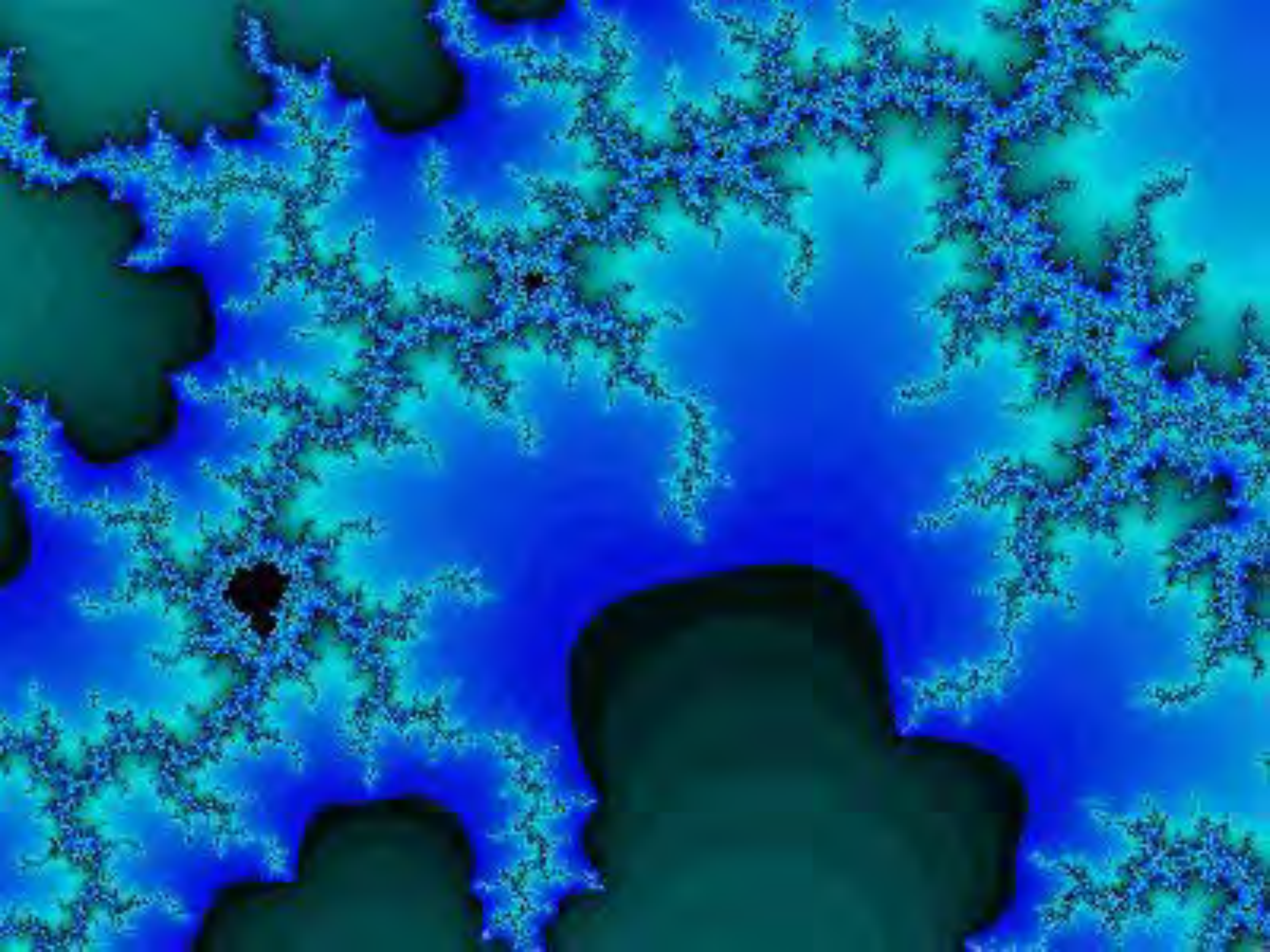
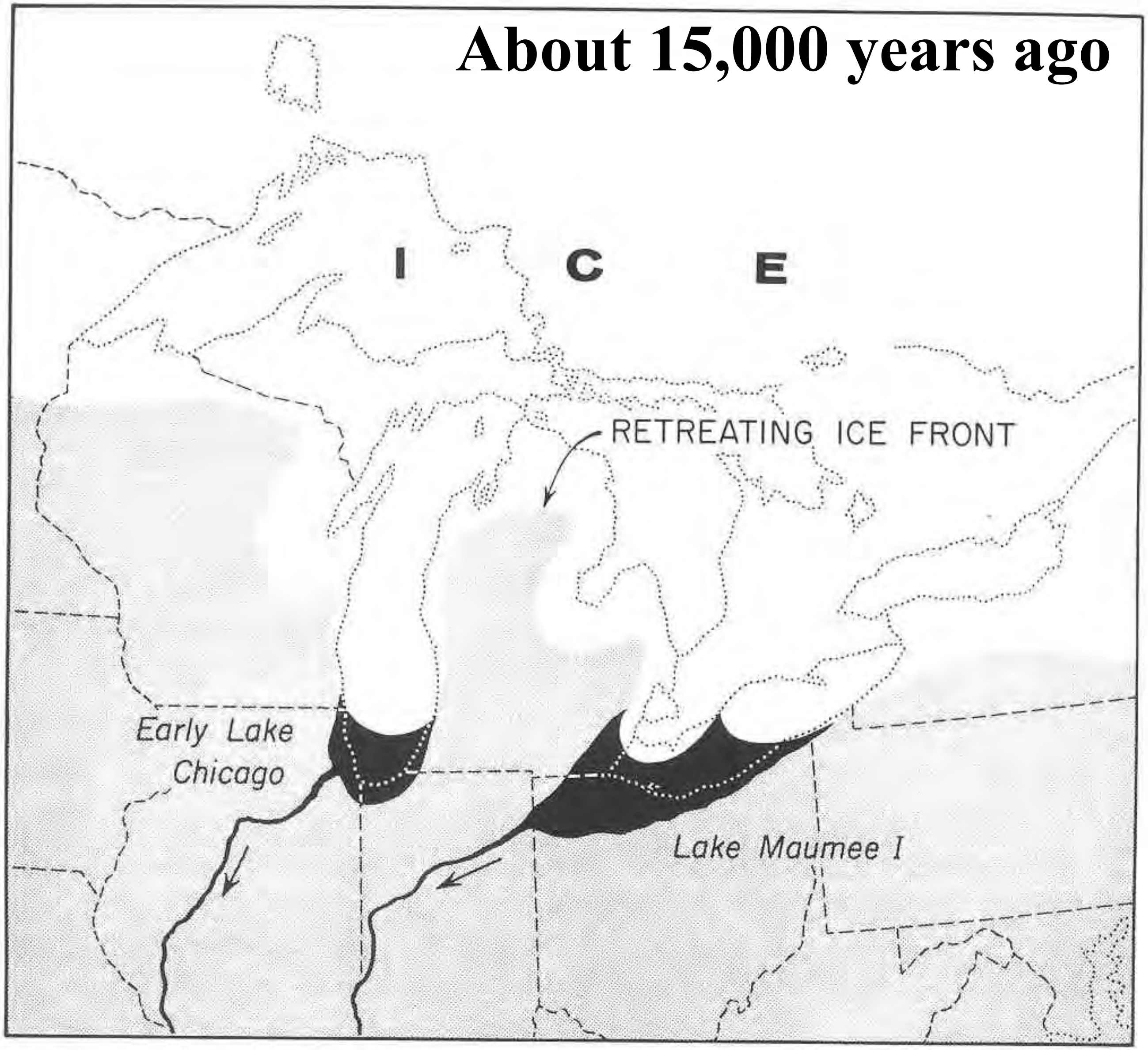


CRAM CEW 2015 WORKSHOP

Geogrids and Geotextiles in Roads, Bridges, Slope Stabilization & Retaining Walls

Christopher R. Byrum, Ph.D., P.E.
SME, Inc.
Plymouth, MI Office

About 15,000 years ago



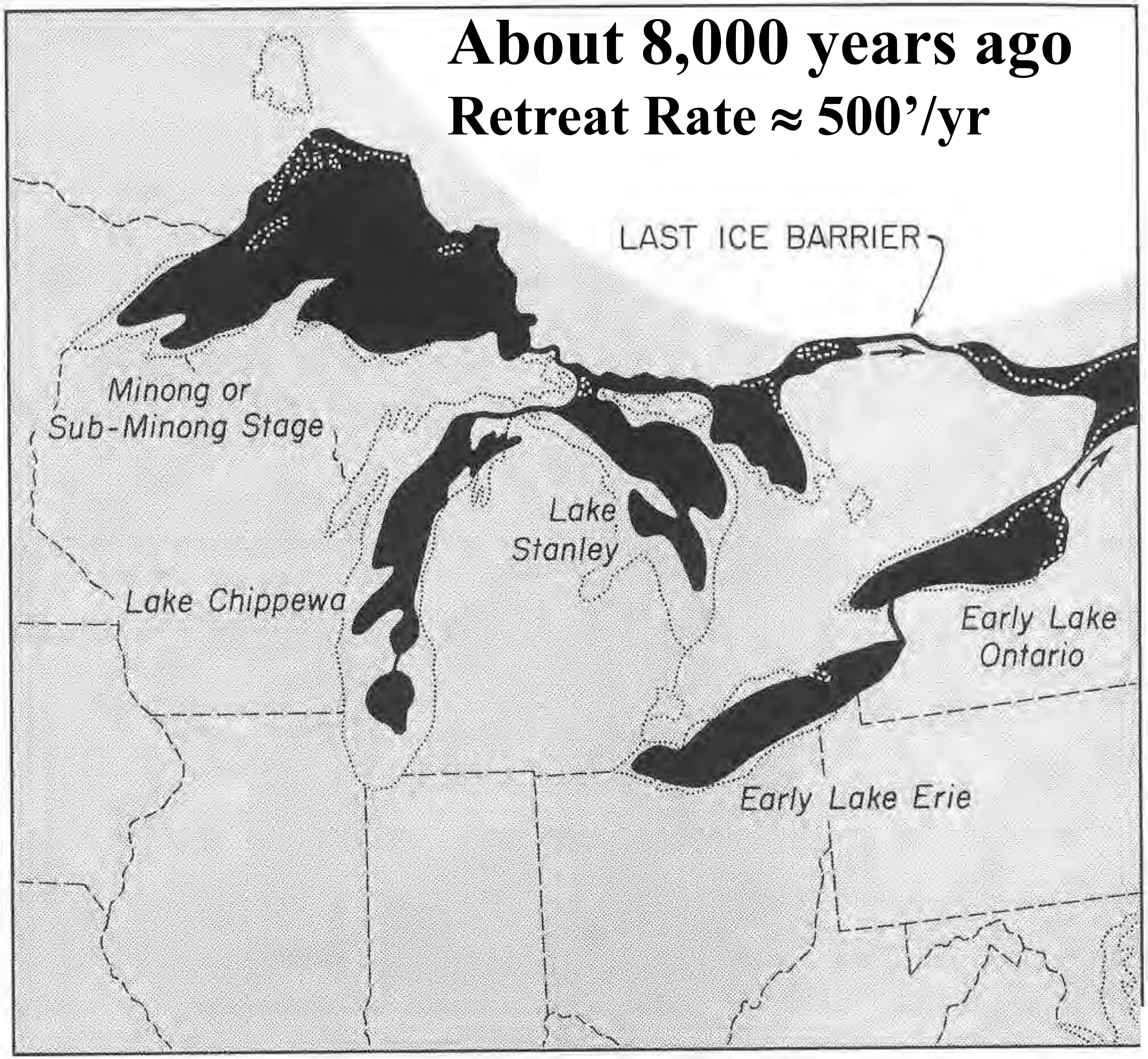
From Dorr & Eschman's "Geology of Michigan"

From Dorr & Eschman’s “Geology of Michigan”

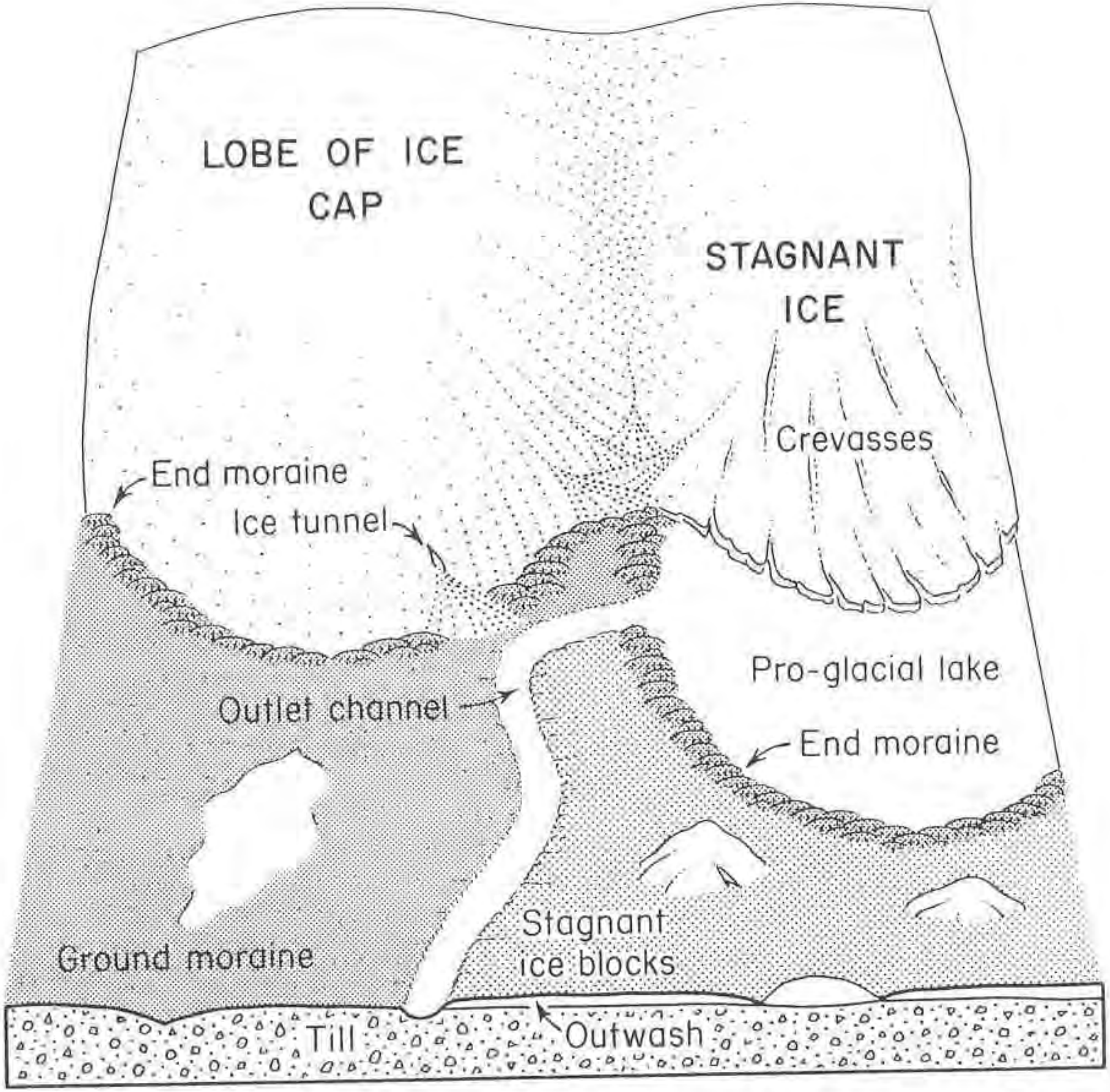
C. Byrum

About 8,000 years ago

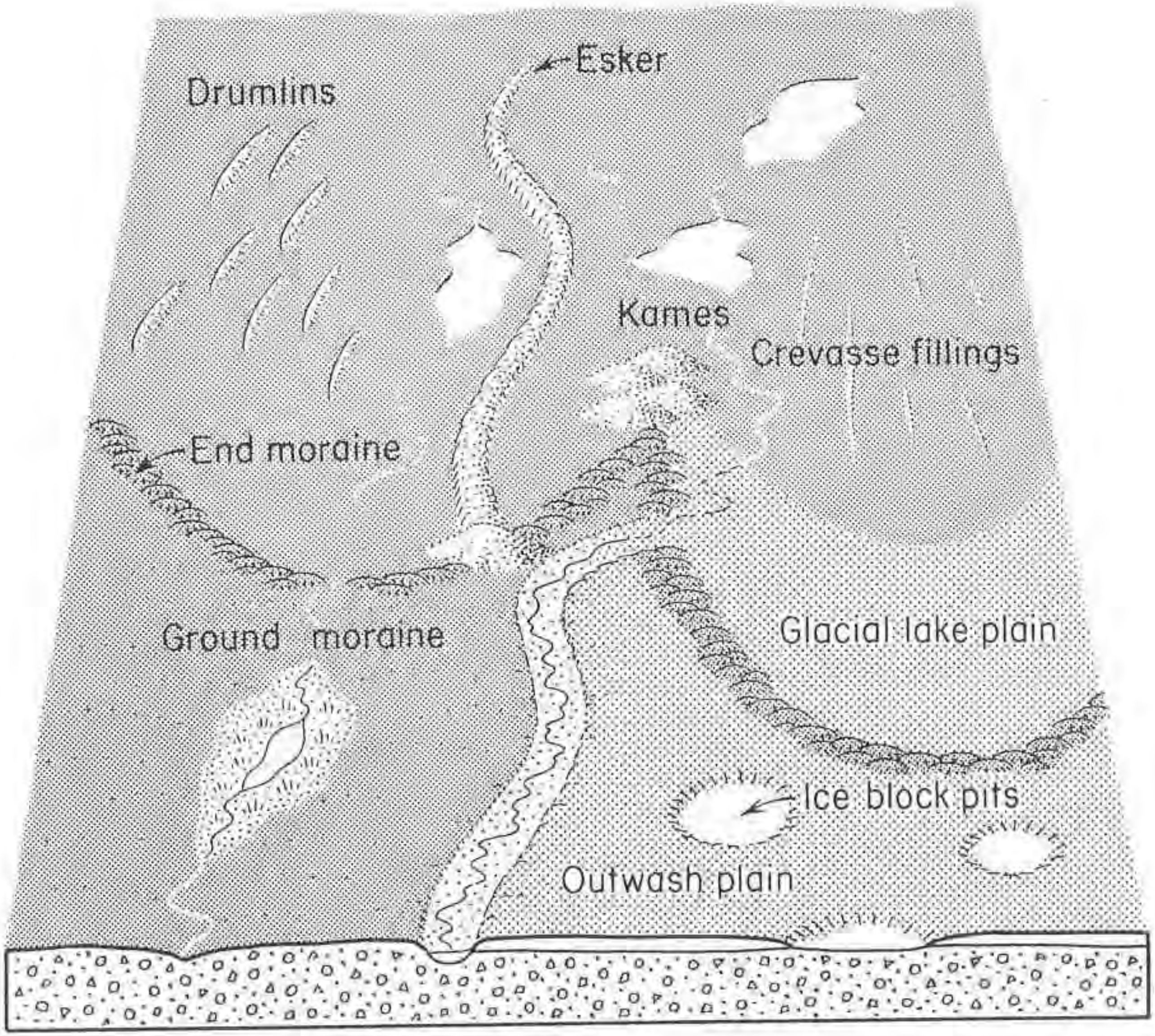
Retreat Rate ≈ 500’/yr



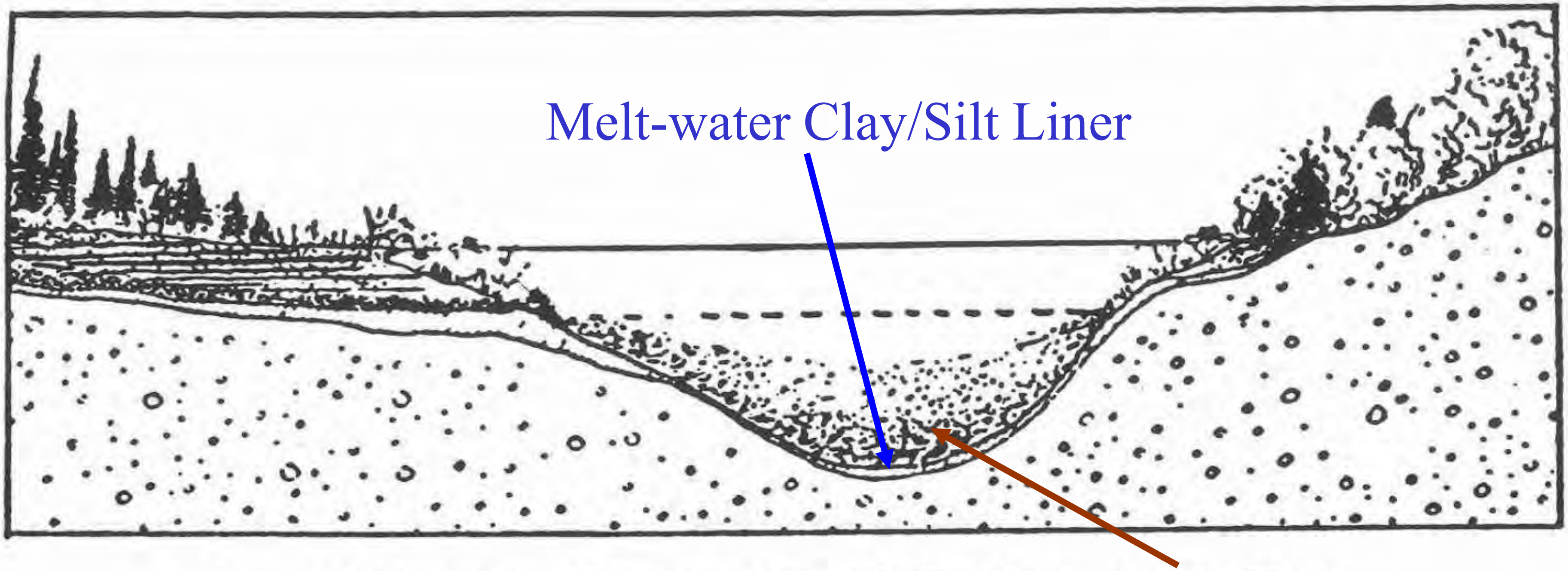
From Dorr & Eschman’s “Geology of Michigan”



From Dorr & Eschman's "Geology of Michigan"



From Dorr & Eschman's "Geology of Michigan"



Melt-water Clay/Silt Liner

Fig. 2.10—The Formation of Sedimentary Peat.

From MDOT’s “Field Manual of Soils Engineering”

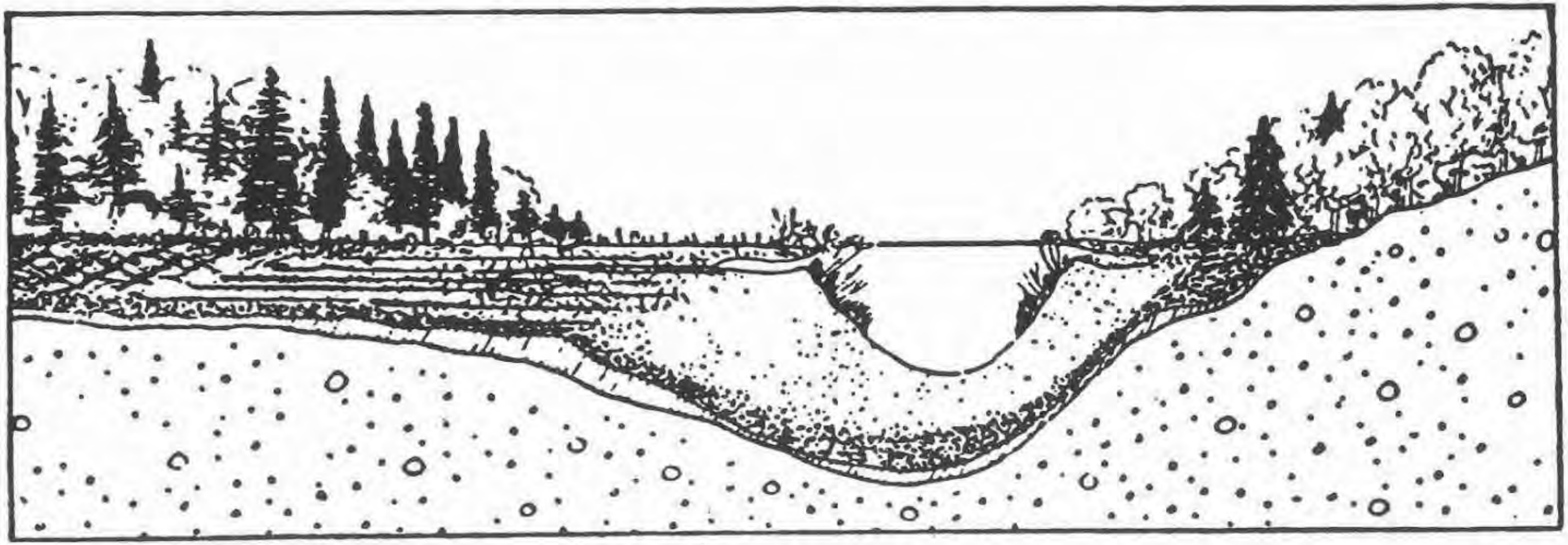


Fig. 2.11—The Formation of Fibrous Peat.

From MDOT's "Field Manual of Soils Engineering"

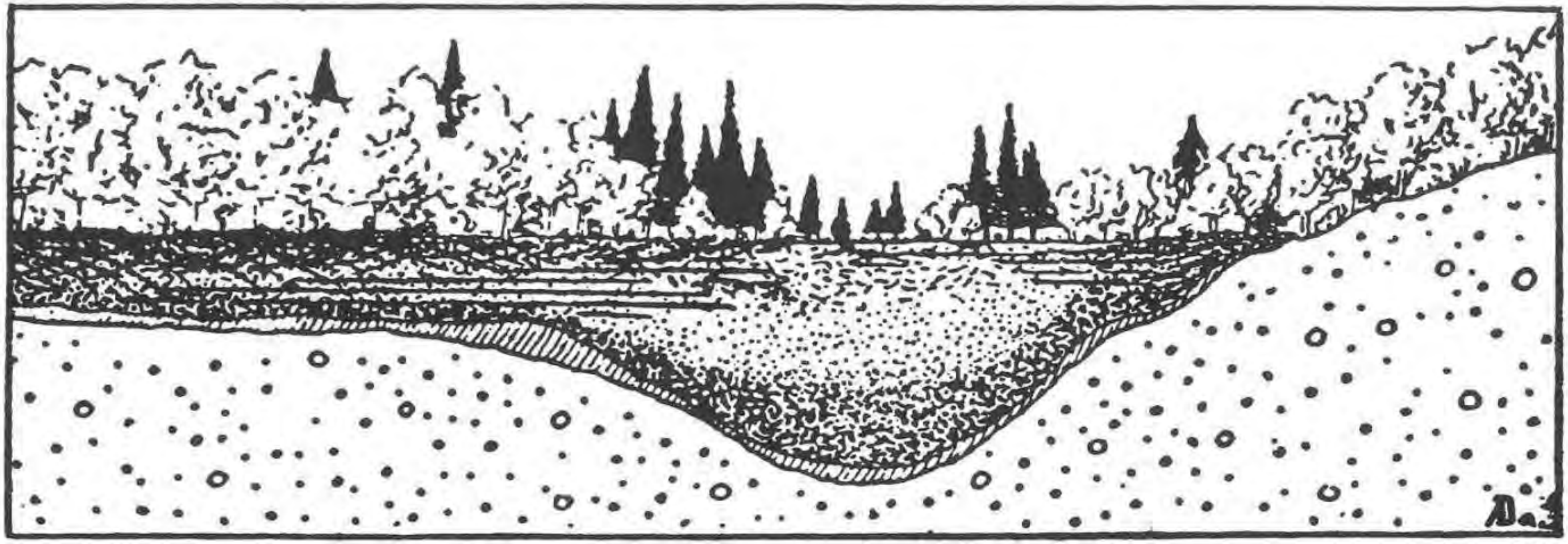
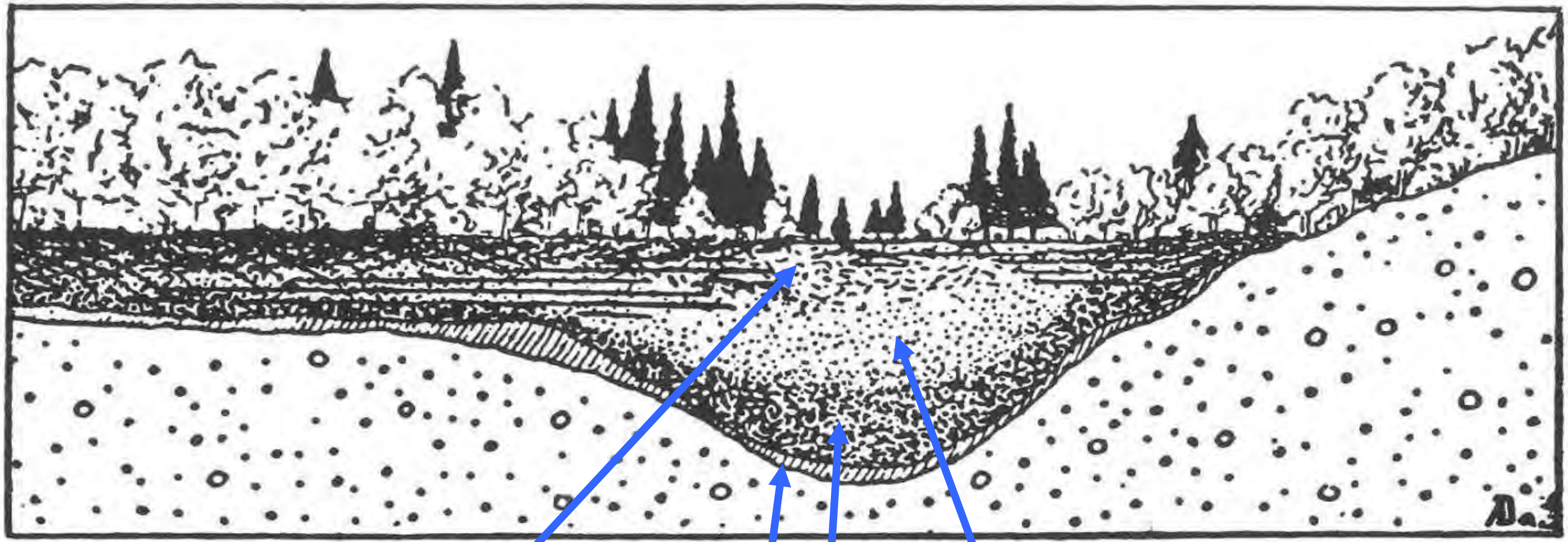


Fig. 2.12—The Formation of Woody Peat.

From MDOT’s “Field Manual of Soils Engineering”



Woody Peat

Fibrous Peat

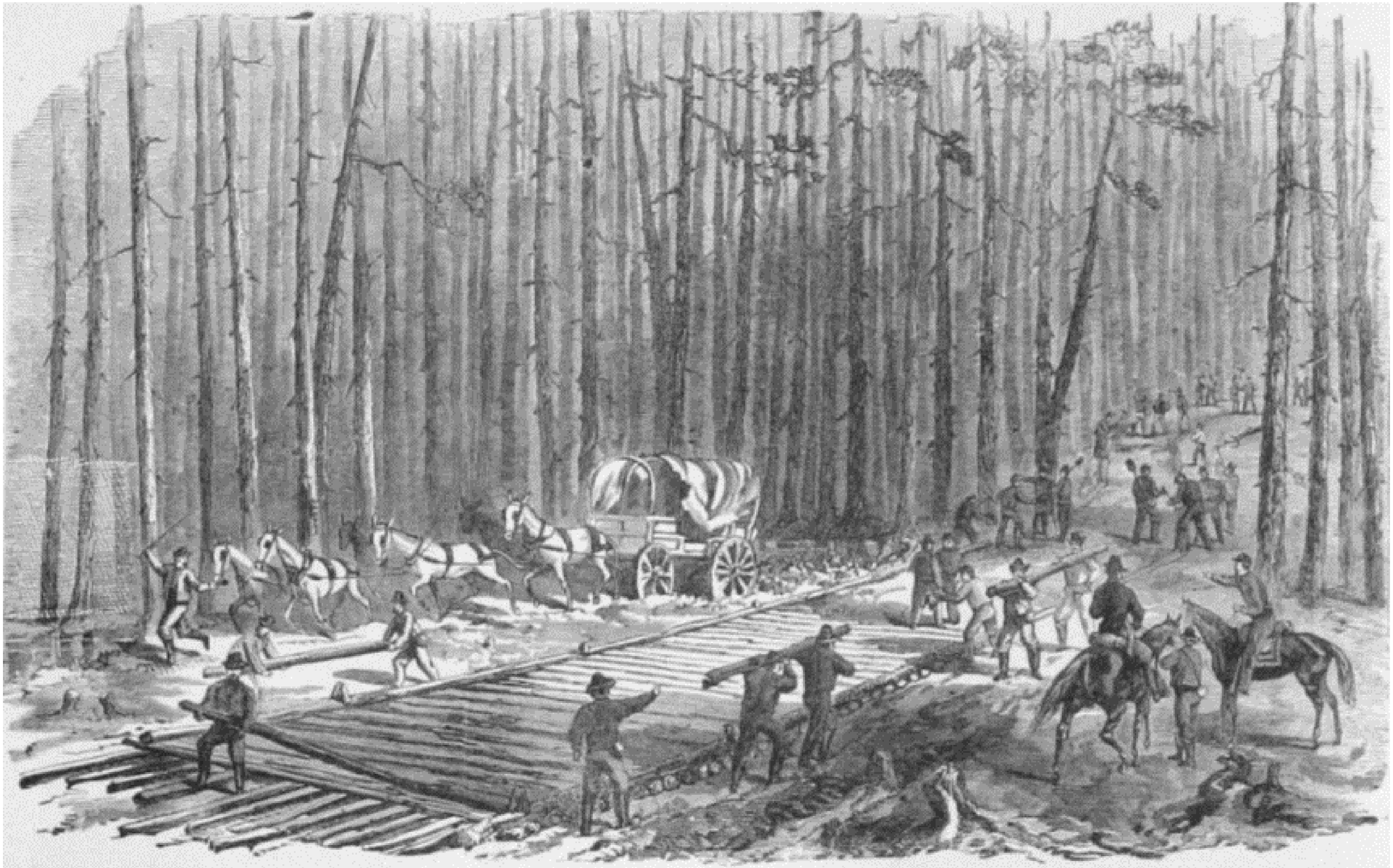
Sedimentary-Amorphous Peat

Soft Clay/Marl

No Swamp – Like New

Continuously Breaking Up and Moving over Swamp

Bamboo Fascine laid over Separator Geotextile TS-80 Controlled Stage Construction of Geotextile Reinforced Embankment of 7.0 m high over a 9.0 m of extremely soft soil using high tensile strength Geotextile



BUILDING A CORDUROY ROAD IN THE WOODS, NEAR THE WELDON RAILROAD, VA.—From a Sketch by A. McCallum.

1930s ➔ 1st recorded use of a “Textile” in Road construction in South Carolina. Cotton based, so not very durable.

1950s ➔ 1st use of a “synthetic” material textile, a woven fabric used for beach erosion control in Florida.

1960s ➔ Use of geosynthetics explodes! Worldwide.

1970s ➔ First modern polymer type geosynthetics
First documented use -embankments soft ground

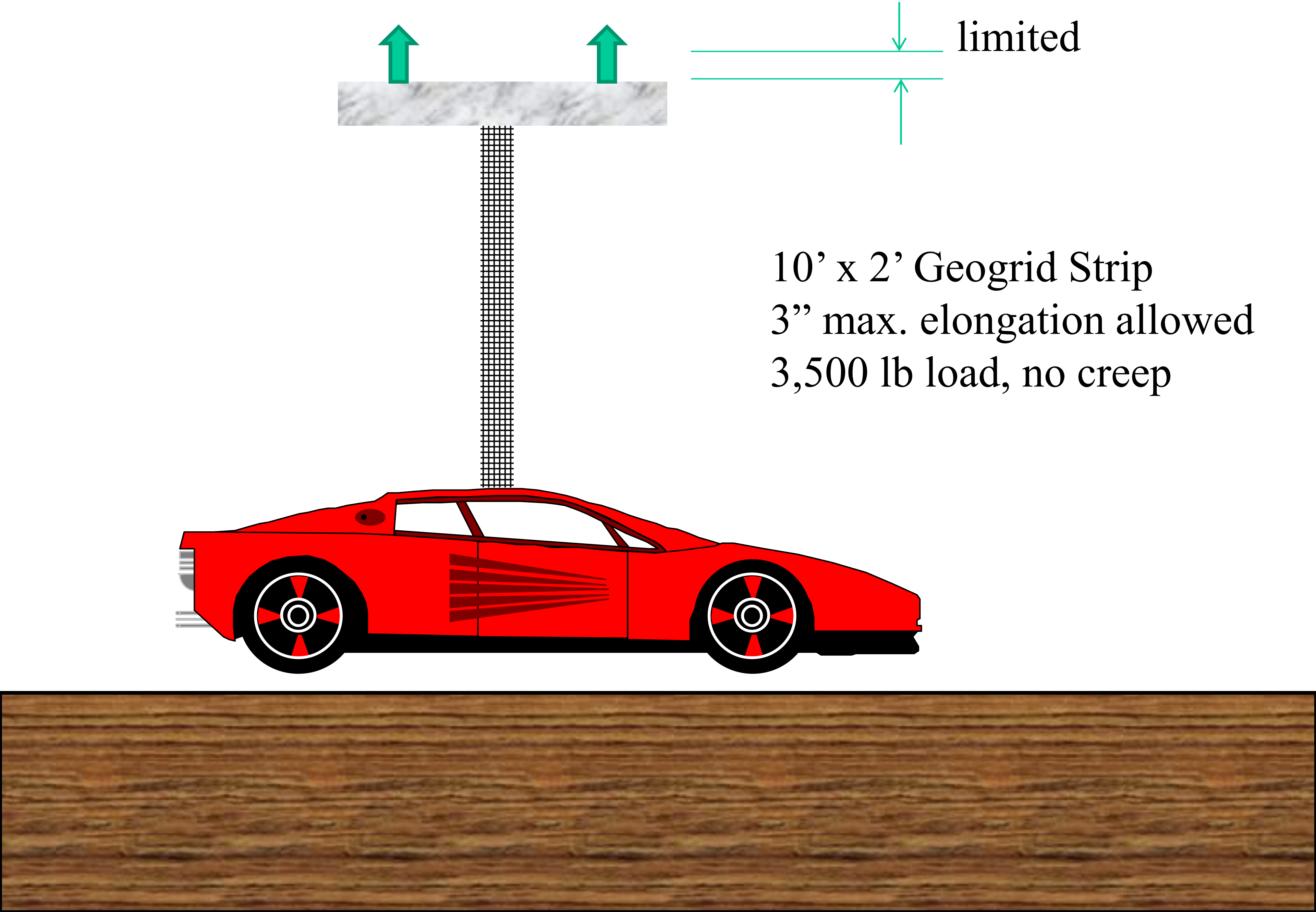
1982 ➔ First Government subcommittee (Task Force No 25) formed with goal to make first specifications for use in transportation works. International Geotextile Society was formed.

1990s ➔ MDOT adds geotextile classes/specifications to the Standard Plans for Construction. MDOT’s first Geogrid Special Provisions.

From: FHWA-HI-89-050, Geotextile Engineering Manual

Understanding Product Data Sheets and Specifications

Example: STRENGTH vs DEFORMATION:



10’ x 2’ Geogrid Strip
3” max. elongation allowed
3,500 lb load, no creep

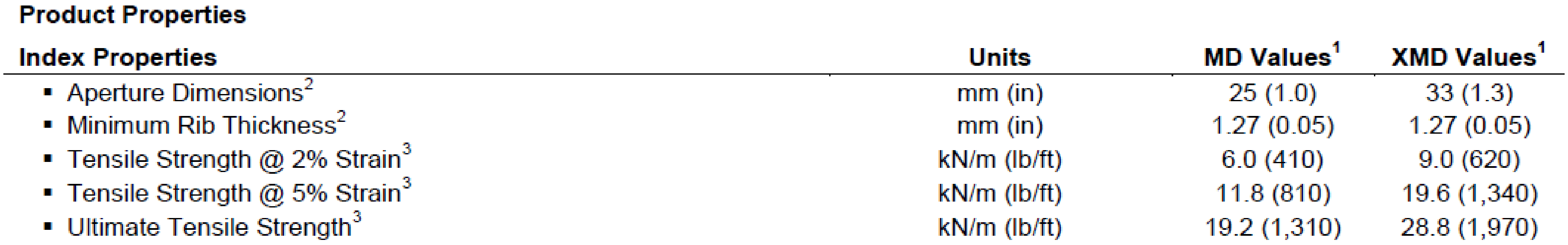
Can we use a:
“MDOT Commonly Used Special Provision” Geogrid?

MDOT “Biaxial Geogrid” special provision

Product Properties

Index Properties	Units	MD Values[1]	XMD Values[1]
▪ Aperture Dimensions[2]	mm (in)	25 (1.0)	33 (1.3)
▪ Minimum Rib Thickness[2]	mm (in)	0.76 (0.03)	0.76 (0.03)
▪ Tensile Strength @ 2% Strain[3]	kN/m (lb/ft)	4.1 (280)	6.6 (450)
▪ Tensile Strength @ 5% Strain[3]	kN/m (lb/ft)	8.5 (580)	13.4 (920)
▪ Ultimate Tensile Strength[3]	kN/m (lb/ft)	12.4 (850)	19.0 (1,300)

MDOT “High Performance Biaxial Geogrid” s.p.



Product Properties

Index Properties	Units	MD Values[1]	XMD Values[1]
▪ Aperture Dimensions[2]	mm (in)	25 (1.0)	33 (1.3)
▪ Minimum Rib Thickness[2]	mm (in)	1.27 (0.05)	1.27 (0.05)
▪ Tensile Strength @ 2% Strain[3]	kN/m (lb/ft)	6.0 (410)	9.0 (620)
▪ Tensile Strength @ 5% Strain[3]	kN/m (lb/ft)	11.8 (810)	19.6 (1,340)
▪ Ultimate Tensile Strength[3]	kN/m (lb/ft)	19.2 (1,310)	28.8 (1,970)

Step 1: Calculate Limiting Percent Strain

%strain = (3)/ (10*12) x 100 = 2.5% strain max.

Step 2: Calculate lb/ft Service Load in Geogrid

Service Load = 3,500/2 = 1,750 lb/ft resistance

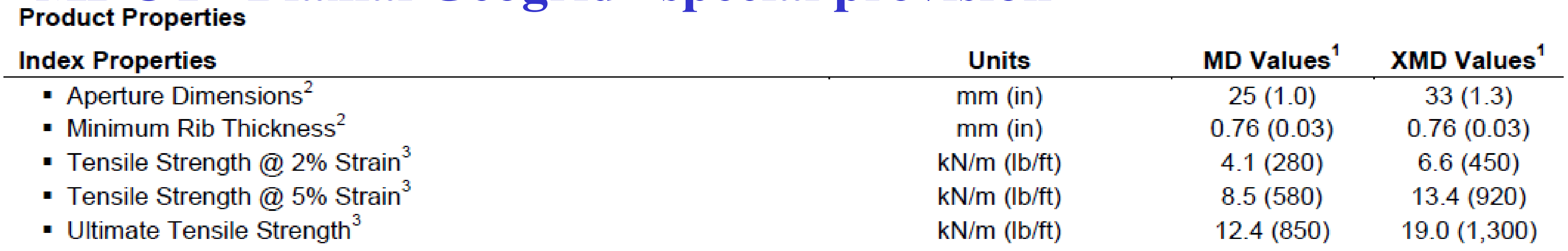
Step 3: Find Products that can meet this spring stiffness requirement and be below creep threshold for the material.

Geosynthetics are Complex Non-Linear Springs that work in "Tension" only.

They "creep" at load levels below ultimate strength.

Can we use a:
“MDOT Commonly Used Special Provision” Geogrid?

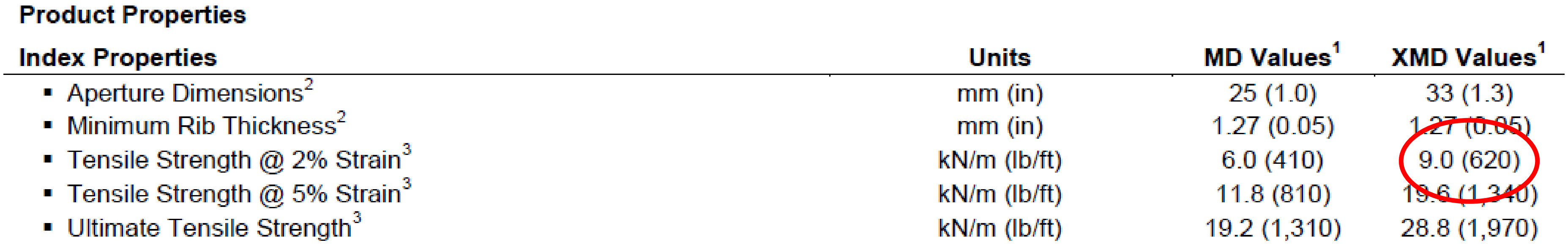
MDOT “Biaxial Geogrid” special provision



Product Properties

Index Properties	Units	MD Values^{1}	XMD Values^{1}
▪ Aperture Dimensions^{2}	mm (in)	25 (1.0)	33 (1.3)
▪ Minimum Rib Thickness^{2}	mm (in)	0.76 (0.03)	0.76 (0.03)
▪ Tensile Strength @ 2% Strain^{3}	kN/m (lb/ft)	4.1 (280)	6.6 (450)
▪ Tensile Strength @ 5% Strain^{3}	kN/m (lb/ft)	8.5 (580)	13.4 (920)
▪ Ultimate Tensile Strength^{3}	kN/m (lb/ft)	12.4 (850)	19.0 (1,300)

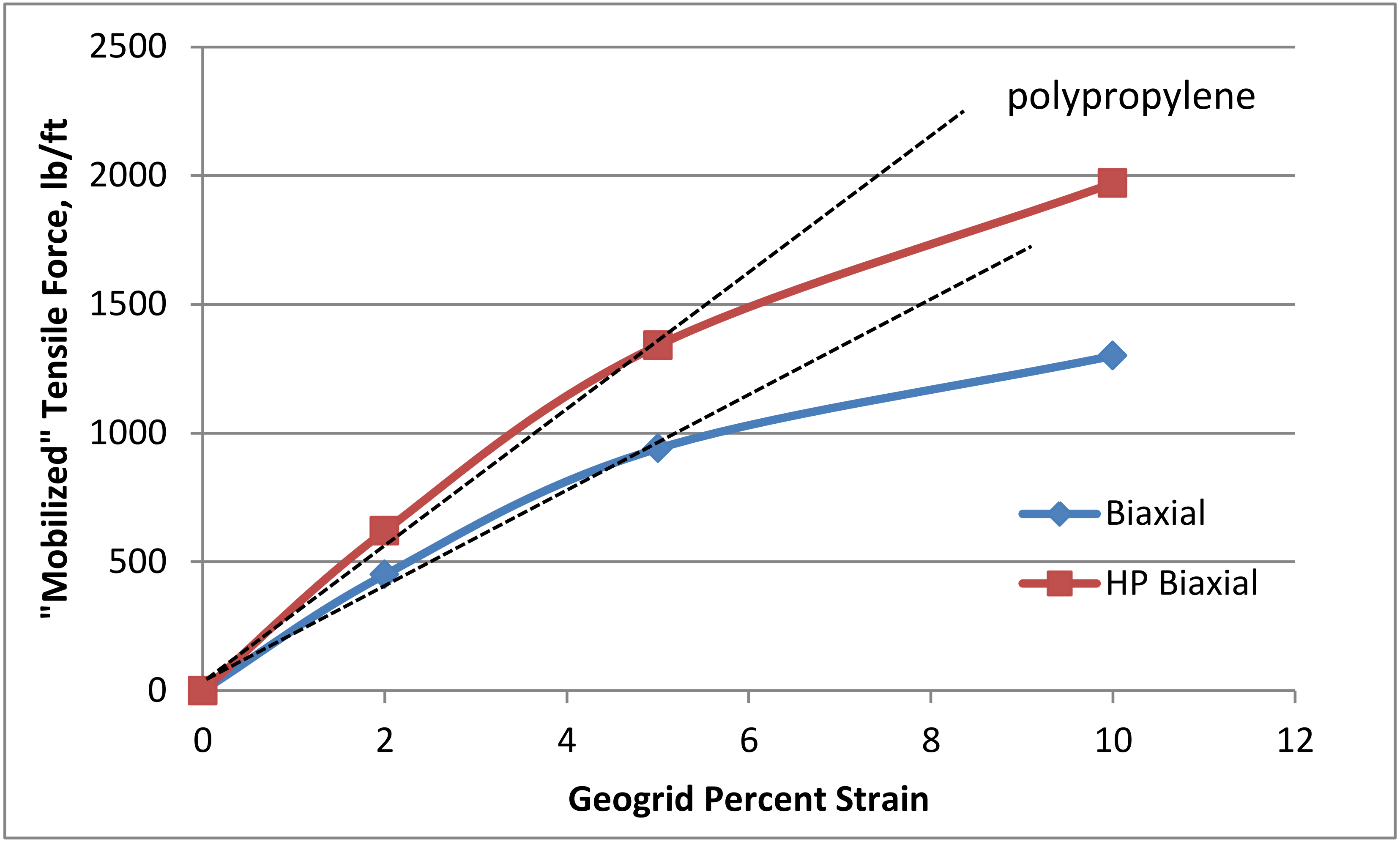
MDOT “High Performance Biaxial Geogrid” s.p.

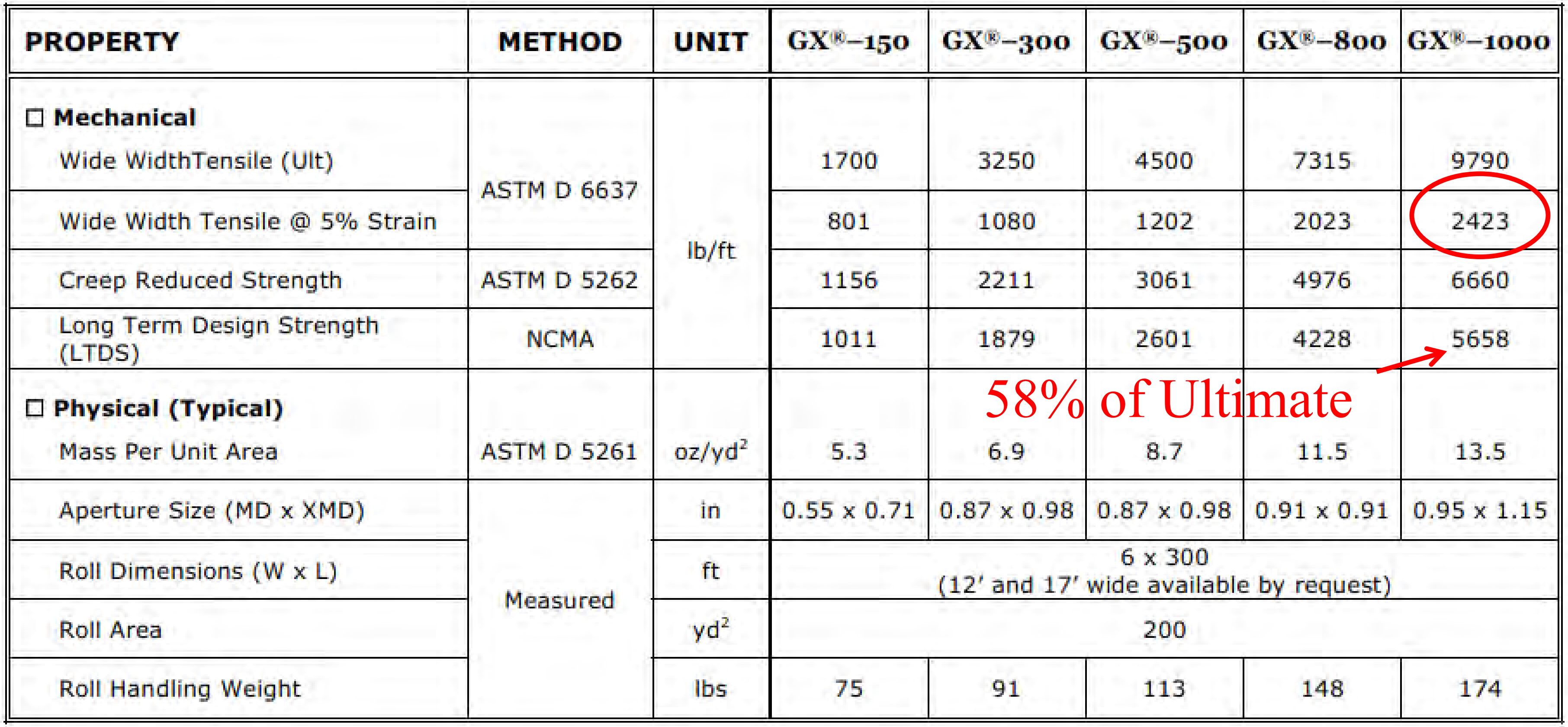


Product Properties

Index Properties	Units	MD Values^{1}	XMD Values^{1}
▪ Aperture Dimensions^{2}	mm (in)	25 (1.0)	33 (1.3)
▪ Minimum Rib Thickness^{2}	mm (in)	1.27 (0.05)	1.27 (0.05)
▪ Tensile Strength @ 2% Strain^{3}	kN/m (lb/ft)	6.0 (410)	9.0 (620)
▪ Tensile Strength @ 5% Strain^{3}	kN/m (lb/ft)	11.8 (810)	19.6 (1,340)
▪ Ultimate Tensile Strength^{3}	kN/m (lb/ft)	19.2 (1,310)	28.8 (1,970)

620 lb/ft @ 2% ➔ need 5-ft wide strip… NO GO


polypropylene
"Mobilized" Tensile Force, lb/ft
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
Geogrid Percent Strain
Biaxial
HP Biaxial

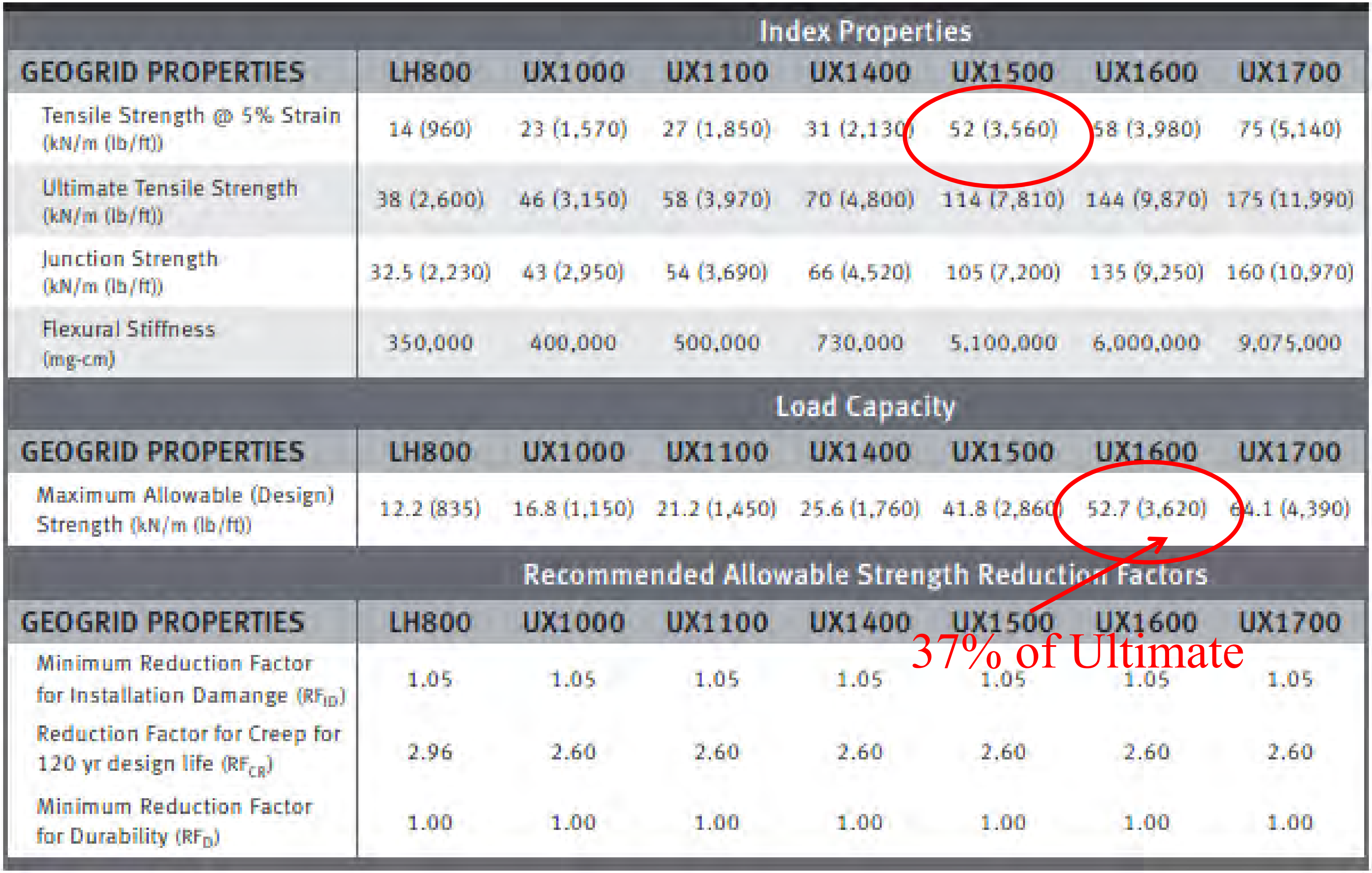


PROPERTY	METHOD	UNIT	GX®–150	GX®–300	GX®–500	GX®–800	GX®–1000
☐ **Mechanical**							
Wide WidthTensile (Ult)	ASTM D 6637	lb/ft	1700	3250	4500	7315	9790
Wide Width Tensile @ 5% Strain			801	1080	1202	2023	2423
Creep Reduced Strength	ASTM D 5262		1156	2211	3061	4976	6660
Long Term Design Strength (LTDS)	NCMA		1011	1879	2601	4228	5658
☐ **Physical (Typical)**							
Mass Per Unit Area	ASTM D 5261	oz/yd^2	5.3	6.9	8.7	11.5	13.5
Aperture Size (MD x XMD)	Measured	in	0.55 x 0.71	0.87 x 0.98	0.87 x 0.98	0.91 x 0.91	0.95 x 1.15
Roll Dimensions (W x L)		ft	6 x 300 (12′ and 17′ wide available by request)				
Roll Area		yd^2	200				
Roll Handling Weight		lbs	75	91	113	148	174

58% of Ultimate

1,750 lb/ft @ 2.5% ➔ 3,500 lb/ft @ 5.0%

Reduction factor for creep = 9790/6660 = 1.47
creep strength is 68% of Ultimate



Index Properties							
GEOGRID PROPERTIES	**LH800**	**UX1000**	**UX1100**	**UX1400**	**UX1500**	**UX1600**	**UX1700**
Tensile Strength @ 5% Strain (kN/m (lb/ft))	14 (960)	23 (1,570)	27 (1,850)	31 (2,130)	52 (3,560)	58 (3,980)	75 (5,140)
Ultimate Tensile Strength (kN/m (lb/ft))	38 (2,600)	46 (3,150)	58 (3,970)	70 (4,800)	114 (7,810)	144 (9,870)	175 (11,990)
Junction Strength (kN/m (lb/ft))	32.5 (2,230)	43 (2,950)	54 (3,690)	66 (4,520)	105 (7,200)	135 (9,250)	160 (10,970)
Flexural Stiffness (mg-cm)	350,000	400,000	500,000	730,000	5,100,000	6,000,000	9,075,000

Load Capacity							
GEOGRID PROPERTIES	**LH800**	**UX1000**	**UX1100**	**UX1400**	**UX1500**	**UX1600**	**UX1700**
Maximum Allowable (Design) Strength (kN/m (lb/ft))	12.2 (835)	16.8 (1,150)	21.2 (1,450)	25.6 (1,760)	41.8 (2,860)	52.7 (3,620)	64.1 (4,390)

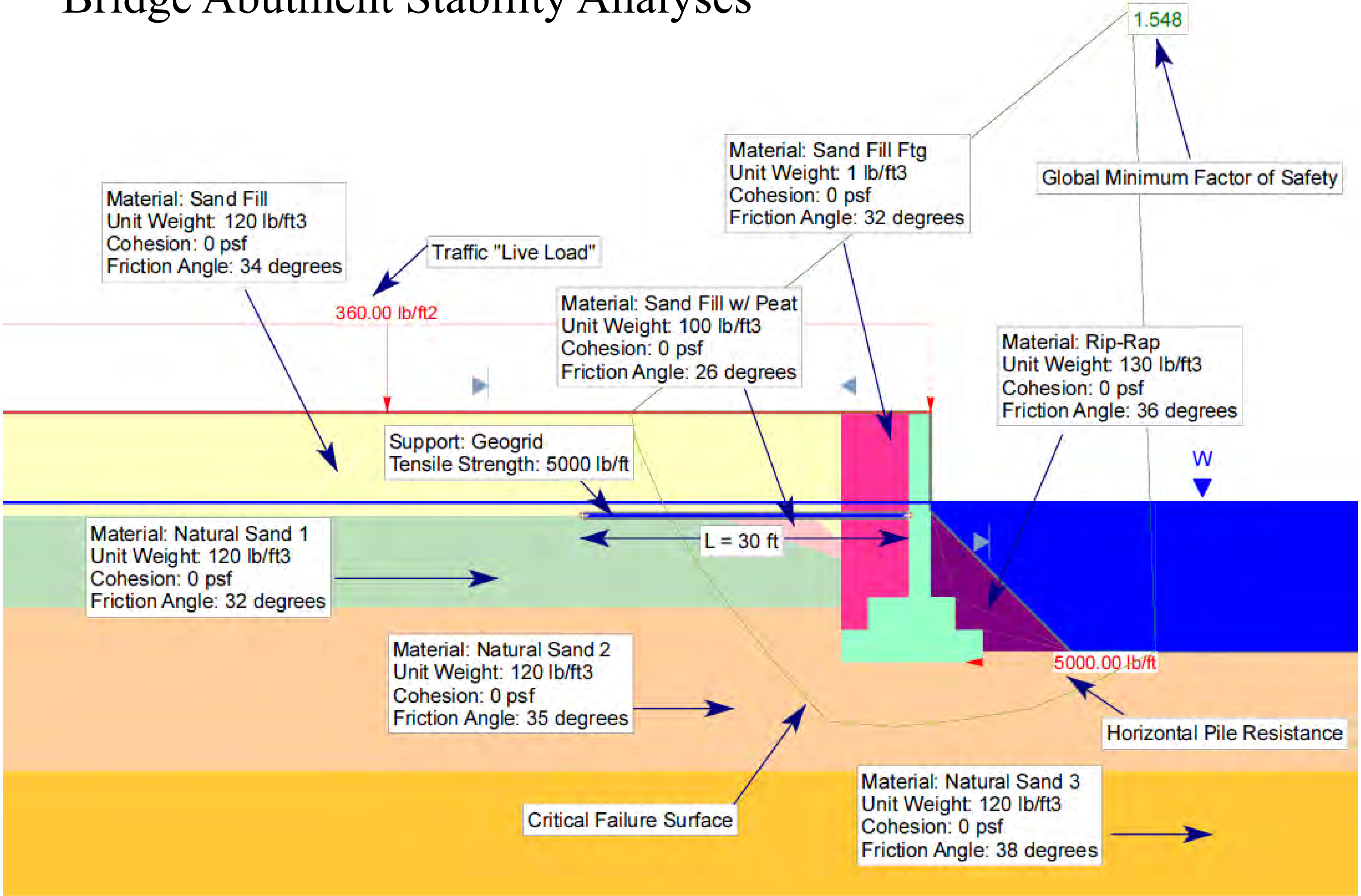
Recommended Allowable Strength Reduction Factors							
GEOGRID PROPERTIES	**LH800**	**UX1000**	**UX1100**	**UX1400**	**UX1500**	**UX1600**	**UX1700**
Minimum Reduction Factor for Installation Damange (RF_{ID})	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Reduction Factor for Creep for 120 yr design life (RF_{CR})	2.96	2.60	2.60	2.60	2.60	2.60	2.60
Minimum Reduction Factor for Durability (RF_D)	1.00	1.00	1.00	1.00	1.00	1.00	1.00

37% of Ultimate

1,750 lb/ft @ 2.5% ➔ 3,500 lb/ft @ 5.0%

120-yr ➔ 92500/(2.6*1.05*1) = 3615 ➔ OK

Bridge Abutment Stability Analyses



1.548

Global Minimum Factor of Safety

Material: Sand Fill Ftg
Unit Weight: 1 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees

Material: Sand Fill
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 34 degrees

Traffic "Live Load"

360.00 lb/ft2

Material: Sand Fill w/ Peat
Unit Weight: 100 lb/ft3
Cohesion: 0 psf
Friction Angle: 26 degrees

Material: Rip-Rap
Unit Weight: 130 lb/ft3
Cohesion: 0 psf
Friction Angle: 36 degrees

Support: Geogrid
Tensile Strength: 5000 lb/ft

Material: Natural Sand 1
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 32 degrees

L = 30 ft

Material: Natural Sand 2
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 35 degrees

5000.00 lb/ft

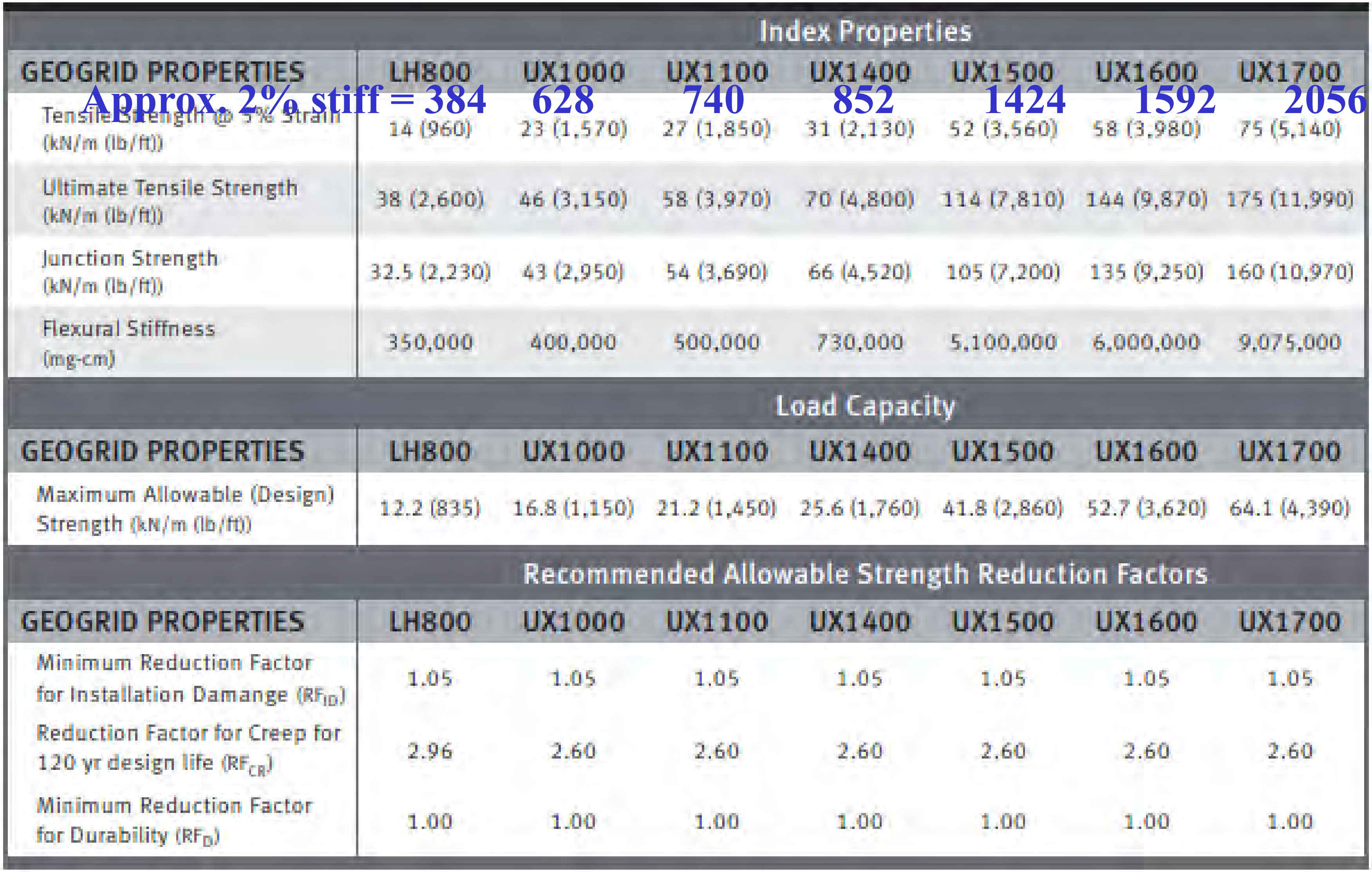
Horizontal Pile Resistance

Critical Failure Surface

Material: Natural Sand 3
Unit Weight: 120 lb/ft3
Cohesion: 0 psf
Friction Angle: 38 degrees

No. of Layers = 13 8 7 6 4 4 3

Approx. 2% stiff = 384 628 740 852 1424 1592 2056



Index Properties

GEOGRID PROPERTIES	LH800	UX1000	UX1100	UX1400	UX1500	UX1600	UX1700
Tensile Strength @ 5% Strain (kN/m (lb/ft))	14 (960)	23 (1,570)	27 (1,850)	31 (2,130)	52 (3,560)	58 (3,980)	75 (5,140)
Ultimate Tensile Strength (kN/m (lb/ft))	38 (2,600)	46 (3,150)	58 (3,970)	70 (4,800)	114 (7,810)	144 (9,870)	175 (11,990)
Junction Strength (kN/m (lb/ft))	32.5 (2,230)	43 (2,950)	54 (3,690)	66 (4,520)	105 (7,200)	135 (9,250)	160 (10,970)
Flexural Stiffness (mg-cm)	350,000	400,000	500,000	730,000	5,100,000	6,000,000	9,075,000

Load Capacity

GEOGRID PROPERTIES	LH800	UX1000	UX1100	UX1400	UX1500	UX1600	UX1700
Maximum Allowable (Design) Strength (kN/m (lb/ft))	12.2 (835)	16.8 (1,150)	21.2 (1,450)	25.6 (1,760)	41.8 (2,860)	52.7 (3,620)	64.1 (4,390)

Recommended Allowable Strength Reduction Factors

GEOGRID PROPERTIES	LH800	UX1000	UX1100	UX1400	UX1500	UX1600	UX1700
Minimum Reduction Factor for Installation Damange (RF_{ID})	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Reduction Factor for Creep for 120 yr design life (RF_{CR})	2.96	2.60	2.60	2.60	2.60	2.60	2.60
Minimum Reduction Factor for Durability (RF_D)	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Separation and Filtration

Migration of silt and clay fines up into aggregate base air voids = settlement and rutting

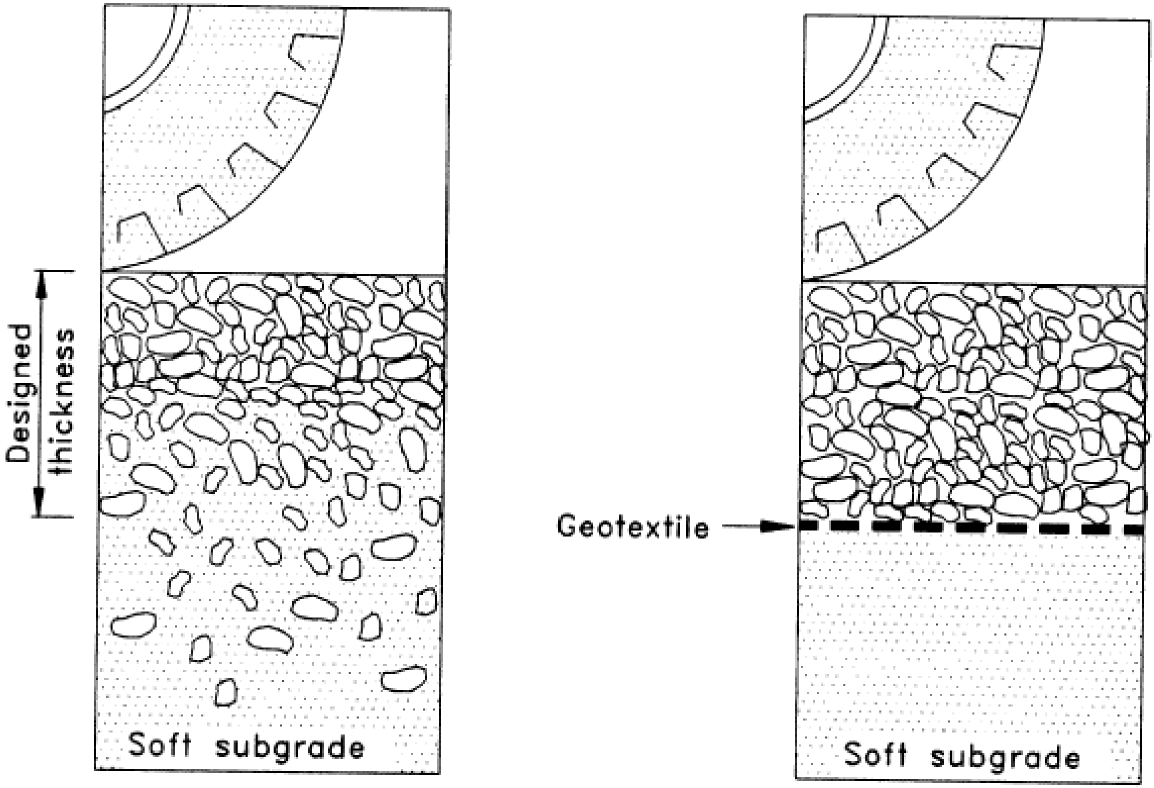


Figure 5-1 Concept of geotextile separation in roadways (after Rankilor, 1981).

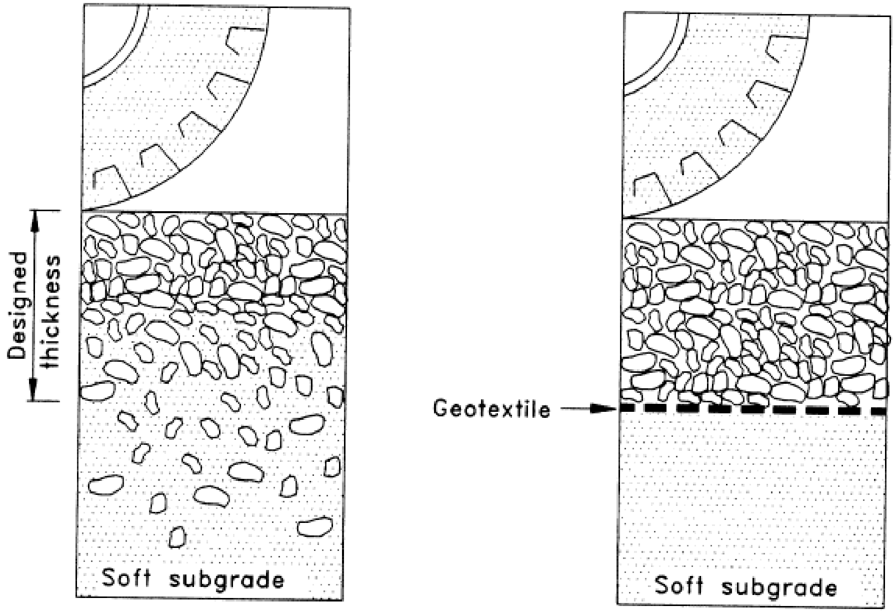
4G- OG

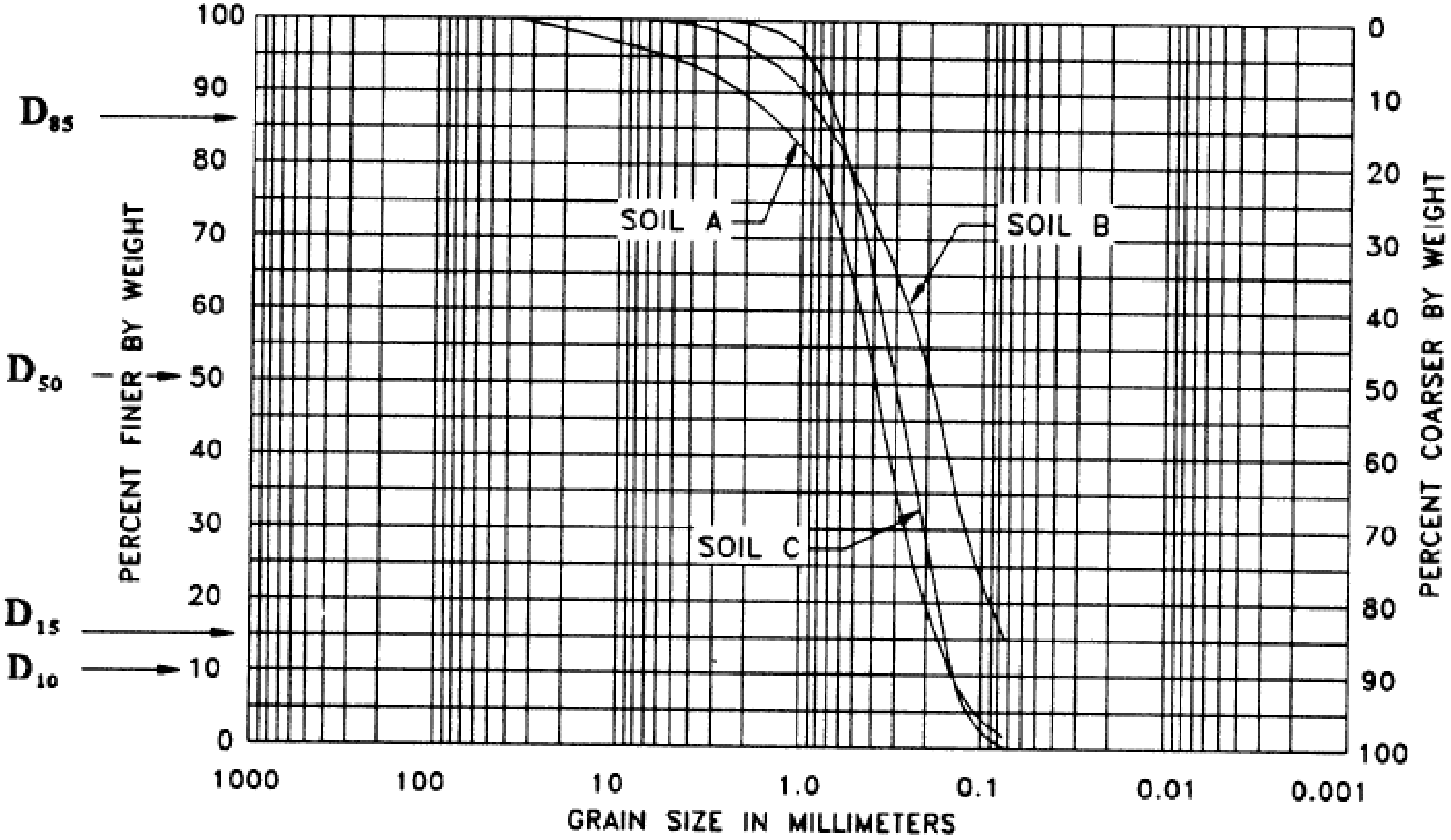
21AA - DG

Class II or Sand

Clayey Sand/Sandy Clay

Fat Clays, very low sand





COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

…compared to the "glass beads" test for fabric:

O_{95} = AOS = 95% passing opening size for fabric

O_{50} = mean opening size in fabric

US Army Criteria

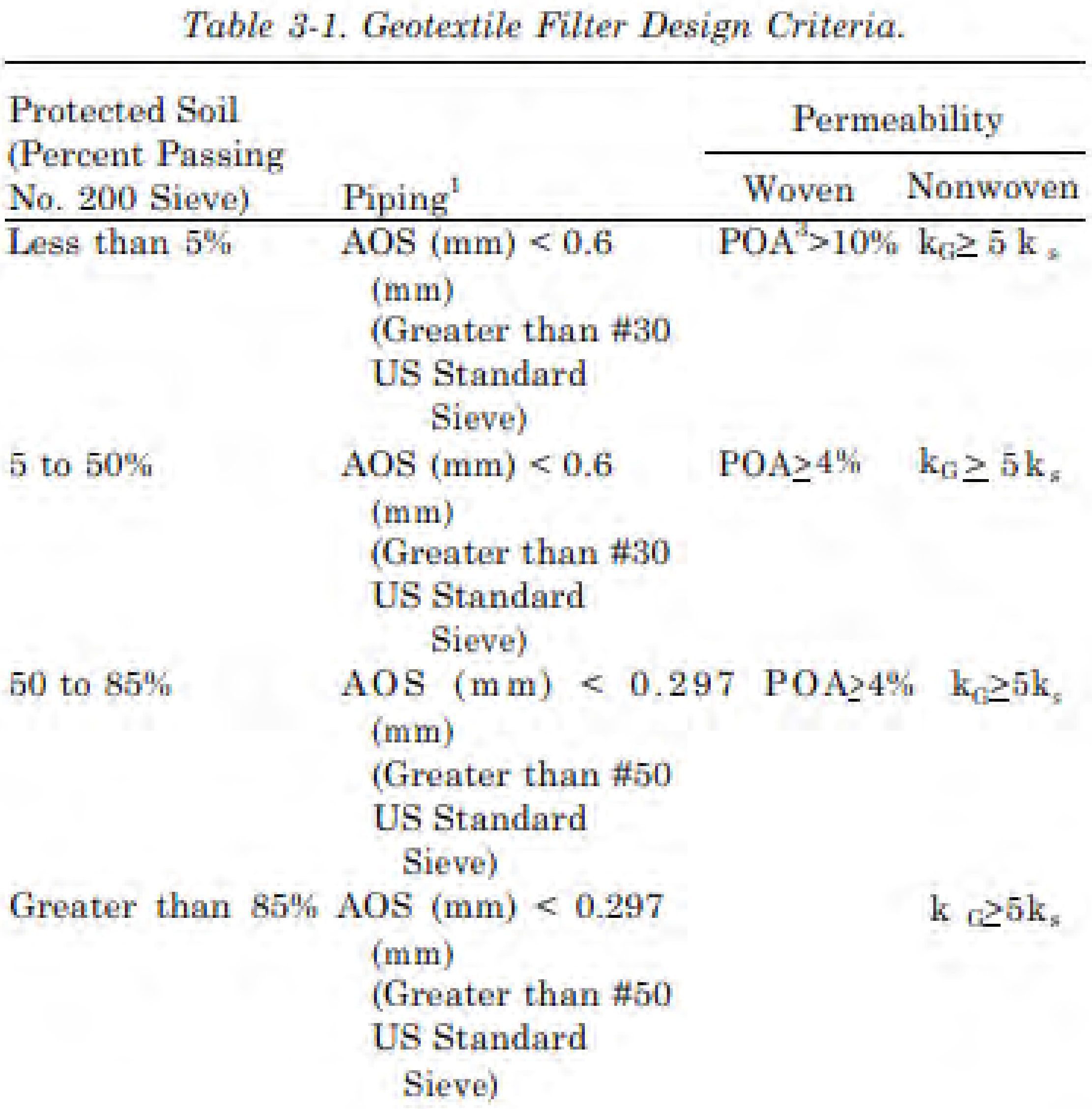


Table 3-1. Geotextile Filter Design Criteria.

Protected Soil (Percent Passing No. 200 Sieve)	Piping[1]	Permeability	
		Woven	Nonwoven
Less than 5%	AOS (mm) < 0.6 (mm) (Greater than #30 US Standard Sieve)	POA[3]>10%	$k_G \geq 5 k_s$
5 to 50%	AOS (mm) < 0.6 (mm) (Greater than #30 US Standard Sieve)	POA≥4%	$k_G \geq 5 k_s$
50 to 85%	AOS (mm) < 0.297 (mm) (Greater than #50 US Standard Sieve)	POA≥4%	$k_G \geq 5k_s$
Greater than 85%	AOS (mm) < 0.297 (mm) (Greater than #50 US Standard Sieve)		$k_G \geq 5k_s$

POA = % open area

k_G – geotextile permeability

k_s – soil permeab

Permittivity, gal/ft^2/min per *psf* of head

k_G…Q=kiA flow

O_{95} = AOS = 95% passing size for fabric
O_{50} = mean opening size in fabric

MDOT Criteria

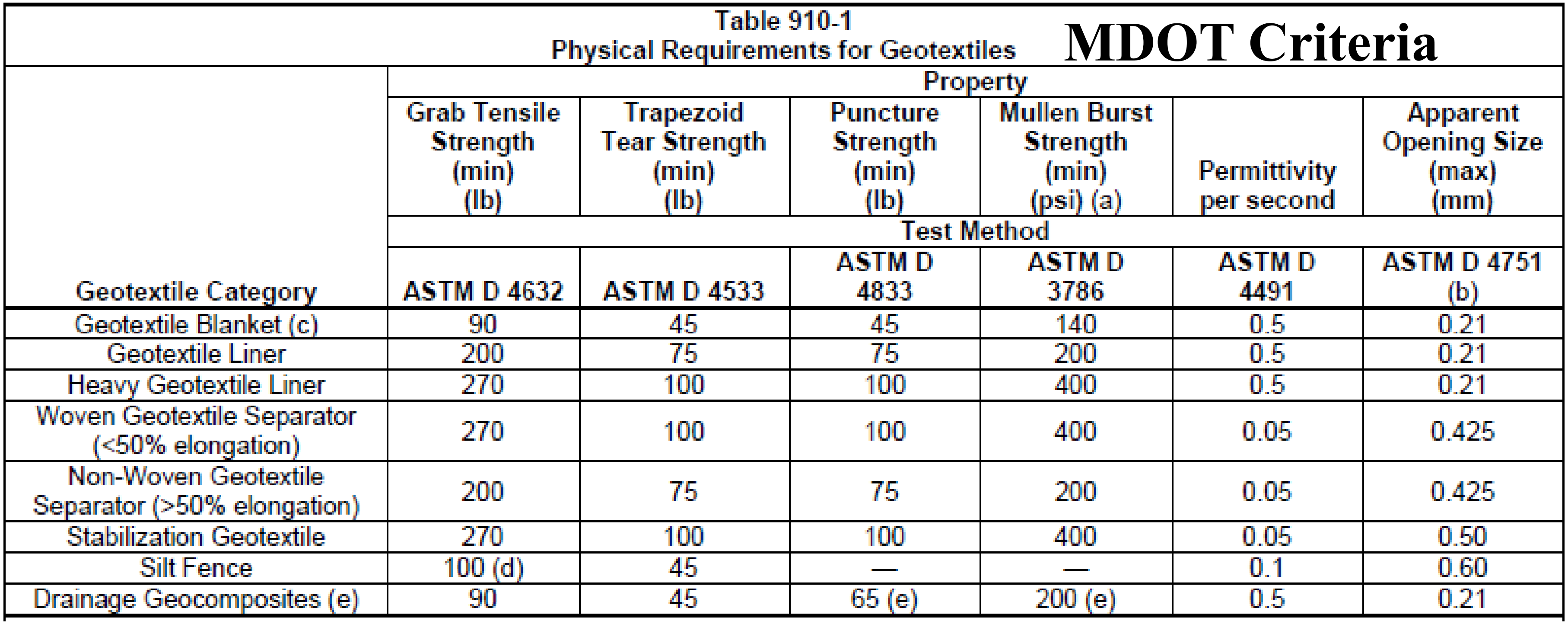
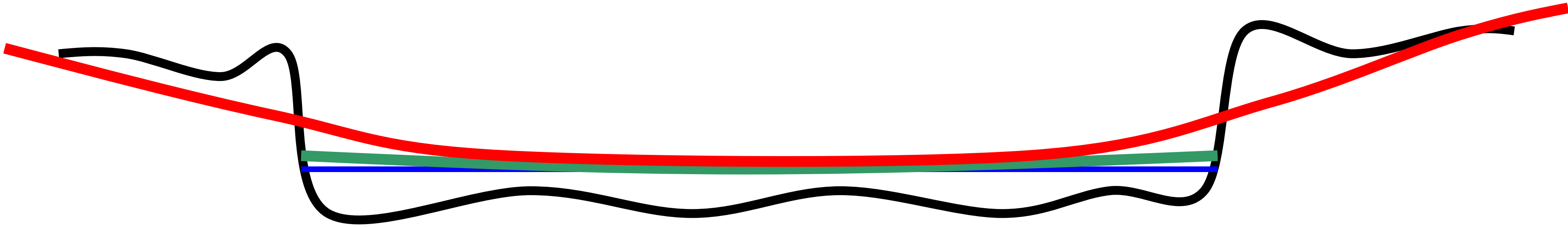


Table 910-1
Physical Requirements for Geotextiles

Geotextile Category	Grab Tensile Strength (min) (lb)	Trapezoid Tear Strength (min) (lb)	Puncture Strength (min) (lb)	Mullen Burst Strength (min) (psi) (a)	Permittivity per second	Apparent Opening Size (max) (mm)
	Test Method					
	ASTM D 4632	ASTM D 4533	ASTM D 4833	ASTM D 3786	ASTM D 4491	ASTM D 4751 (b)
Geotextile Blanket (c)	90	45	45	140	0.5	0.21
Geotextile Liner	200	75	75	200	0.5	0.21
Heavy Geotextile Liner	270	100	100	400	0.5	0.21
Woven Geotextile Separator (<50% elongation)	270	100	100	400	0.05	0.425
Non-Woven Geotextile Separator (>50% elongation)	200	75	75	200	0.05	0.425
Stabilization Geotextile	270	100	100	400	0.05	0.50
Silt Fence	100 (d)	45	—	—	0.1	0.60
Drainage Geocomposites (e)	90	45	65 (e)	200 (e)	0.5	0.21

Permittivity, $\text{gal/ft}^2\text{/min}$
per *psf* of head

= 1/min



CASE 1:

Switch an Aggregate Road
to a ***Paved Surface***, over
20 to 30 feet of peat and marl.

*Small (1- 2 ft) Grade Increase

*No Embankment Widening

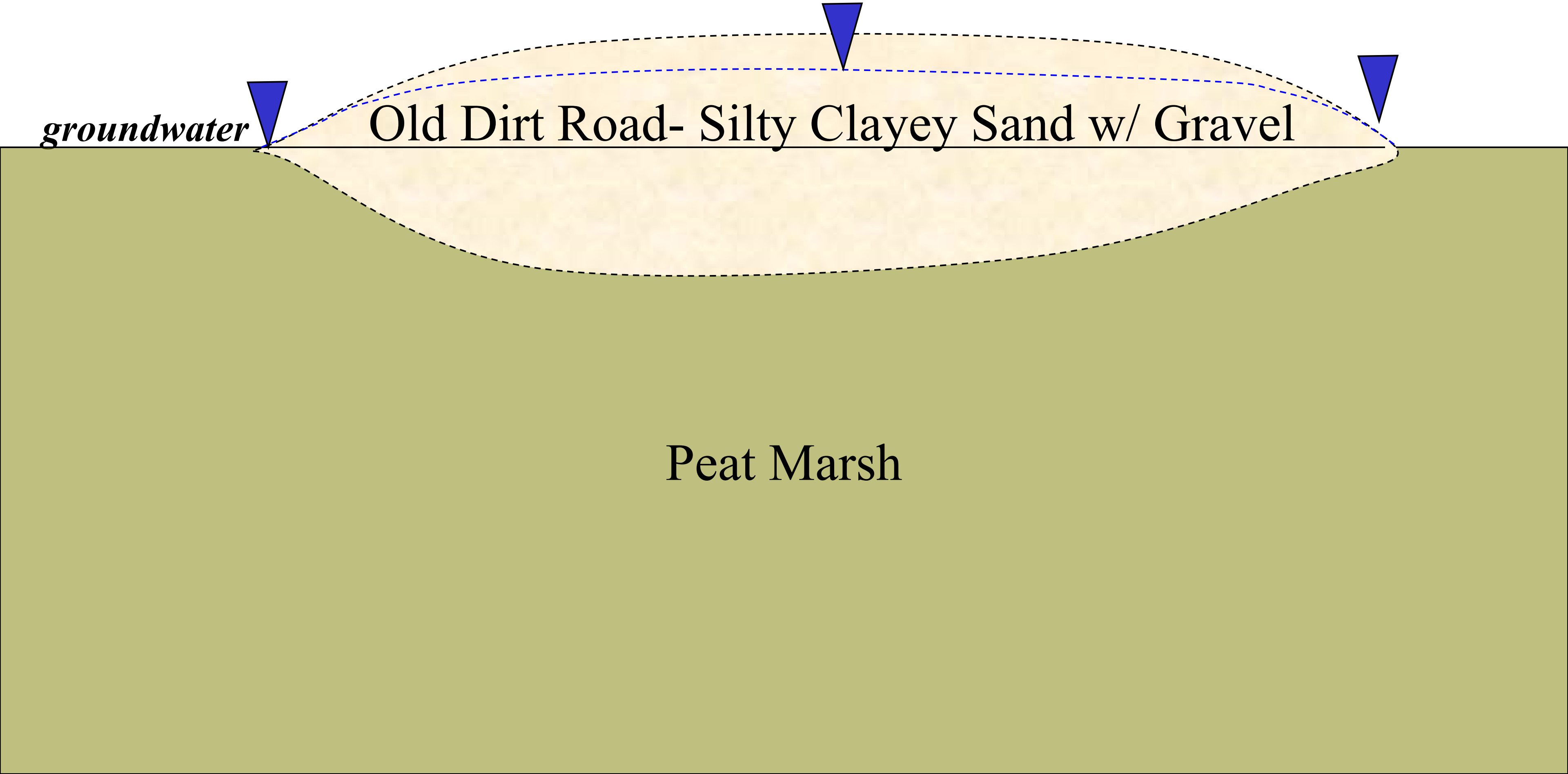
*Embankment H < 3 to 4 feet


Maltby Road- near Brighton, MI

8/9/2001


8/9/2001

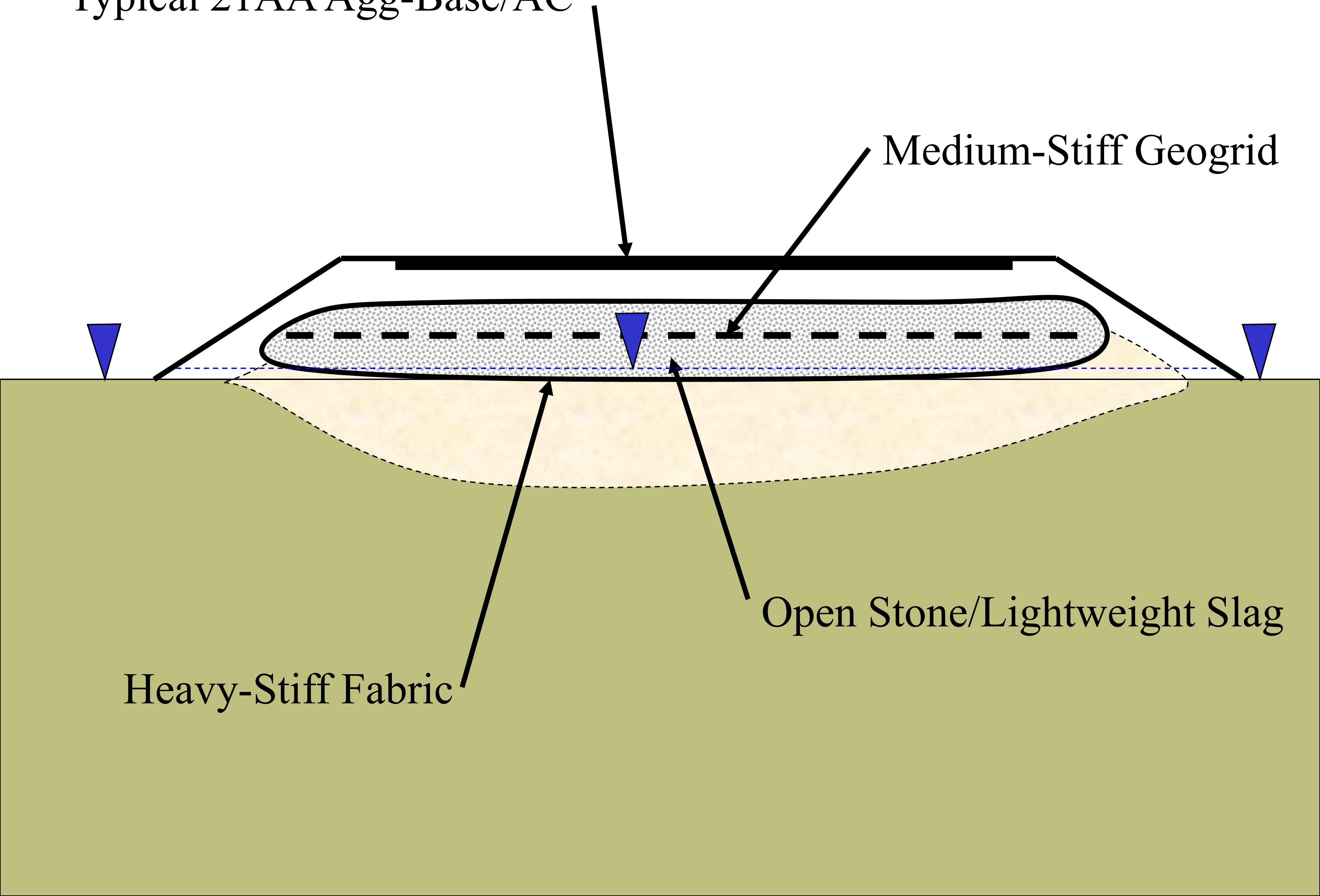
Cross Section



groundwater

Old Dirt Road- Silty Clayey Sand w/ Gravel

Peat Marsh



Typical 21AA Agg-Base/AC

Medium-Stiff Geogrid

Open Stone/Lightweight Slag

Heavy-Stiff Fabric


8/9/2001

Constructed to Smooth Elevation Grades

New

4-yrs Old

AC mixture is doing well, and appears to be unusually flexible – ideal.

Big Settlement – No Settlement Cracks

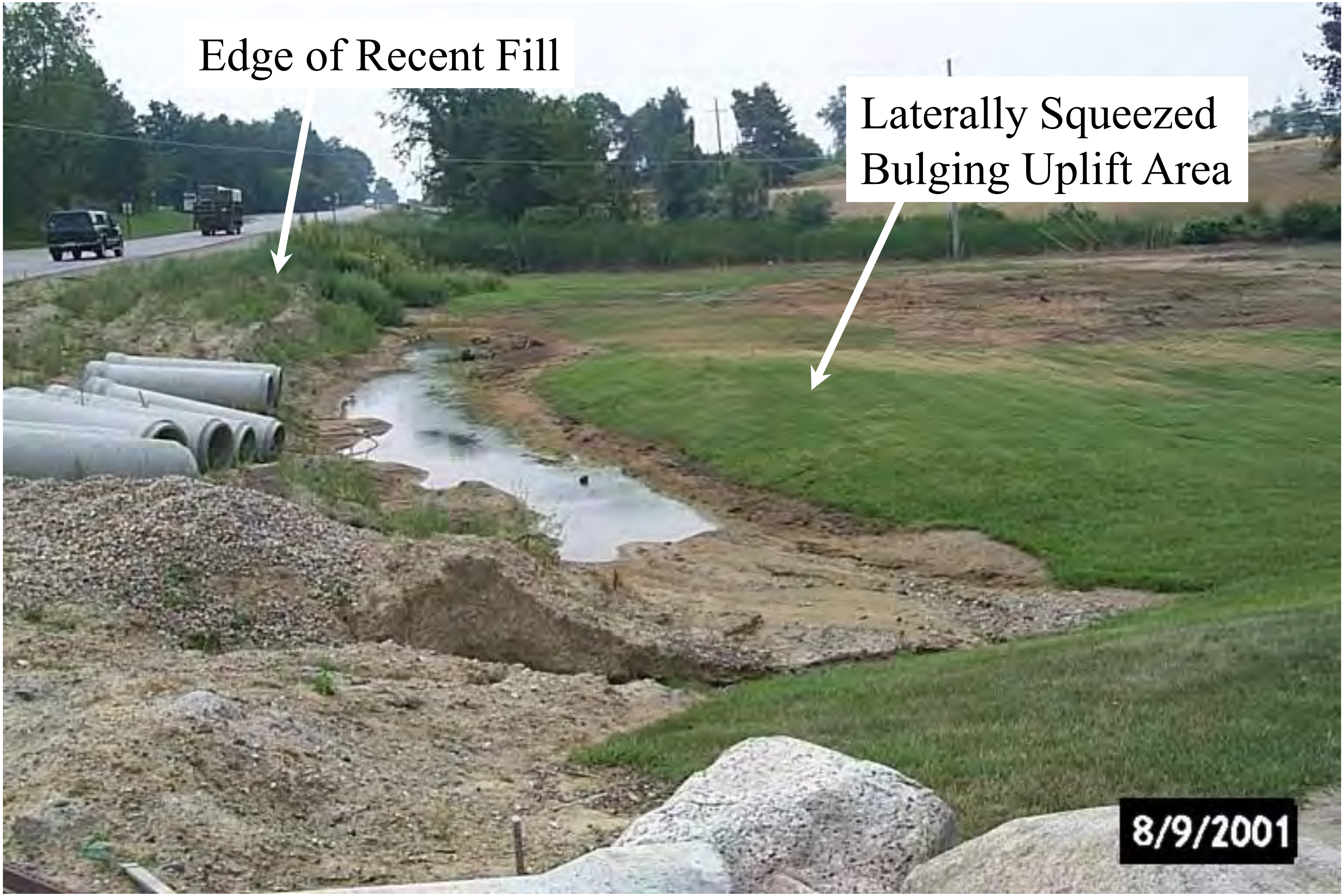
8-yrs Old

CASE 2:

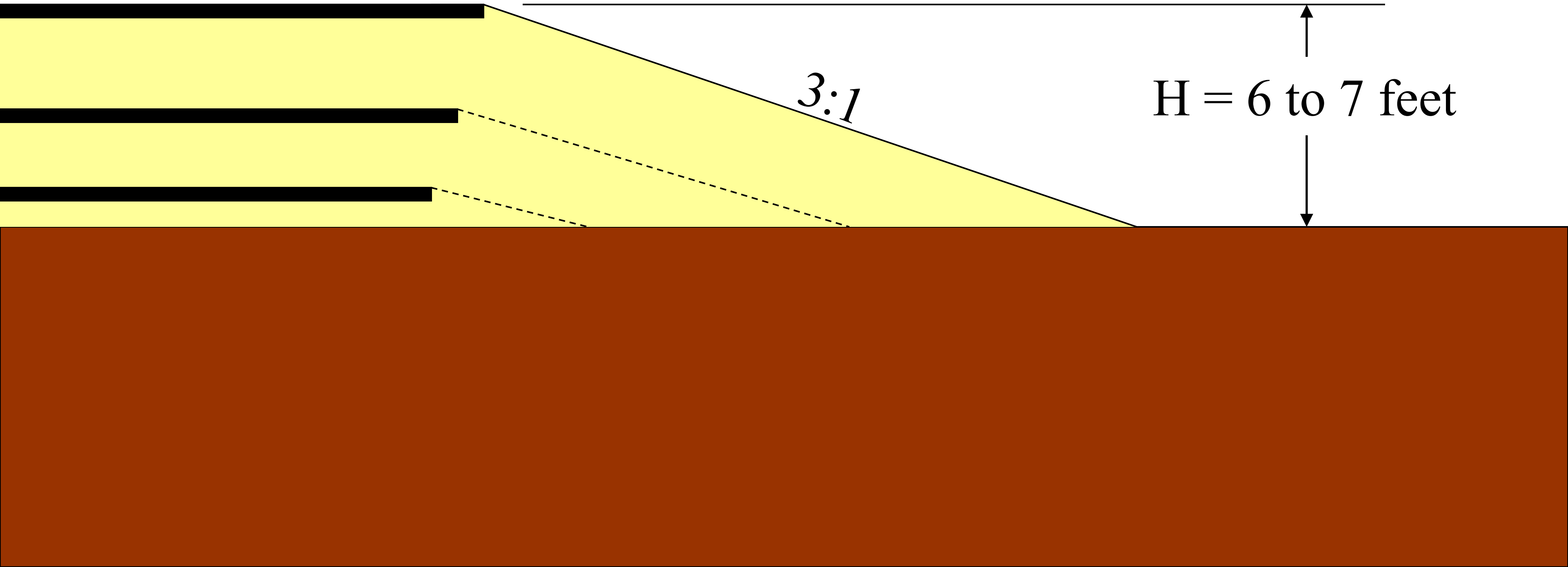
UTILITY CONTRACTOR BROKE THE EMBANKMENT!!!


Primary Shear
8/9/2001

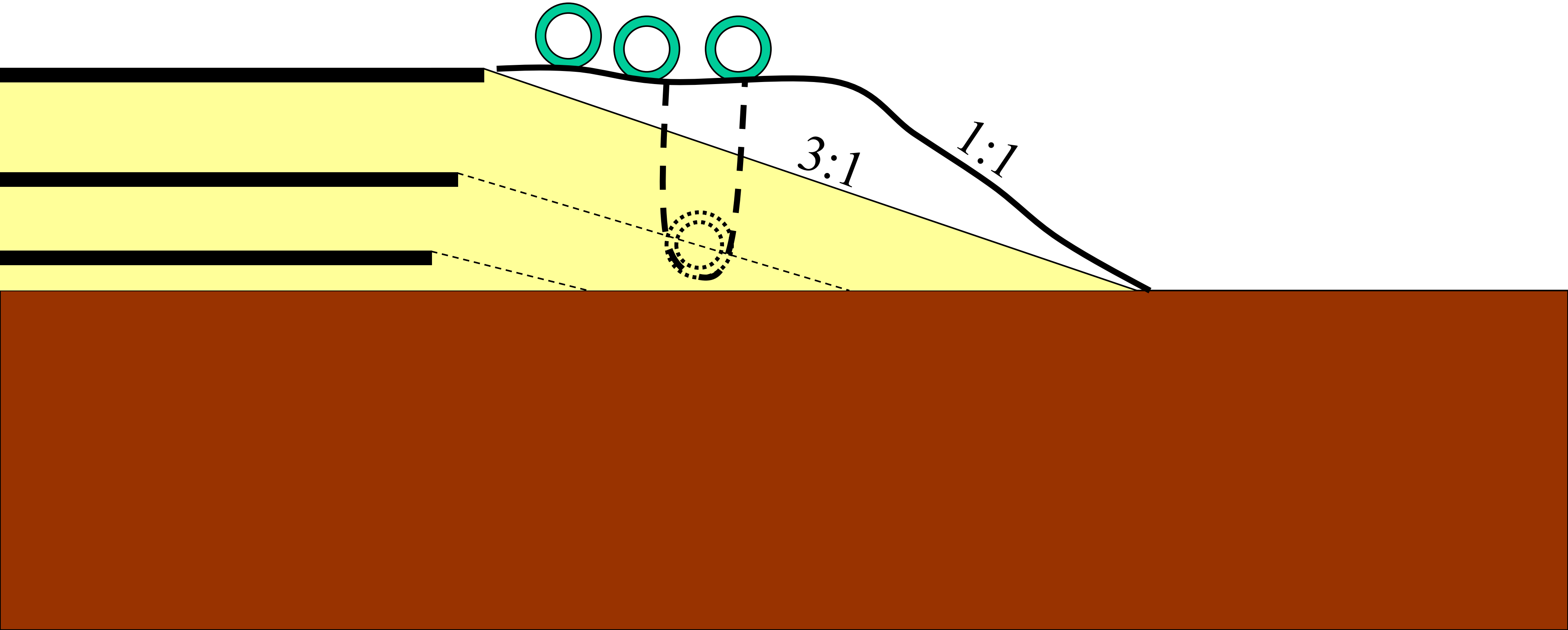
“Secondary/Sympathy” Shear


Edge of Recent Fill
Laterally Squeezed Bulging Uplift Area
8/9/2001

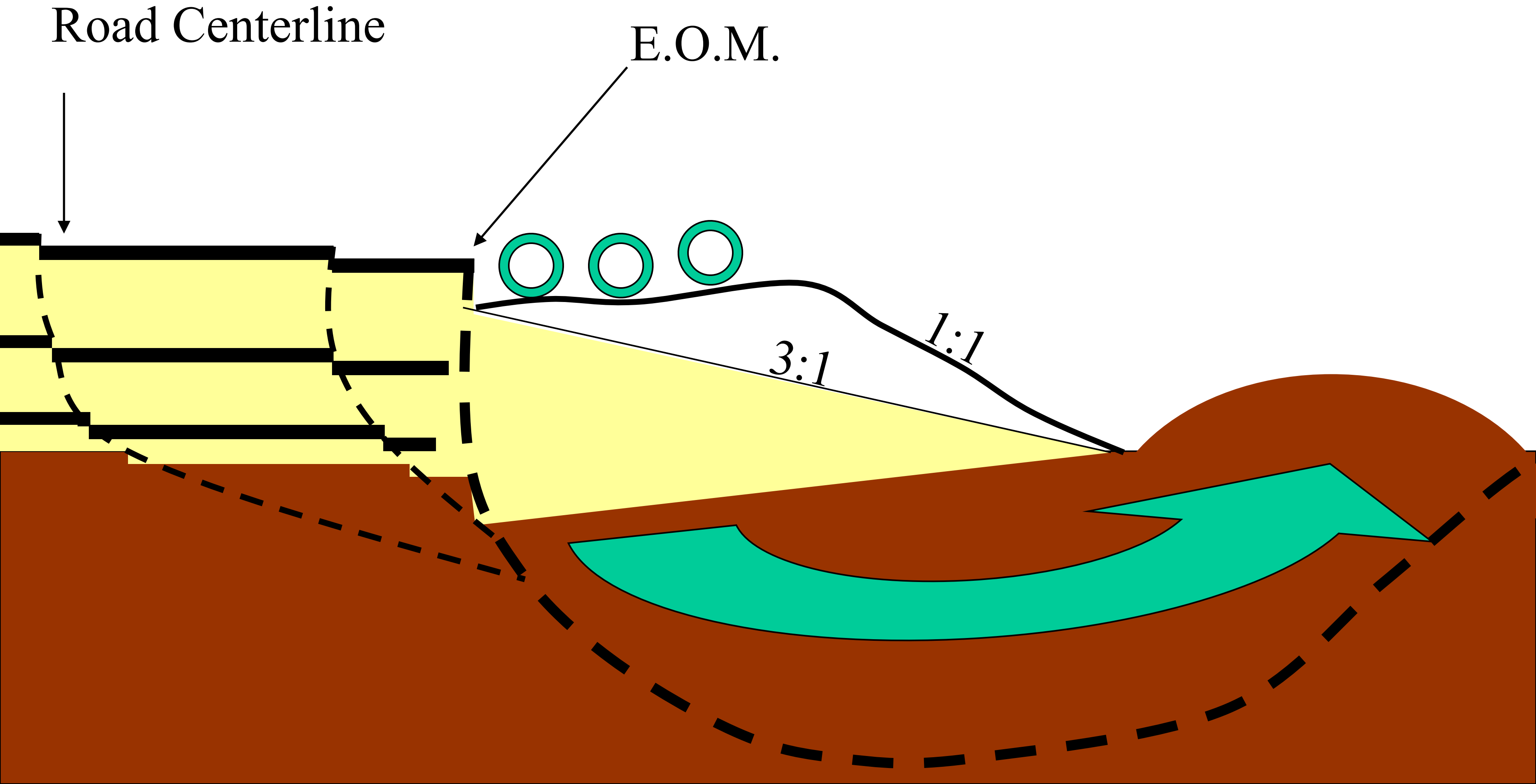
Previous Scenario



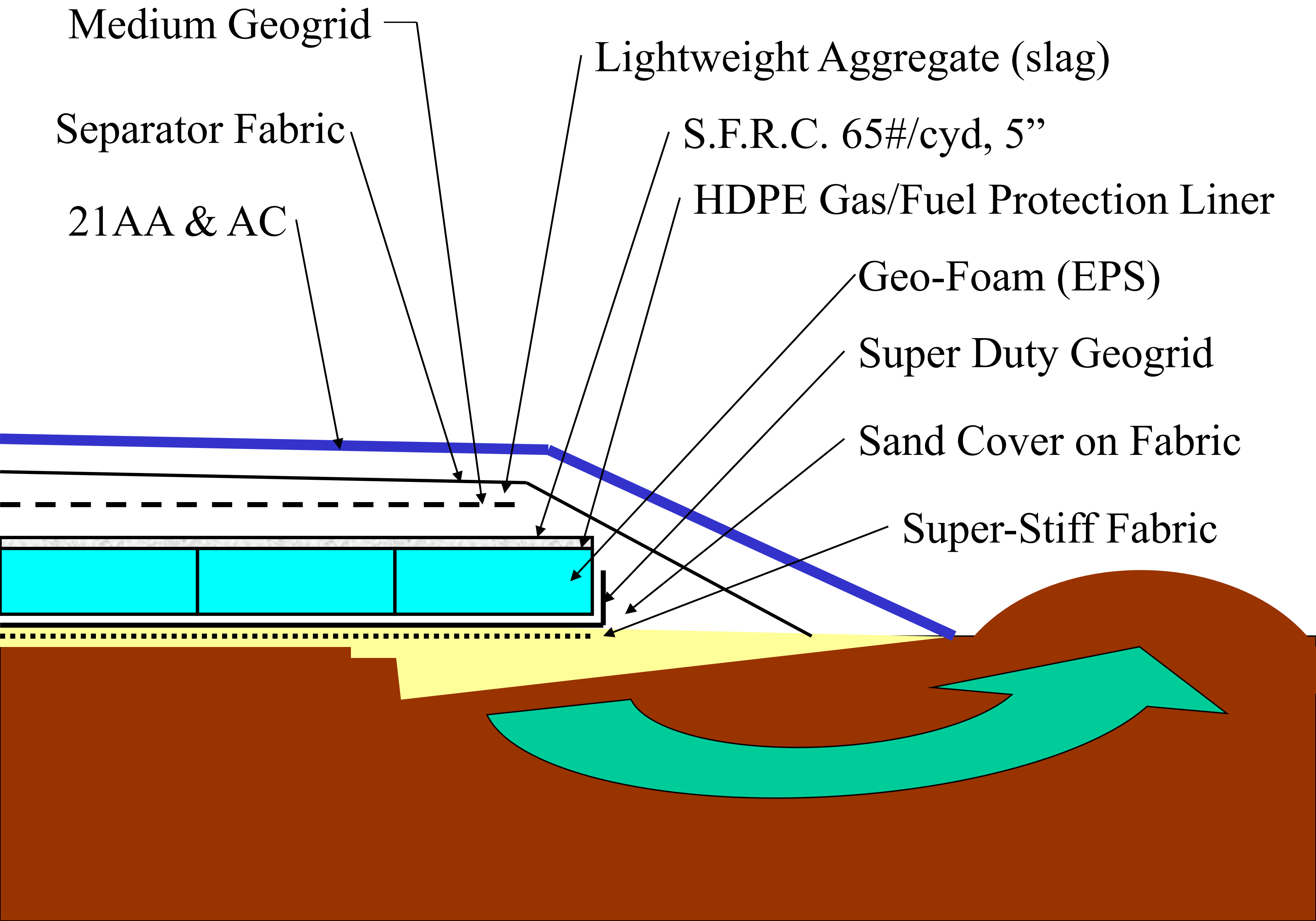
Utility Contractor Adds Weight



Reaches ➔ **F.S. = 1.0 Condition**



SOLUTION



Medium Geogrid

Lightweight Aggregate (slag)

Separator Fabric

S.F.R.C. 65#/cyd, 5”

HDPE Gas/Fuel Protection Liner

21AA & AC

Geo-Foam (EPS)

Super Duty Geogrid

Sand Cover on Fabric

Super-Stiff Fabric

Old Embankment Weight:

1(150) + 5(125) = 775 psf

Sliding and Squeeze factors of safety near 1.0 for 6-ft of fill.

New Embankment Weight:

1(150) + 3(10) + 1(125) + 1(85) = 390 psf (50% of Previous)

Internal forces restrained by new AC, grids, fabrics and S.F.R.C.


TENSAR
TENSAR
TENSAR

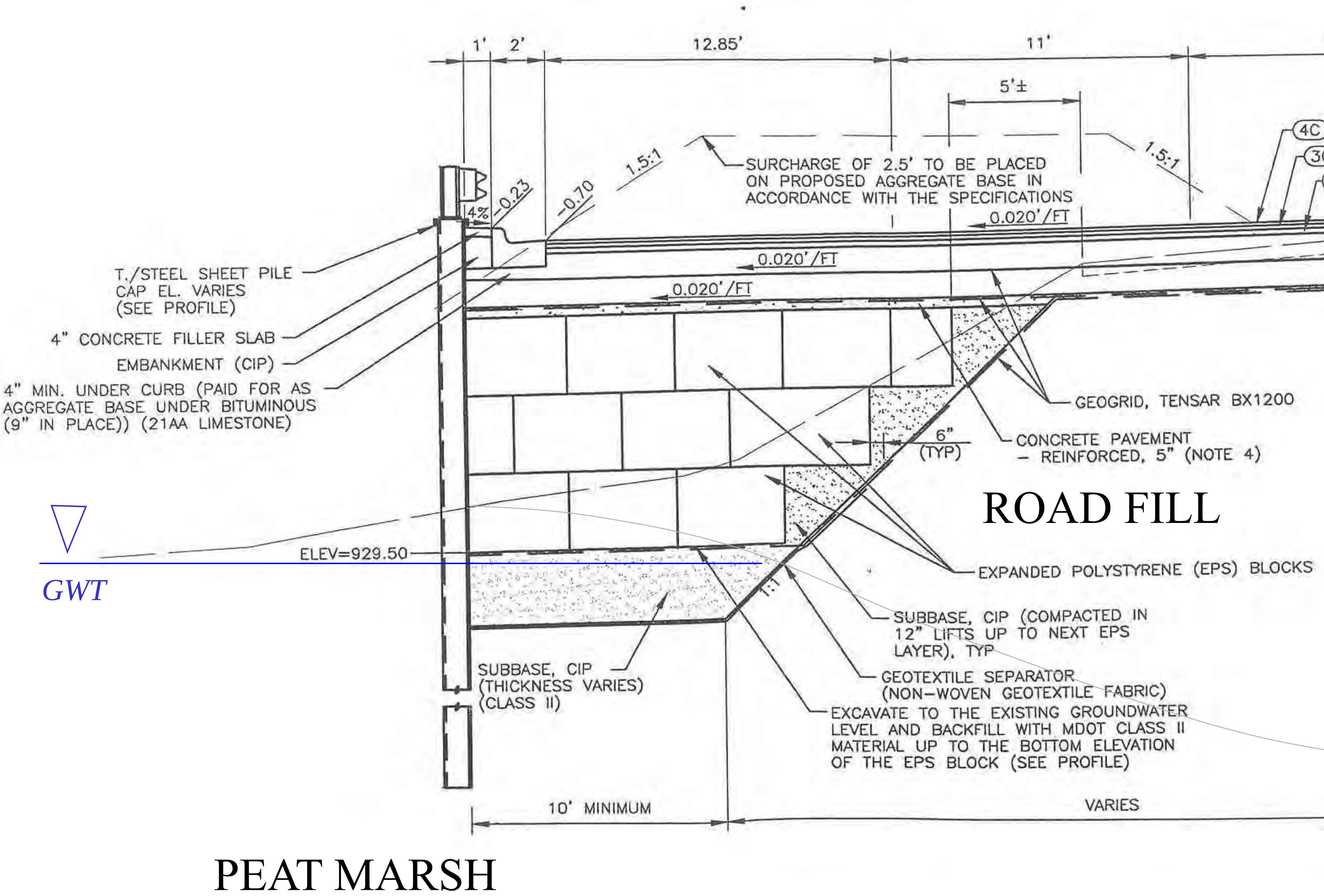
New

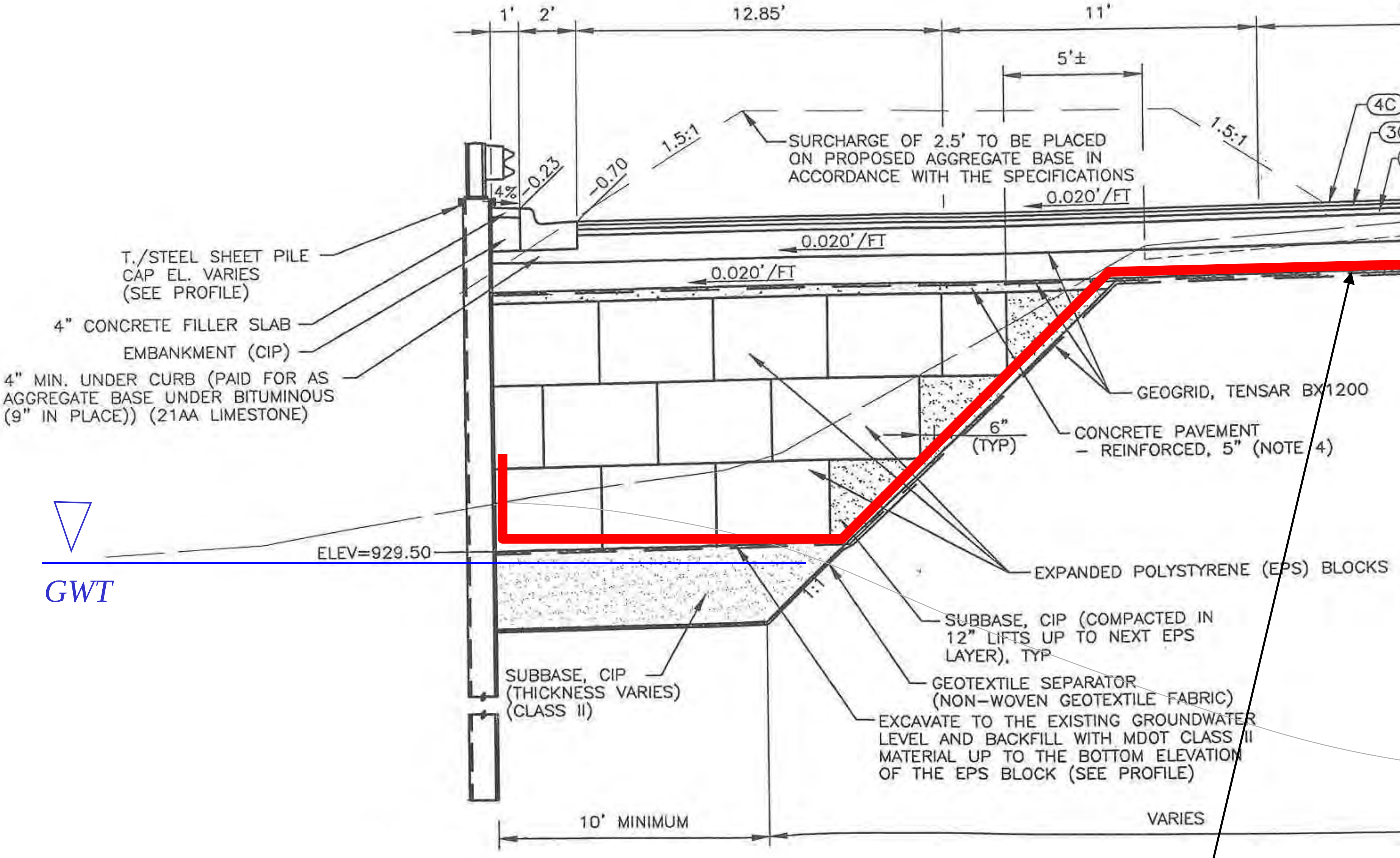

8-yrs Old


8-yrs Old

CASE 5:

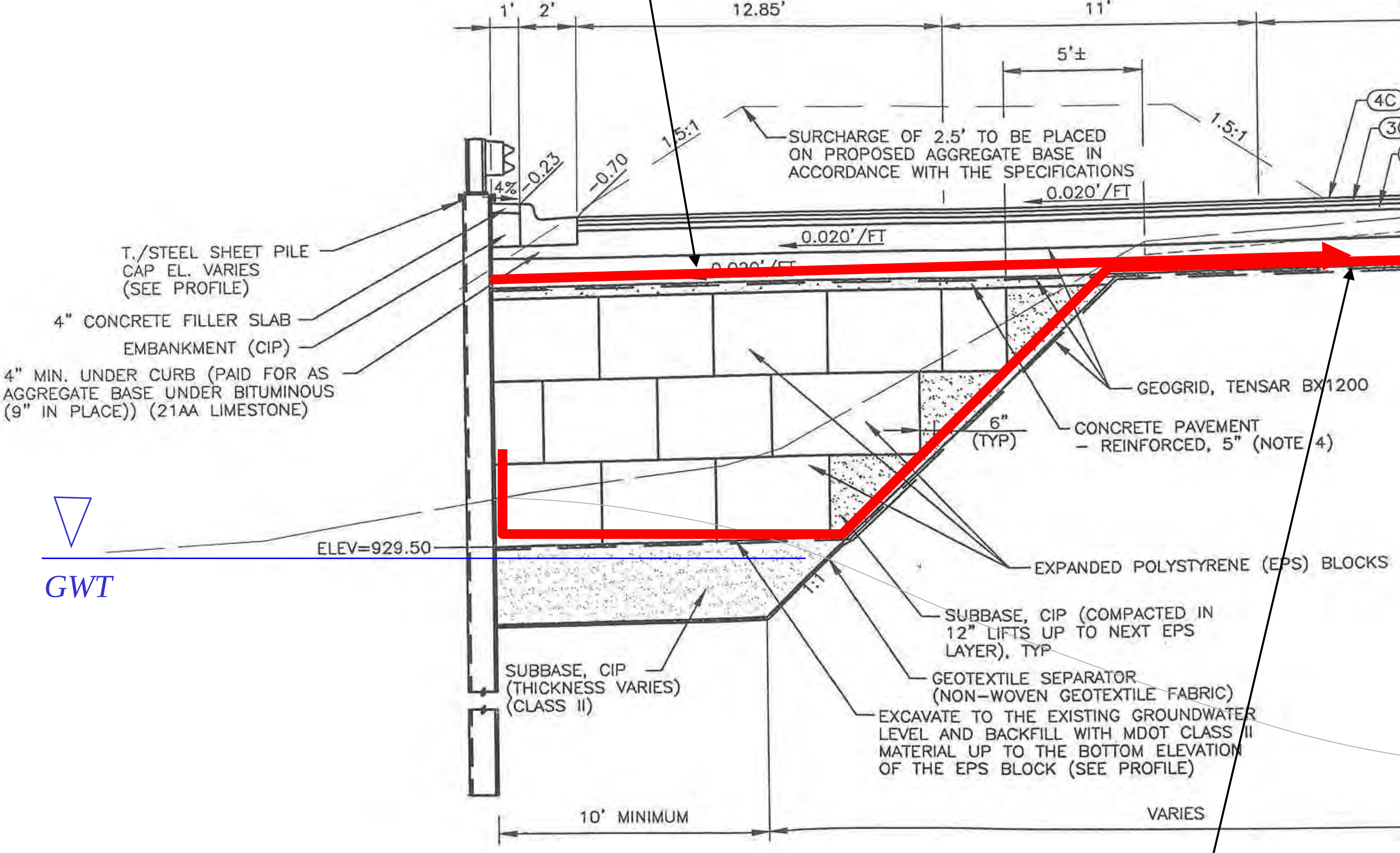
DO NOT ENCROACH INTO THE WETLAND!!!


1'
2'
12.85'
11'
5'±
4C
3C
1.5:1
1.5:1
4%
-0.23
-0.70
SURCHARGE OF 2.5' TO BE PLACED ON PROPOSED AGGREGATE BASE IN ACCORDANCE WITH THE SPECIFICATIONS
0.020'/FT
0.020'/FT
0.020'/FT
T./STEEL SHEET PILE CAP EL. VARIES (SEE PROFILE)
4" CONCRETE FILLER SLAB
EMBANKMENT (CIP)
4" MIN. UNDER CURB (PAID FOR AS AGGREGATE BASE UNDER BITUMINOUS (9" IN PLACE)) (21AA LIMESTONE)
GEOGRID, TENSAR BX1200
CONCRETE PAVEMENT – REINFORCED, 5" (NOTE 4)
6" (TYP)
ROAD FILL
ELEV=929.50
GWT
EXPANDED POLYSTYRENE (EPS) BLOCKS
1:1
SUBBASE, CIP (COMPACTED IN 12" LIFTS UP TO NEXT EPS LAYER), TYP
SUBBASE, CIP (THICKNESS VARIES) (CLASS II)
GEOTEXTILE SEPARATOR (NON-WOVEN GEOTEXTILE FABRIC)
EXCAVATE TO THE EXISTING GROUNDWATER LEVEL AND BACKFILL WITH MDOT CLASS II MATERIAL UP TO THE BOTTOM ELEVATION OF THE EPS BLOCK (SEE PROFILE)
10' MINIMUM
VARIES
PEAT MARSH



CONTINUOUS GEOGRID #1

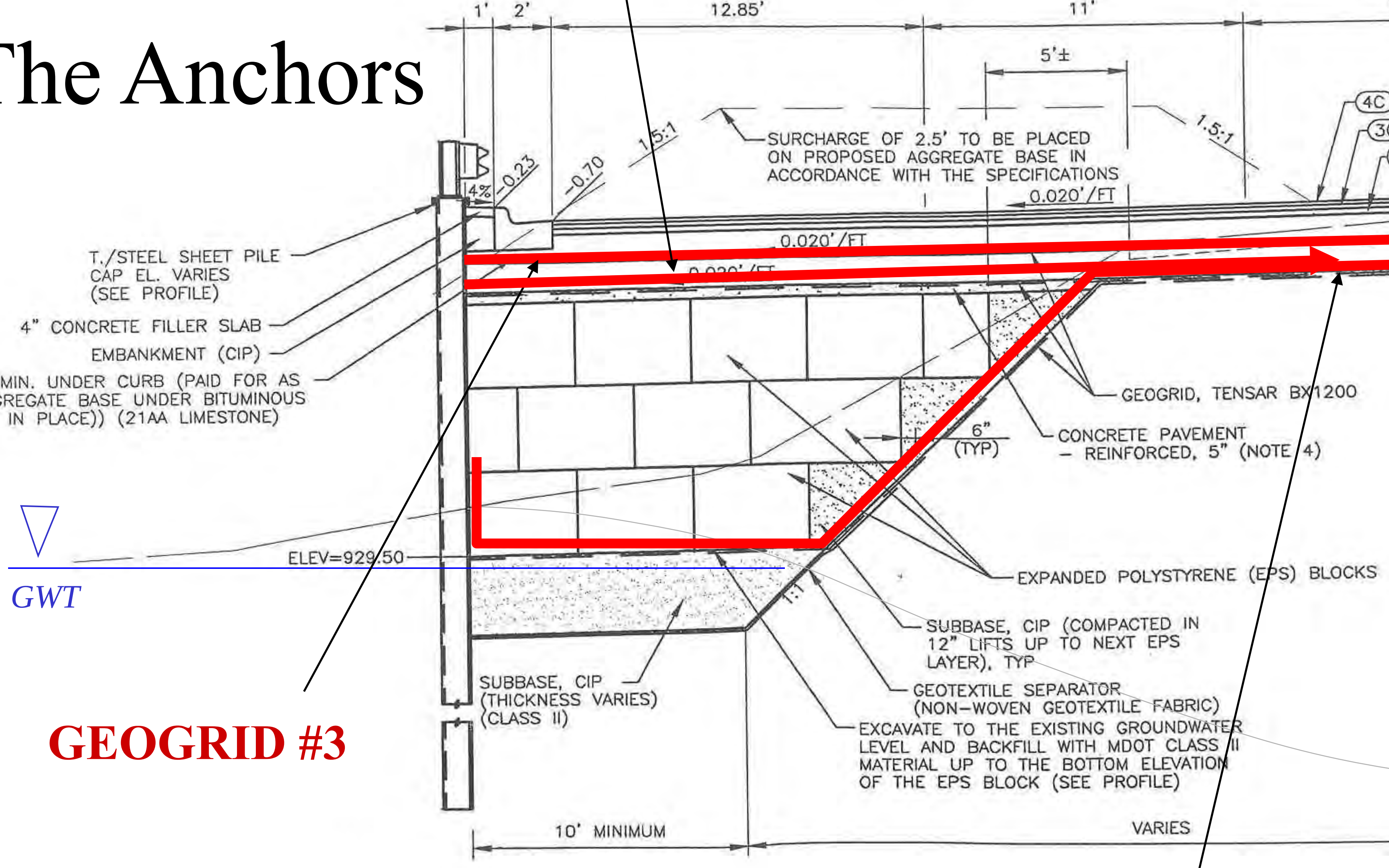
CONTINUOUS GEOGRID #2



CONTINUOUS GEOGRID #1

The Anchors

CONTINUOUS GEOGRID #2

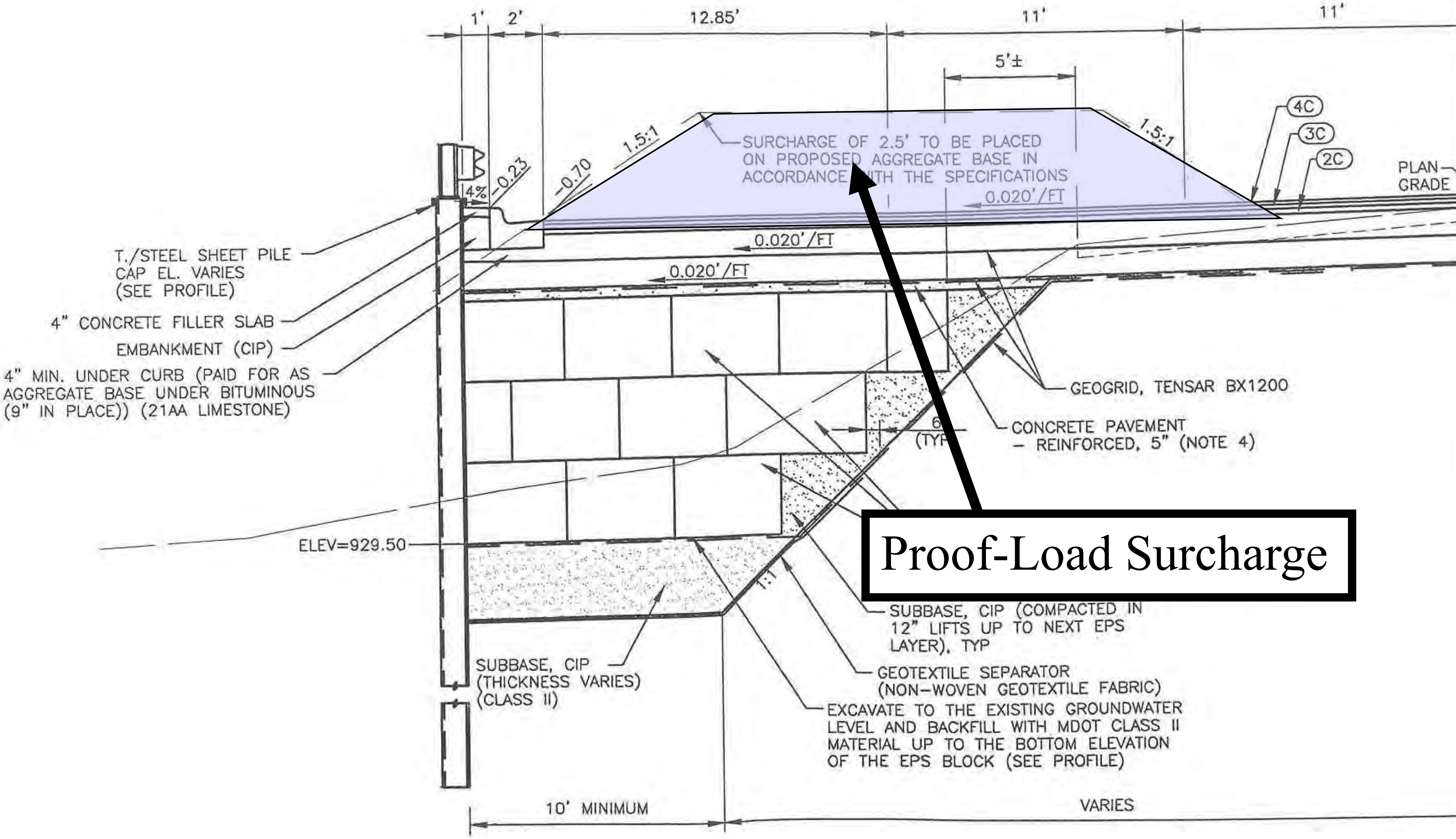


GEOGRID #3

CONTINUOUS GEOGRID #1

Preparation of marsh surface at base of EPS

Placement of EPS and Geogrid behind sheeting.



Proof-Load Surcharge

Pre-Load also Pre-Tensions the Grids
Prior to Base Compaction for Pavement

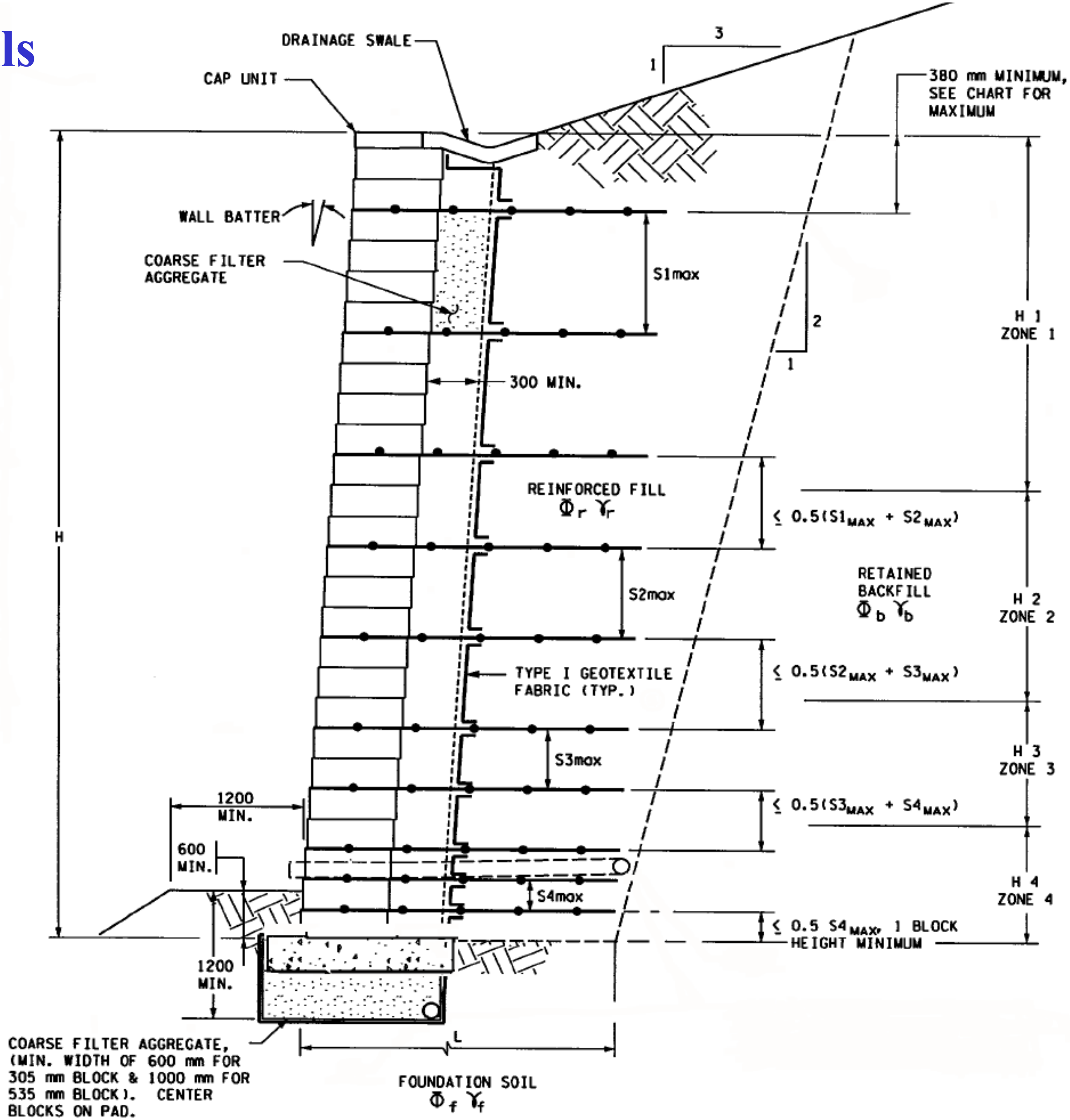
11/8/2002

View of Final Product, Looking West

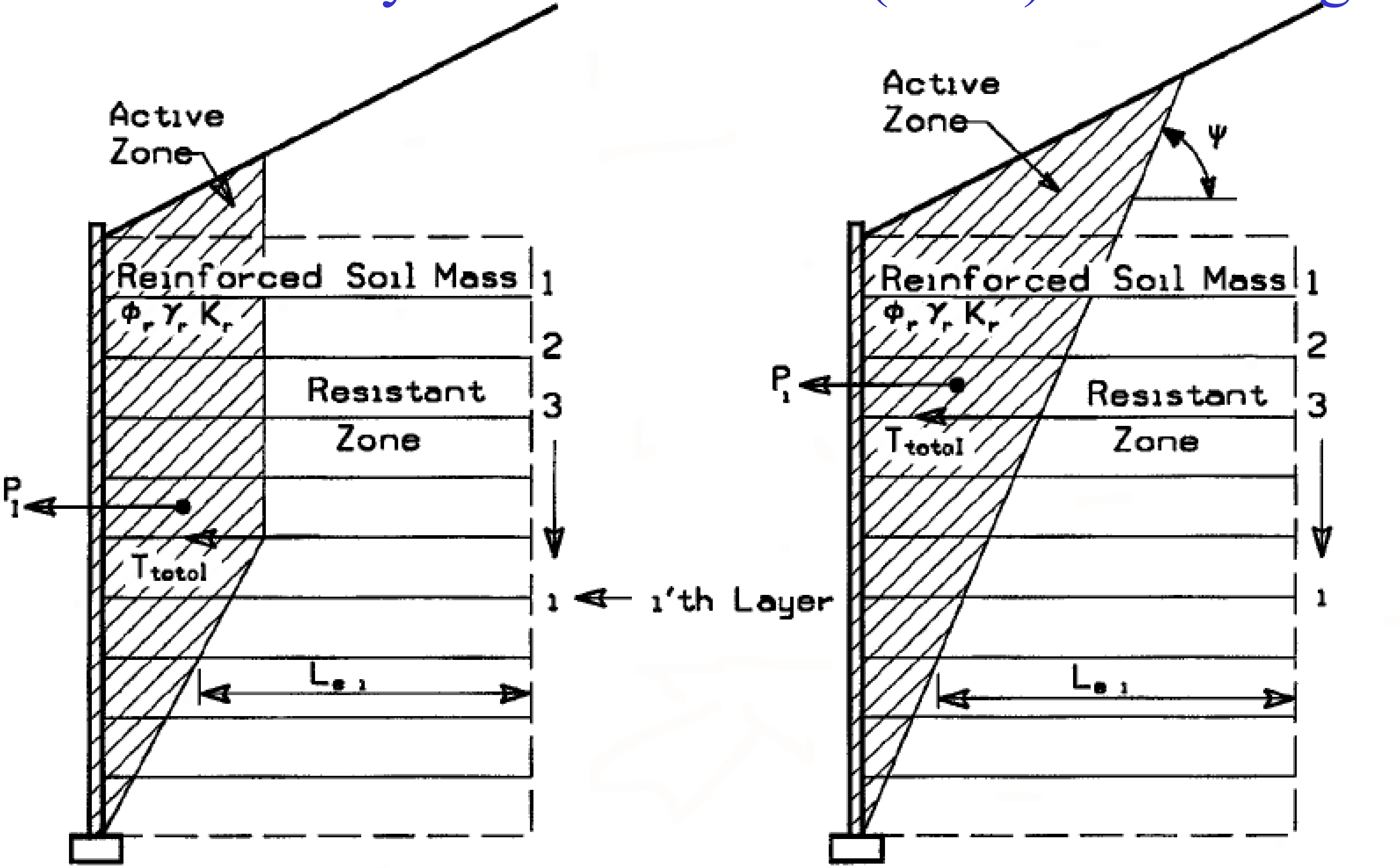
3-yrs Old

7-yrs Old

MSE Walls


DRAINAGE SWALE
CAP UNIT
3
1
380 mm MINIMUM, SEE CHART FOR MAXIMUM
WALL BATTER
COARSE FILTER AGGREGATE
S1max
2
1
H 1 ZONE 1
300 MIN.
H
REINFORCED FILL Φ_r γ_r
≤ 0.5(S1$_{MAX}$ + S2$_{MAX}$)
RETAINED BACKFILL Φ_b γ_b
S2max
H 2 ZONE 2
TYPE I GEOTEXTILE FABRIC (TYP.)
≤ 0.5(S2$_{MAX}$ + S3$_{MAX}$)
S3max
H 3 ZONE 3
1200 MIN.
≤ 0.5(S3$_{MAX}$ + S4$_{MAX}$)
600 MIN.
S4max
H 4 ZONE 4
≤ 0.5 S4$_{MAX}$, 1 BLOCK HEIGHT MINIMUM
1200 MIN.
L
COARSE FILTER AGGREGATE, (MIN. WIDTH OF 600 mm FOR 305 mm BLOCK & 1000 mm FOR 535 mm BLOCK). CENTER BLOCKS ON PAD.
FOUNDATION SOIL Φ_f γ_f

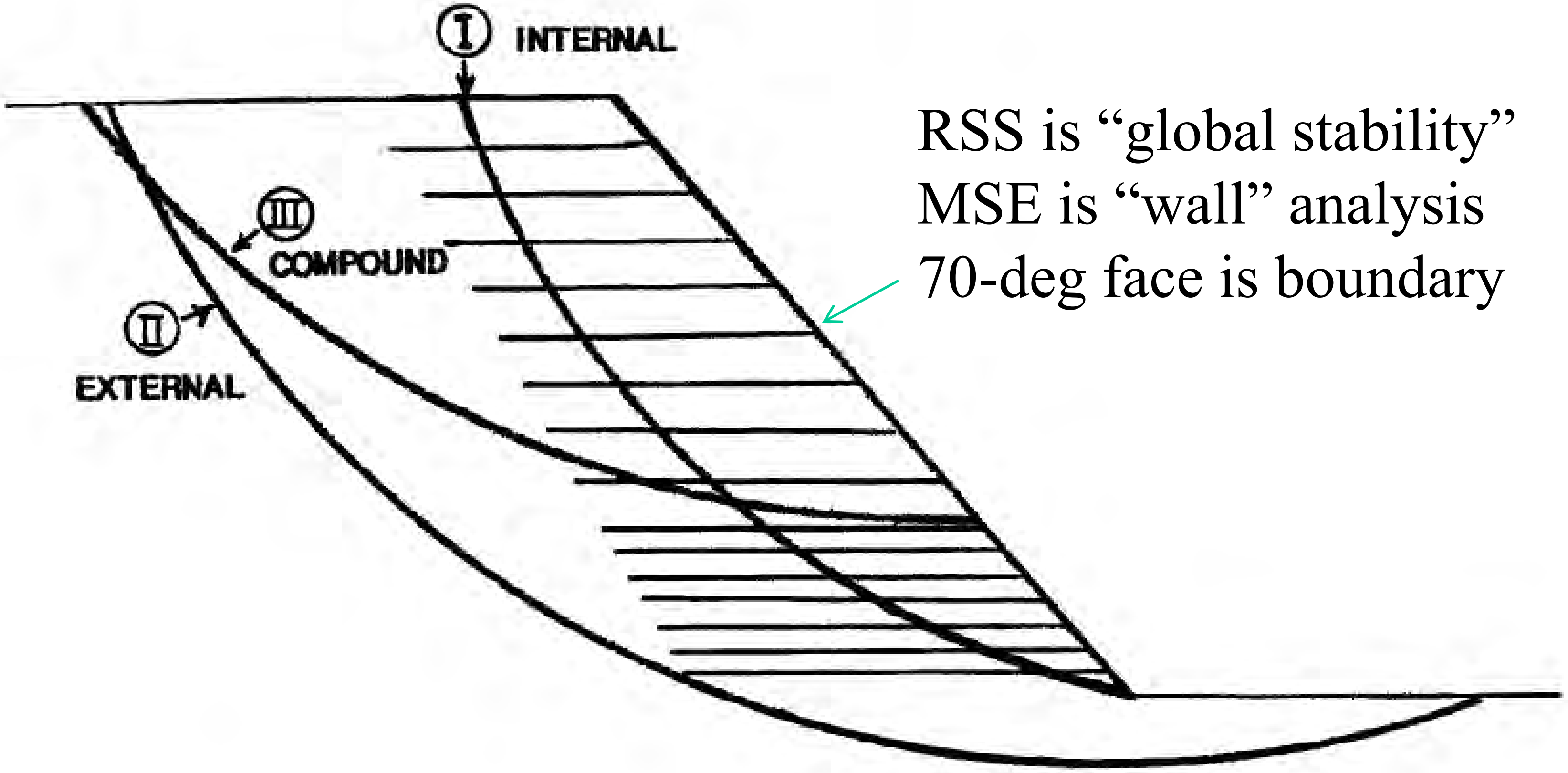
Mechanically Stabilized Earth (MSE) Wall Design



Inextensible Reinforcements

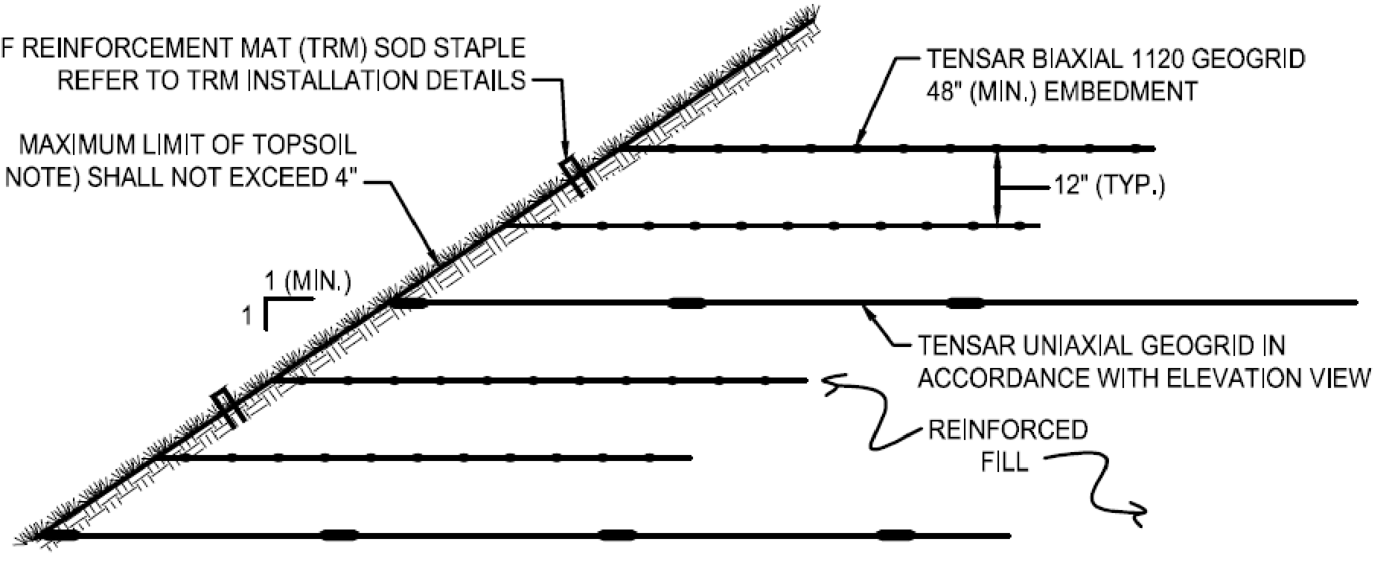
Extensible Reinforcements

Reinforced Soil Slope (RSS) Design



RSS is “global stability”
MSE is “wall” analysis
70-deg face is boundary

Figure 53. Failure modes for reinforced soil slopes.

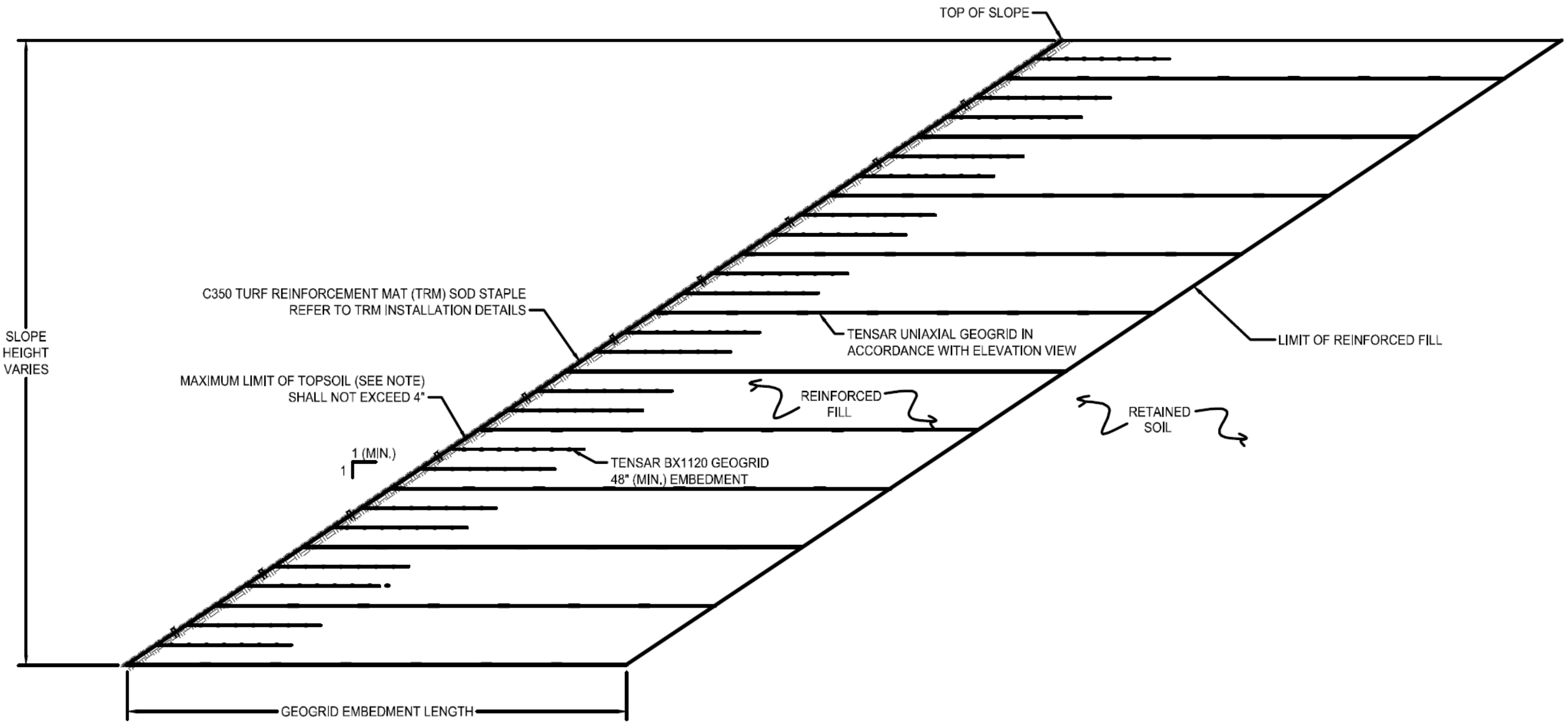


NOTE:

TOPSOIL SHALL BE LOAMY SAND OR FINER GRADATION WITH 10% - 15% ORGANIC CONTENT OR MATERIAL APPROVED BY A QUALIFIED LANDSCAPE ARCHITECT. VEGETATION TYPE SHALL BE SPECIFIED BY A QUALIFIED LANDSCAPE ARCHITECT.

GRADED SIERRA SLOPE DETAIL

NOT TO SCALE



NOTE:

TOPSOIL SHALL BE LOAMY SAND OR FINER GRADATION WITH 10% - 15% ORGANIC CONTENT OR MATERIAL APPROVED BY A QUALIFIED LANDSCAPE ARCHITECT. VEGETATION TYPE SHALL BE SPECIFIED BY A QUALIFIED LANDSCAPE ARCHITECT.

GRADED SIERRA SLOPE TYPICAL CROSS-SECTION

NOT TO SCALE

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-00-043

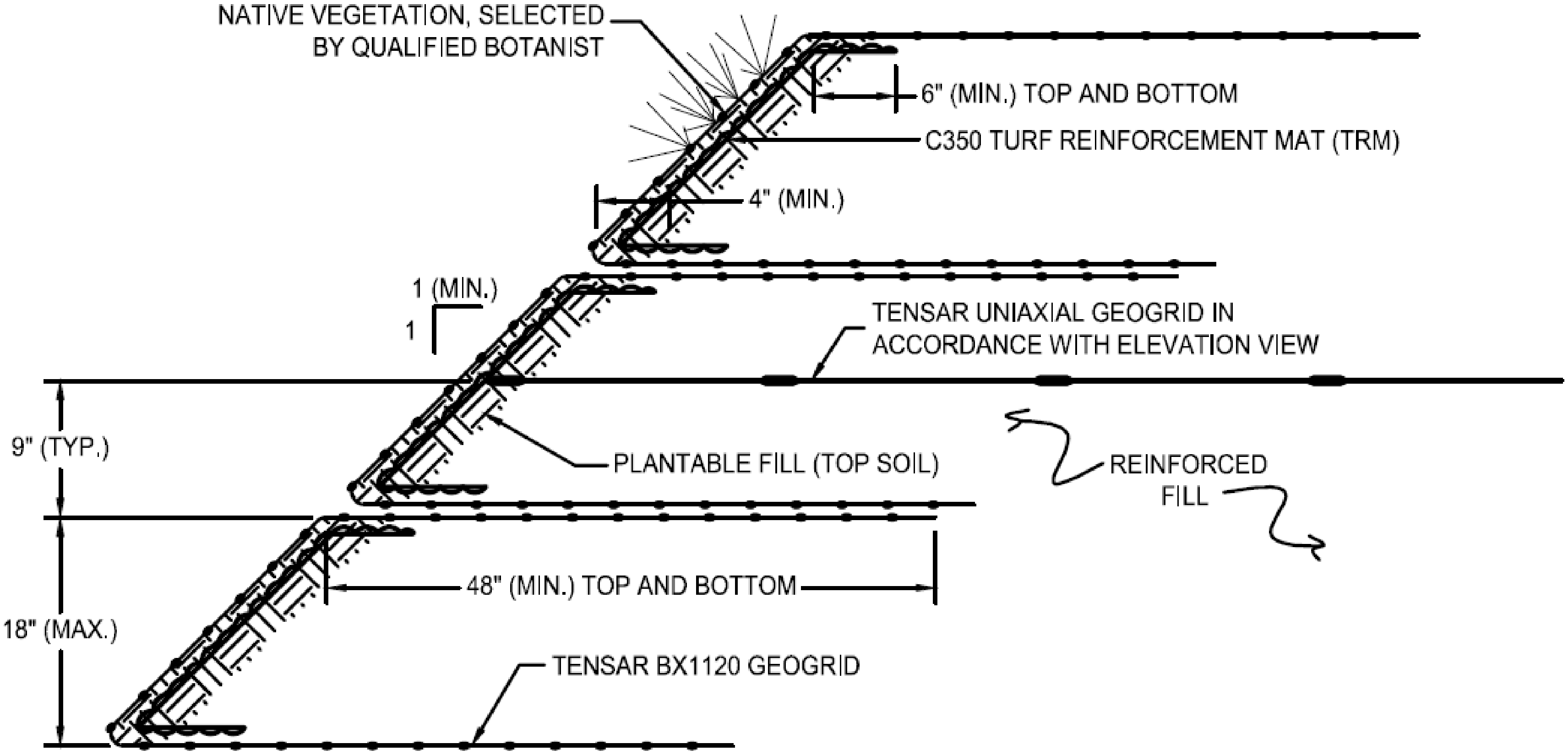
NHI Course No. 132042

MECHANICALLY STABILIZED EARTH WALLS AND REINFORCED SOIL SLOPES
DESIGN & CONSTRUCTION GUIDELINES

NHI – National Highway Institute
Office of Bridge Technology

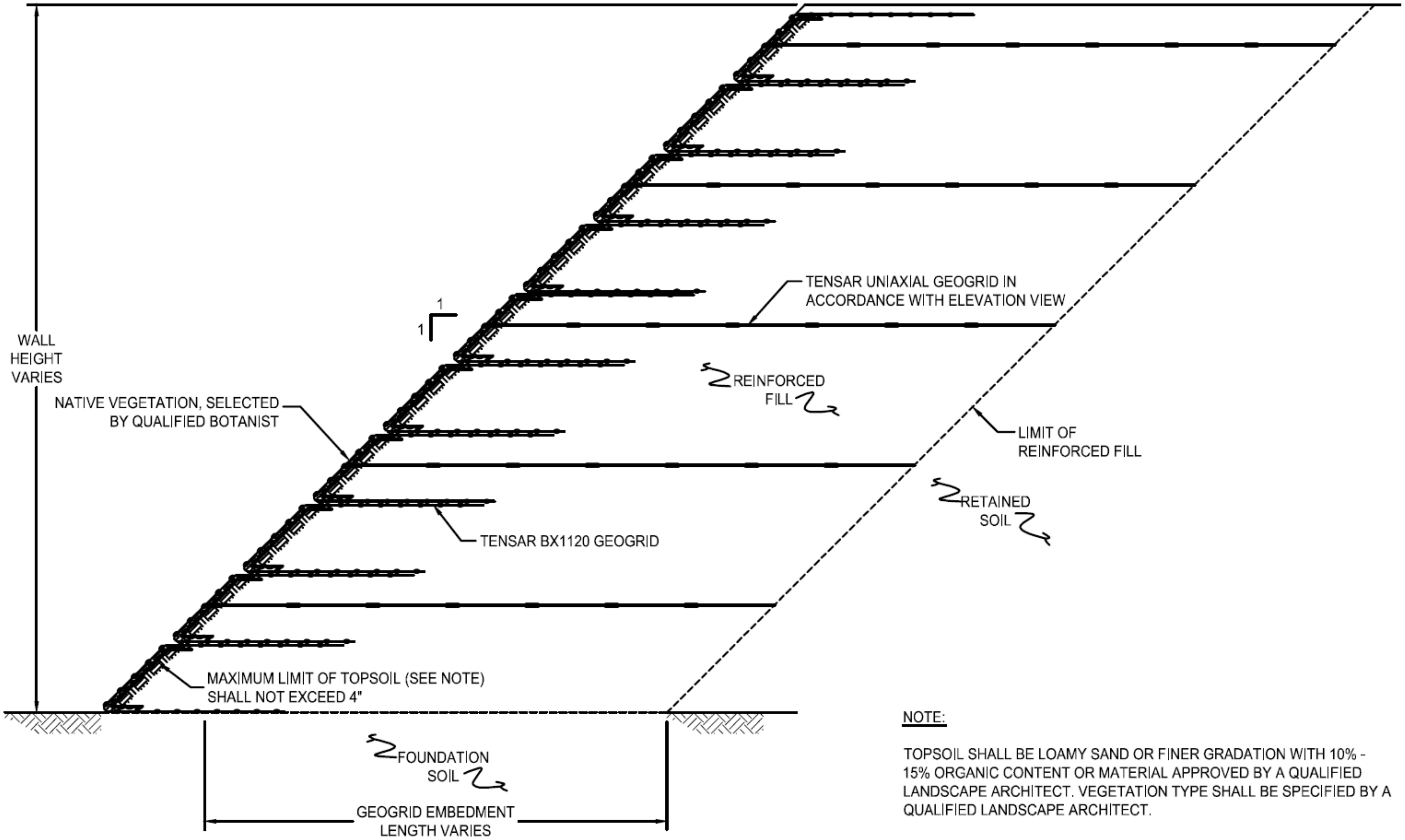
March 2001


CATERPILLAR
D7H
7



WRAP FACE SIERRA SLOPE DETAIL

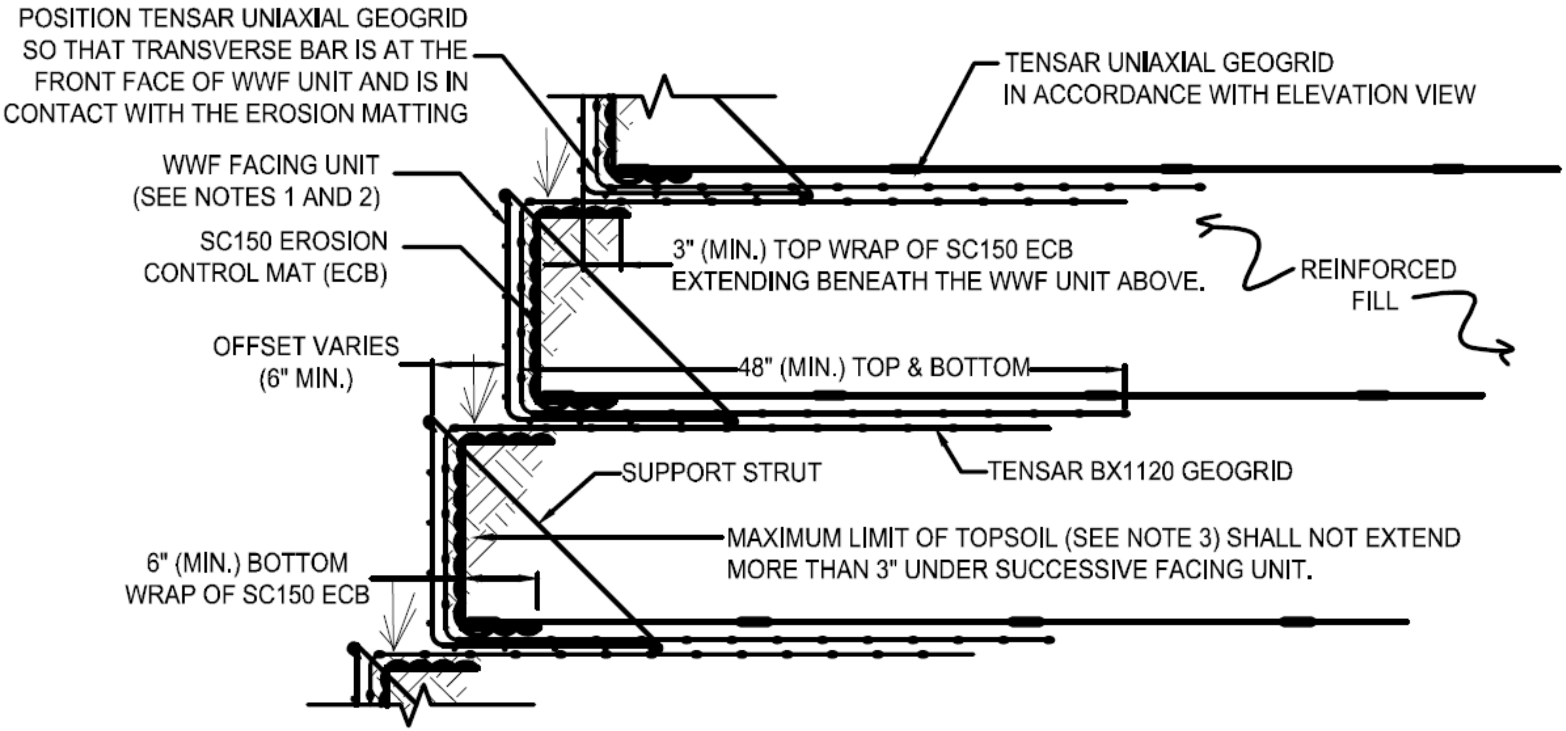
NOT TO SCALE



NOTE:

TOPSOIL SHALL BE LOAMY SAND OR FINER GRADATION WITH 10% - 15% ORGANIC CONTENT OR MATERIAL APPROVED BY A QUALIFIED LANDSCAPE ARCHITECT. VEGETATION TYPE SHALL BE SPECIFIED BY A QUALIFIED LANDSCAPE ARCHITECT.

WRAPPED FACE SIERRA SLOPE TYPICAL CROSS-SECTION



NOTES:

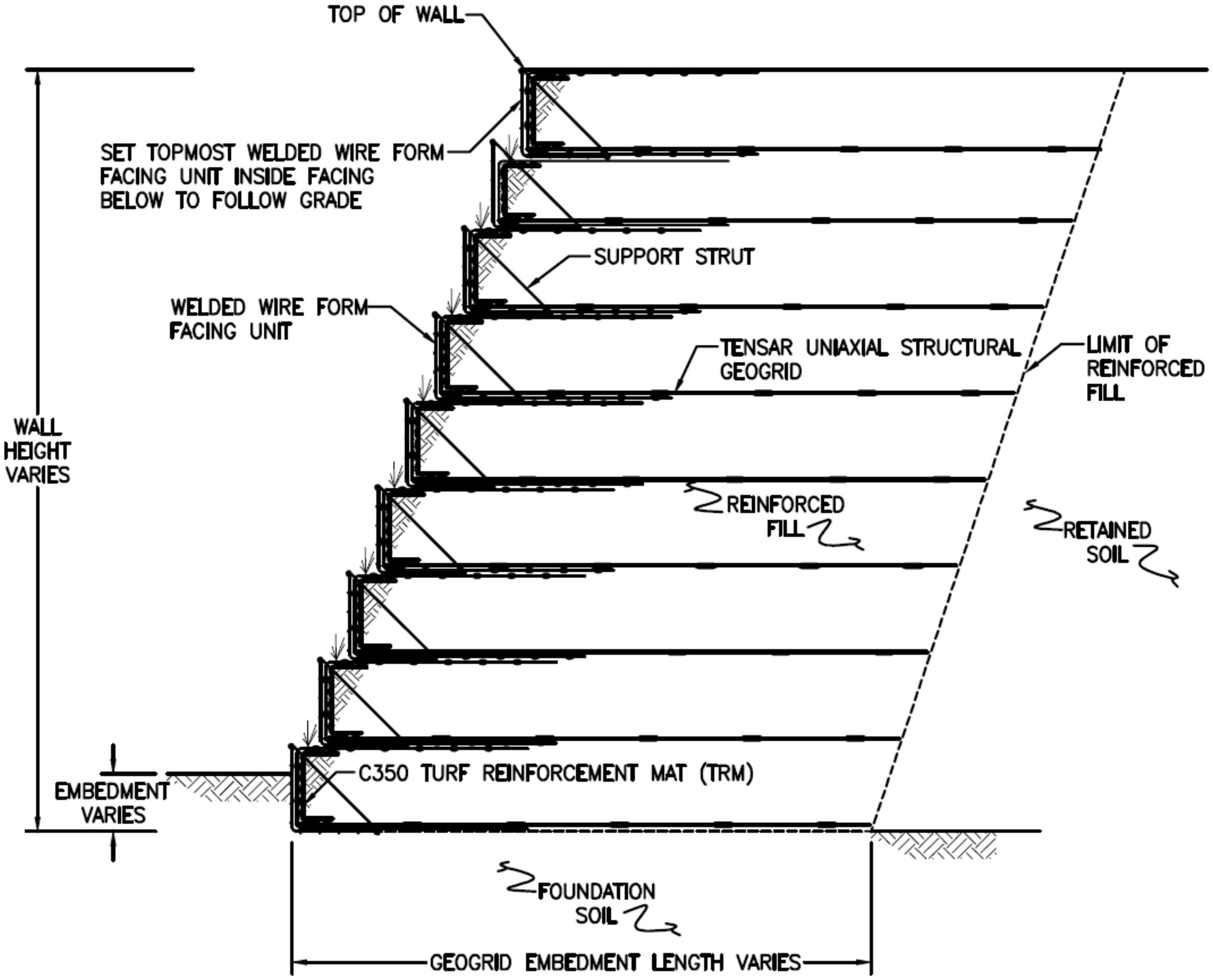
1. SEE WELDED WIRE FORM (WWF) FACING UNIT DETAIL FOR FACING MATERIAL AND DIMENSIONS.

2. ALL FACING UNITS SHALL BE FABRICATED FROM BLACK STEEL.

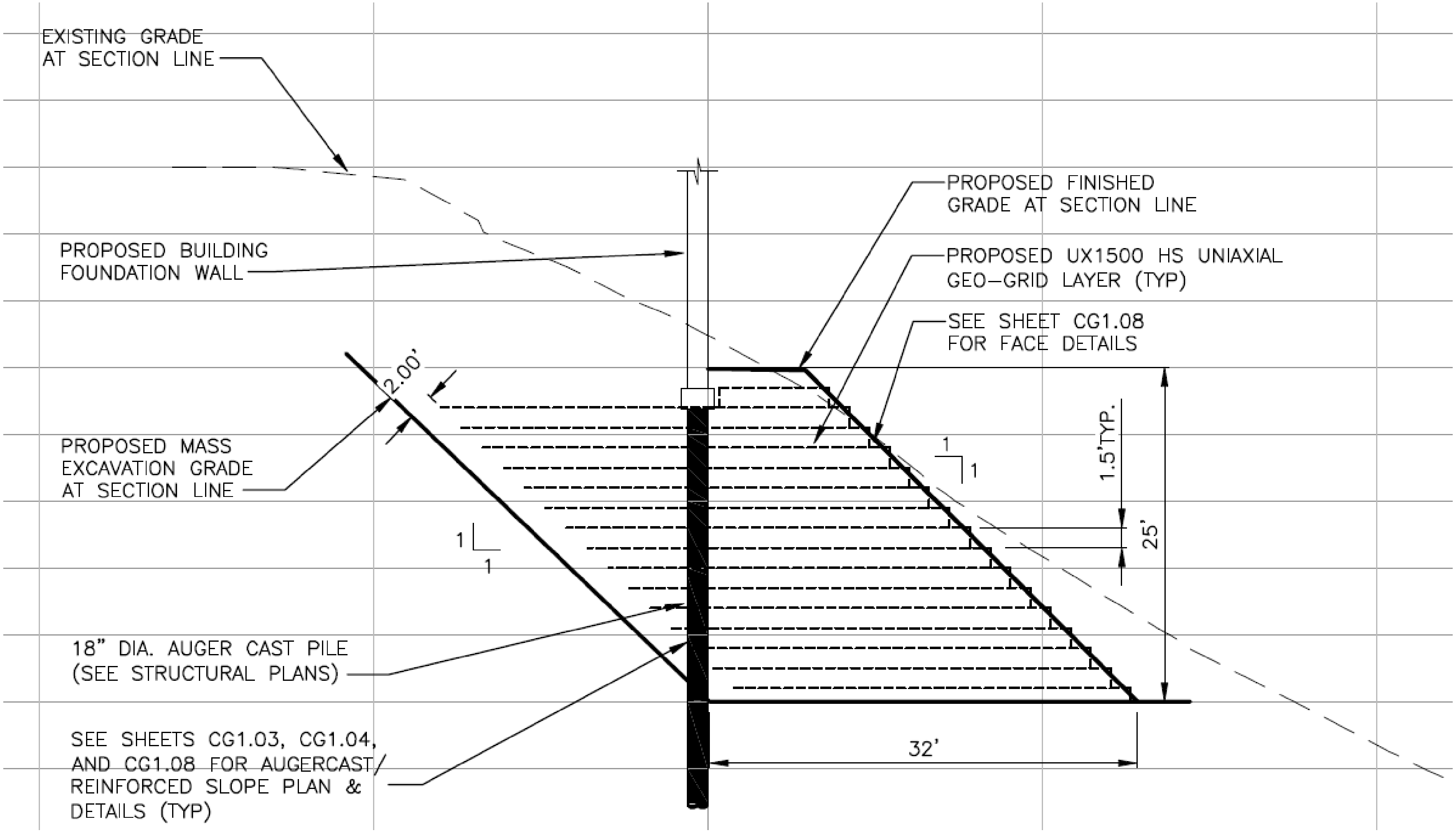
3. TOPSOIL SHALL BE LOAMY SAND OR FINER GRADATION WITH 10% - 15% ORGANIC CONTENT OR MATERIAL APPROVED BY A QUALIFIED LANDSCAPE ARCHITECT. VEGETATION TYPE SHALL BE SPECIFIED BY A QUALIFIED LANDSCAPE ARCHITECT.

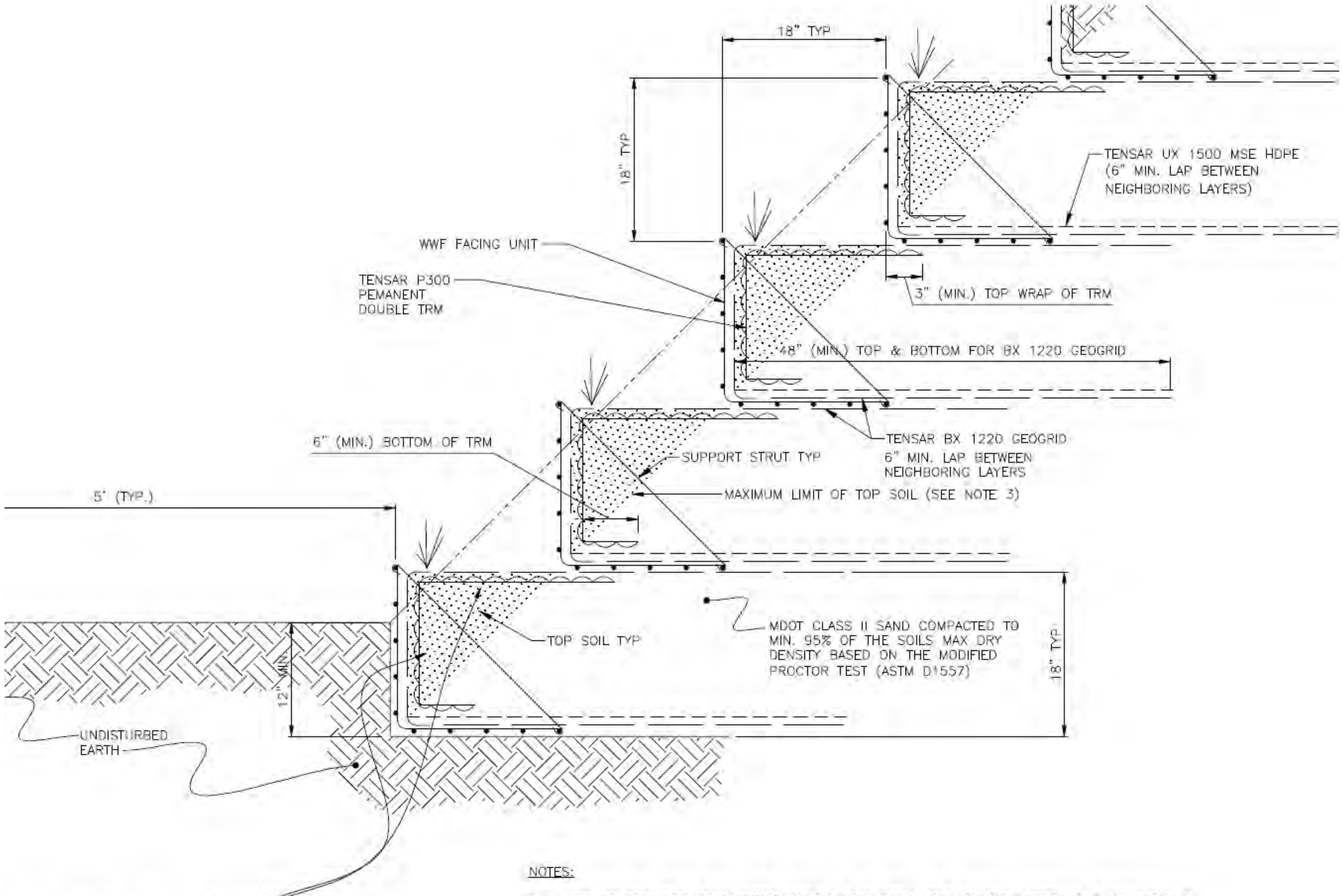
WELDED WIRE FORM FACING DETAIL (PLANTABLE FACE FILL)

NOT TO SCALE



SIERRA SLOPE TYPICAL CROSS-SECTION


EXISTING GRADE AT SECTION LINE
PROPOSED FINISHED GRADE AT SECTION LINE
PROPOSED BUILDING FOUNDATION WALL
PROPOSED UX1500 HS UNIAXIAL GEO-GRID LAYER (TYP)
SEE SHEET CG1.08 FOR FACE DETAILS
2.00'
1
1
1.5'TYP.
25'
PROPOSED MASS EXCAVATION GRADE AT SECTION LINE
1
1
18" DIA. AUGER CAST PILE (SEE STRUCTURAL PLANS)
SEE SHEETS CG1.03, CG1.04, AND CG1.08 FOR AUGERCAST/ REINFORCED SLOPE PLAN & DETAILS (TYP)
32'



SEED FOR SLOPE VEGITATION TO
BE MIXED INTO UPPER 3 INCHES
OF TOPSOIL AGAINST THE TRM.
SEE SPECIFICATIONS FOR SEEDING
MIX TYPE & QUANTITY. SEED
SHALL BE WATERED DAILY AS
REQUIRED TO START SEED
GERMINATION.

NOTES:

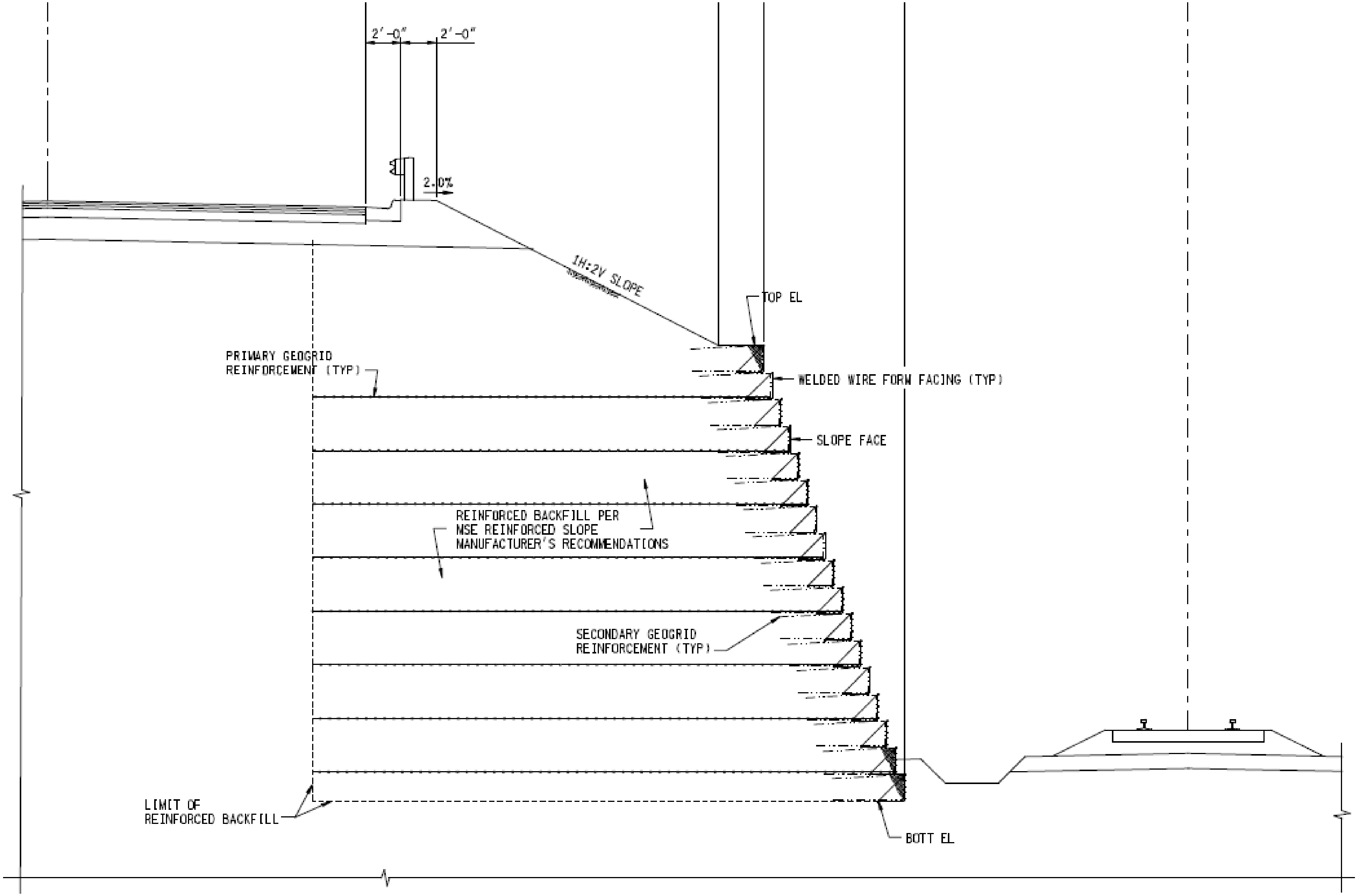
1. SEE WELDED WIRE FORM (WWF) FACING UNIT DETAIL FOR FACING MATERIALS & DIMENSIONS.
2. ALL FACING UNITS SHALL BE FABRICATED FROM GALVANIZED STEEL.
3. SEE SPECIFICATIONS FOR TOP SOIL PROPERTIES.

TYPICAL MSE SLOPE ENLARGED DETAIL

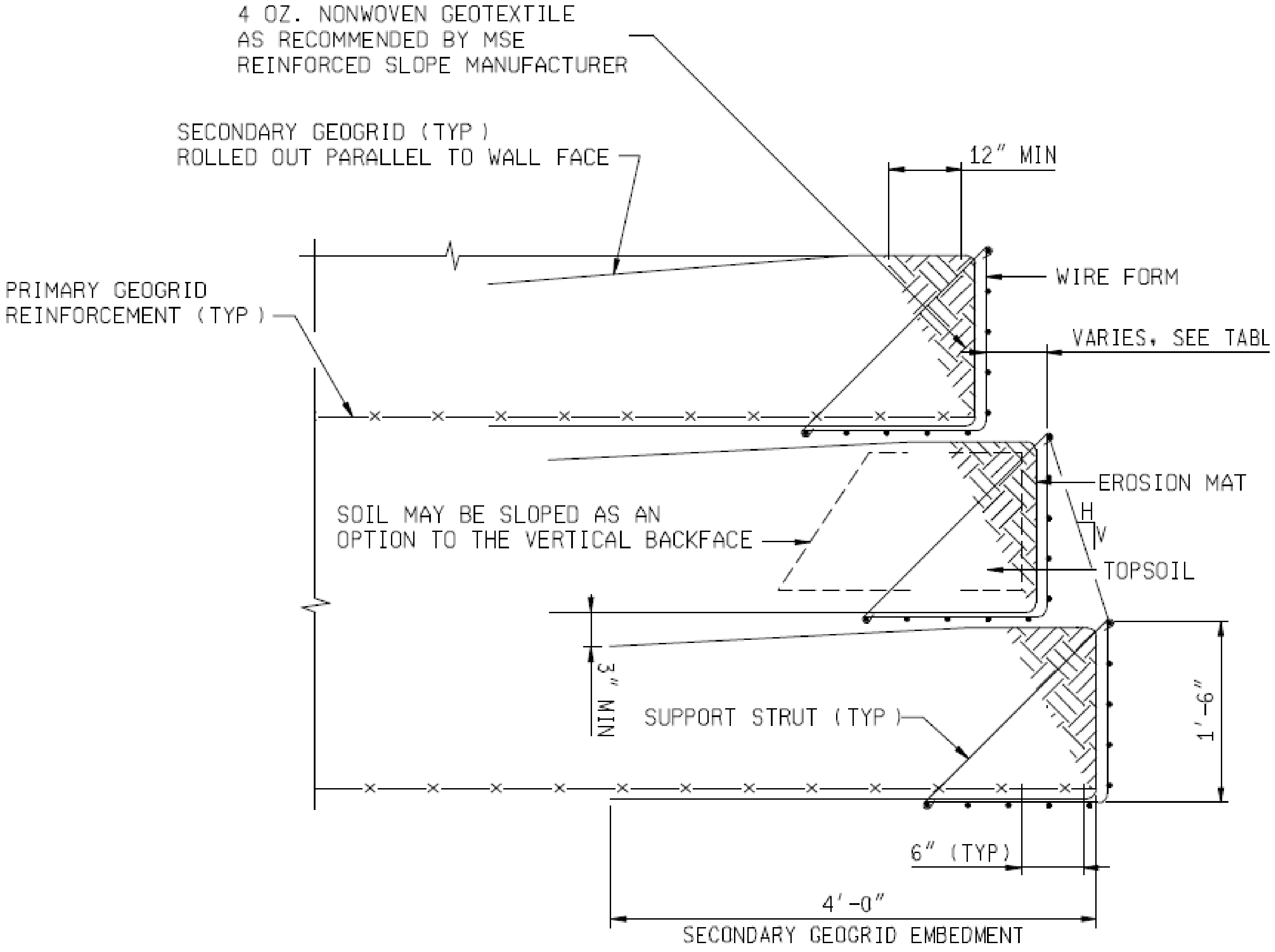

S&S
FIRE PROTECTION


CSIC
Geoturf

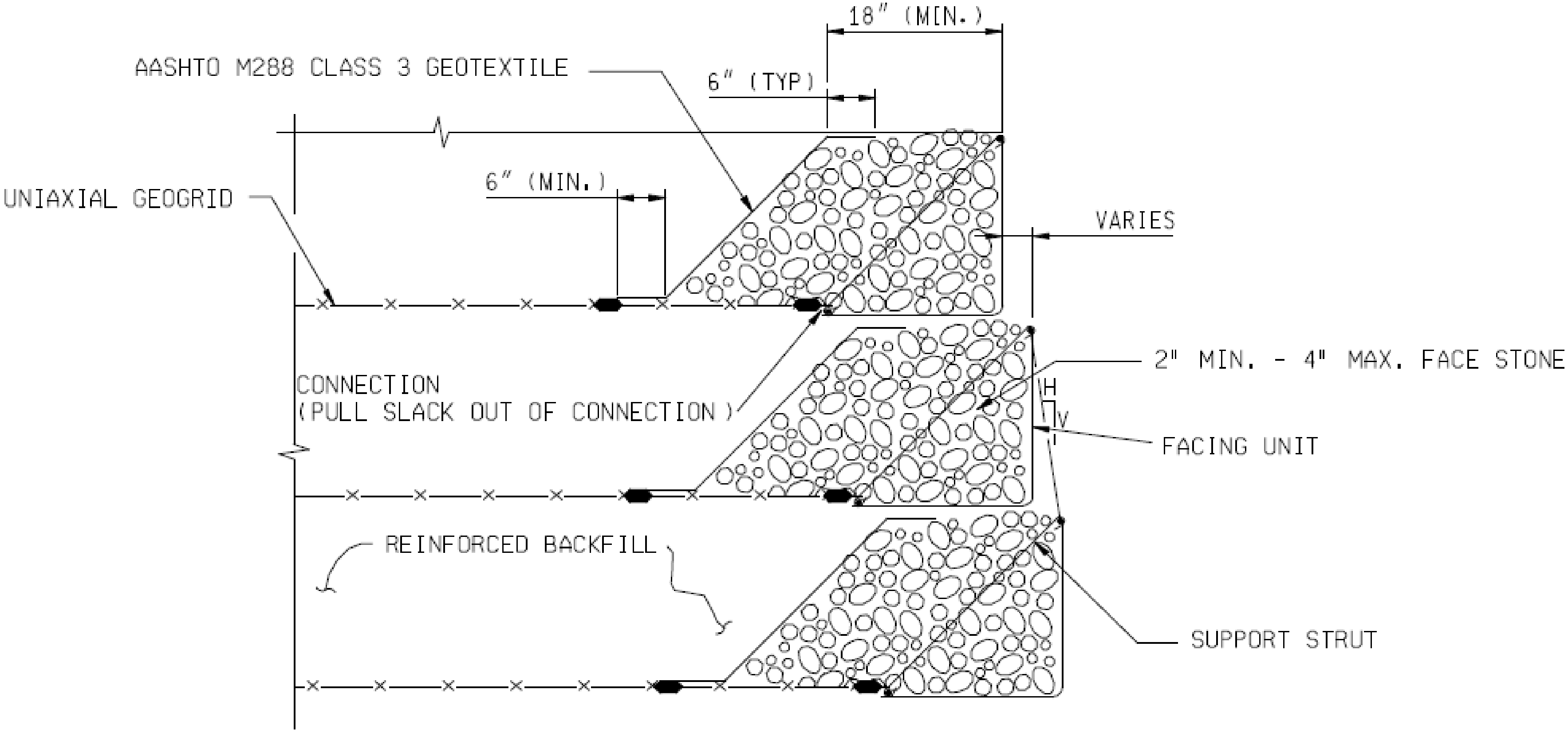

DEERE
120



TYPICAL MSE REINFORCED SLOPE SECTION
WALLS A,C, & F



MSE REINFORCED SLOPE FACING DETAIL



RETAINING WALL FACING DETAIL

NOT TO SCALE


West
Circuit Judge

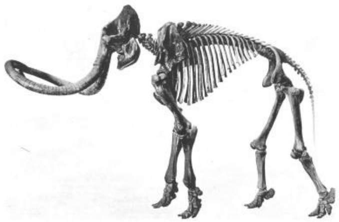
Byrum's Favorite Michigan "Beach"
Grand Portal Point, Pictured Rocks

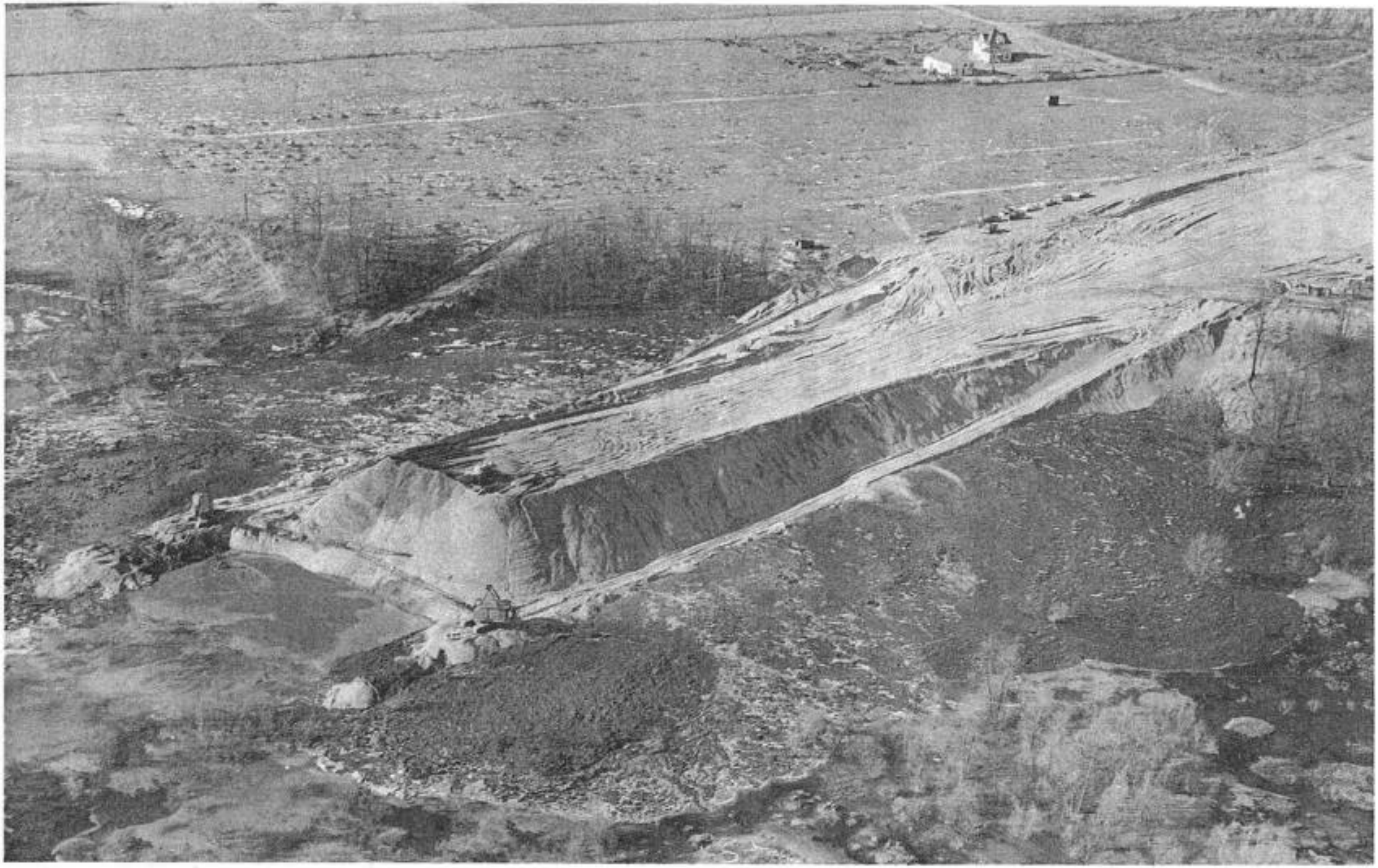
Any Questions?

Michigan's State Fossil:

Mastodon

$$M = EI \frac{d^2 z}{dx^2}$$





MDOT: Leader in Soft Soil Engineering, see 1920's TRB proceedings regarding MDOT swamp embankment research = great work!

TABLE 3-1
SUMMARY OF GEOTEXTILE DESIGN AND SELECTION CRITERIA FOR HARD ARMOR EROSION CONTROL APPLICATIONS

I. SOIL RETENTION (PIPING RESISTANCE CRITERIA)[1]

Soils	Steady State Flow	Dynamic, Pulsating and Cyclic Flow (if geotextile can move)
$<50\%$ Passing[2] 0.075 mm	AOS or $0_{95} \le B\,D_{85}$	
	$C_u \le 2$ or ≥ 8: $B=1$	
	$2 \le C_u \le 4$: $B=0.5\,C_u$	$0_{95} \le 0.5\,D_{85}$
	$4 \le C_u \le 8$: $B=8/C_u$	
$\ge 50\%$ Passing 0.075 mm	Woven: $0_{95} \le D_{85}$	$0_{95} \le 0.5\,D_{85}$
	Nonwoven: $0_{95} \le 1.8\,D_{85}$	
For cohesive soils ($PI > 7$)	0_{95} (geotextile) ≤ 0.3 mm	

STEP 2. OBTAIN SOIL SAMPLES

A. GRAIN SIZE ANALYSES

Plot gradations of representative soils. The D_{60}, D_{10}, and D_{85} sizes from the gradation plot are noted in the table below for Samples A, B, and C. Determine uniformity coefficient, C_u, coefficient B, and the maximum AOS.

Worst case soil for retention (*i.e.*, smallest B *x* D_{85}) is Soil C, from the following table.

Soil Sample	$D_{60} \div D_{10} = C_u$	B =	AOS (mm) ≤ B *x* D_{85}
A	$0.48 \div 0.15 = 3.2$	$0.5\ C_u = 0.5 \times 3.2 = 1.6$	1.6 *x* 1.0 = 1.6
B	$0.25 \div 0.06 = 4.2$	$8 \div C_u = 8 \div 4.2 = 1.9$	1.9 *x* 0.75 = 1.4
C	$0.36 \div 0.14 = 2.6$	$0.5\ C_u = 0.5 \times 2.6 = 1.3$	1.3 *x* 0.55 = 0.72

II. PERMEABILITY/PERMITTIVITY CRITERIA[3]

A. Critical/Severe Applications

$$k_{geotxtile} \geq 10\, k_{soil}$$

B. Less Critical/Less Severe Applications (with Clean Medium to Coarse Sands and Gravels)

$$k_{geotextile} \geq k_{soil}$$

C. Permittivity Requirement

$\psi \geq 0.7$ sec^{-1} for $< 15\%$ passing 0.075 mm
$\psi \geq 0.2$ sec^{-1} for 15 to 50% passing 0.075 mm
$\psi \geq 0.1$ sec^{-1} for $> 50\%$ passing 0.075 mm

III. CLOGGING CRITERIA

B. PERMEABILITY TESTS

Noncritical application, drain will be conservatively designed with an estimated permeability.

The largest D_{10} controls permeability; therefore, Soil A with $D_{10} = 0.15$ mm controls. Therefore,

$$k \approx (D_{10})^2 = (0.15)^2 = 2\,(10)^{-2} \text{ cm/s} = 2\,(10)^{-4} \text{ m/s}$$

III. CLOGGING CRITERIA

A. Critical/Severe Applications[4]
Select geotextile meeting I, II, IIIB, and perform soil/geotextile filtration tests before specification, prequalifying the geotextile, or after selection before bid closing. Alternative: use approved list specification for filtration applications. Suggested performance test method: Gradient Ratio, ASTM D 5101 for cohesionless soils or Hydraulic Conductivity Ratio, ASTM D 5567 for cohesive soils.

B. Less Critical/Less Severe Applications

1. Perform soil-geotextile filtration tests.
2. Alternative: $0_{95} \geq 3 D_{15}$ for $C_u > 3$
3. For $C_u \leq 3$, specify geotextile with maximum opening size possible from retention criteria
4. Apparent Open Area Qualifiers

For soils with % passing 0.075 mm	> 5%	< 5%
Woven monofilament geotextiles: Percent Open Area : ≥	4%	10%
Nonwoven geotextiles: Porosity[5] ≥	50%	70%

A. RETENTION CRITERIA

Sample C controls (see table above), therefore, **AOS $\leq$ 0.72 mm**

B. PERMEABILITY CRITERIA

From given data, it has been judged that this application is a less critical/less severe application. Therefore, $k_{geotextile} \geq k_{soil}$

Soil C controls, therefore **$k_{geotextile} \geq 2\ (10)^{-4}$ m/sec**

Flow capacity requirements of the system - details of which are not included within this example.

C. PERMITTIVITY CRITERIA

All three soils have < 15% passing the 0.075 mm, therefore **$\psi \geq 0.5\ \text{sec}^{-1}$**

D. CLOGGING CRITERIA

From given data, it has been judged that this application is a less critical/less severe application, and Soils A and B have a C_u greater than 3. Therefore, for soils A and B, $O_{95} \geq 3\ D_{15}$

$O_{95} \geq$ $3 \times 0.15 = 0.45$ mm for Sample A
$3 \times 0.075 = 0.22$ mm for Sample B

Soil A controls [Note that sand size particles typically don't create clogging problems, therefore, Soil B could have been used as the design control.], therefore, **AOS $\geq$ 0.45 mm**

For Soil C, a geotextile with the maximum AOS value determined from the retention criteria should be used. Therefore **AOS $\approx$ 0.72 mm**