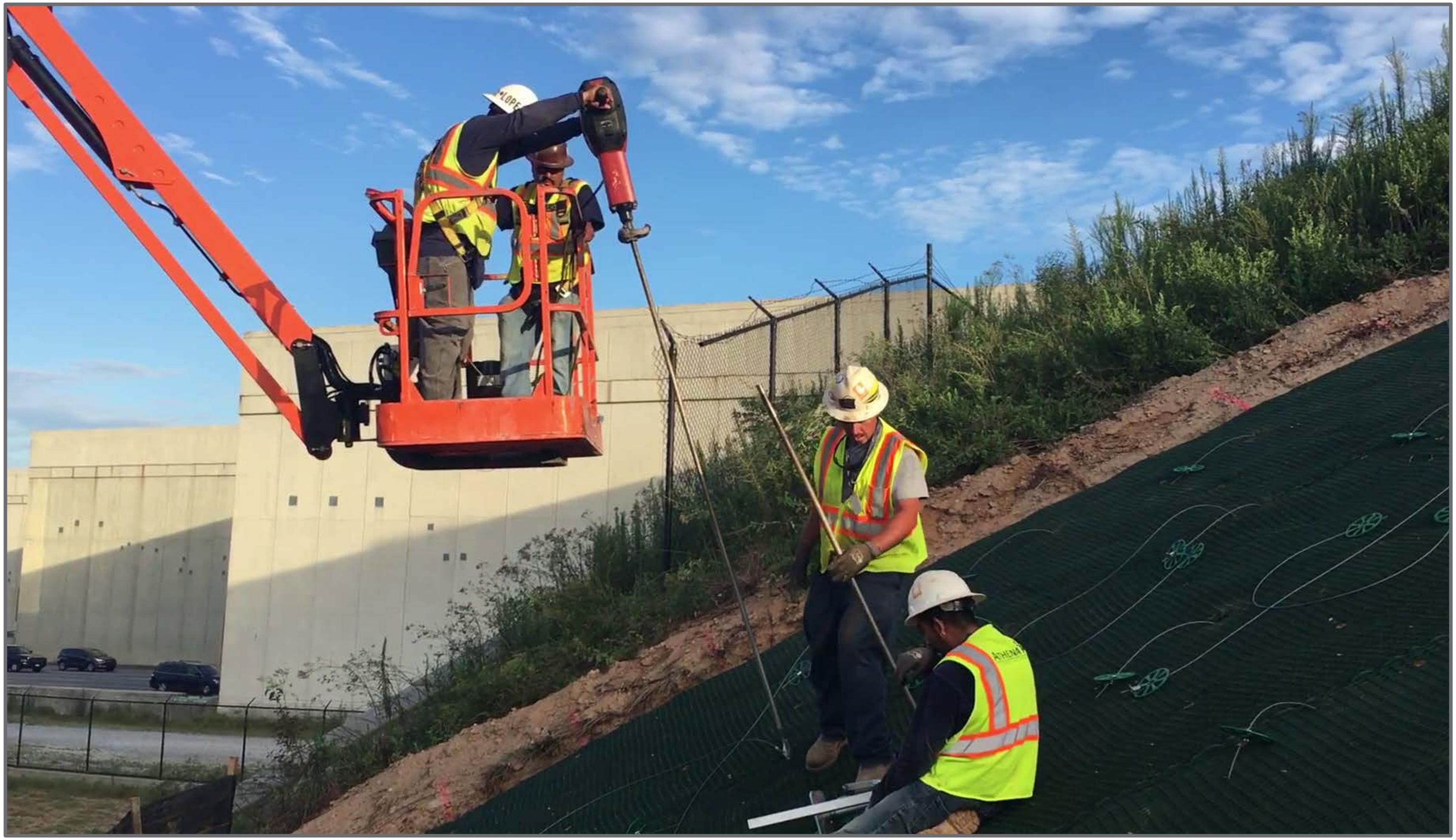

5th Runway Slope Stabilization

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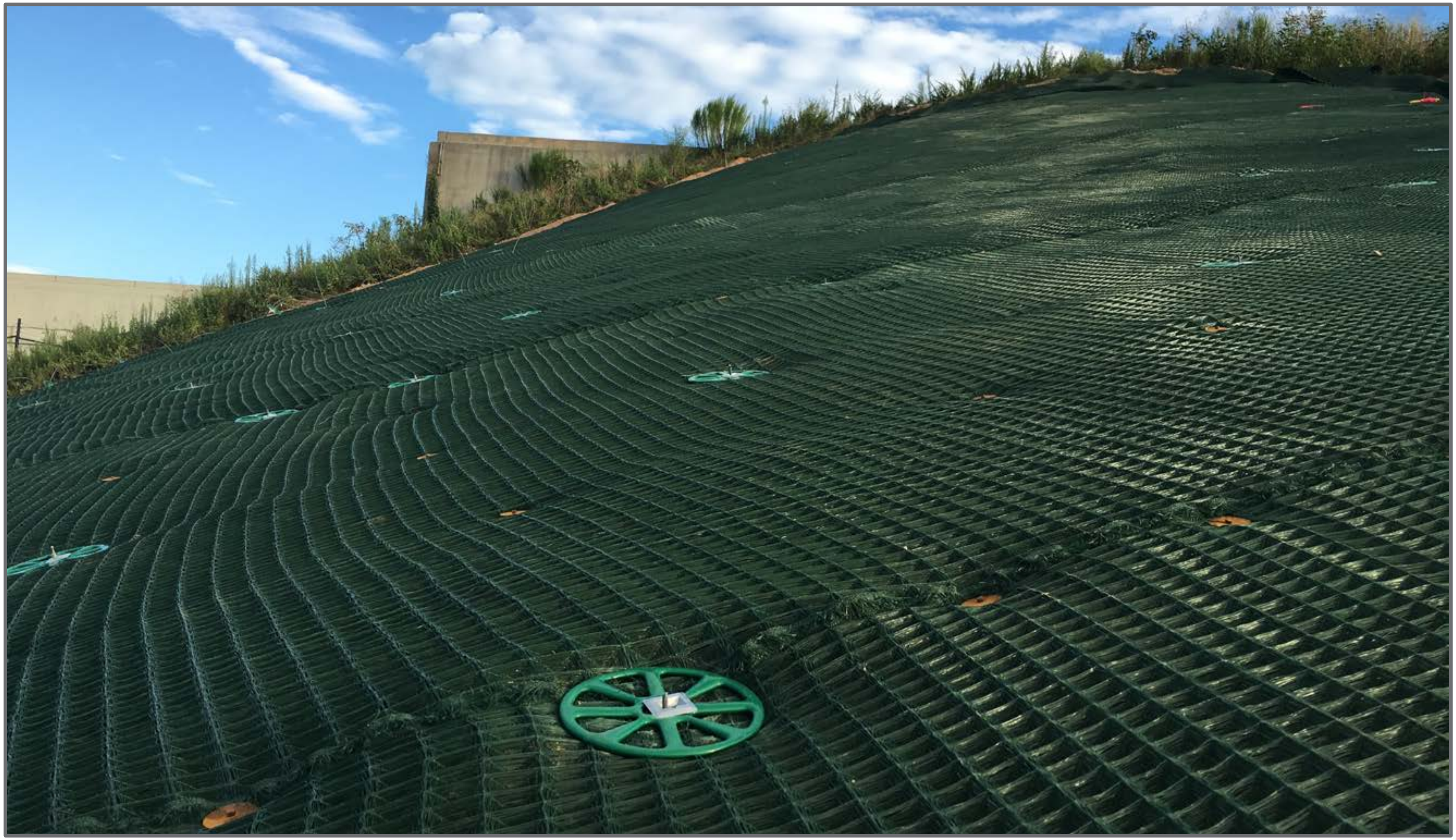

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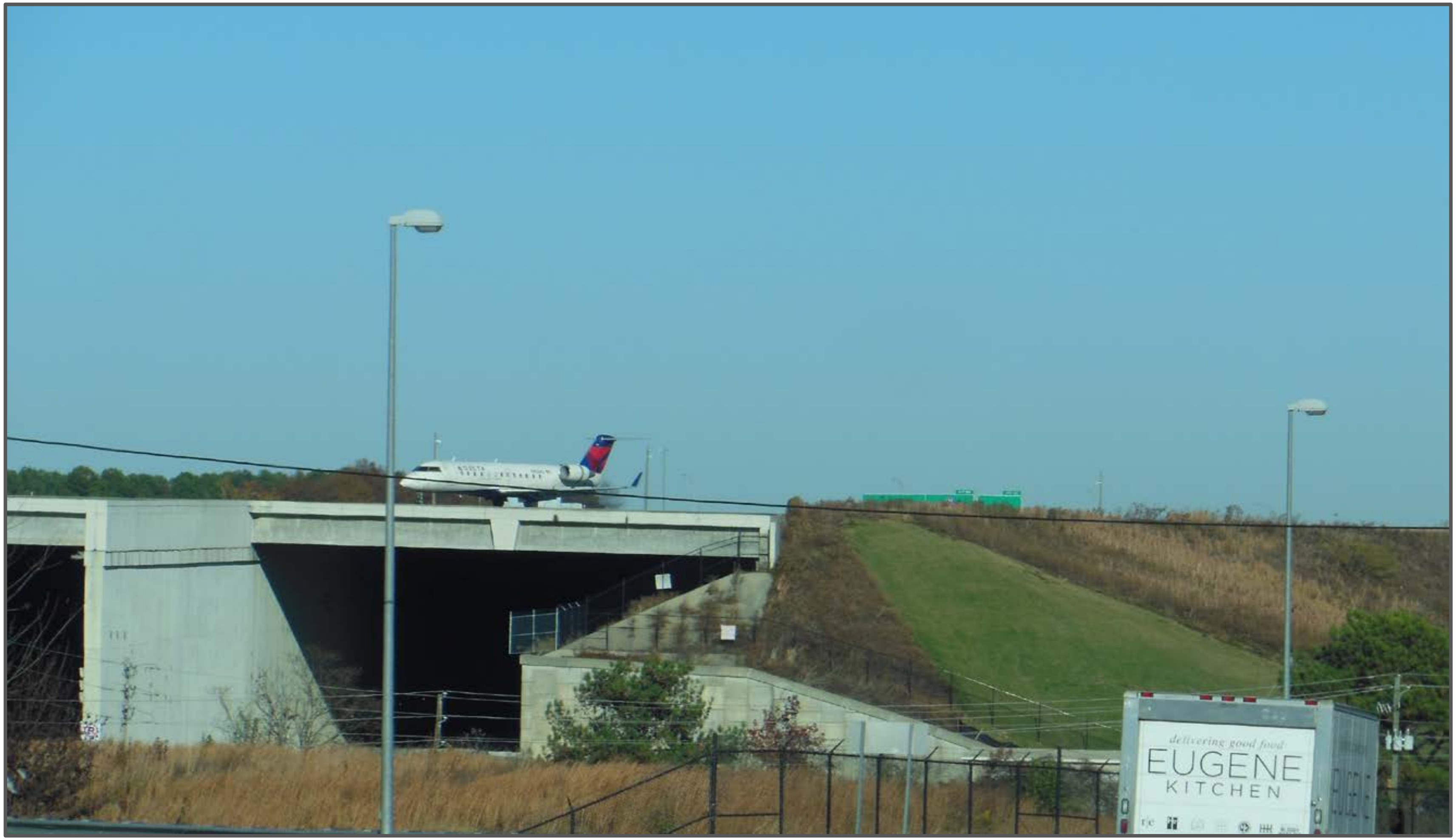

Propex GEOSOLUTIONS

Questions?

Jared Hill, EIT

Applications Engineer