ECS CAROLINAS, LLP
"Setting the Standard for Service"
Geotechnical • Construction Materials • Environmental • Facilities
NC Registered Engineering Firm F-1078

June 4, 2013

Mr. Wayne Sullivan
Municipal Engineering Services Co. PA
PO Box 97
Garner, NC 27529

| Permit No. | Date | Document ID No. |
|---|---|---|
| **96-06** | **June 04, 2013** | **19023** |

Received by an e-mail
Date: **June 04, 2013**
Solid Waste Section
Raleigh Central Office

**RE: Revised Slope Stability Analyses**
**Wayne County Landfill, Phase 3**
**460 S. Landfill Road**
**Dudley, North Carolina**
**ECS Project No. 06:16642-A**

Dear Wayne:

Based on the attached interface friction test results (performed by others) provided by you and as requested by you, ECS rerun the slope stability analyses for this project using a friction angle of 25.2 degrees and an adhesion of 48 psf for the HDPE liner material, and the results area attached herewith. Based on these results, it is evident that the factors of safety are unchanged from the previous analyses.

Should you have any questions or if we could be of further assistance, please do not hesitate to contact us.

Respectfully,

**ECS CAROLINAS, LLP represented by;**
Firm License Number: F-1078

NORTH CAROLINA PROFESSIONAL SEAL 19937 06/04/13 ENGINEER C NALLAINATHAN

Christina N. Warr, PE
Project Manager
NC PE License No. 039235

C. (Nathan) Nallainathan
Principal Engineer
NC PE License No. 019937

# INTERFACE FRICTION TEST RESULTS
## ASTM D 5321

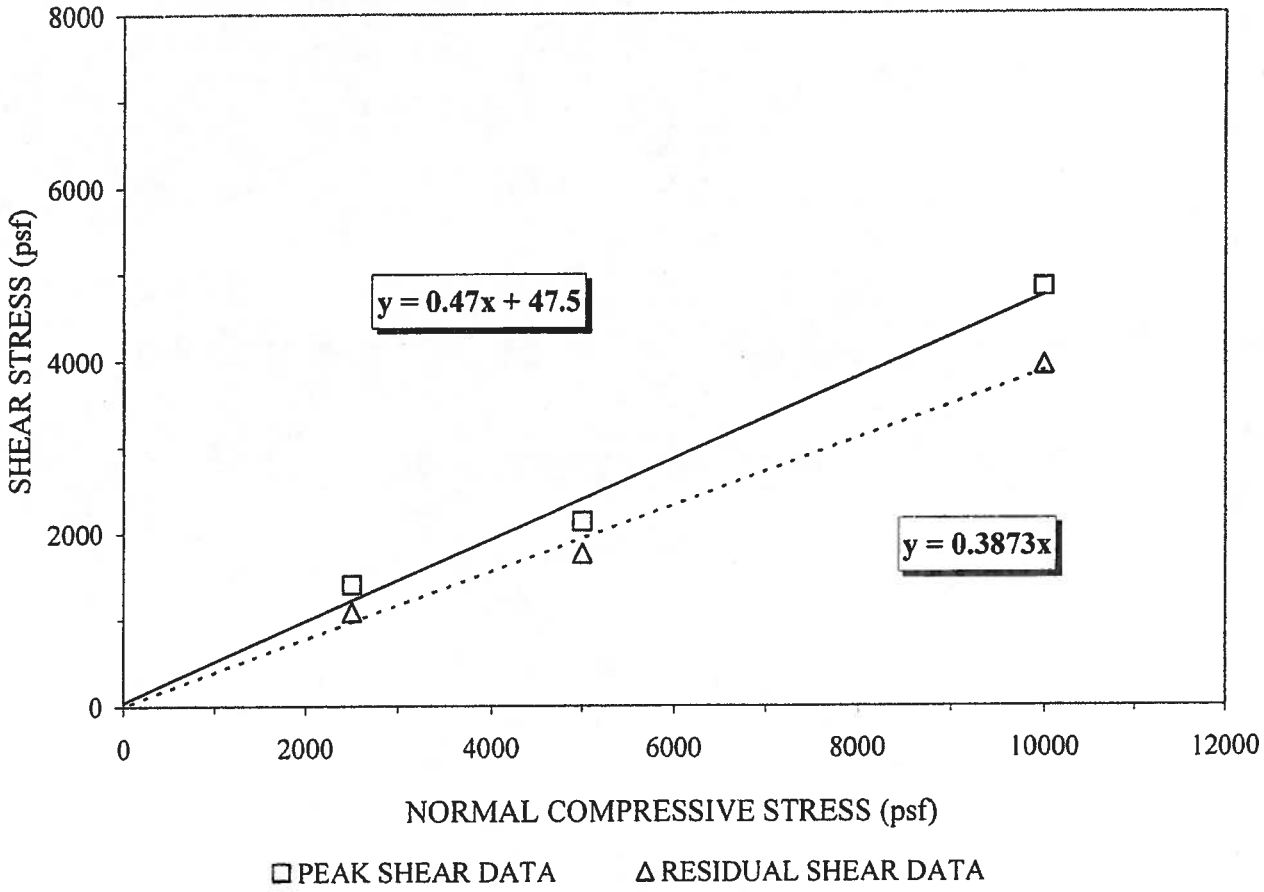
geotechnics
INTEGRITY IN TESTING

CLIENT : MESCO
CLIENT PROJECT : Wayne County Landfill
PROJECT NO. : L13046-01
LAB I. D. NO.: Soil (L13046-01-03)
Agru 60 mil HDPE Microspike (L13046-01-01)

INTERFACE : **Soil @ 110 pcf & 13.8 % M.C.**
**vs. 60 mil HDPE Microspike (Bottom Side)**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | 25.2 | Φ = | 21.2 |
| COEFFICIENT OF FRICTION : | = | 0.470 | = | 0.387 |
| ADHESION [Calculated] (psf): | a = | 48 | a = | 0 |

NOTES:
1.) Soil placement was provided by client.
2.) The interface was loaded, inundated with water and consolidated for 24 hours prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.







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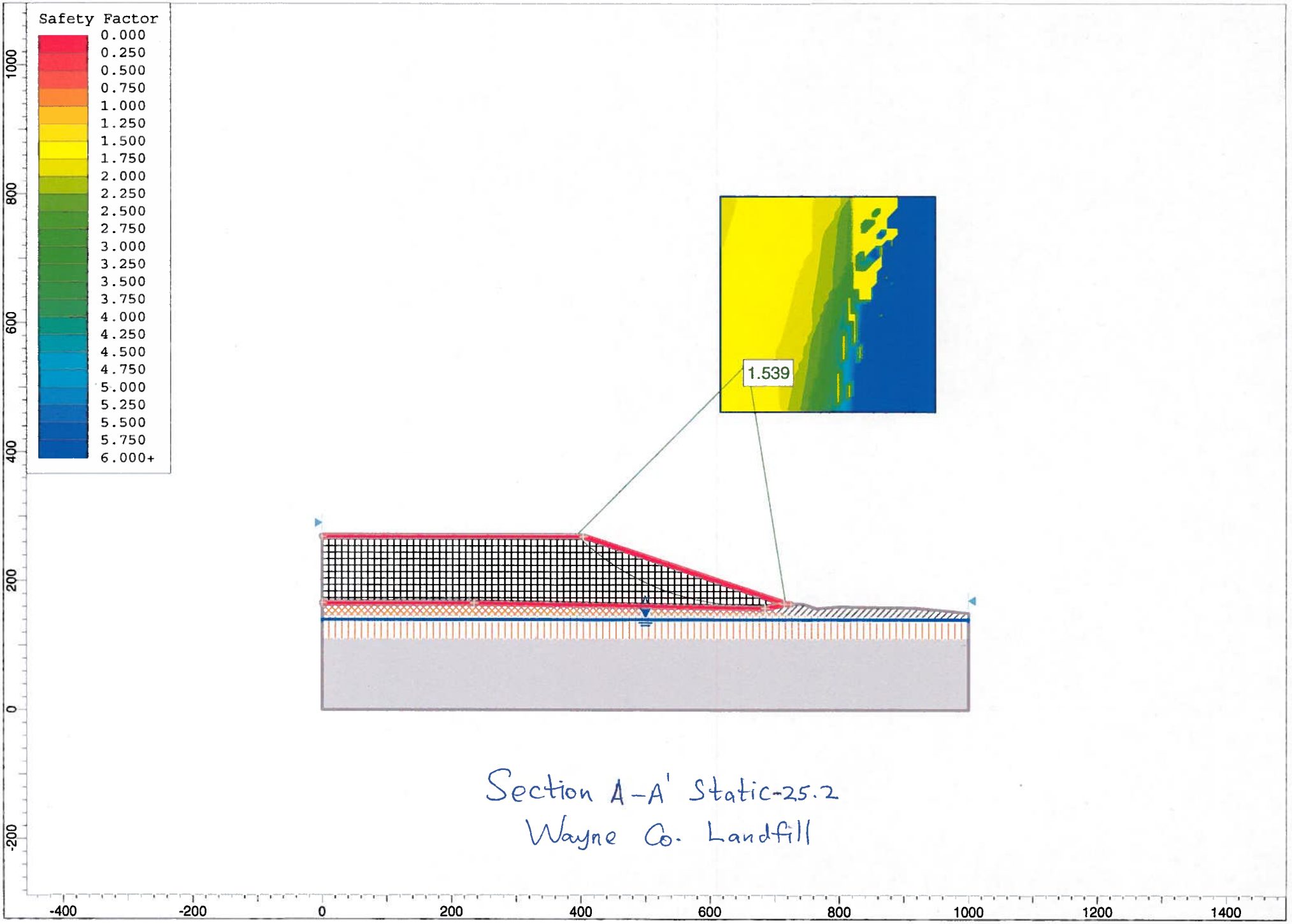



Section A-A' Static-25.2
Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section A-A' Static-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section A-A' Static
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees

Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

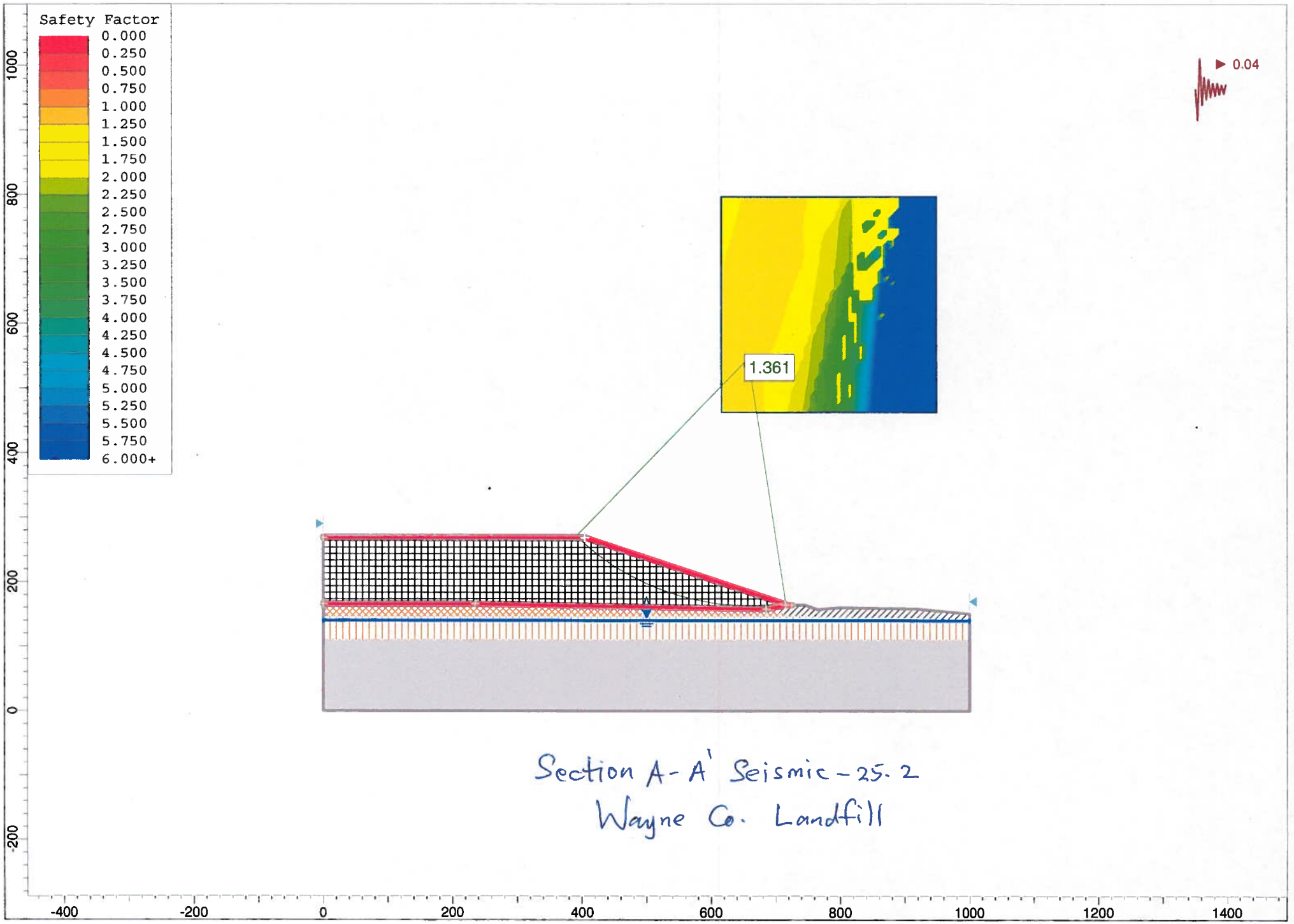
Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 0 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

## Support Properties

Support: Liner and Drainage Net (Frict Angle = 25.2)
Liner and Drainage Net (Frict Angle = 25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.539300
Center: 657.682, 537.565
Radius: 375.425
Left Slip Surface Endpoint: 393.321, 271.000
Right Slip Surface Endpoint: 716.615, 166.795
Resisting Moment=1.26393e+008 lb-ft
Driving Moment=8.21108e+007 lb-ft




Section A-A' Seismic - 25.2

Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section A-A' Seismic-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section A-A' Seismic
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Loading

Seismic Load Coefficient (Horizontal): 0.04

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner

Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 0 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

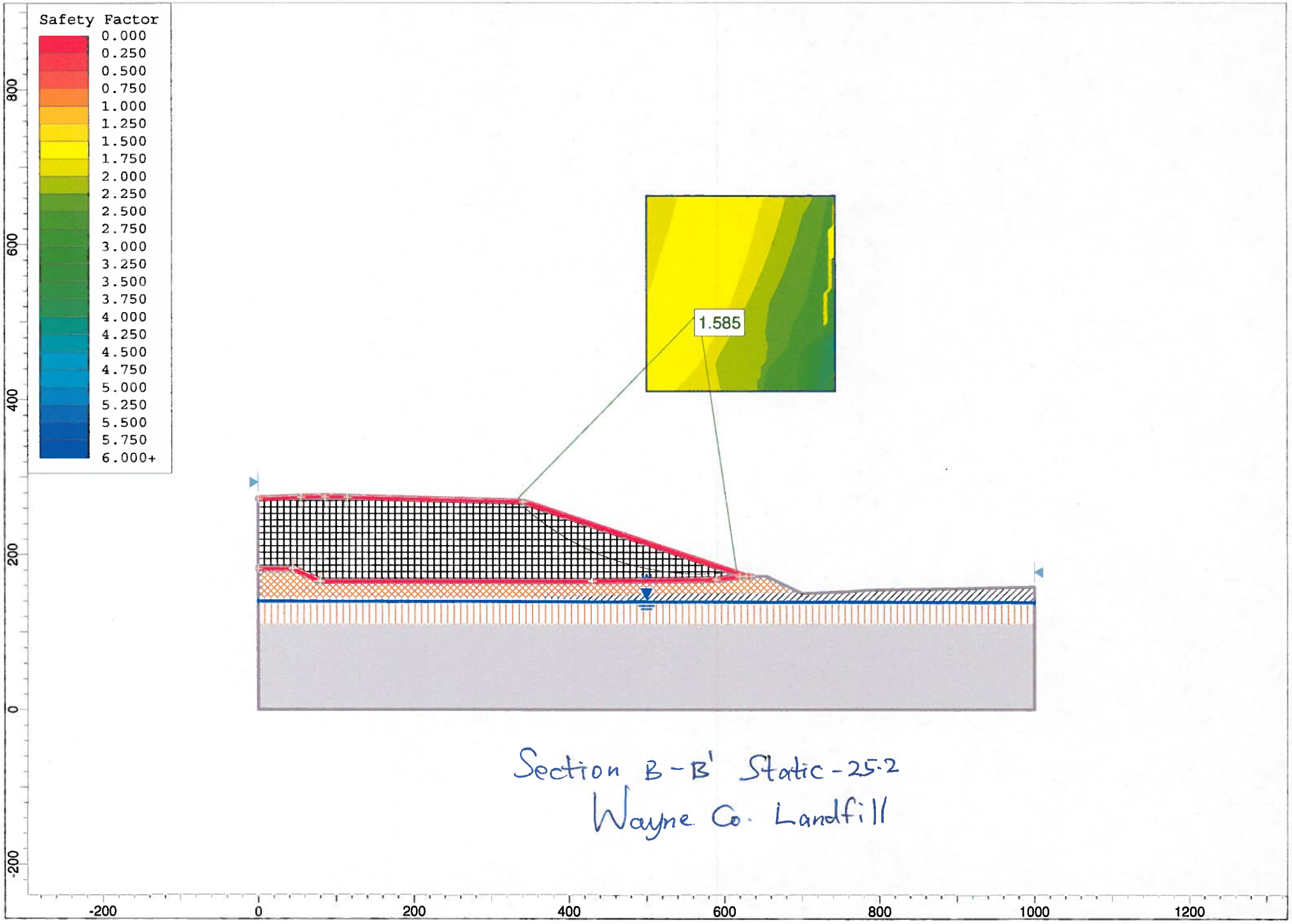
## Support Properties

Support: Liner and Drainage Net (Frict Angle = 25.2)
Liner and Drainage Net (Frict Angle = 25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear

Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.361210
Center: 657.682, 545.915
Radius: 382.970
Left Slip Surface Endpoint: 391.059, 271.000
Right Slip Surface Endpoint: 715.154, 167.282
Resisting Moment=1.2732e+008 lb-ft
Driving Moment=9.3534e+007 lb-ft




Section B-B' Static-25.2

Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section B-B' Static-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section B-B' Static
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees

Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

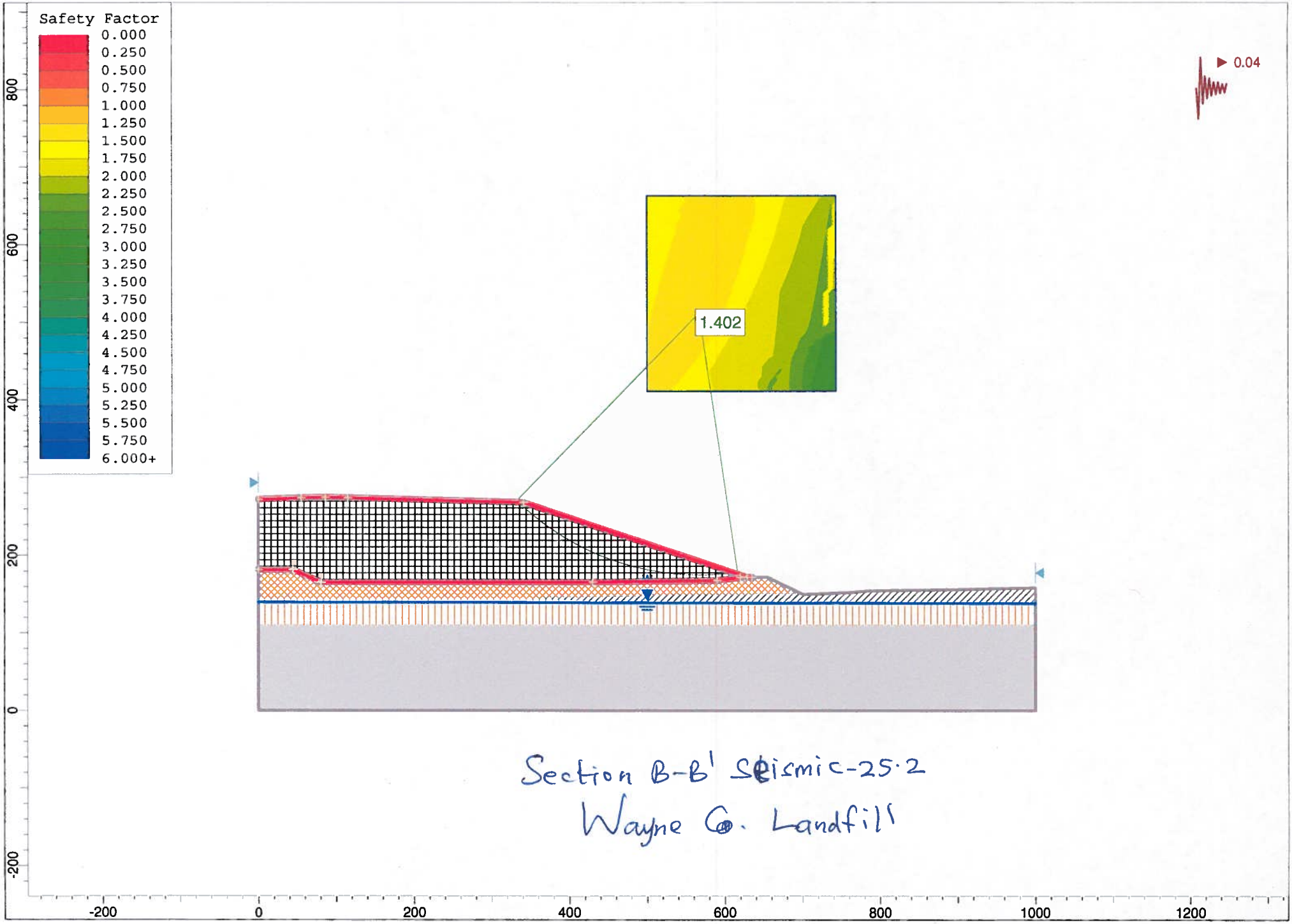
Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 0 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

## Support Properties

Support: Liner & Drainage Net (Frict Angle =25.2)
Liner & Drainage Net (Frict Angle =25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.585210
Center: 567.187, 511.833
Radius: 337.082
Left Slip Surface Endpoint: 332.123, 270.236
Right Slip Surface Endpoint: 616.061, 178.313
Resisting Moment=8.93168e+007 lb-ft
Driving Moment=5.63439e+007 lb-ft




Section B-B' Seismic-25.2

Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section B-B' Seismic-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section B-B' Seismic
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Loading

Seismic Load Coefficient (Horizontal): 0.04

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner

Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 0 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

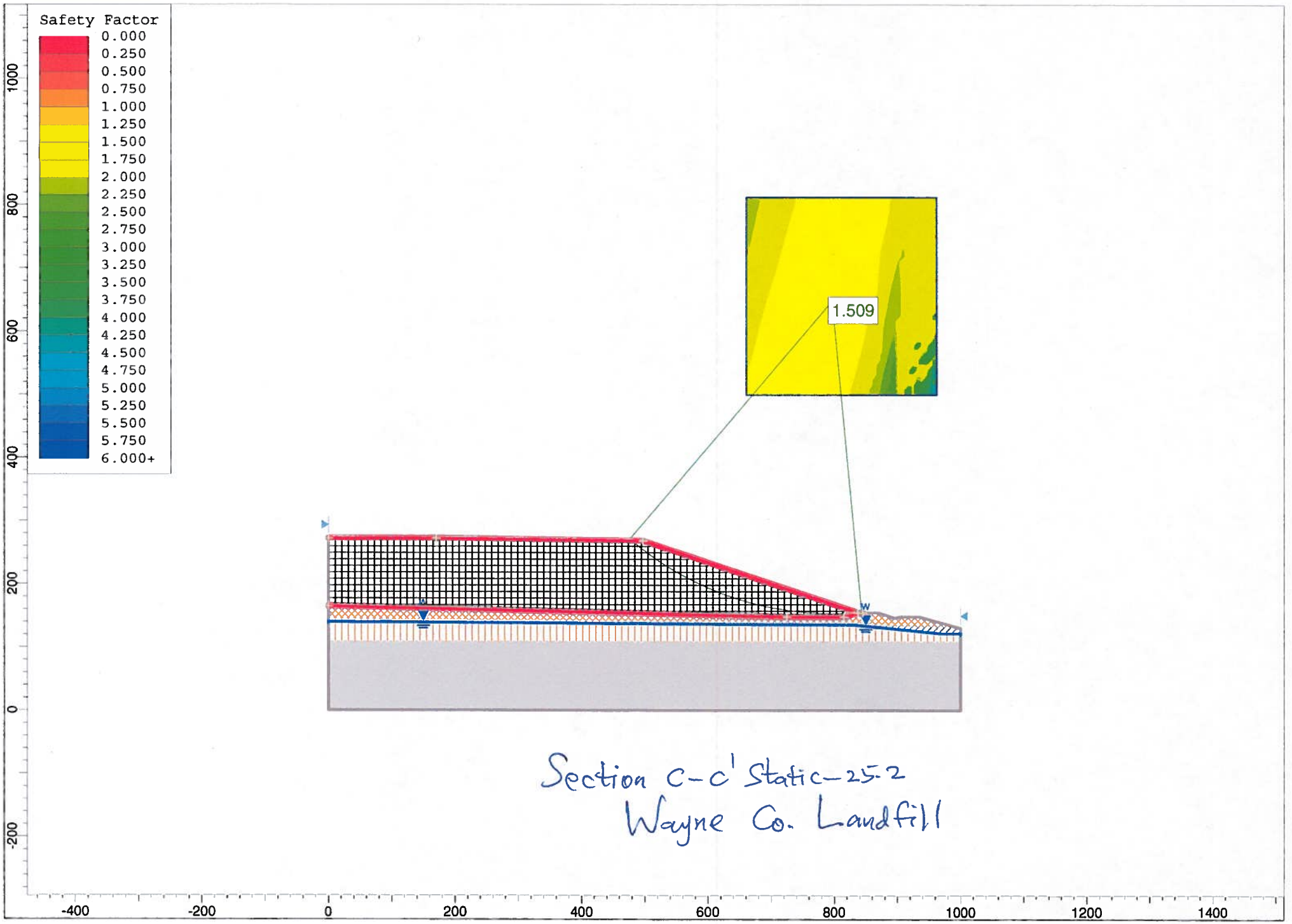
## Support Properties

Support: Liner & Drainage Net (Frict Angle =25.2)
Liner & Drainage Net (Frict Angle =25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear

Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.401860
Center: 567.187, 511.833
Radius: 337.082
Left Slip Surface Endpoint: 332.123, 270.236
Right Slip Surface Endpoint: 616.061, 178.313
Resisting Moment=8.85279e+007 lb-ft
Driving Moment=6.31505e+007 lb-ft




Section C-C' Static-25.2
Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section C-C' Static-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section C-C' Static
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees

Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

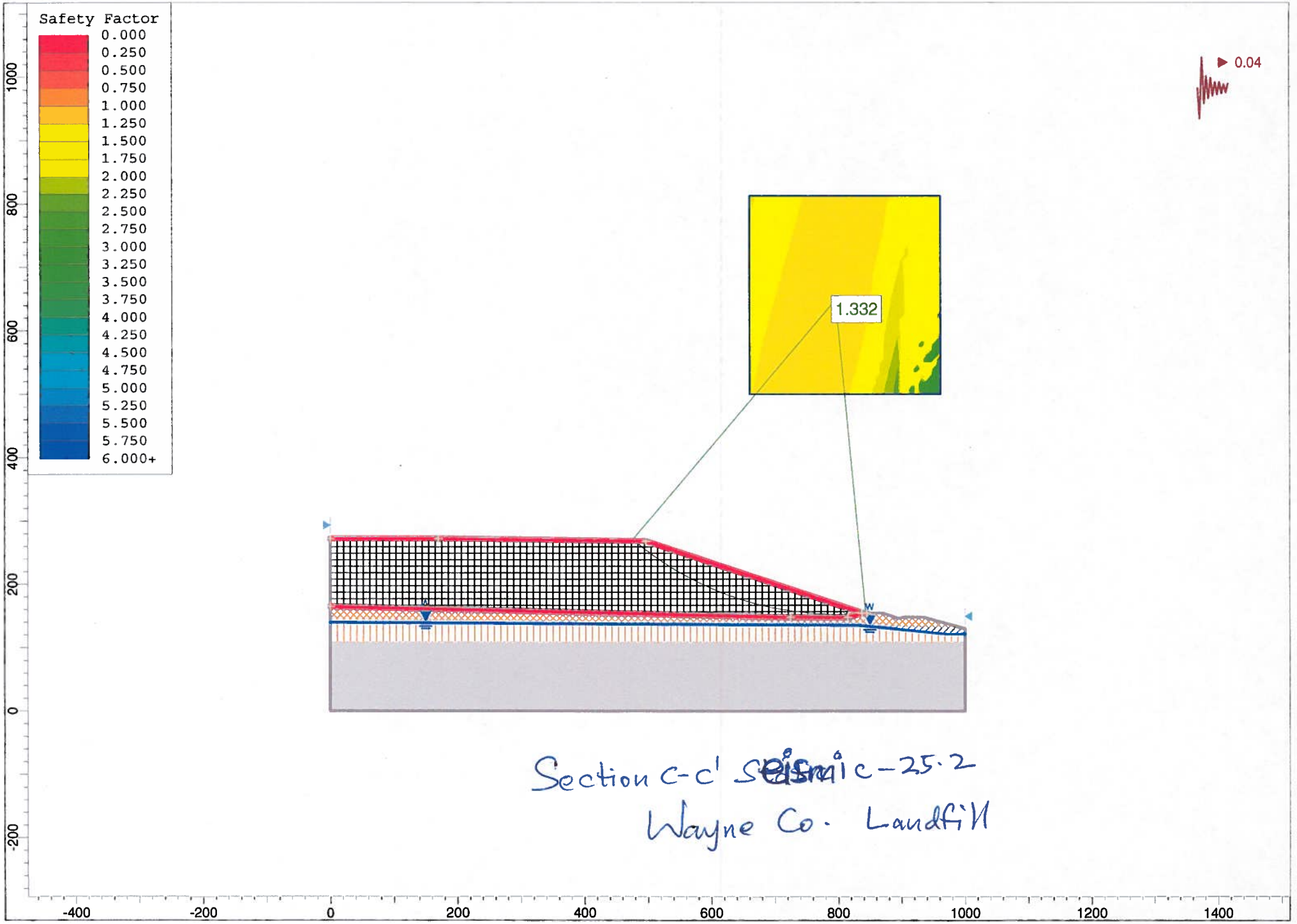
Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 1 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

## Support Properties

Support: Liner & Drainage Net (Frict Angle = 25.2)
Liner & Drainage Net (Frict Angle = 25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.508860
Center: 796.466, 648.089
Radius: 495.718
Left Slip Surface Endpoint: 475.556, 270.262
Right Slip Surface Endpoint: 843.250, 154.583
Resisting Moment=1.89655e+008 lb-ft
Driving Moment=1.25694e+008 lb-ft




Section C-C' Seismic-25.2

Wayne Co. Landfill

# *Slide Analysis Information*

## Document Name

File Name: Section C-C' Seismic-25.2.sli

## Project Settings

Project Title: Wayne County Landfill Section C-C' Seismic
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 62.4 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

## Analysis Methods

Analysis Methods used:
Bishop simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

## Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

## Loading

Seismic Load Coefficient (Horizontal): 0.04

## Material Properties

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 70 lb/ft3
Cohesion: 200 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay Liner

Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 0

Material: Fill: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 150 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Clay
Strength Type: Mohr-Coulomb
Unit Weight: 115 lb/ft3
Cohesion: 400 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Silty Sand
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 150 psf
Friction Angle: 32 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Black Creek Clay
Strength Type: Mohr-Coulomb
Unit Weight: 130 lb/ft3
Cohesion: 800 psf
Friction Angle: 20 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Protective
Strength Type: Mohr-Coulomb
Unit Weight: 125 lb/ft3
Cohesion: 1 psf
Friction Angle: 30 degrees
Water Surface: Water Table
Custom Hu value: 1

## Support Properties

Support: Liner & Drainage Net (Frict Angle = 25.2)
Liner & Drainage Net (Frict Angle = 25.2)
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear

Strip Coverage: 100 percent
Tensile Strength: 0 lb/ft
Pullout Strength Adhesion: 48 lb/ft2
Pullout Strength Friction Angle: 25.2 degrees

## Global Minimums

Method: bishop simplified
FS: 1.332100
Center: 796.466, 648.089
Radius: 495.718
Left Slip Surface Endpoint: 475.556, 270.262
Right Slip Surface Endpoint: 843.250, 154.583
Resisting Moment=1.87891e+008 lb-ft
Driving Moment=1.41049e+008 lb-ft

**From:** Wayne Sullivan
**To:** Chao, Ming-tai
**Cc:** "Tim Rogers"; "CNathan"
**Subject:** Wayne Co. Phase 3
**Date:** Tuesday, June 04, 2013 12:41:38 PM
**Attachments:** CQA Item 19ii.pdf

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Ming,

Hope you had a good weekend. Please find attached the response to CQA Item 19 (ii). If you have any questions or need additional information, please do not hesitate to contact me.

Thanks and have a nice day.

D. Wayne Sullivan
Municipal Engineering Services Co., Inc.
Phone: (919) 772-5393
Fax: (919) 772-1176
email: wsullivan@mesco.com