FIGURES

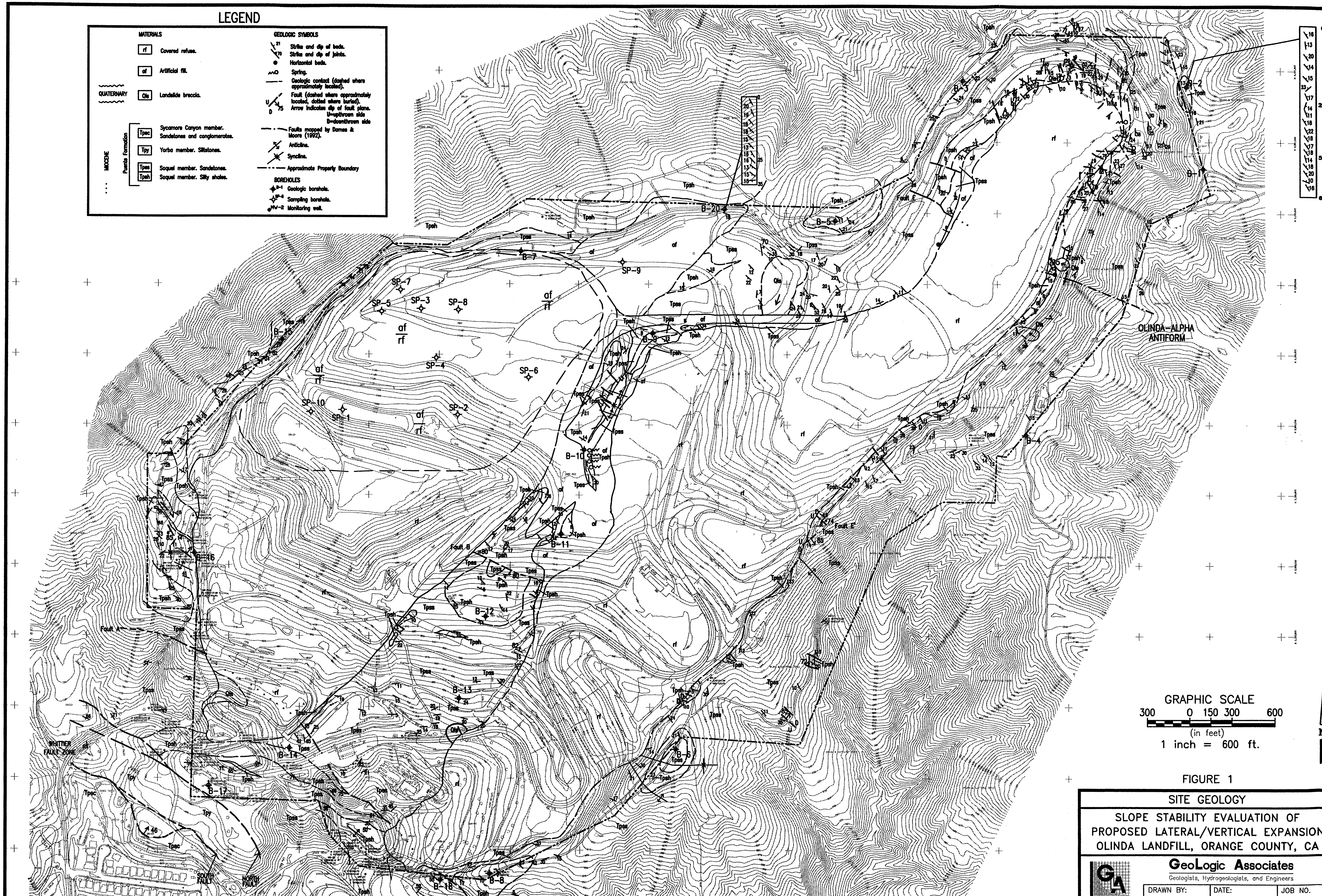


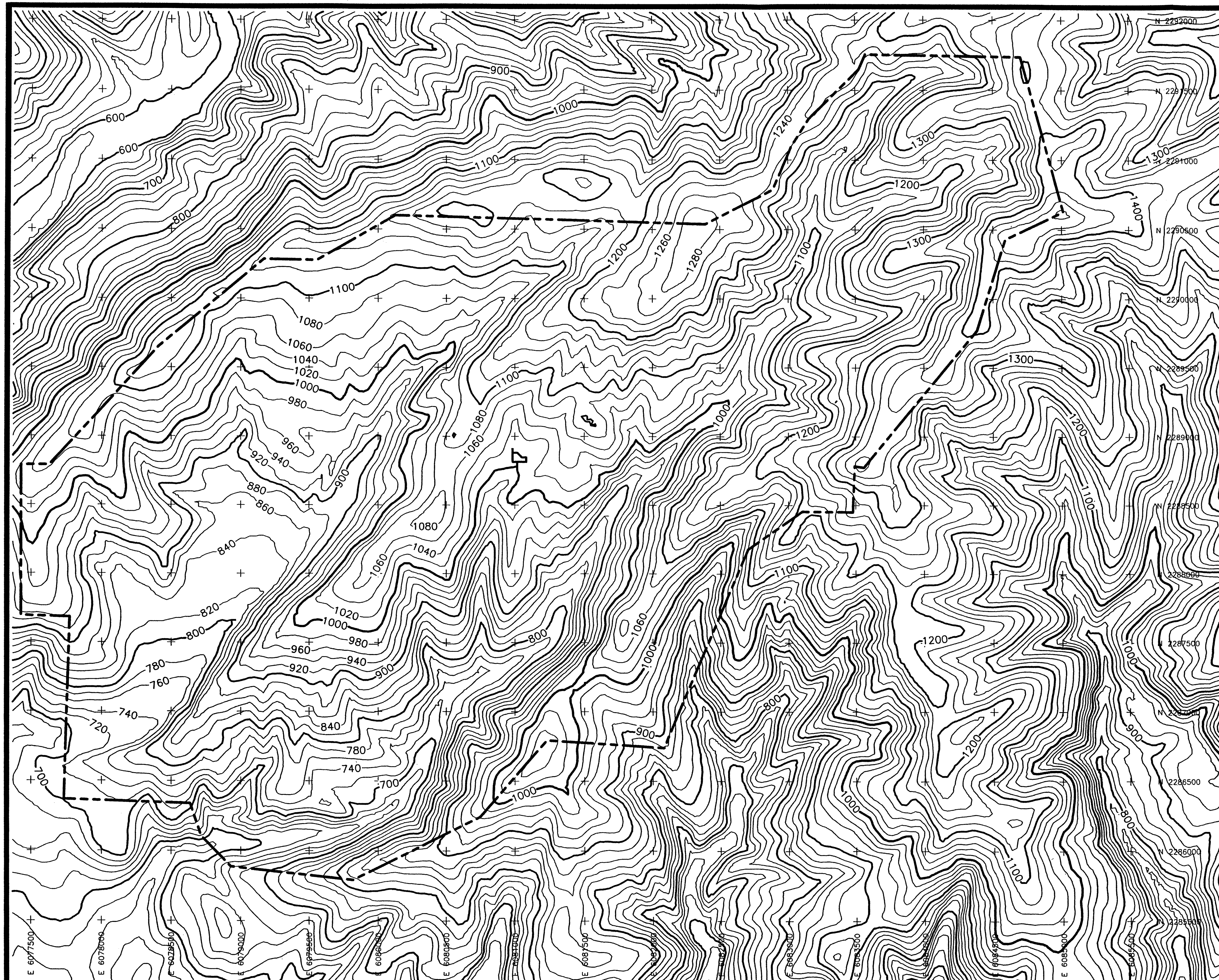
FIGURE 1

SITE GEOLOGY

SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022



LEGEND:

APPROXIMATE PROPERTY BOUNDARY

PRE-LANDFILL GROUND SURFACE CONTOUR

SOURCE: USGS, 1964

N

GRAPHIC SCALE

700 0 350 700 1400

(IN FEET)

1 inch = 700 ft.

FIGURE 2

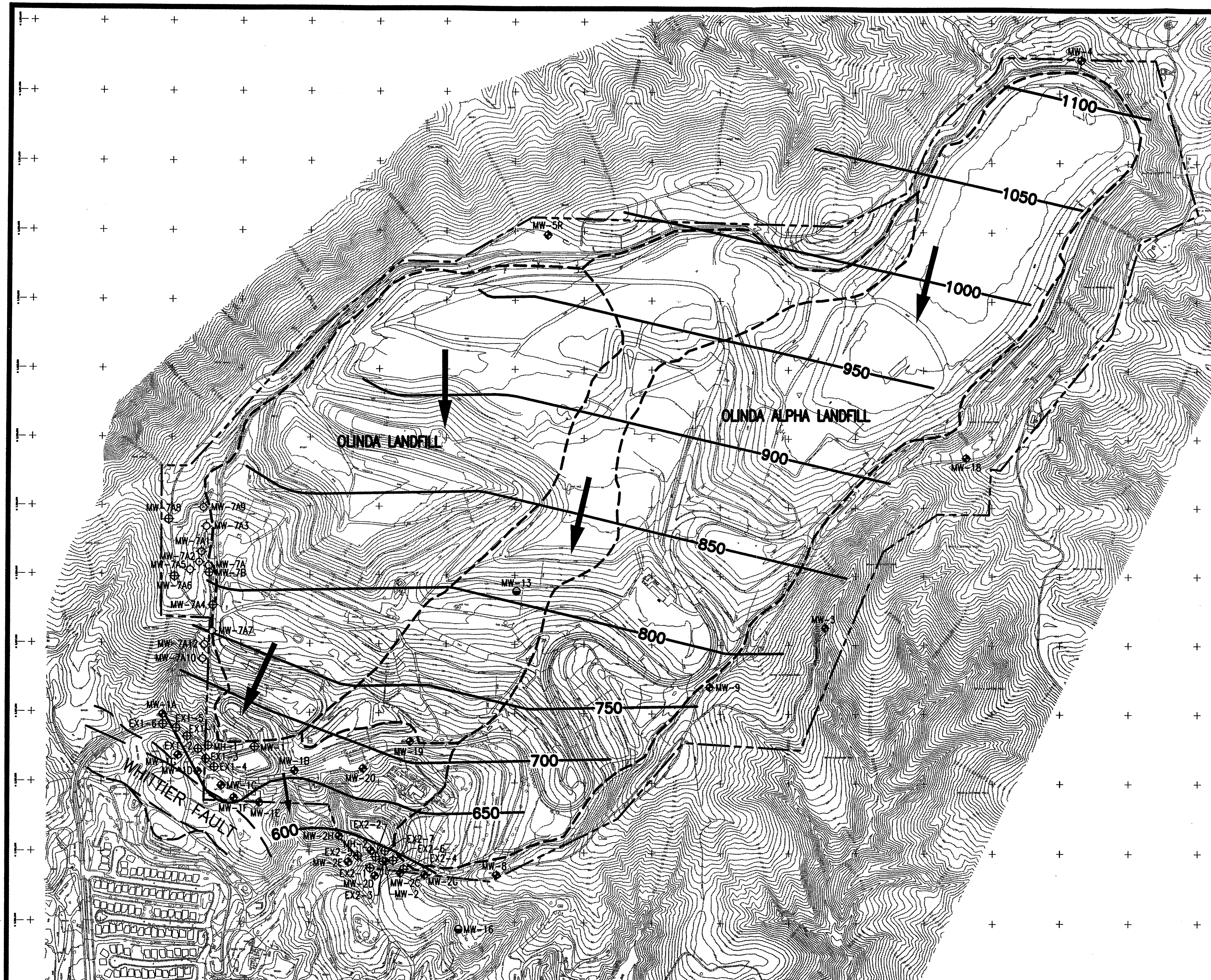
SITE PLAN WITH PRE-LANDFILL TOPOGRAPHY

SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022



LEGEND:

- GROUNDWATER MONITORING WELL SCREENED IN THE UPPERMOST GROUNDWATER BODY
- GROUNDWATER EXTRACTION WELL SCREENED IN THE UPPERMOST GROUNDWATER BODY
- GROUNDWATER EXTRACTION WELL SCREENED IN PERCHED GROUNDWATER (ABOVE THE UPPERMOST GROUNDWATER BODY)
- ABANDONED GROUNDWATER MONITORING WELL
- APPROXIMATE LOCATION OF WHITTIER FAULT
- APPROXIMATE WASTE MANAGEMENT UNIT BOUNDARY
- APPROXIMATE PROPERTY BOUNDARY
- 900 — UPPERMOST GROUNDWATER BODY GROUNDWATER SURFACE ELEVATION CONTOUR AS OF 8/5/2003 (FEET ABOVE MEAN SEA LEVEL)
- APPROXIMATE GROUNDWATER FLOW DIRECTION IN THE UPPERMOST GROUNDWATER BODY

SOURCE: GEOSYNTEC, SEPTEMBER 2003

N

GRAPHIC SCALE

700 0 350 700 1400

(IN FEET)

1 inch = 700 ft.

FIGURE 3

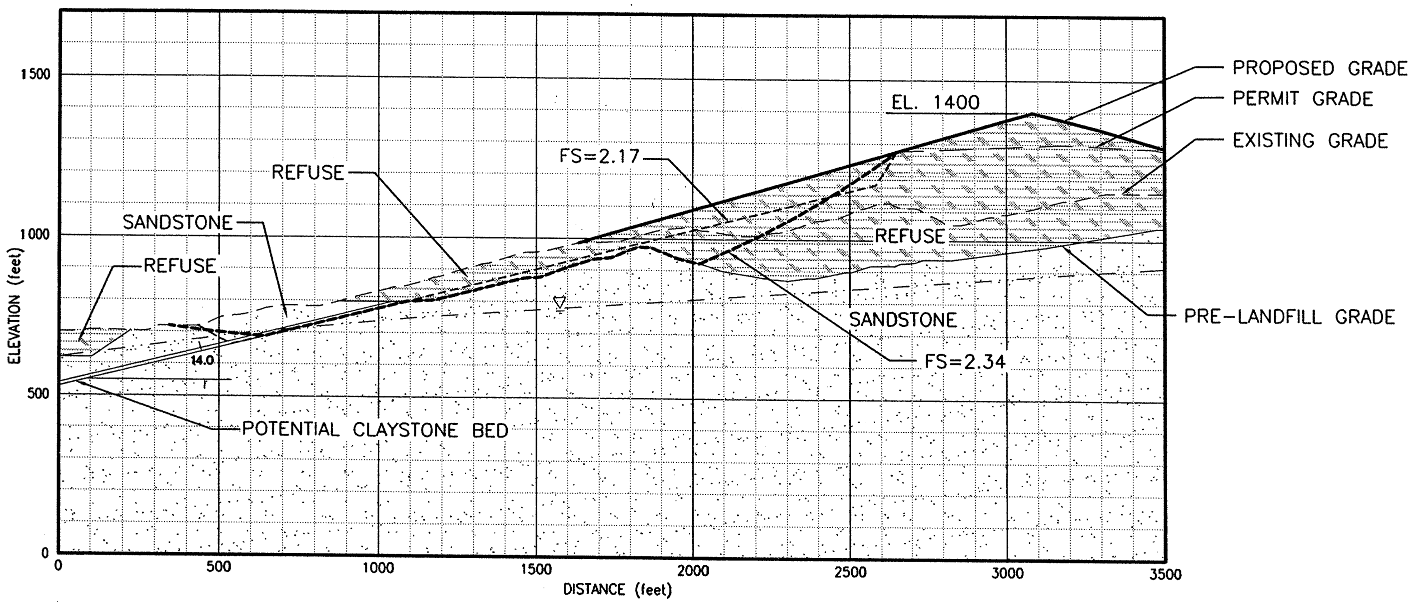
AUGUST 2003 GROUNDWATER ELEVATION CONTOURS

SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

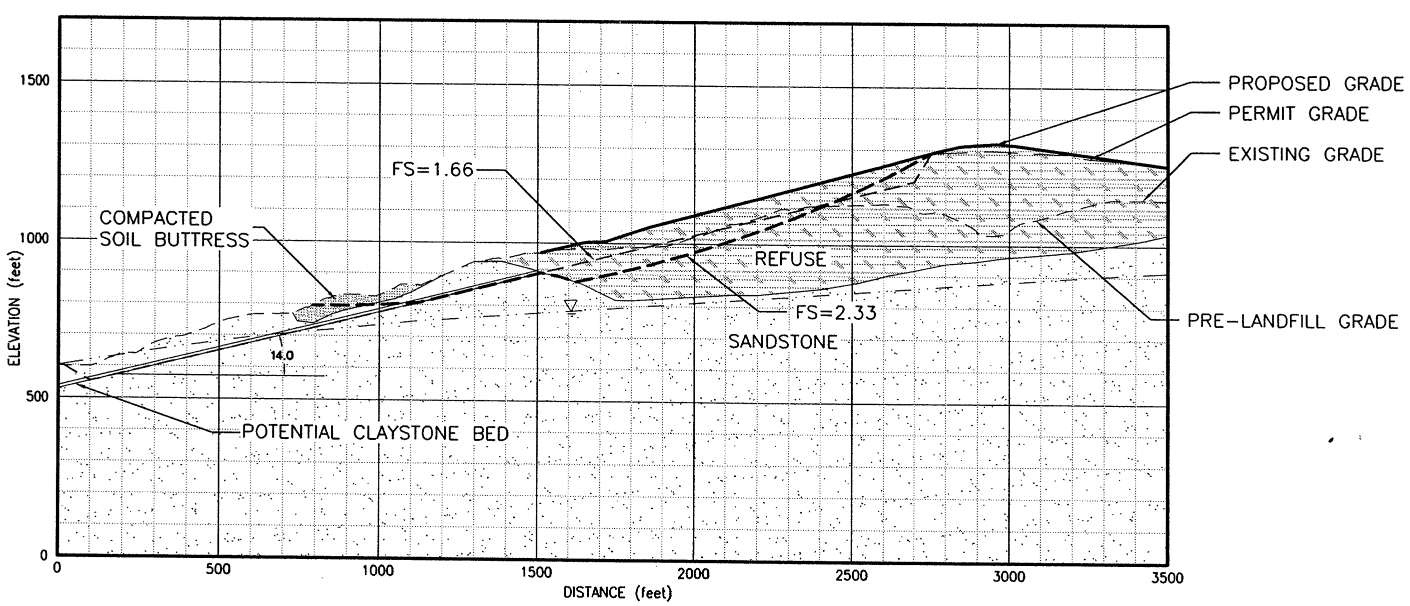
GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

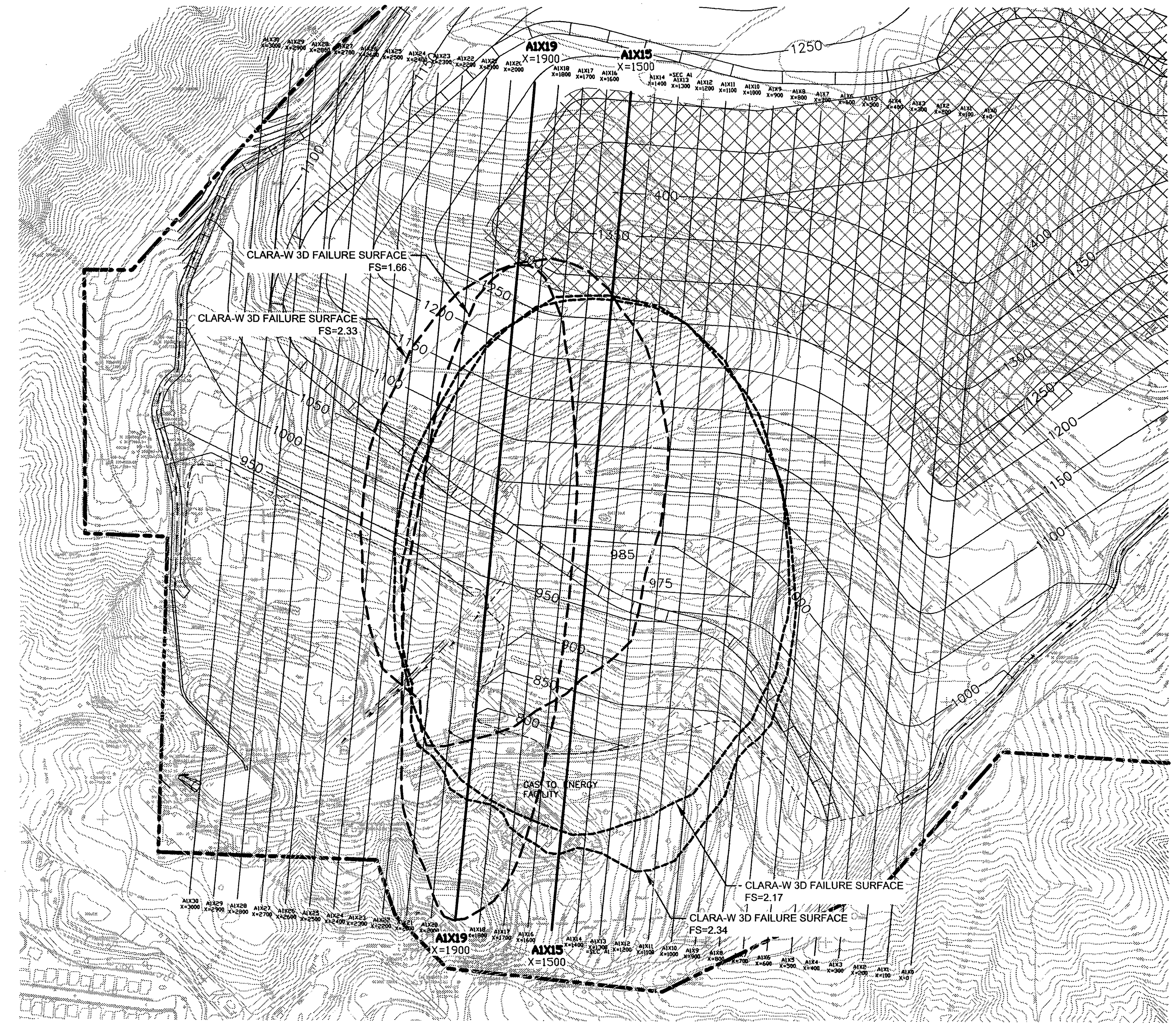
DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022



CLARA-W SECTION A1X15



CLARA-W SECTION A1X19



LEGEND

PERIMETER/DAYLIGHT LINE OF ELLIPSOIDAL FAILURE SURFACE FROM 3-D SLOPE STABILITY ANALYSIS; FACTOR-OF-SAFETY (FS) AS SPECIFIED

A1X19 X=1900 / A1X19 X=1900 — CLARA-W CROSS-SECTION LOCATION

EXTENT OF PROPOSED VERTICAL/HORIZONTAL EXPANSION

APPROXIMATE PROPERTY BOUNDARY

GRAPHIC SCALE
300 0 150 300 600
(in feet)
1 inch = 600 ft.

N

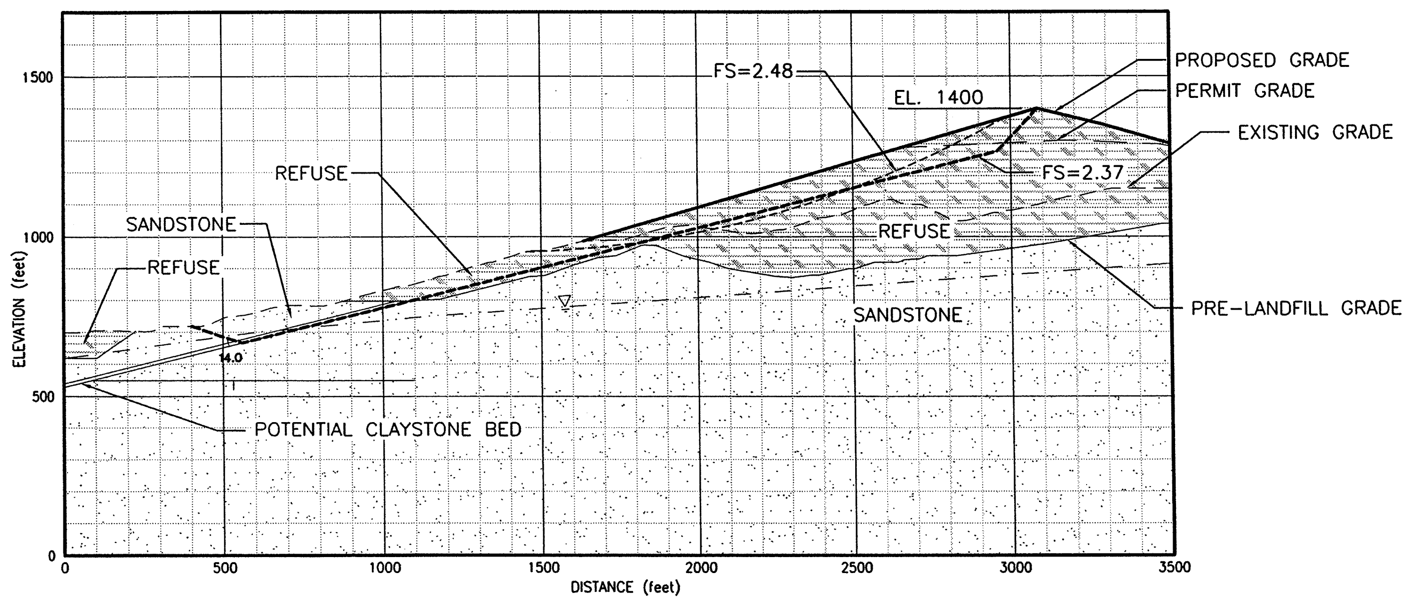
FIGURE 4

POTENTIAL FAILURES AT PERMIT GRADE IN SOUTH-FACING SLOPE

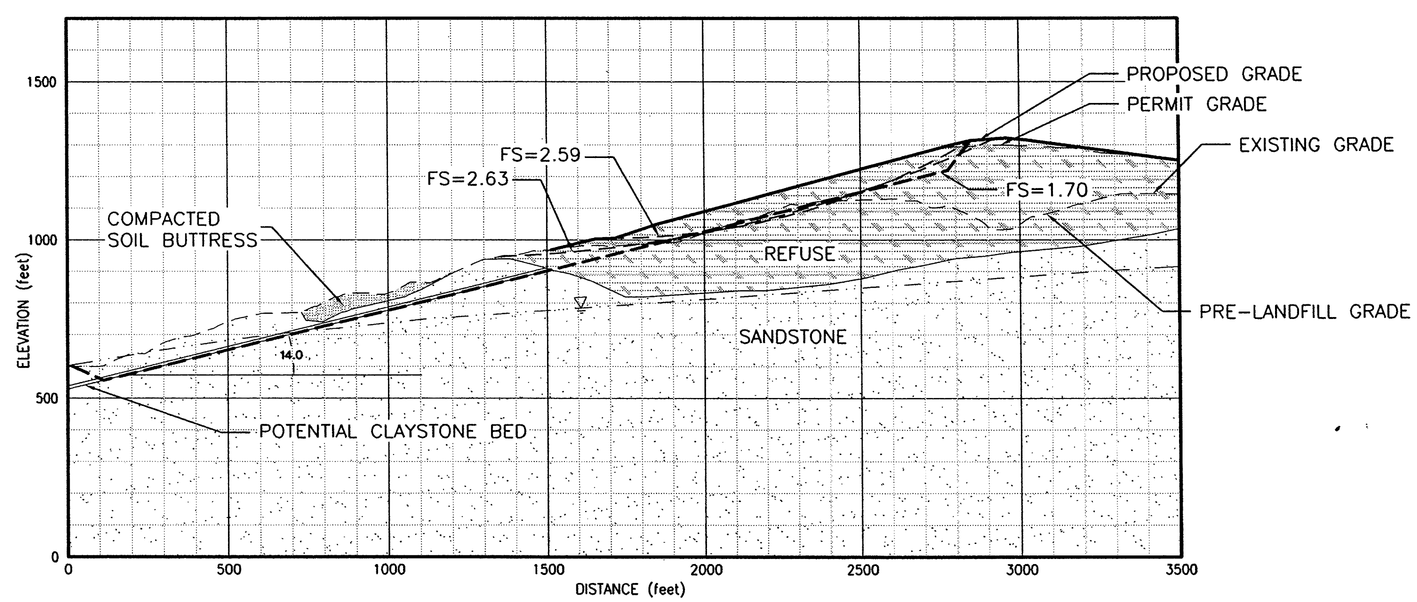
SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

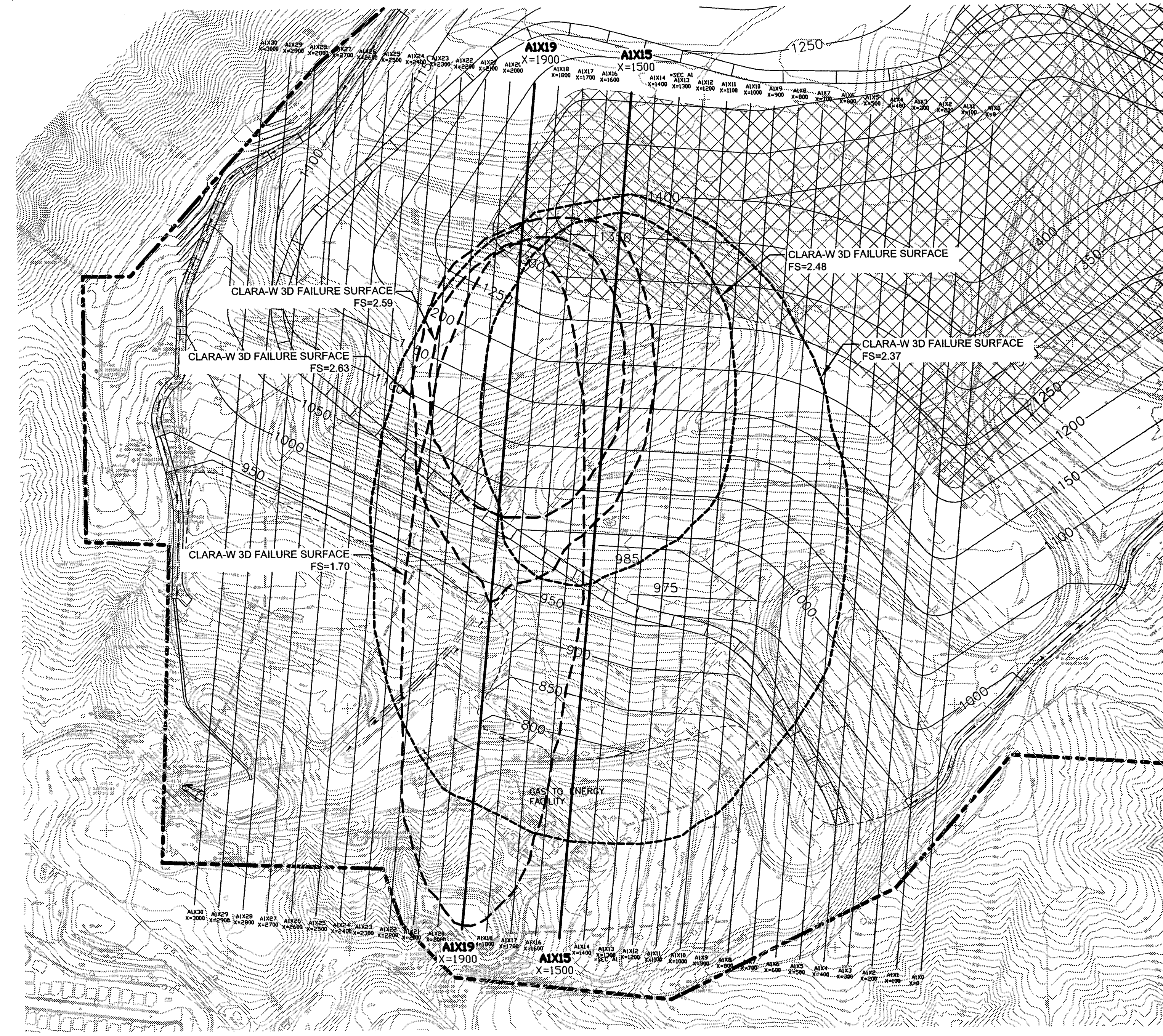
DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022



CLARA-W SECTION A1X15



CLARA-W SECTION A1X19



LEGEND

PERIMETER/DAYLIGHT LINE OF ELLIPSOIDAL FAILURE SURFACE FROM 3-D SLOPE STABILITY ANALYSIS; FACTOR-OF-SAFETY (FS) AS SPECIFIED

A1X19 X=1900 — CLARA-W CROSS-SECTION LOCATION

EXTENT OF PROPOSED VERTICAL/HORIZONTAL EXPANSION

APPROXIMATE PROPERTY BOUNDARY

GRAPHIC SCALE

300 0 150 300 600

(in feet)

1 inch = 600 ft.

N

FIGURE 5

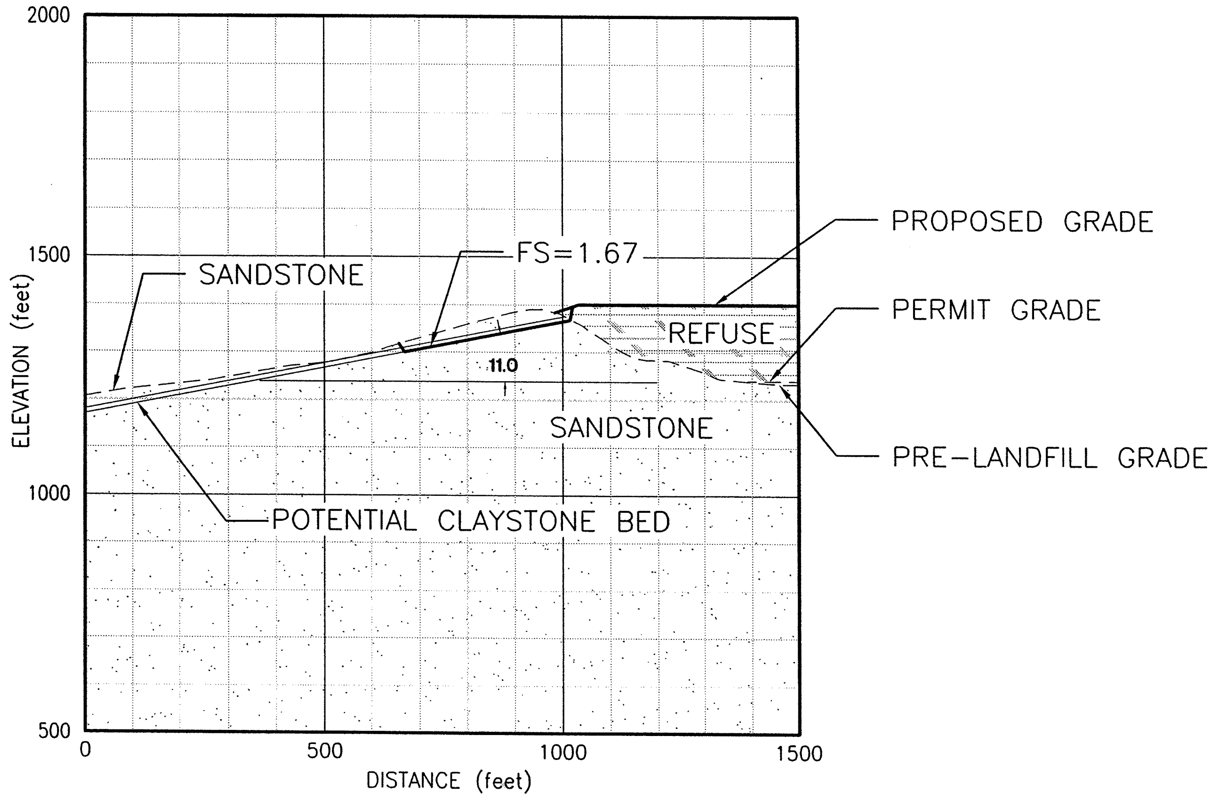
POTENTIAL FAILURES AT PROPOSED GRADE IN SOUTH-FACING SLOPE

SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

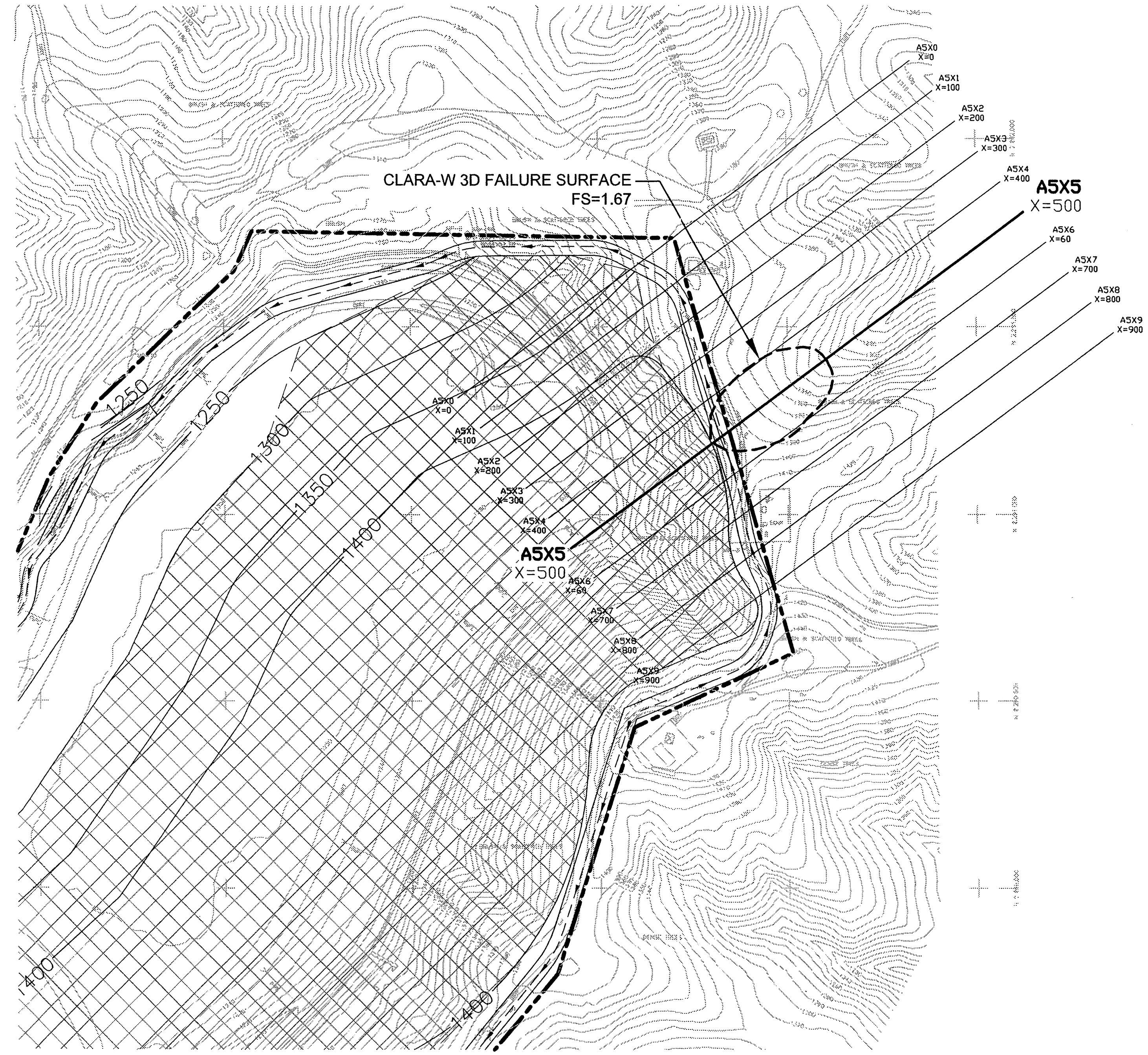
GeoLogic Associates

Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022



CLARA-W SECTION A5X5



PROPOSED GRADE PLAN

LEGEND

- PERIMETER/DAYLIGHT LINE OF ELLIPSOIDAL FAILURE SURFACE FROM 3-D SLOPE STABILITY ANALYSIS; FACTOR-OF-SAFETY (FS) AS SPECIFIED
- A5X5 X=500 — A5X5 X=500: CLARA-W CROSS-SECTION LOCATION
- EXTENT OF PROPOSED VERTICAL/HORIZONTAL EXPANSION
- APPROXIMATE PROPERTY BOUNDARY

GRAPHIC SCALE
200 0 100 200 400
(in feet)
1 inch = 400 ft.

N

FIGURE 6

POTENTIAL FAILURES IN NORTHEAST-FACING SLOPE

SLOPE STABILITY EVALUATION OF PROPOSED LATERAL/VERTICAL EXPANSION OLINDA LANDFILL, ORANGE COUNTY, CA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	MAY 2004	2004-022

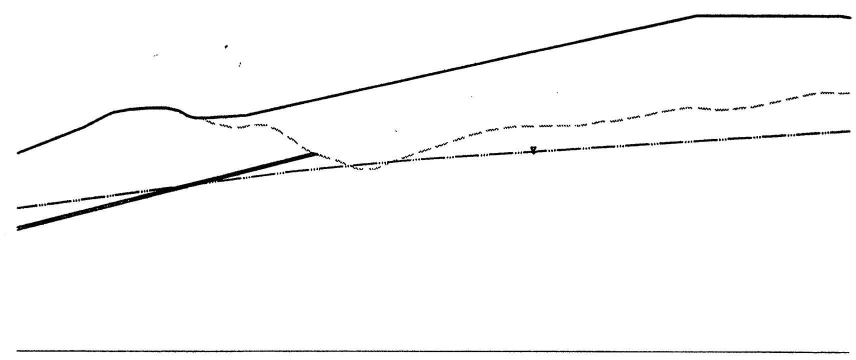
ATTACHEMENT 1

CLARA-W 3-D STABILITY ANALYSIS

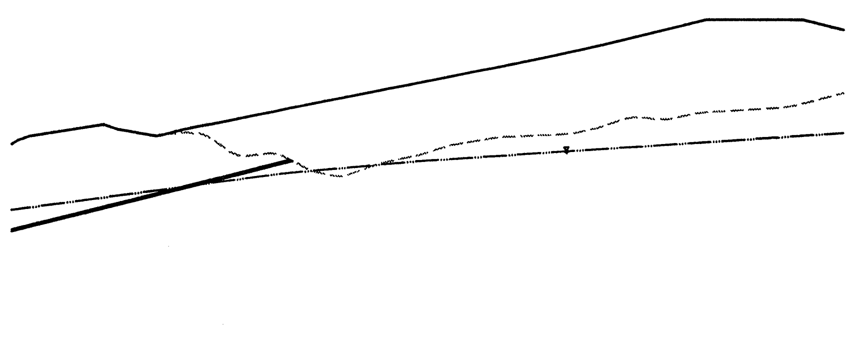
3/22/04 RMW
2004–022 OLINDA LANDFILL

CLARA CROSS SECTIONS A1X — FINALIZED FOR CLARA; LOWER 14 DEGREE DIP CLAYSTONE BED BY 20' NORMAL TO BED

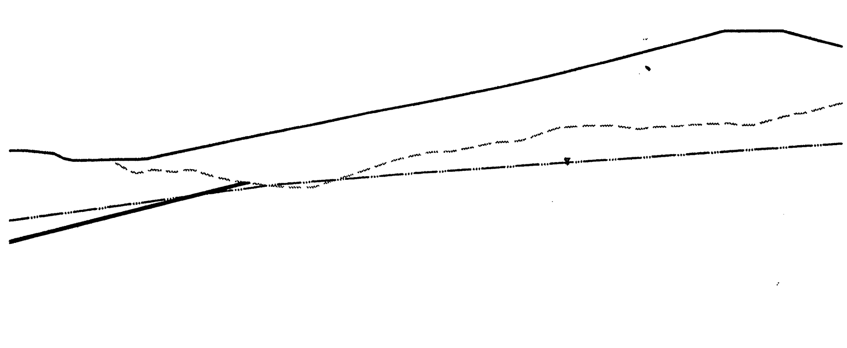
A1X0



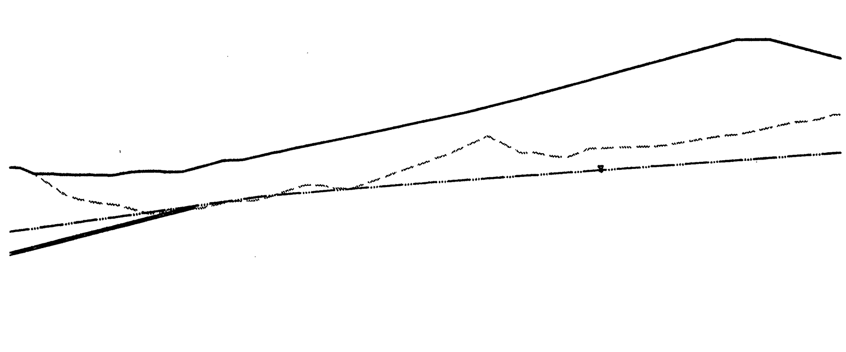
A1X2



A1X4



A1X6



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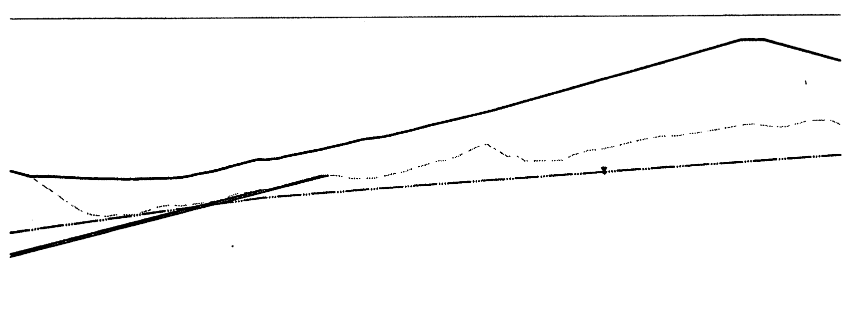

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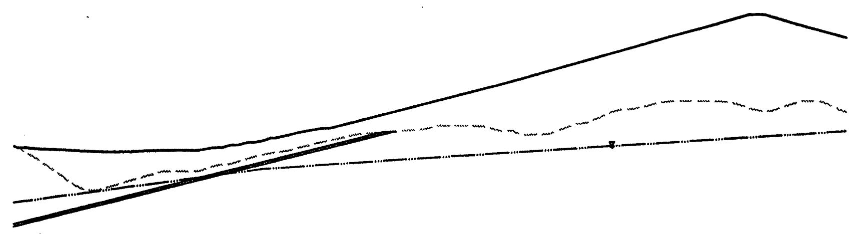
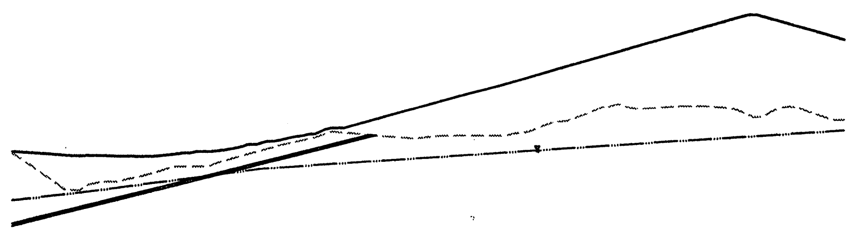
3/22/04 RMW
2004-022 OLINDA LANDFILL

CLARA CROSS SECTIONS A1X -- FINALIZED FOR CLARA; LOWER 14 DEGREE DIP CLAYSTONE BED BY 20' NORMAL TO BED

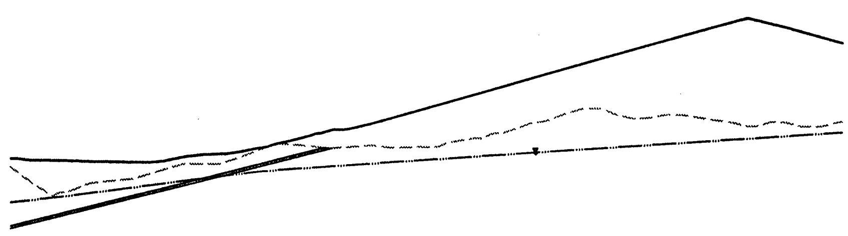
A1X8



A1X9



A1X10



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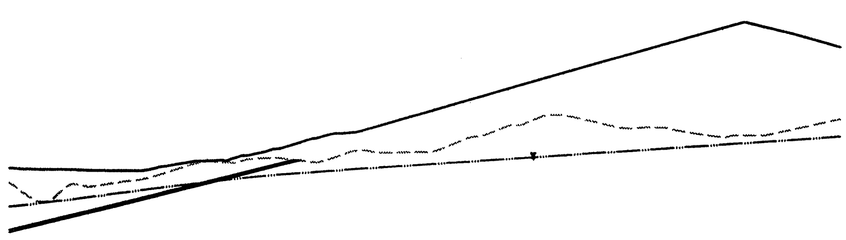

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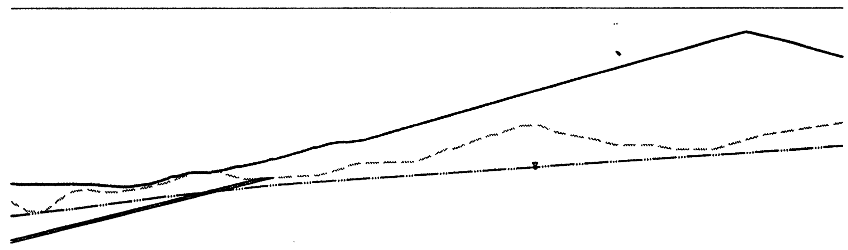

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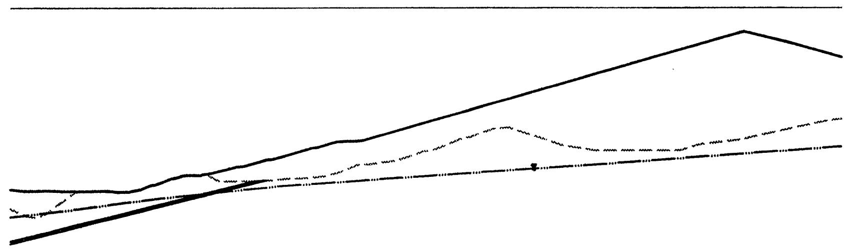

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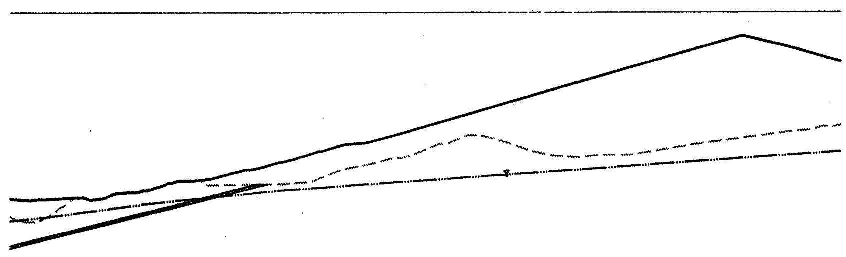
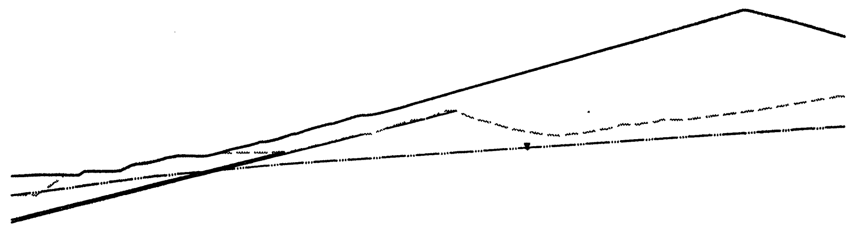


3/22/04 RMW
2004-022 OLINDA LANDFILL

CLARA CROSS SECTIONS A1X -- FINALIZED FOR CLARA; LOWER 14 DEGREE DIP CLAYSTONE BED BY 20' NORMAL TO BED

A1X15



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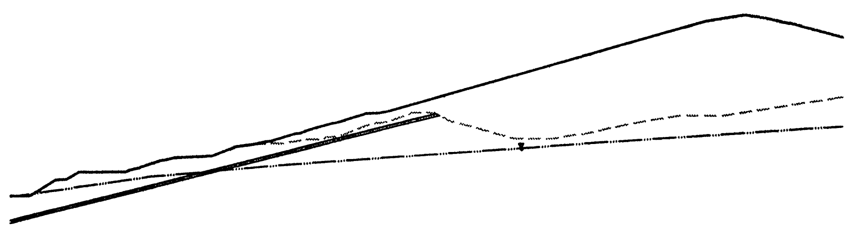

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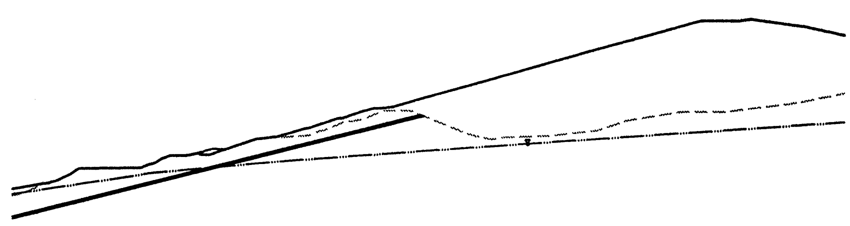

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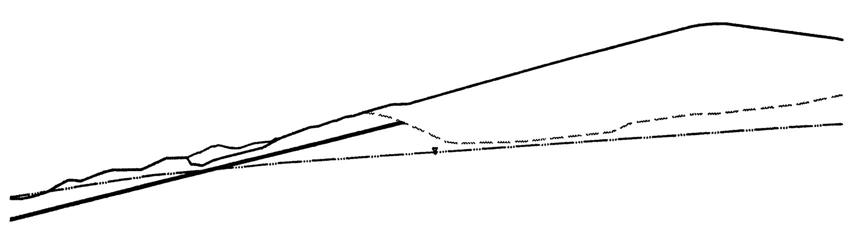

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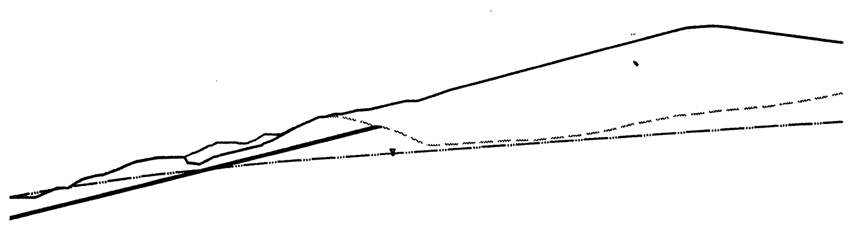
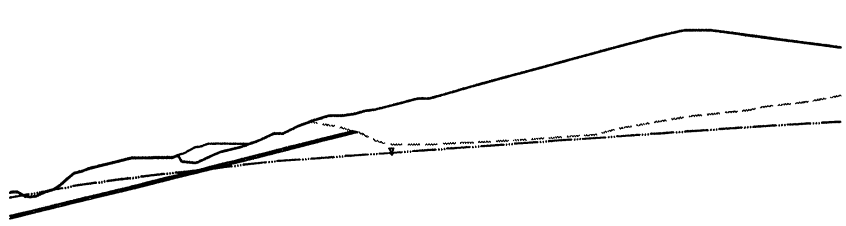
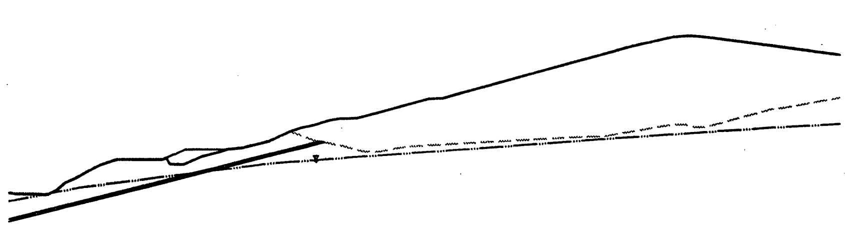


A1X20



A1X21



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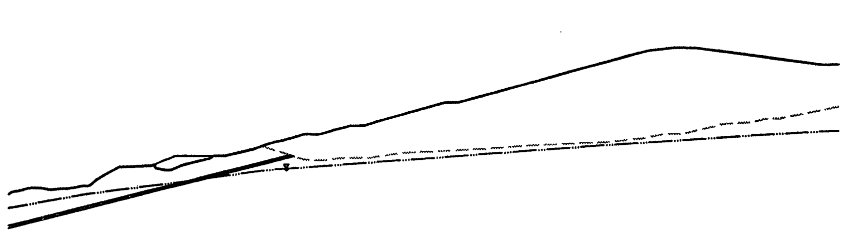
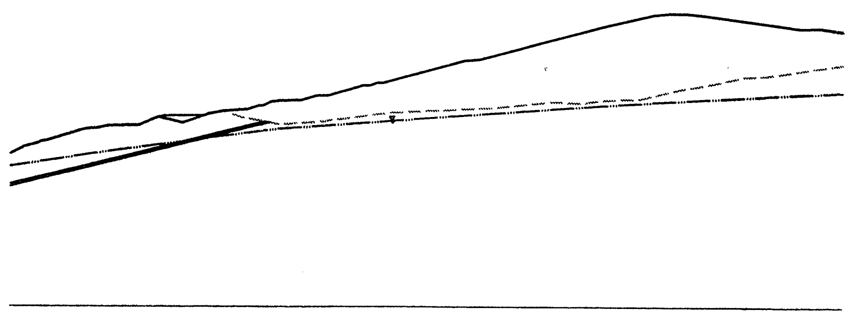


3/22/04 RMW
2004-022 OLINDA LANDFILL

CLARA CROSS SECTIONS A1X -- FINALIZED FOR CLARA; LOWER 14 DEGREE DIP CLAYSTONE BED BY 20' NORMAL TO BED

A1X23



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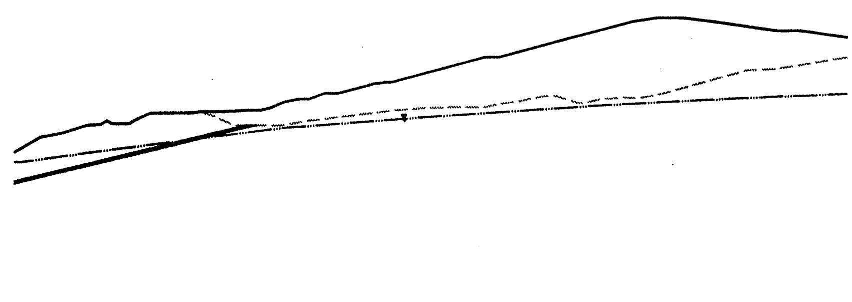

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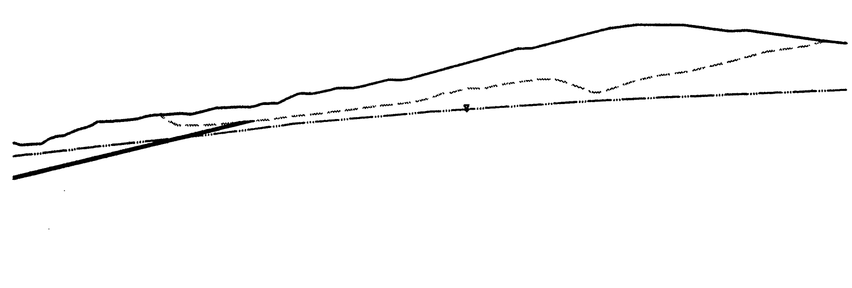

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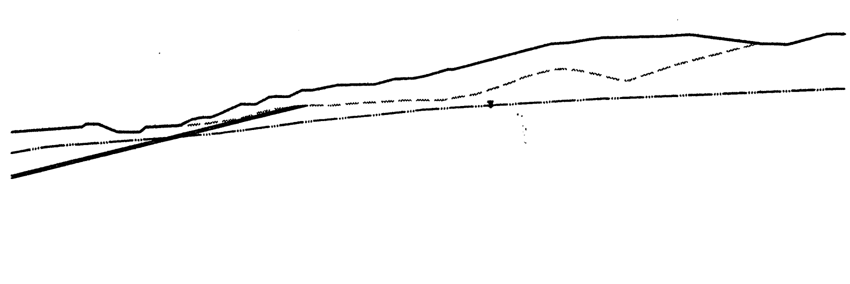
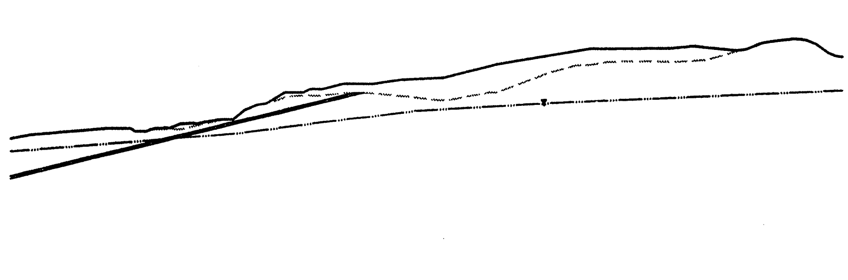


A1X30



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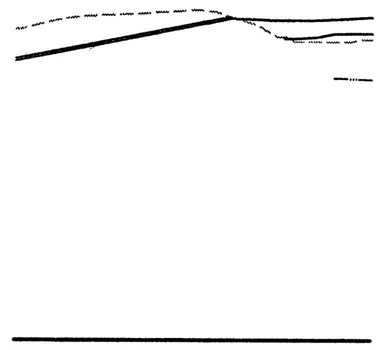
3/12/04 RMW
2004-022 OLINDA LANDFILL

CLARA CROSS SECTIONS A5X -- FINALIZED FOR CLARA; CLAYSTONE BED DIPS AT 11 DEGREES



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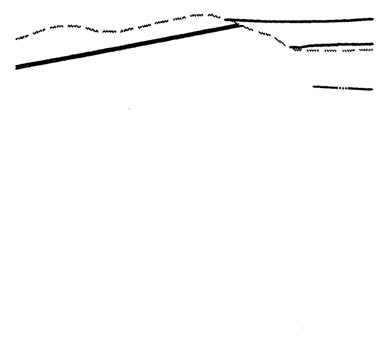

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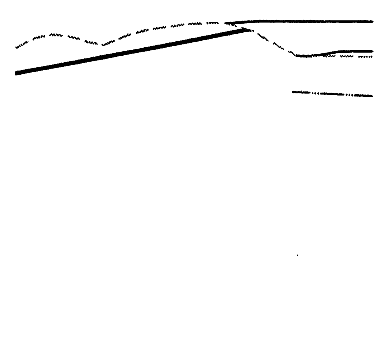
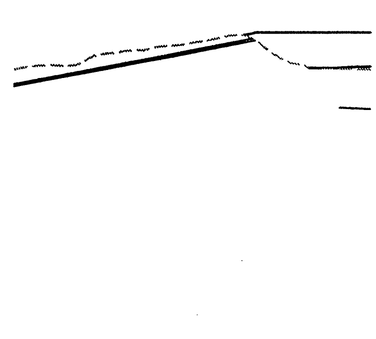


A5X2

A5X3



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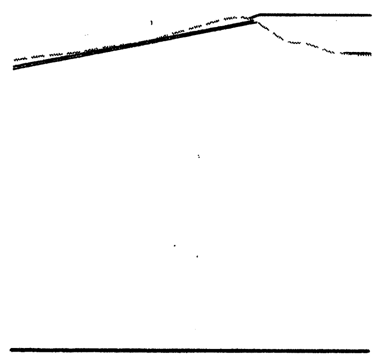
3/12/04 RMW
2004-022 OLINDA LANDFILL

CLARA CROSS SECTIONS A5X — FINALIZED FOR CLARA; CLAYSTONE BED DIPS AT 11 DEGREES



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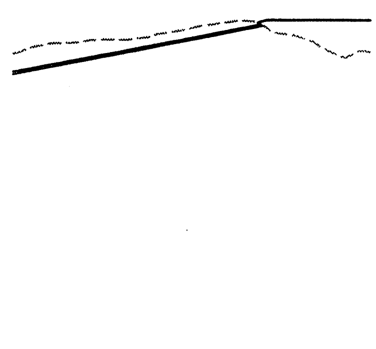

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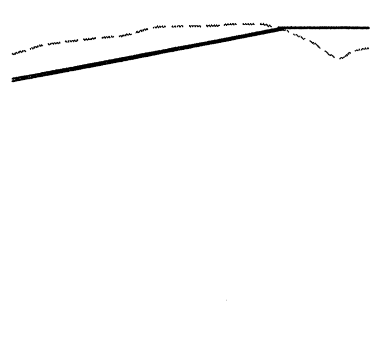

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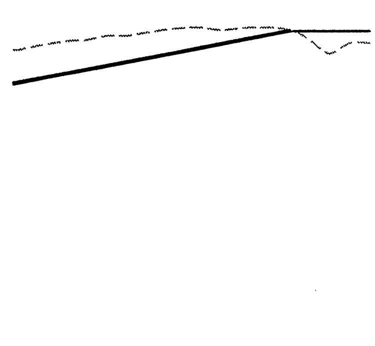

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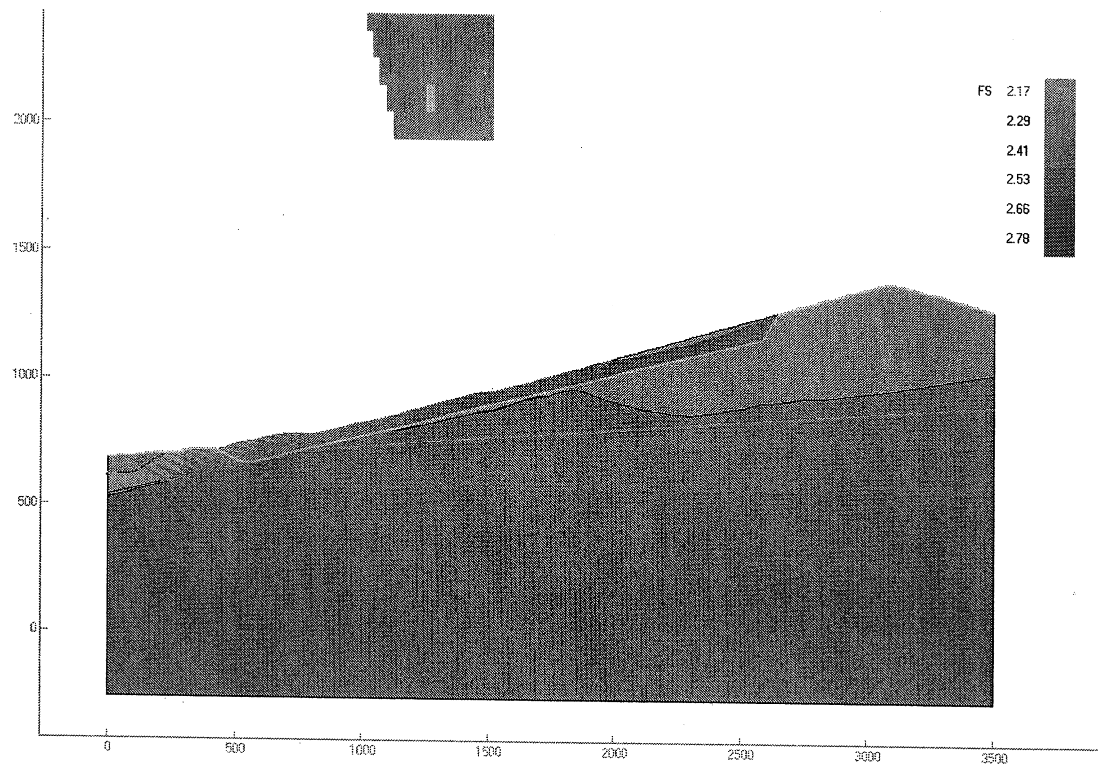
A5X9



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/26/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

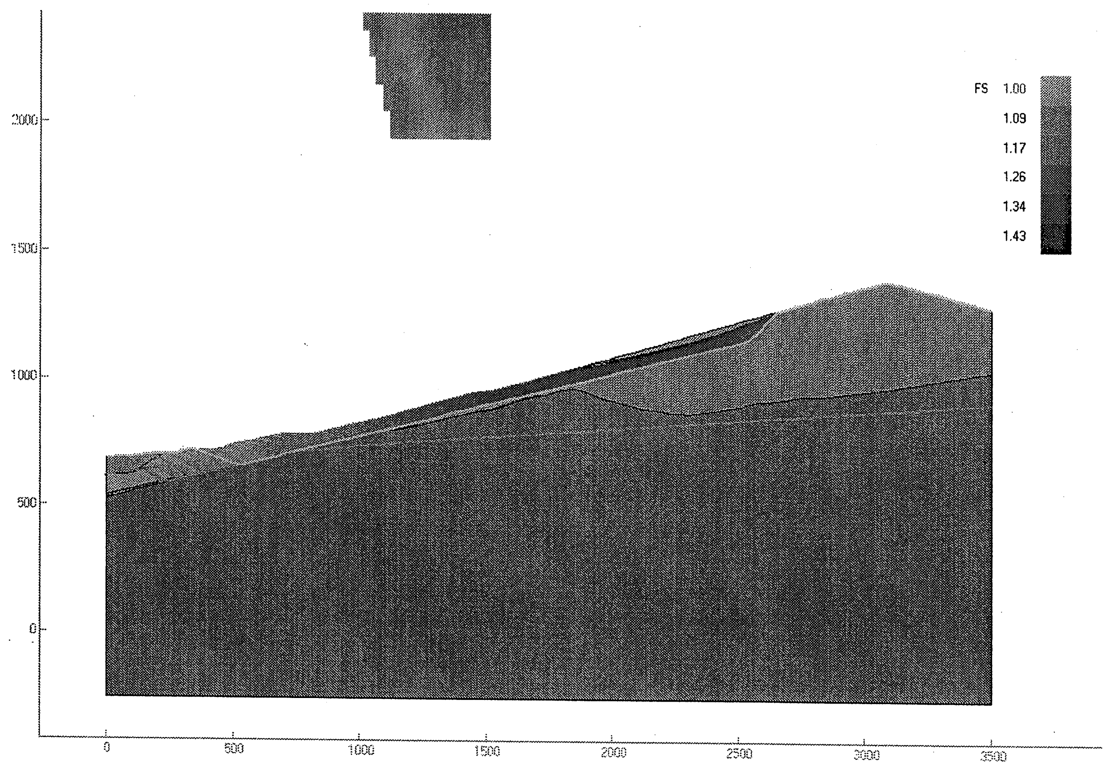
Factor of Safety:	**2.17**
Slide Volume:	170729700.00
Slide Weight:	14955260000.00
Unbalanced Force:	848.0859
Sliding Surface Area:	3155936.00
No. of Active Columns:	2739
Rotation angle:	0.00
Centre Y:	-269.03
Centre Z:	8191.47

Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	174138500.00
Slide Weight:	15388040000.00
Unbalanced Force:	-587183.8000
Sliding Surface Area:	3301114.00
No. of Active Columns:	2885
Rotation angle:	0.00
Centre Y:	-250.97
Centre Z:	8202.54

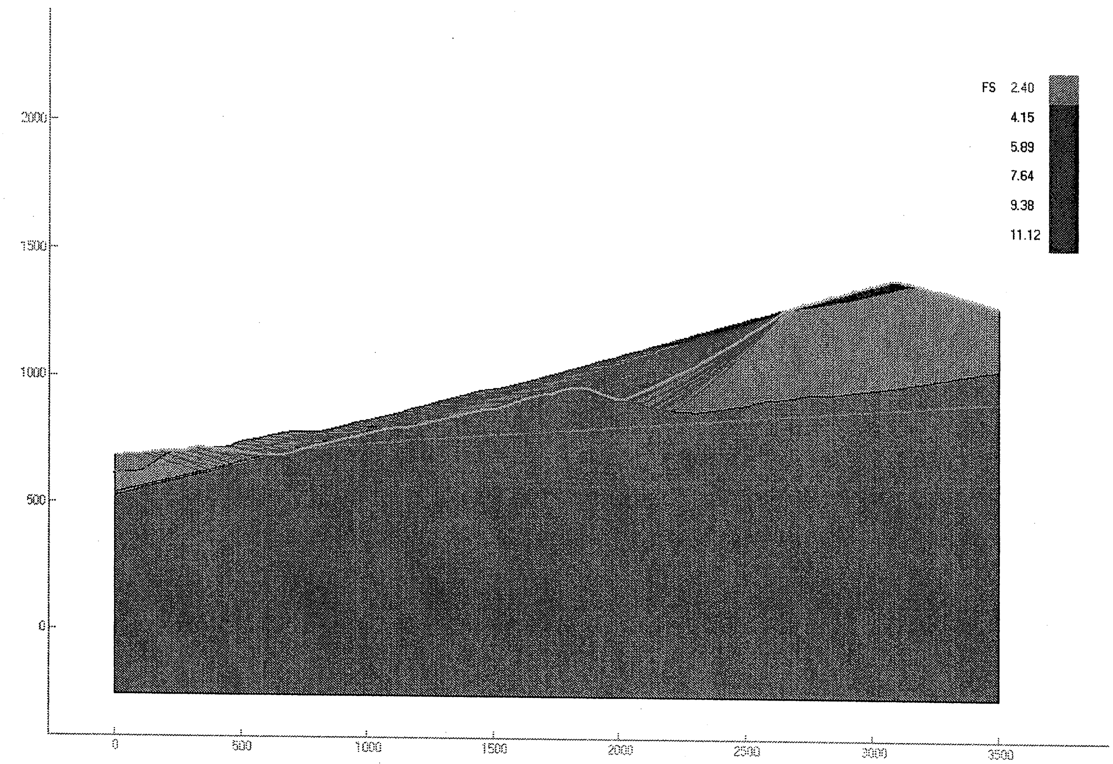
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.24

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1670bS01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/26/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**2.34**
Slide Volume:	214730400.00
Slide Weight:	17881480000.00
Unbalanced Force:	372847.7000
Sliding Surface Area:	3291794.00
No. of Active Columns:	2853
Rotation angle:	0.00
Centre Y:	821.43
Centre Z:	3800.00

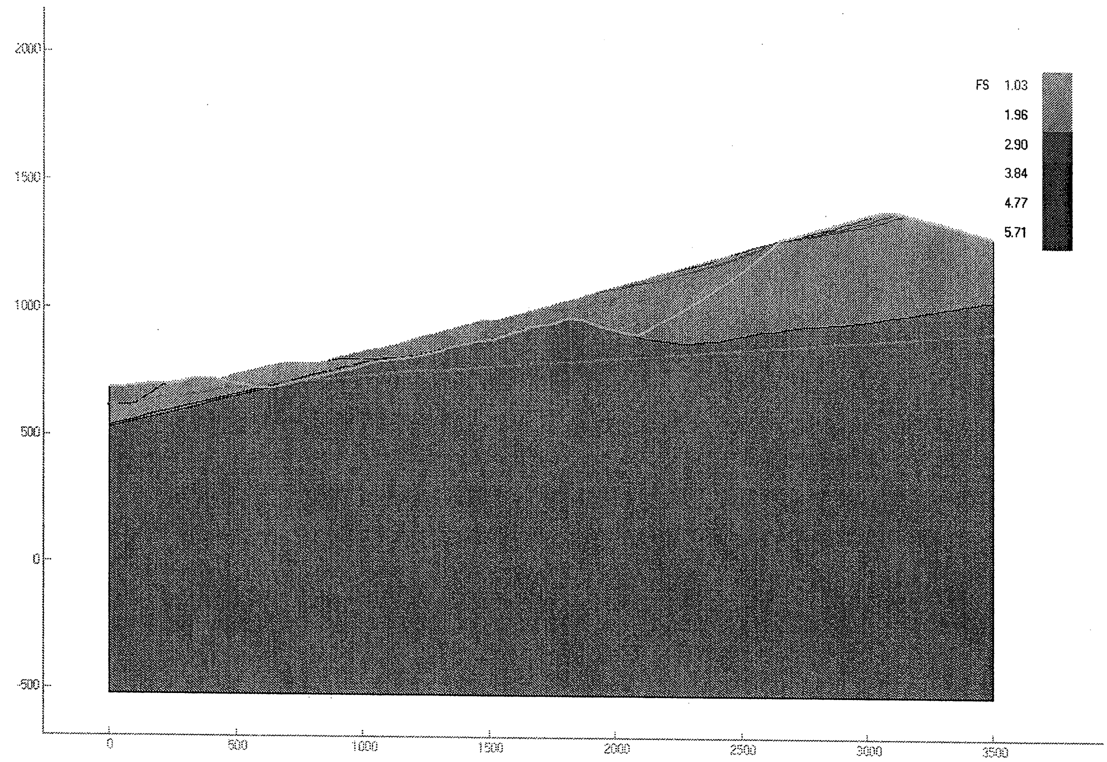
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674503



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/26/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	236401000.00
Slide Weight:	19423940000.00
Unbalanced Force:	958879.0000
Sliding Surface Area:	3188495.00
No. of Active Columns:	2712
Rotation angle:	0.00
Centre Y:	987.50
Centre Z:	3200.00

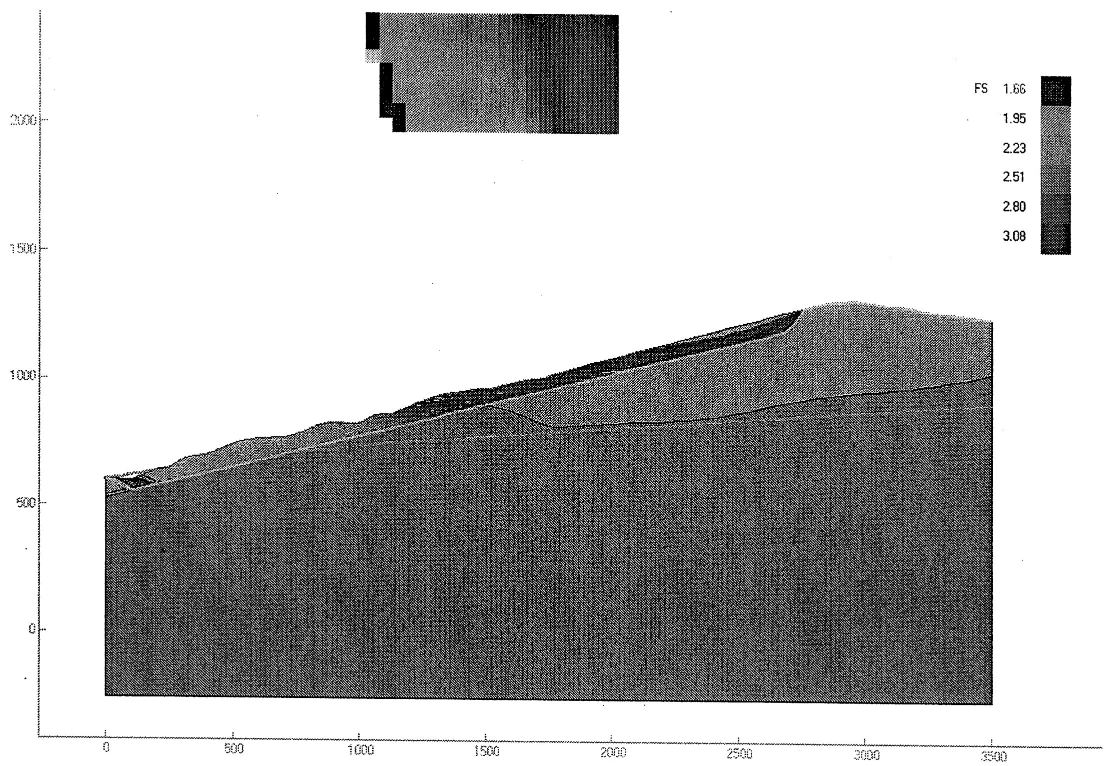
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0:30

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674503501



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/26/2004

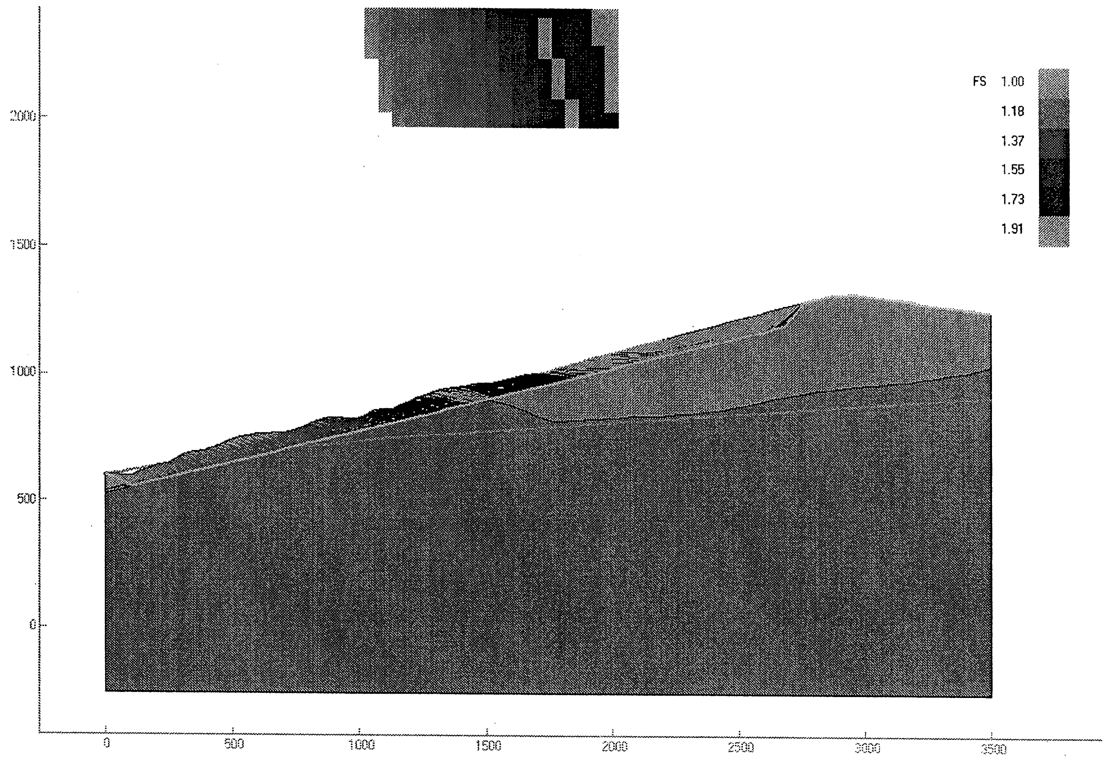
Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety: **1.66**
Slide Volume: 93121690.00
Slide Weight: 9417803000.00
Unbalanced Force: 7383488.0000
Sliding Surface Area: 1664526.00
No. of Active Columns: 1406
Rotation angle: 0.00
Centre Y: -3010.83
Centre Z: 18563.16
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	92327540.00
Slide Weight:	9339719000.00
Unbalanced Force:	32913420.0000
Sliding Surface Area:	1663189.00
No. of Active Columns:	1405
Rotation angle:	0.00
Centre Y:	-2795.16
Centre Z:	17657.42

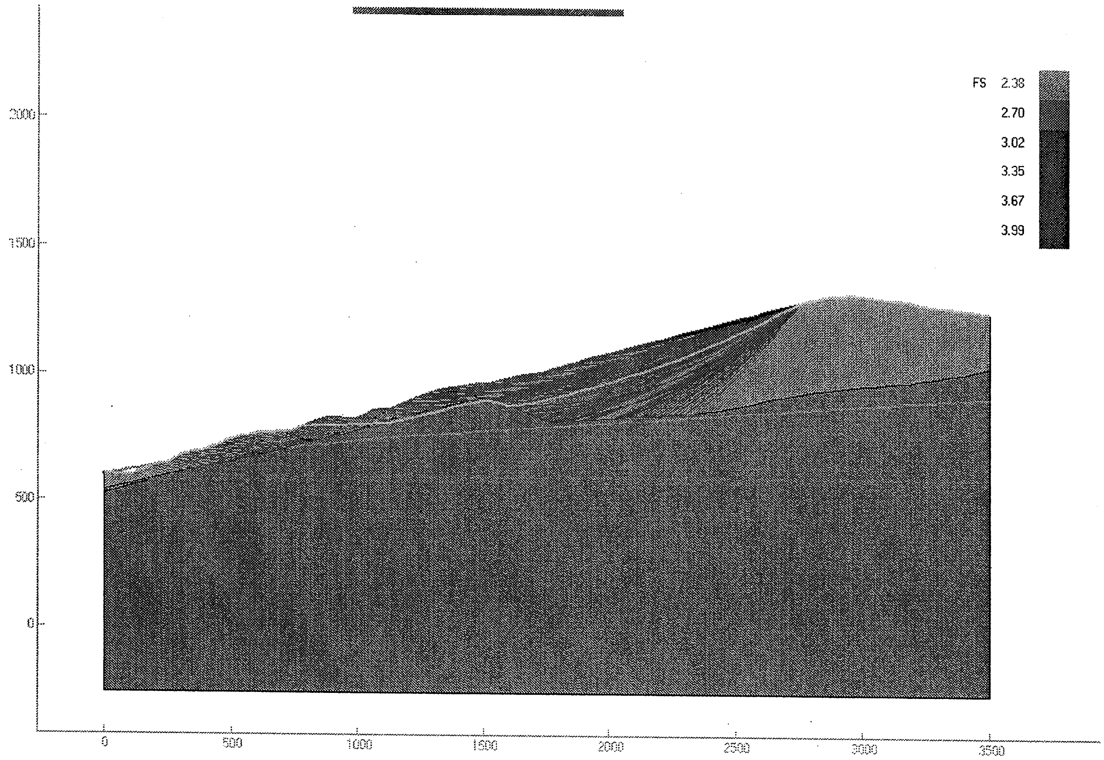
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.15

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1673e P01S01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**2.33**
Slide Volume:	108984300.00
Slide Weight:	8596120000.00
Unbalanced Force:	-105792.5000
Sliding Surface Area:	2085165.00
No. of Active Columns:	1849
Rotation angle:	0.00
Centre Y:	821.41
Centre Z:	4821.43

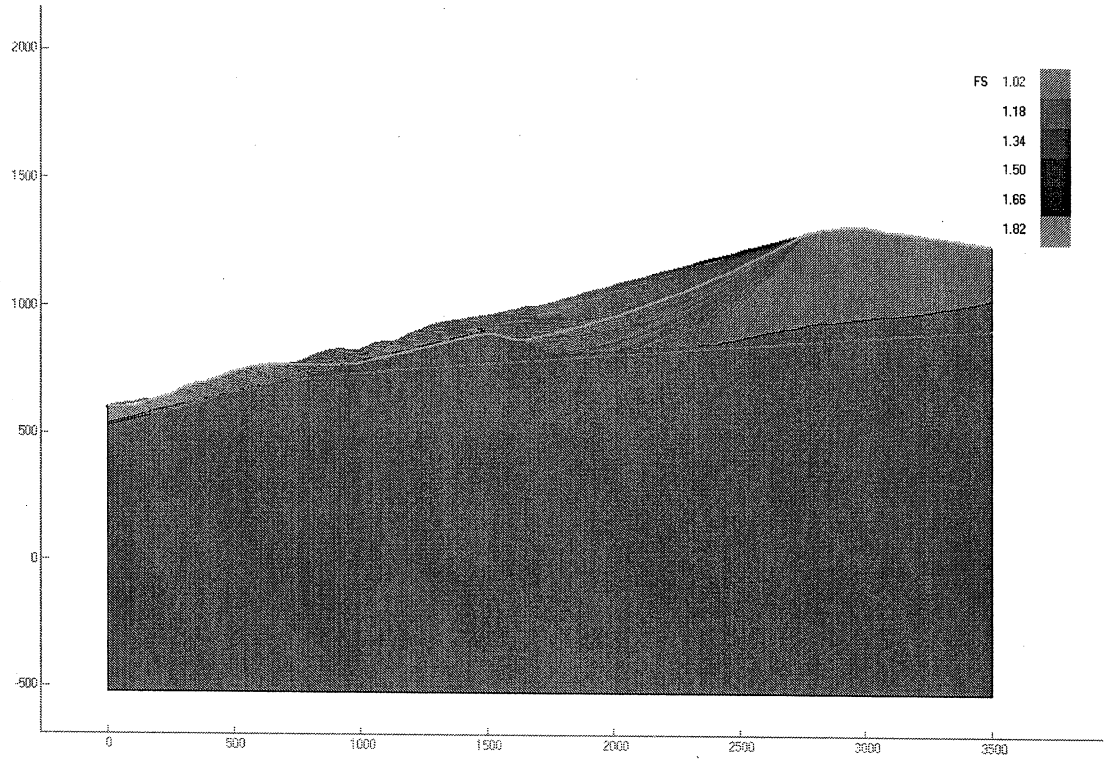
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx3e



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	129675800.00
Slide Weight:	10432690000.00
Unbalanced Force:	-41331.5500
Sliding Surface Area:	2405236.00
No. of Active Columns:	2132
Rotation angle:	0.00
Centre Y:	714.27
Centre Z:	5000.00

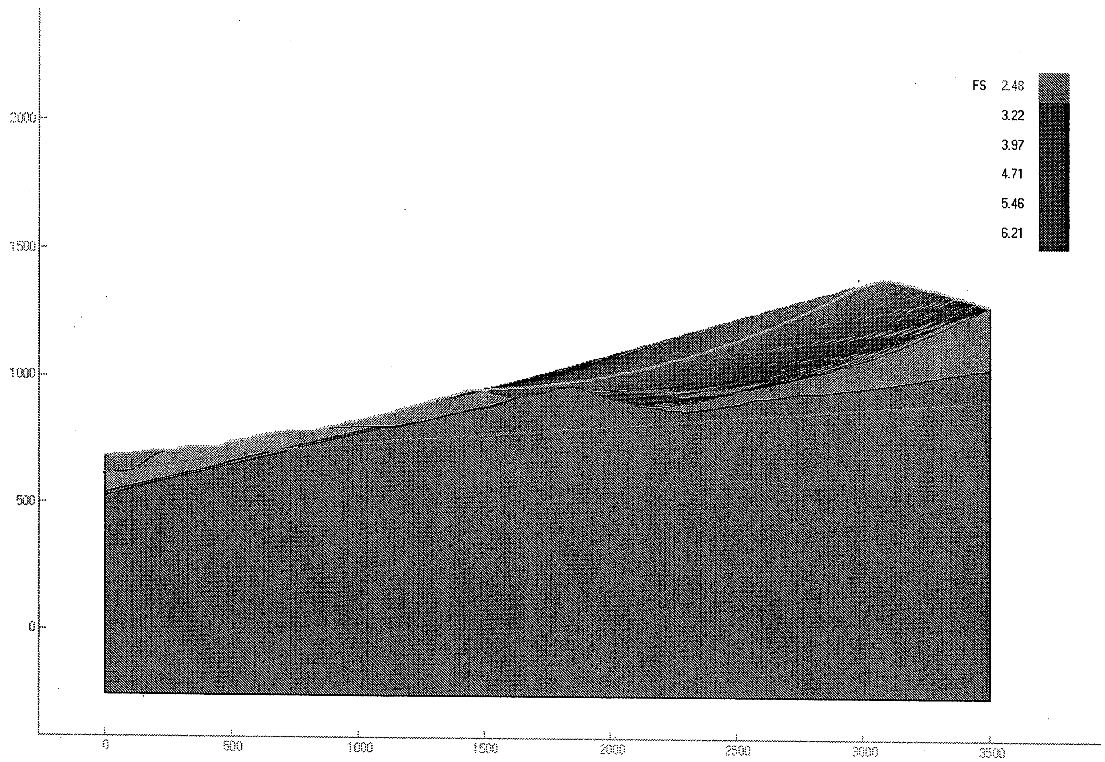
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.29

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx3es01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

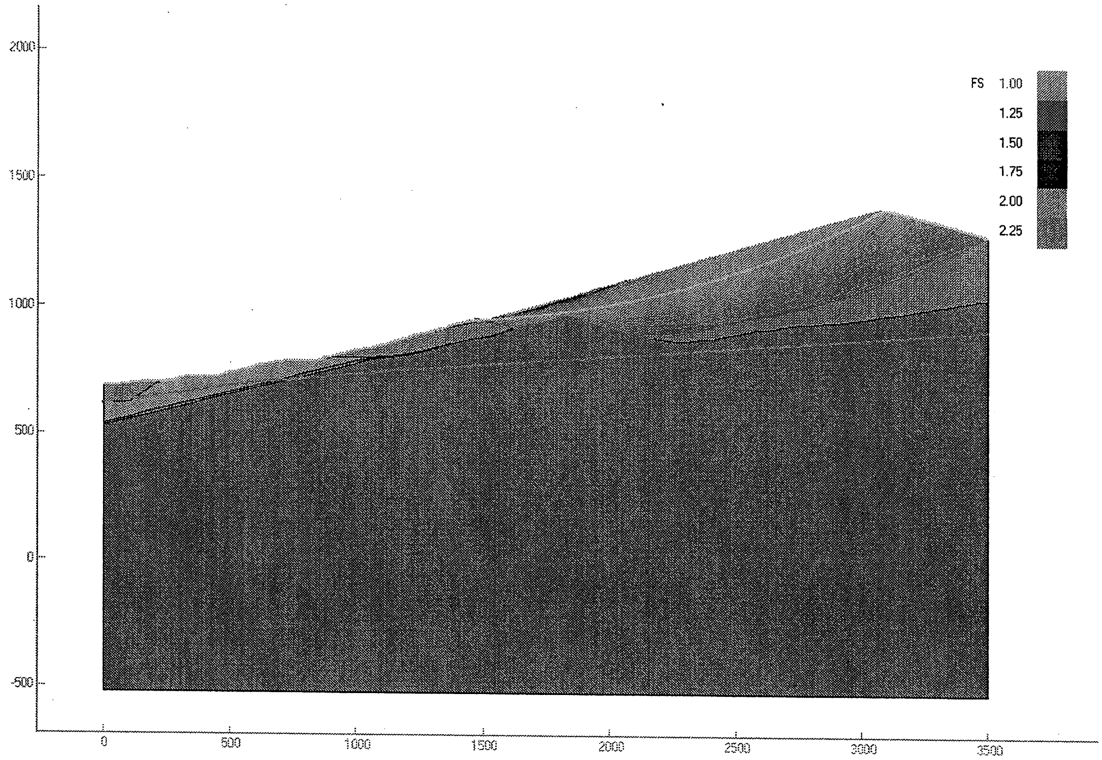
Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety: **2.48**
Slide Volume: 57856920.00
Slide Weight: 4165694000.00
Unbalanced Force: 1318665.0000
Sliding Surface Area: 1329009.00
No. of Active Columns: 1177
Rotation angle: 0.00
Centre Y: 1357.14
Centre Z: 4300.00
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/6/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	67977570.00
Slide Weight:	4894380000.00
Unbalanced Force:	-9534489.0000
Sliding Surface Area:	1515610.00
No. of Active Columns:	1346
Rotation angle:	0.00
Centre Y:	1285.71
Centre Z:	4785.71

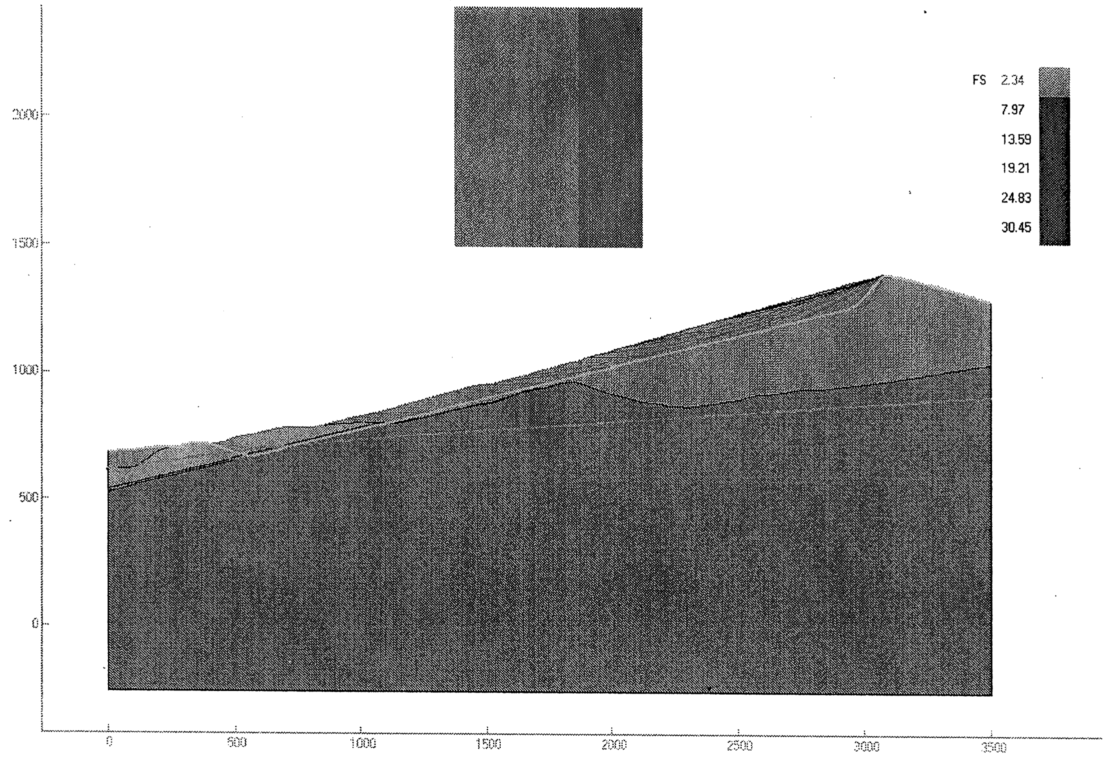
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.35

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674SX1S01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**2.37**
Slide Volume:	254425500.00
Slide Weight:	21149040000.00
Unbalanced Force:	168289.0000
Sliding Surface Area:	4531549.00
No. of Active Columns:	3971
Rotation angle:	0.00
Centre Y:	33.66
Centre Z:	8057.51

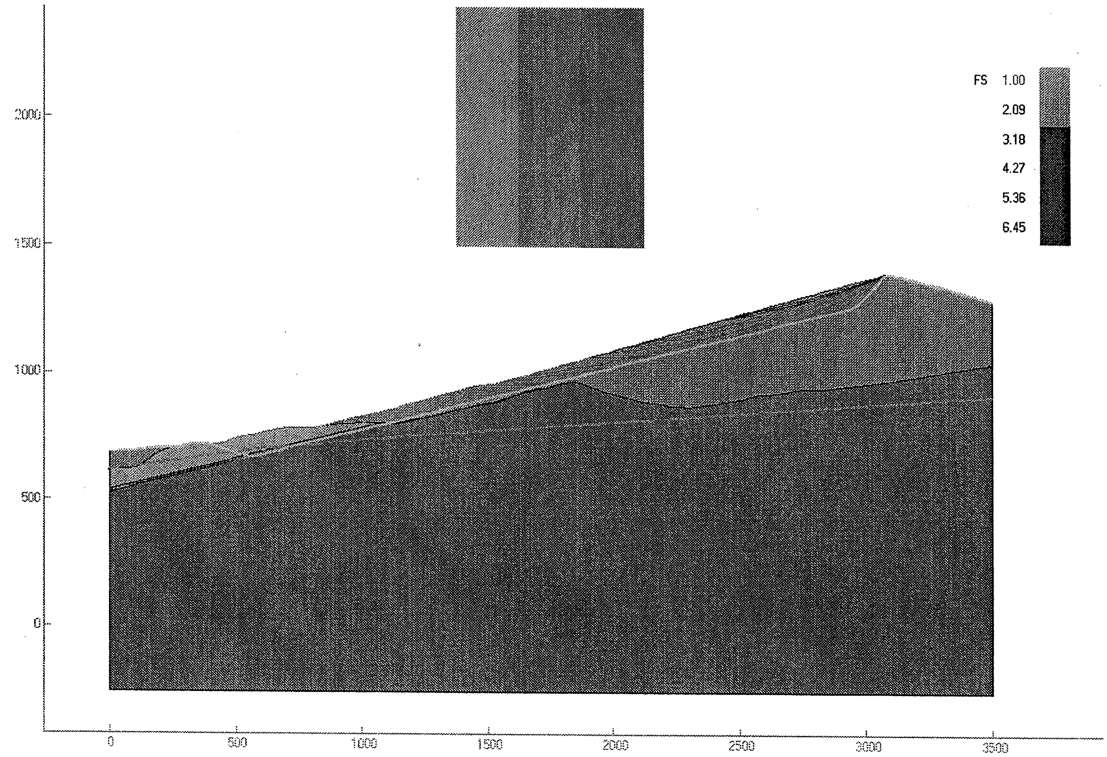
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1670a



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	254425500.00
Slide Weight:	21149040000.00
Unbalanced Force:	-152577.7000
Sliding Surface Area:	4531549.00
No. of Active Columns:	3971
Rotation angle:	0.00
Centre Y:	33.66
Centre Z:	8057.51

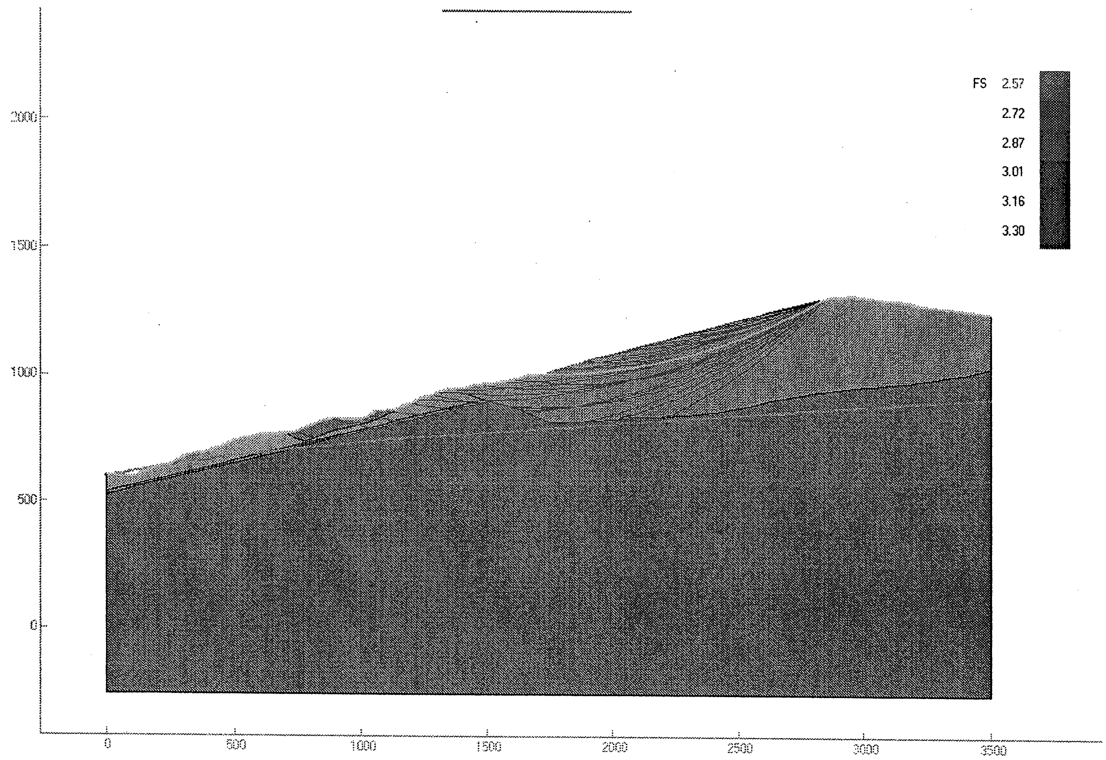
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.28

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

16709501



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

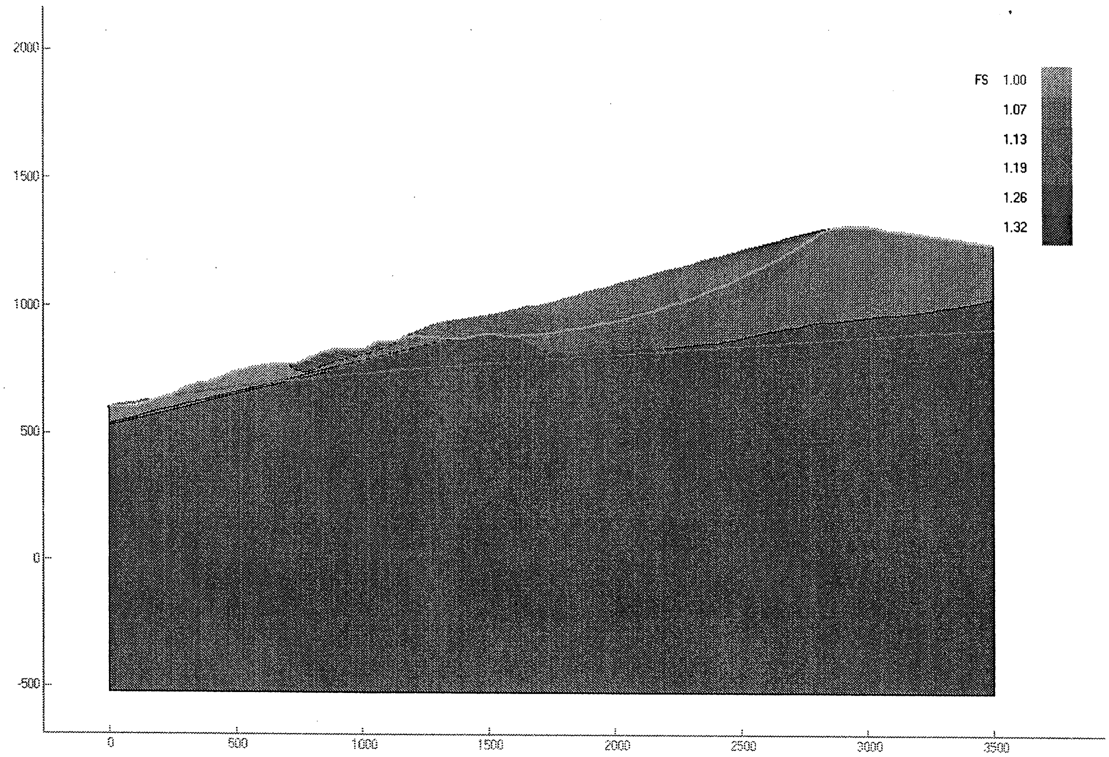
Factor of Safety: **2.59**
Slide Volume: 32515920.00
Slide Weight: 2341230000.00
Unbalanced Force: 46426.0500
Sliding Surface Area: 795581.90
No. of Active Columns: 702
Rotation angle: 0.00
Centre Y: 1700.00
Centre Z: 3300.00
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx3



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/6/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	106591500.00
Slide Weight:	7926826000.00
Unbalanced Force:	26836.2900
Sliding Surface Area:	1612253.00
No. of Active Columns:	1408
Rotation angle:	0.00
Centre Y:	1400.00
Centre Z:	3500.00

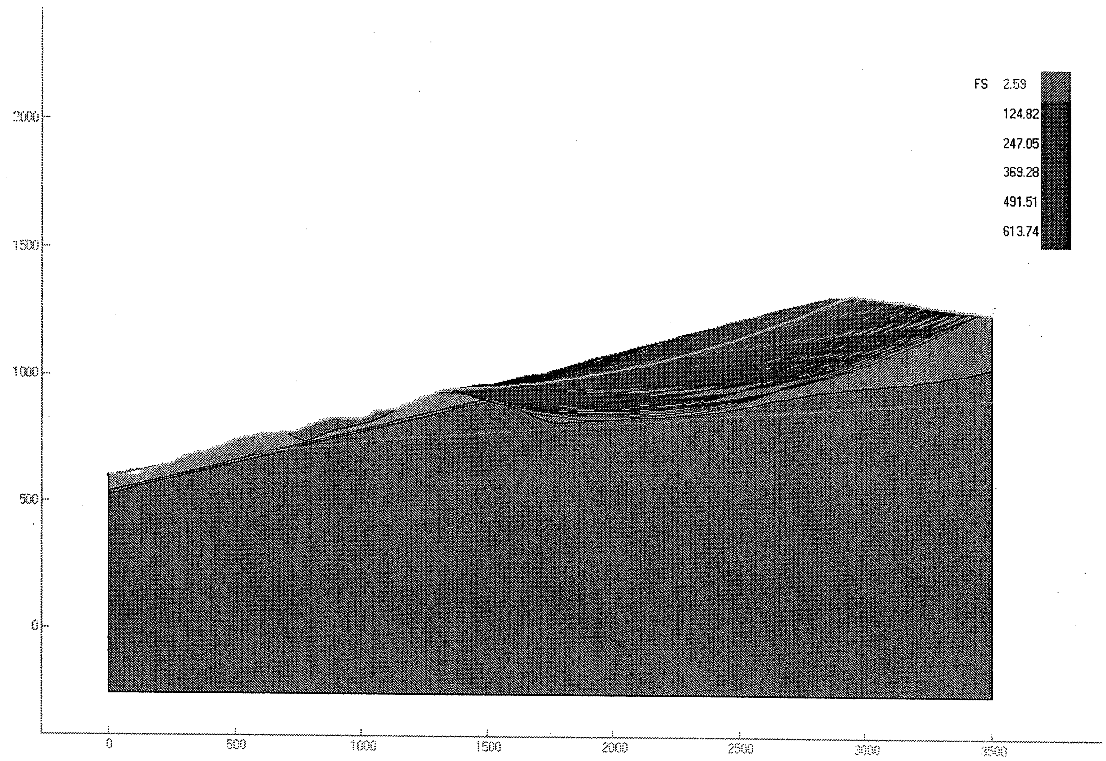
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.35

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx3S01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**2.63**
Slide Volume:	47074560.00
Slide Weight:	3389605000.00
Unbalanced Force:	126415.7000
Sliding Surface Area:	1244051.00
No. of Active Columns:	1112
Rotation angle:	0.00
Centre Y:	1214.29
Centre Z:	5028.57

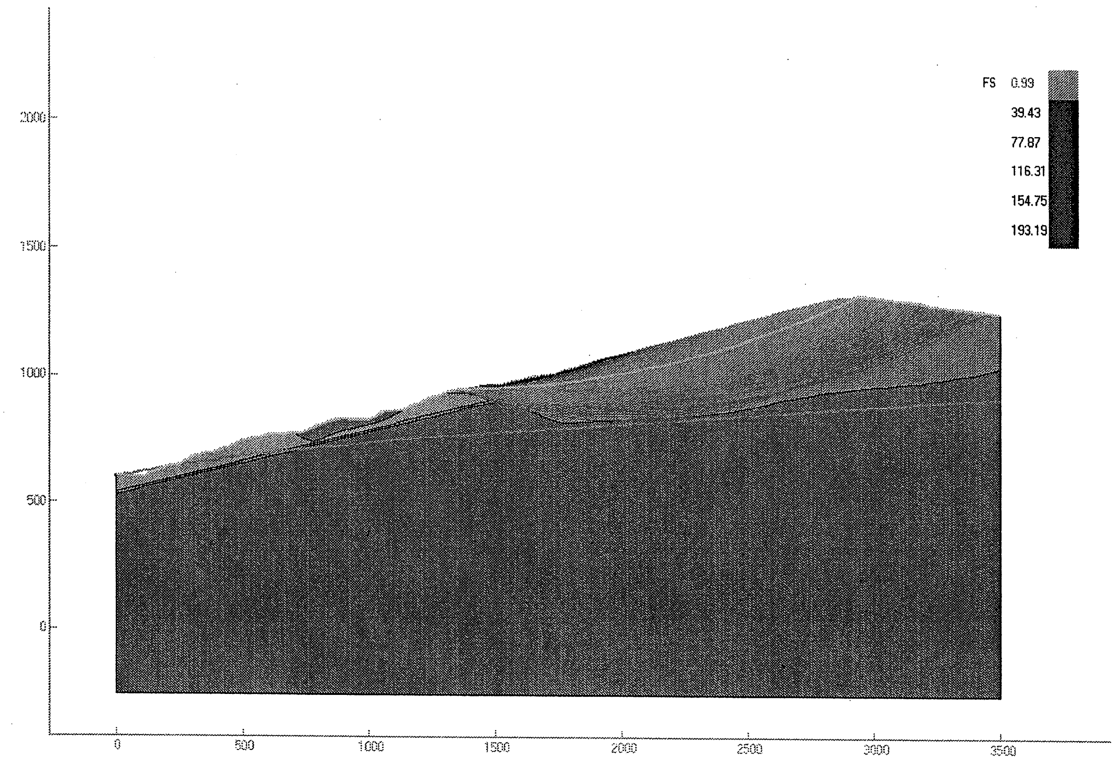
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx6



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/6/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	54652080.00
Slide Weight:	3935305000.00
Unbalanced Force:	138966.1000
Sliding Surface Area:	1309783.00
No. of Active Columns:	1169
Rotation angle:	0.00
Centre Y:	1285.71
Centre Z:	4785.71

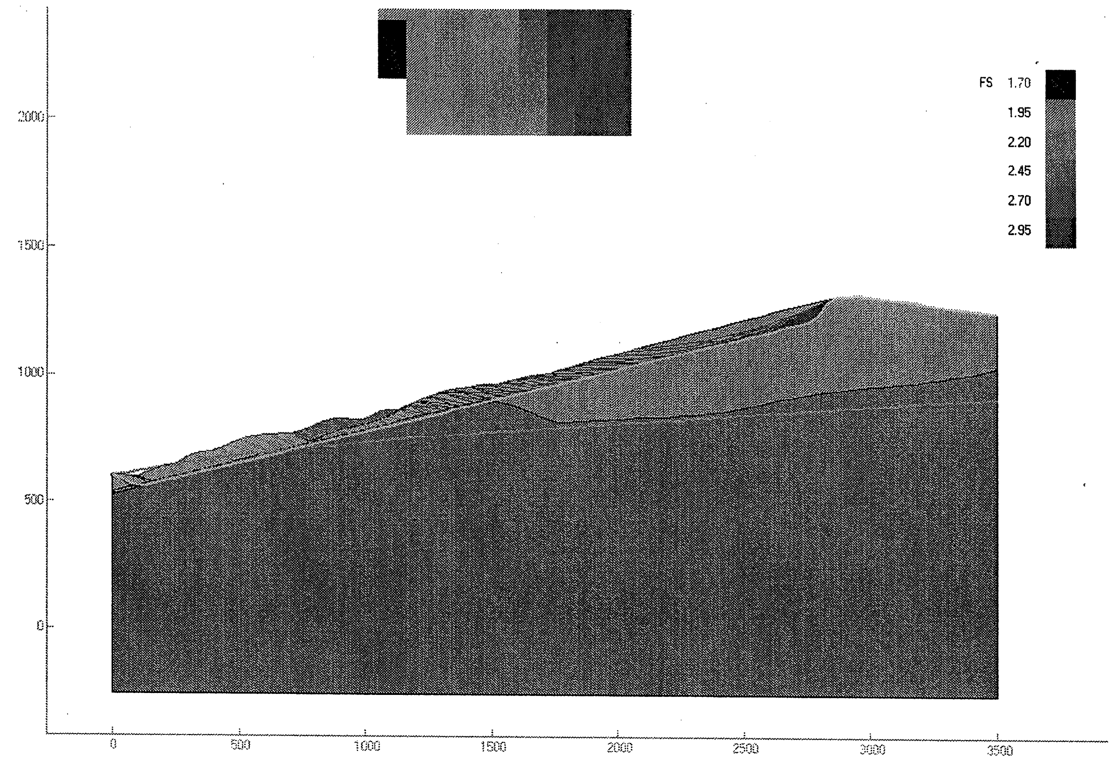
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.37

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1674jx6S01



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.70**
Slide Volume:	98975220.00
Slide Weight:	9872332000.00
Unbalanced Force:	-15286690.0000
Sliding Surface Area:	1781935.00
No. of Active Columns:	1510
Rotation angle:	0.00
Centre Y:	-2753.44
Centre Z:	17570.93

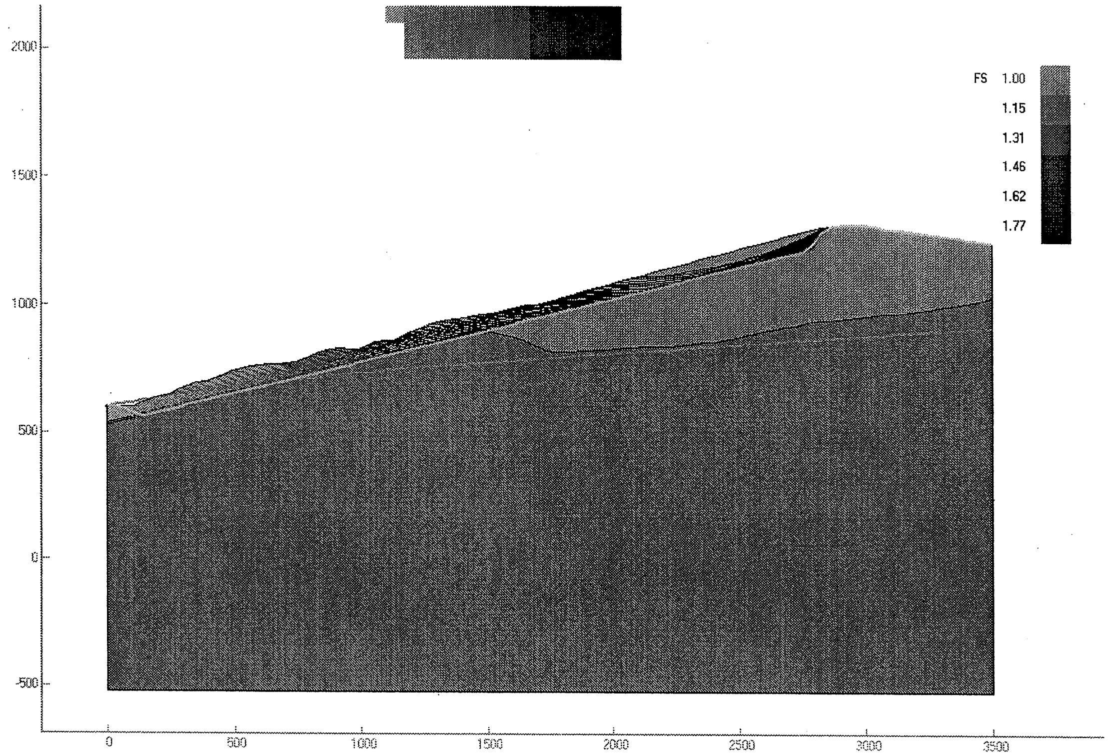
Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

18



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 5/7/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

Factor of Safety:	**1.00**
Slide Volume:	96972660.00
Slide Weight:	9647908000.00
Unbalanced Force:	22769310.0000
Sliding Surface Area:	1756263.00
No. of Active Columns:	1486
Rotation angle:	0.00
Centre Y:	-2673.74
Centre Z:	17115.66

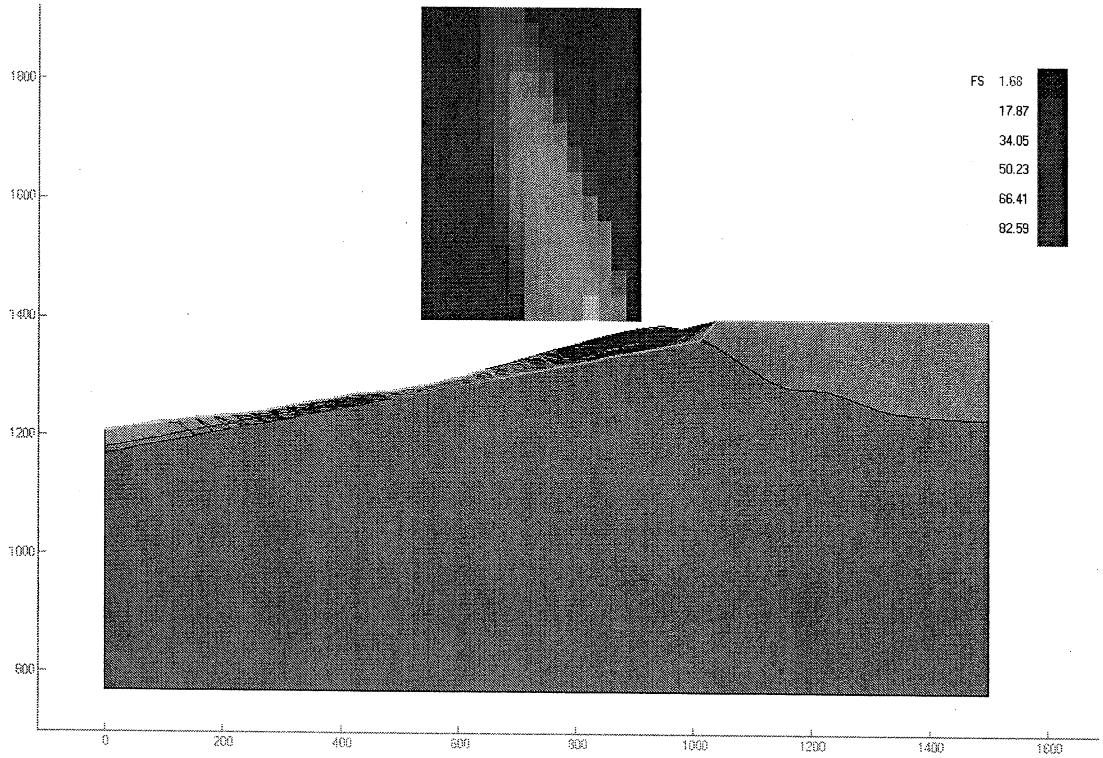
Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.16

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	1	0	0
Sandstone	130	400	34	1	0	0
Refuse	72	100	33	1	0	0
Buttress Soil	120	500	28.5	1	0	0

1673C501



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/25/2004

Sliding Surface:
Critical surface by grid search
Bishop's Method

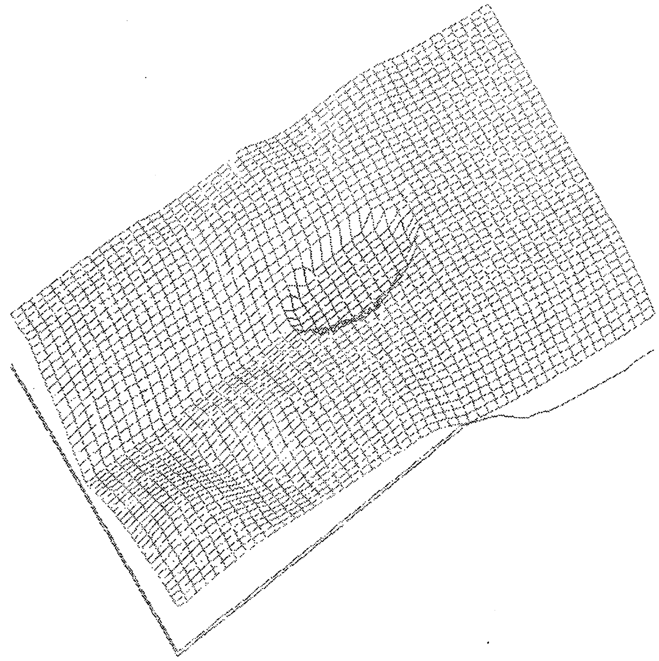
Factor of Safety:	**1.67**
Slide Volume:	2133875.00
Slide Weight:	272164700.00
Unbalanced Force:	-11937.1400
Sliding Surface Area:	72255.56
No. of Active Columns:	110
Rotation angle:	0.00
Centre Y:	825.00
Centre Z:	1420.00

Negative normal stresses in 0% of weight

Unit Weight of Water: 62.4 (pcf)

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	0	0	0
Sandstone	130	400	34	0	0	0
Refuse	72	100	33	0	0	0



PROJECT: **Olinda Landfill**

Input By: RMW
Date: 3/26/2004

Sliding Surface:
Single ellipsoidal sliding surface
Bishop's Method

Factor of Safety:	**0.99**
Slide Volume:	2133001.00
Slide Weight:	272060100.00
Unbalanced Force:	-89996.3400
Sliding Surface Area:	72265.18
No. of Active Columns:	110
Rotation angle:	0.00
Centre Y:	825.00
Centre Z:	1420.00

Negative normal stresses in 0% of weight

Unit Weight of Water:	62.4 (pcf)
Hor. Earthquake Accel.:	0.15

List of Materials:

Name	*Unit Weight*	*Cohesion*	*Friction Angle*	*Piezo #*	*Press. Ratio*	*B-bar Coeff.*
Claystone	125	50	11	0	0	0
Sandstone	130	400	34	0	0	0
Refuse	72	100	33	0	0	0

1205501

ATTACHMENT 2

SEISMIC DISPLACEMENT ANALYSIS

Geo-Logic ASSOCIATES

Calculation Brief

By: RMW Date: 5/6/04 Subject: Calculate seismic displacement of Olinda Landfill Lateral/Vertical Expansion Sheet No. 1 of 3 .
Chkd. by: LAM Date: 5/7/04 Proj. No. 2004-022

Purpose:

For the proposed lateral/vertical expansion of the Olinda Landfill, calculate the seismically-induced permanent displacement as a result of the Maximum Credible Earthquake (MCE) for the most critical slope stability analysis case: the highest, southern-facing landfill slope.

Background:

A procedure described by Bray and Rathje (Reference 1) is used to determine estimated seismic-induced permanent displacement. The procedure is based on the one described by Newmark (Reference 2) for determining displacement of a rigid block resting on a sliding plane subjected to earthquake-type motions. The procedure is based on the premise that the sliding block will undergo displacement only during the periods when the maximum ground acceleration (k_{max}) exceeds the yield acceleration (k_y) for the sliding block, and no displacements occur when k_y is greater than k_{max} (i.e. $k_y/k_{max}>1$). The yield acceleration k_y is that which causes incipient failure (i.e. FS = 1.0) in a pseudo-static slope stability analysis. Bray and Rathje refined Newmark's analysis for waste fills to incorporate the dynamic response characteristics of the sliding block and intensity and duration of ground motions at the site during the MCE.

In order to determine the maximum horizontal acceleration (MHA) at the site from the maximum credible earthquake (MCE), a deterministic search was performed using EQFAULT (Blake, 2000) using the site latitude/longitude coordinates. The search was performed using several applicable attenuation relationships, and the most conservative result was selected for this seismic displacement analysis. The MCE was estimated to be a magnitude 6.8 earthquake event on the nearby (< 1 mile) Whittier fault, with a corresponding peak acceleration of 0.75 g at the landfill site (Reference 4; see Attachment 1).

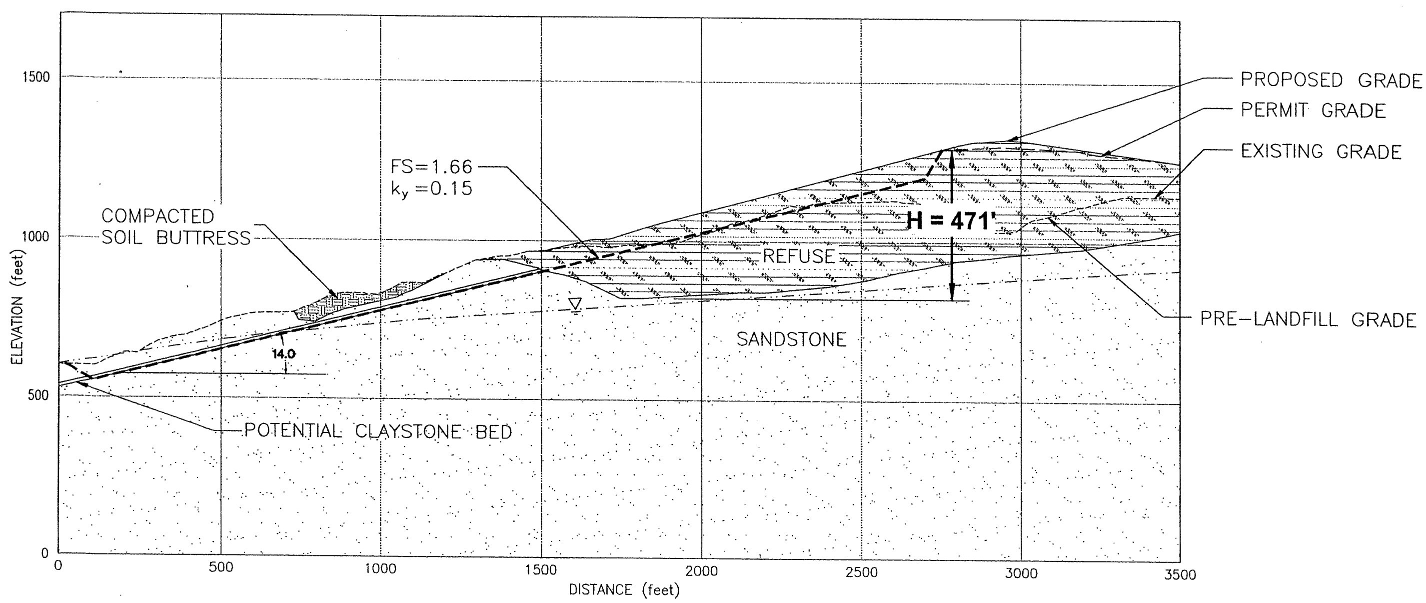
References:

1. Bray, J.D., and Rathje, E.M., 1998, "Earthquake-Induced Displacements of Solid-Waste Landfills," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, March, Vol. 124, No. 3.
2. Newmark, N.M., 1965, "Effects of Earthquakes on Dams and Embankments," *Geotechnique*, Vol. 15(2), pp. 139-160.
3. Bray, J.D., Rathje, E.M., Augelo, A.J., and S.M. Perry, 1998, "Simplified Seismic Design Procedure for Geosynthetic-Lined, Solid-Waste Landfills," *Geosynthetics International*, Vol. 5, Nos. 1-2.
4. Blake, T.F., 2000, "EQFAULT for Windows," Version 3.00b, Thousand Oaks, California.

Geo-Logic ASSOCIATES

Calculation Brief

By: RMW Date: 5/6/04 Subject: Calculate seismic displacement of Olinda Landfill Lateral/Vertical Expansion Sheet No. 2 of 3.
Chkd. by: [signature] Date: 5/7/04 Proj. No. 2004-022



CROSS–SECTION A1X19

Solution:

I. Input Data

Site Condition = **Rock**

Waste Fill Height, H = **471 ft. = 144 m** (see sketch above)

Maximum Credible Earthquake (MCE) Magnitude = **6.8** (associated with Whittier fault at < 1 mile, Reference 4)

Yield Acceleration, k_y = **0.15g** (from 3-D pseudo-static analysis; Case: composite circular-wedge failure daylighting at Permit Grade)

II. Determine Additional Seismic Parameters

Maximum Horizontal Site Acceleration, MHA ≈ **0.75g** (for the MCE at the Site; Reference 4)

Mean Period of Input Rock Motion for MCE, T_m = **0.48 sec** (for the MCE at the Site; Figure 2b, Reference 3)

Significant Duration, $D_{5\text{-}95}$ ≈ **12 sec** (for the MCE at the Site, Figure 2c, Reference 3)

Geo-Logic ASSOCIATES

Calculation Brief

By: RMW Date: 5/6/04 Subject: Calculate seismic displacement of Olinda Landfill Lateral/Vertical Expansion Sheet No. 3 of 3.
Chkd. by: TM Date: 5/7/04 Proj. No. 2004-022

Average Shear Wave Velocity for Fill, V_s = 500 m/sec (for H = 471 ft. = 144 m,
= **1,640 ft/sec** Figure 2, Reference 1)

III. Calculate Fundamental Period of Waste Fill

Initial Fundamental Period of Waste Fill, T_s $= 4 \times H/V_s$ (Reference 1, pg. 243)
$= 4 \times 471/1{,}640$
= **1.15 sec**

IV. Calculate Maximum Horizontal Equivalent Acceleration

Ratio T_s / T_m = 1.15/0.48
= 2.40

Ratio MHEA/MHA = 0.27 (Figure 7b for rock site, Reference 1)

Where:
MHEA = Maximum Horizontal Equivalent Acceleration @ base of Waste Fill = k_{max}
MHA = Maximum Horizontal Acceleration of Site Input Rock Motion

Thus, k_{max} $= 0.27 \times$ MHA
$= 0.27 \times 0.75g$ = **0.20 g**

V. Calculate Seismically-Induced Permanent Displacement

Ratio k_y / k_{max} = 0.15/ 0.20 = 0.75

Normalized Displacement $U/(k_{max} \times D_{5\text{-}95})$ = 0.4 cm/sec (with 16% probability of exceedance; Figure 11, Reference 1)

Displacement, U $= [U/(k_{max} \times D_{5\text{-}95})] \times k_{max} \times D_{5\text{-}95}$
$= 0.4 \times 0.20 \times 12$
= **1 cm or 0.4 inches**

Note: Since the magnitude of seismic-induced permanent displacements that are considered acceptable in the industry is about 6 to 12 inches for solid waste slopes, the minor displacements calculated here are acceptable.

ATTACHMENT 1

DETERMINISTIC SEARCH RESULTS FOR MAXIMUM CREDIBLE EARTHQUAKE AND MAXIMUM HORIZONTAL ACCELERATION PERFORMED USING EQFAULT (Reference 4)

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*                    *
*    E Q F A U L T   *
*                    *
*    Version 3.00    *
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DETERMINISTIC ESTIMATION OF
PEAK ACCELERATION FROM DIGITIZED FAULTS

JOB NUMBER: 2004-022

DATE: 03-16-2004

JOB NAME: Olinda Landfill

CALCULATION NAME: Run 05

FAULT-DATA-FILE NAME: CDMGFLTE.DAT

SITE COORDINATES:
SITE LATITUDE: 33.9350
SITE LONGITUDE: 117.8430

SEARCH RADIUS: 100 mi

ATTENUATION RELATION: 22) Abrahamson & Silva (1995b/1997) Horiz.- Rock
UNCERTAINTY (M=Median, S=Sigma): M Number of Sigmas: 0.0
DISTANCE MEASURE: clodis
SCOND: 1
Basement Depth: 5.00 km Campbell SSR: 1 Campbell SHR: 0
COMPUTE PEAK HORIZONTAL ACCELERATION

FAULT-DATA FILE USED: CDMGFLTE.DAT

MINIMUM DEPTH VALUE (km): 0.0

EQFAULT SUMMARY

DETERMINISTIC SITE PARAMETERS

Page 1

ABBREVIATED FAULT NAME	APPROXIMATE DISTANCE mi (km)	ESTIMATED MAX. EARTHQUAKE EVENT: MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
WHITTIER	0.6(1.0)	6.8	0.748	XI
SAN JOSE	7.5(12.1)	6.5	0.355	IX
CHINO-CENTRAL AVE. (Elsinore)	7.7(12.4)	6.7	0.533	X
ELYSIAN PARK THRUST	8.4(13.5)	6.7	0.340	IX
ELSINORE-GLEN IVY	13.0(21.0)	6.8	0.177	VIII
COMPTON THRUST	13.7(22.0)	6.8	0.219	IX
SIERRA MADRE	13.7(22.1)	7.0	0.235	IX
CUCAMONGA	14.7(23.7)	7.0	0.220	IX
RAYMOND	18.5(29.8)	6.5	0.140	VIII
CLAMSHELL-SAWPIT	19.0(30.6)	6.5	0.136	VIII
NEWPORT-INGLEWOOD (L.A.Basin)	19.1(30.8)	6.9	0.125	VII
VERDUGO	22.4(36.0)	6.7	0.125	VII
NEWPORT-INGLEWOOD (Offshore)	24.1(38.8)	6.9	0.098	VII
HOLLYWOOD	25.6(41.2)	6.4	0.094	VII
PALOS VERDES	27.5(44.3)	7.1	0.095	VII
SAN JACINTO-SAN BERNARDINO	28.6(46.1)	6.7	0.074	VII
SAN ANDREAS - 1857 Rupture	31.3(50.3)	7.8	0.120	VII
SAN ANDREAS - Mojave	31.3(50.3)	7.1	0.083	VII
SAN ANDREAS - Southern	31.4(50.5)	7.4	0.097	VII
SAN ANDREAS - San Bernardino	31.4(50.5)	7.3	0.092	VII
CLEGHORN	33.9(54.5)	6.5	0.056	VI
SANTA MONICA	34.0(54.7)	6.6	0.076	VII
ELSINORE-TEMECULA	34.8(56.0)	6.8	0.063	VI
SIERRA MADRE (San Fernando)	35.1(56.5)	6.7	0.077	VII
SAN JACINTO-SAN JACINTO VALLEY	35.2(56.6)	6.9	0.066	VI
SAN GABRIEL	36.4(58.6)	7.0	0.067	VI
MALIBU COAST	40.1(64.5)	6.7	0.067	VI
NORTHRIDGE (E. Oak Ridge)	40.2(64.7)	6.9	0.075	VII
NORTH FRONTAL FAULT ZONE (West)	41.2(66.3)	7.0	0.077	VII
SANTA SUSANA	46.0(74.1)	6.6	0.054	VI
CORONADO BANK	46.3(74.5)	7.4	0.067	VI
ANACAPA-DUME	49.0(78.8)	7.3	0.077	VII
HOLSER	51.9(83.6)	6.5	0.045	VI
SAN JACINTO-ANZA	54.7(88.1)	7.2	0.050	VI
OAK RIDGE (Onshore)	58.7(94.5)	6.9	0.050	VI
SIMI-SANTA ROSA	60.0(96.6)	6.7	0.043	VI
ROSE CANYON	60.6(97.5)	6.9	0.037	V
HELENDALE - S. LOCKHARDT	61.0(98.2)	7.1	0.042	VI
ELSINORE-JULIAN	61.3(98.6)	7.1	0.042	VI
NORTH FRONTAL FAULT ZONE (East)	62.9(101.3)	6.7	0.041	V

Olinda05.OUT

DETERMINISTIC SITE PARAMETERS

Page 2

ABBREVIATED FAULT NAME	APPROXIMATE DISTANCE mi (km)	ESTIMATED MAX. EARTHQUAKE EVENT MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
SAN CAYETANO	63.1(101.5)	6.8	0.043	VI
PINTO MOUNTAIN	64.8(104.3)	7.0	0.037	V
SAN ANDREAS - Carrizo	65.2(104.9)	7.2	0.042	VI
LENWOOD-LOCKHART-OLD WOMAN SPRGS	74.7(120.2)	7.3	0.039	V
SANTA YNEZ (East)	75.0(120.7)	7.0	0.032	V
JOHNSON VALLEY (Northern)	78.2(125.9)	6.7	0.025	V
SAN ANDREAS - Coachella	78.7(126.7)	7.1	0.032	V
VENTURA - PITAS POINT	79.7(128.2)	6.8	0.034	V
OAK RIDGE(Blind Thrust Offshore)	79.8(128.5)	6.9	0.036	V
CHANNEL IS. THRUST (Eastern)	81.7(131.5)	7.4	0.050	VI
GARLOCK (West)	81.8(131.6)	7.1	0.031	V
LANDERS	82.1(132.1)	7.3	0.036	V
BURNT MTN.	83.0(133.6)	6.4	0.019	IV
GRAVEL HILLS - HARPER LAKE	83.1(133.7)	6.9	0.027	V
SAN JACINTO-COYOTE CREEK	83.3(134.1)	6.8	0.025	V
EUREKA PEAK	84.1(135.3)	6.4	0.019	IV
M.RIDGE-ARROYO PARIDA-SANTA ANA	84.4(135.8)	6.7	0.030	V
MONTALVO-OAK RIDGE TREND	85.1(136.9)	6.6	0.027	V
EMERSON So. - COPPER MTN.	85.4(137.5)	6.9	0.026	V
PLEITO THRUST	86.1(138.6)	7.2	0.041	V
RED MOUNTAIN	88.5(142.4)	6.8	0.030	V
BLACKWATER	88.9(143.1)	6.9	0.025	V
EARTHQUAKE VALLEY	89.1(143.4)	6.5	0.019	IV
CALICO - HIDALGO	89.6(144.2)	7.1	0.028	V
BIG PINE	90.5(145.7)	6.7	0.021	IV
GARLOCK (East)	93.8(151.0)	7.3	0.031	V
WHITE WOLF	95.5(153.7)	7.2	0.037	V
SANTA CRUZ ISLAND	95.9(154.4)	6.8	0.028	V
PISGAH-BULLION MTN.-MESQUITE LK	96.7(155.7)	7.1	0.026	V

-END OF SEARCH- 69 FAULTS FOUND WITHIN THE SPECIFIED SEARCH RADIUS.

THE WHITTIER FAULT IS CLOSEST TO THE SITE.
IT IS ABOUT 0.6 MILES (1.0 km) AWAY.

LARGEST MAXIMUM-EARTHQUAKE SITE ACCELERATION: 0.7483 g

ATTACHMENT 2

VARIOUS CHARTS USED IN SEISMIC DISPLACEMENT ANALYSIS

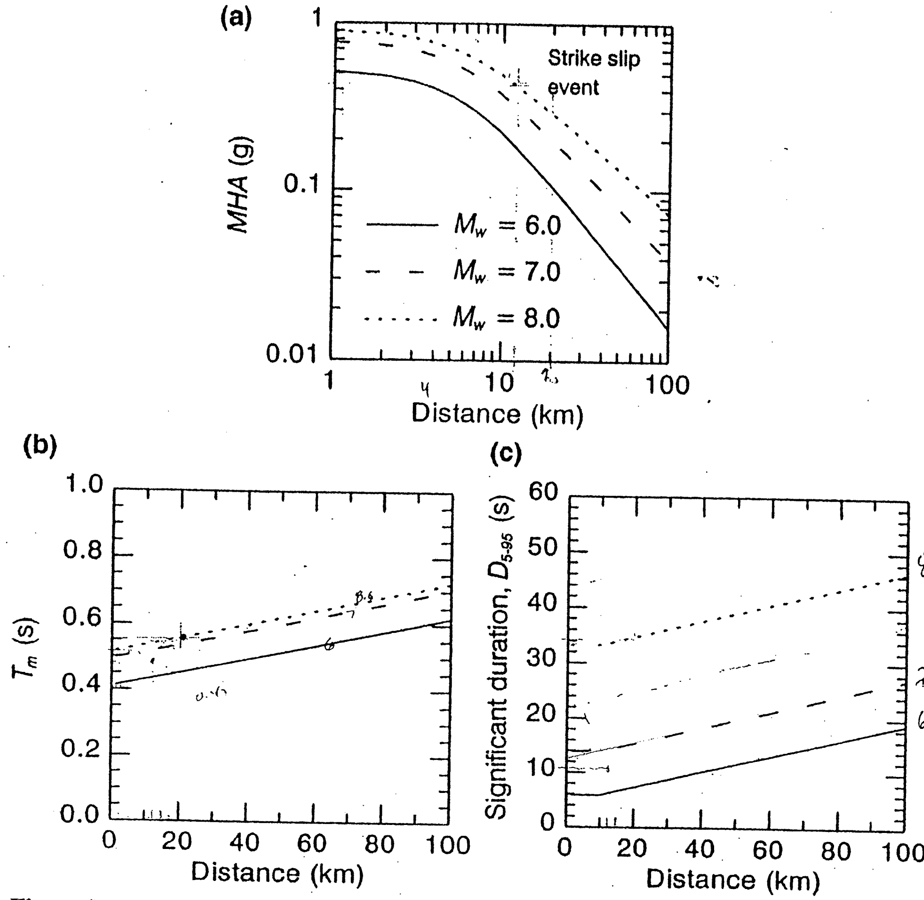

Figure 2. Simplified characterization of earthquake rock motions: (a) intensity, *MHA* for strike-slip faults (for reverse faults, use 1.3×*MHA* for $M_w \geq 6.4$ and 1.64×*MHA* for $M_w = 6.0$, with linear interpolation for $6.0 < M_w < 6.4$) (Abrahamson and Silva 1997); (b) frequency content, T_m (Rathje et al. 1998); (c) duration, $D_{5\text{-}95}$ (Abrahamson and Silva 1996).

A unit weight profile based upon direct measurements of initial weight upon placement; in situ measurements from boreholes and test trenches; inferred values from SASW measurements based on a correlation between depth, V_s, and calibrated unit weights from borehole data; and one-dimensional (1-D) compression tests on large (754 mm) reconstituted samples was also recently developed (Augello et al. 1997). The unit weight profile is 11 kN/m^3 at a depth of 0 m, 14 kN/m^3 at 24 m, and 15 kN/m^3 at and beyond 90 m.

The installation of a pair of accelerometers at the OII landfill in 1987 provided a unique opportunity to evaluate the shear modulus reduction and damping characteristics of solid-waste through back-analysis. Several investigators (e.g. Idriss et al. 1995;

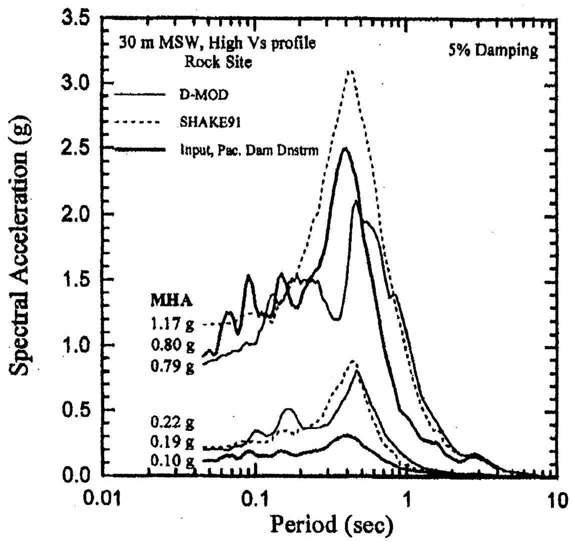

FIG. 1. D-MOD and SHAKE91 Comparison at Two Acceleration Levels

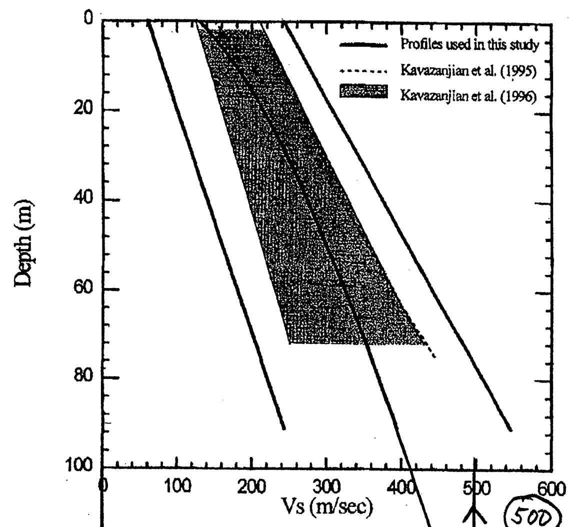

FIG. 2. Shear Wave Velocity Profiles for MSW

well-documented case histories, such as Treasure Island during the Loma Prieta earthquake and the Wildlife Liquefaction site, have validated the use of D-MOD for ground response analysis (Matasovic 1993).

The use of a 1D model to represent the seismic response of an earth/waste fill has been discussed in Vrymoed and Calzascia (1978), Elton et al. (1991), and Bray et al. (1996), and it has been found that dynamic shear stresses near the base of a two-dimensional (2D) earth/waste fill can be approximated reasonably well with 1D analysis. Capturing the cover response is more tenuous, but as the primary focus of the present study is to examine base sliding and key factors affecting seismic response (other than 2D geometry effects for cover systems), the use of 1D analytical procedures is judged to be appropriate.

Cases Analyzed

The nonlinear analyses performed in this study encompassed a large number of landfill configurations to allow evaluation of the relative importance of key parameters on the seismic response of a MSWLF. The landfill configurations included waste heights (H) of 10 m, 20 m, 30 m, 45 m, 60 m, and 90 m, and three shear wave velocity (V_s) profiles (Fig. 2), resulting in initial 1D fundamental periods (T_s-waste = $4H/V_s$, where H = height of waste fill and V_s = average initial shear wave velocity of the waste fill) ranging from 0.17 s to 2.74 s. Recent shear wave velocity measurements at six MSWLFs in southern California indicate that the mean shear wave velocity of municipal solid waste is generally stiffer than previously thought and lies within the Kavazanjian et al. (1996) band shown in Fig. 2. Based on these data, as well as data from other landfills, the lower, medium (best), and high V_s profiles shown in Fig. 2 were used as reasonable variations.

The unit weight of MSW was selected to vary from 6.3 kN/m^3 (40 pcf) at the surface to 11.9 kN/m^3 (75 pcf) at a depth of 45 m. Below this depth, the unit weight remained constant. These values are consistent with those recommended by Kavazanjian et al. (1995). Fig. 3 shows the strain-dependent shear modulus reduction and damping curves used for MSW, as recommended by Kavazanjian et al. (1995). More recent studies [e.g., Idriss et al. (1995); Matasovic et al. (1995); Augello et al. (1998)] have indicated that MSW may respond more elastically than initially thought. Therefore, analyses were also performed with the Vucetic and Dobry (1991) shear modulus reduction and damping curves for a clay with a plasticity index of 30. For these analyses, the maximum shear strain in the waste fill typically ranged from 0.2% to 2%, and the maximum shear stress never exceeded the dynamic strength of waste fill [i.e., an effective friction angle of 35°, Augello et al. (1995b)].

Three site profiles represented disparate landfill foundation conditions: rock, shallow sand, and deep soft clay. The rock site had 3 m of weathered rock (V_s = 760 m/s) overlying hard bedrock. The sand site had 30 m of medium dense sand overlying bedrock. The shear wave velocity profile in the sand varied with overburden pressure and ranged from 135–300 m/s for low waste fill heights (10–20 m) to 350–400 m/s for high waste fill heights (60–90 m). The deep, soft clay site contained 21 m of soft clay, which was overlain by 3 m of stiff clay and underlain by 67 m of stiff clay over bedrock. The shear wave velocity of the soft clay was varied with overburden pressure with V_s = 100–200 m/s for low waste fill heights and V_s = 150–230 m/s for high waste fill heights. The stiff clay was varied in the range of 250–425 m/s. Modulus reduction and damping curves proposed by Seed et al. (1984) for sand and Vucetic and Dobry (1991) for clay were used, with reasonable unit weight profiles.

Four dissimilar baseline rock motions were selected to study the effects of the input earthquake motion characteristics. Two of these records are from the western United States, one is from eastern Canada, and one is a synthetic record, developed by Abrahamson (personal communication, Dec. 1, 1995) for the analysis of the west span of the Oakland–San Francisco Bay Bridge. Significant duration (Trifunac and Brady 1975) ranged from 4.4 to 25 s for these records from Moment Magnitude 5.8, 6.7, 6.9, and 8.0 earthquakes. Fig. 4 shows the normalized acceleration response spectra for the four baseline motions and presents key characteristics of these ground motions. The frequency content of these motions is quite different, and they cover a reasonably wide range of possible input motions. Mean period (T_m) is used, as well as predominant period (T_p). T_m is defined as (Rathje et al. 1998)

$$T_m = \frac{\sum_i C_i^2 \cdot \left(\frac{1}{f_i}\right)}{\sum_i C_i^2} \quad \text{for } 0.25 \text{ Hz} \le f_i \le 20 \text{ Hz} \qquad (1)$$

where C_i = Fourier amplitudes of entire accelerogram; and f_i = discrete Fourier transform frequencies between 0.25 and 20

11

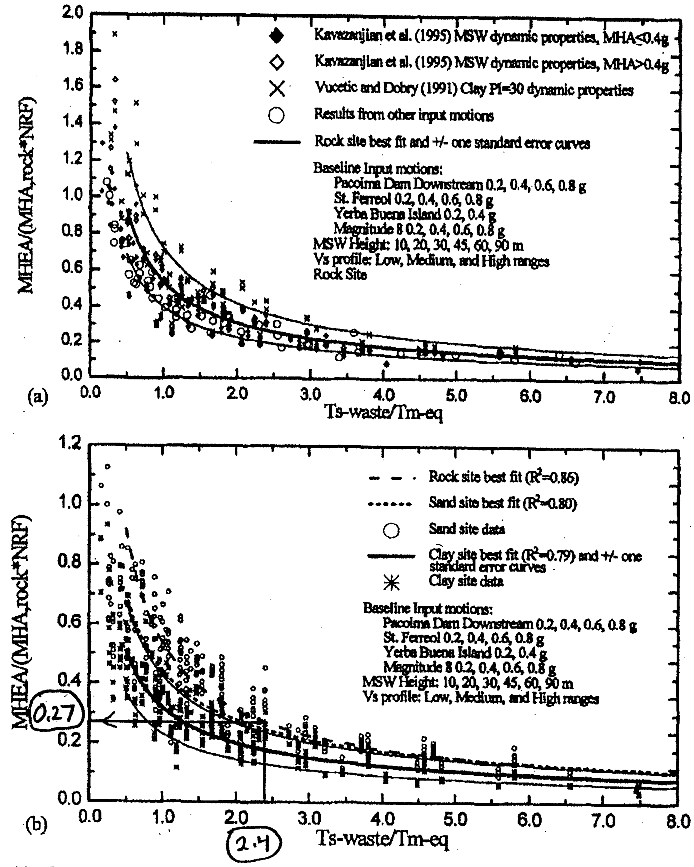

FIG. 7. Normalized Maximum Horizontal Equivalent Acceleration versus Normalized Fundamental Period of Waste Fill: (a) Rock Site; (b) All Sites

stiffnesses of this site category is close to that used for waste fill.

The nonlinear response factor captured the nonlinear variation in seismic loading across a range of ground motion intensities. In Fig. 7, the MHEA at the base of the landfill normalized with respect to the MHA and corresponding NRF of the input rock motion is plotted against the initial fundamental period of the waste fill (T_s-waste) normalized by the mean period of the input rock motion (T_m-eq). Introduction of the nonlinear response factor and replacement of the predominant period by the mean period in this normalization reduced the variation of the data about the median relationship (i.e., R^2 increased from 0.74 to 0.86). For the rock site cases shown in Fig. 7(a), the data (which include 14 rock motions ranging in intensity from 0.2g to 0.8g, three V_s profiles, two pairs of modulus reduction and damping curves, and six waste fill heights, all together 324 analyses) follow a well-defined trend, except near the resonance condition (T_s-waste/T_m-eq < 1). Note that due to modulus reduction, resonance does not occur at T_s/T_m = 1, because T_s is defined as the initial (small strain) fundamental period of the waste fill system. A degraded T_s, as was used by Makdisi and Seed (1978), is difficult to define in a fully nonlinear analysis, and attempts to estimate it with an equivalent-linear approximation did not reduce the scatter. As a check, additional analyses were performed with three landfill configurations using an additional 19 recorded and synthetic high intensity rock motions, and the consistency of the results indicates that Fig. 7(a) is applicable for motions other than those used in this sensitivity study.

Although Fig. 7(a) highlights the importance of the fundamental period of the waste fill (i.e., its shear wave velocity and height), a number of other trends are important. For instance, to a lesser degree, the modulus reduction and damping curves used to represent the waste fill's response at larger strains are important, with the slower reducing Vucetic and Dobry (1991) PI = 30 cohesive soil curves giving uniformly higher responses at comparable T_s/T_m values than analyses performed using the Kavazanjian et al. (1995) waste fill curves.

Site condition effects are displayed in Fig. 7(b). Regression curves for the rock, sand, and clay site results for the various landfill configurations and input rock motions described previously are shown in this figure. In terms of MHEA, the MSWLF responses at rock and sand sites are comparable, but the response at clay sites is lower. At significant levels of shaking, nonlinearity within the deep, soft clay reduces the intensity of the seismic loading. Due to the long period motion amplification at deep, soft clay sites [Fig. 5(b)], these sites may not necessarily be less critical in terms of earthquake-induced displacements, and this will be discussed later in this paper. Fig. 7 is not meant to replace site-specific seismic response analyses; however, it does provide useful insight on the importance of the waste fill's dynamic characteristics and the input rock motion's intensity and frequency content on the calculated MHEA. As this graph has been prepared with normalization parameters that may be estimated based on available information for many projects, Fig. 7 may be used as a guide in the selection of an appropriate seismic coefficient for simplified pseudostatic and deformation analyses. It should be remembered, however, that duration of strong shaking is an important earthquake parameter that is not captured by MHEA.

For comparison with the normalized graph presented by

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coupled analysis may predict smaller displacements than a coupled analysis for systems with larger values of k_y/k_{max}. In these cases, the displacements calculated from both analyses are generally small (i.e., less than a few centimeters). Differences between decoupled and coupled displacements for several input motions are shown in Fig. 9(c). For cases applicable to landfills where only minor earthquake-induced base displacements are generally tolerable (i.e., $k_y/k_{max} > 0.5$), the decoupled approximation is reasonable, so it will be used in this study to evaluate the factors influencing earthquake-induced displacements of MSWLFs. At lower k_y/k_{max} ratios (especially at higher T_s/T_m ratios) where the calculated displacements are large, the decoupled approximation is less reliable, and this may be important in evaluating earth dams.

Results

Calculated seismically induced permanent displacements (U) for the base sliding case for all landfill configurations [see Fig. 7(a)] sited on rock undergoing the 14 input rock motions listed are shown in Fig. 10. In this figure, U is plotted versus selected k_y/k_{max} ratios of 0.2, 0.4, 0.6, and 0.8. Additionally, three landfills were analyzed with another 19 input rock motions, so that 309 data points are plotted at each k_y/k_{max} ratio. There is considerable scatter, both with respect to results from different input motions and results from different landfill configurations undergoing the same input motion. Much of this scatter is expected. For example, the longer duration Magnitude 8 earthquake produces large calculated displacements, and the high frequency St. Ferreol motion produces relatively small displacements. Moreover, at the same intensity level, the Yerba Buena Island record generally produces larger displacements than the Pacoima Dam Downstream record because of its significant long period motion, which better matches the long period response characteristics of most waste fills. For a given input motion, significantly larger displacements are calculated for landfill configurations with stiffer response characteristics that more closely match the short period motions contained in most rock records. As the landfill's fundamental period increases, due to increasing height or decreasing shear wave velocity, the calculated displacements decrease. This finding is consistent with the results presented in Fig. 7(a) and results presented in Augello et al. (1995a). In fact, at a specified k_y/k_{max} ratio, the calculated displacement is roughly proportional to MHEA, indicating that those factors that have been shown to affect MHEA also affect U. However, there is considerably more scatter in the calculated displacements, especially at higher MHEA values.

Several attempts were made to normalize the calculated displacement data presented in Fig. 10. These attempts were of limited success. The best normalization for the cases analyzed is shown in Fig. 11. In this figure, the calculated seismically induced permanent displacement is normalized by k_{max} (MHEA/g) and significant duration ($D_{5-95\%}$) of the input motion. MHEA has been shown to capture the important effects of earthquake intensity and frequency content (e.g., Fig. 7), and significant duration captures another key ground motion characteristic. The normalized displacement decreases with increasing k_y/k_{max}, and shows considerably less inter- and intraearthquake scatter. Hence, an order-of-magnitude estimate of earthquake-induced displacement can be made given an estimate of the intensity (MHA), frequency content (T_m), and duration ($D_{5-95\%}$) of the design rock motion, and the dynamic response characteristics (T_s) and strength (k_y) of the landfill. With this information, the seismic coefficient k_{max} (which is MHEA/g) can be estimated using Fig. 7(a), and the seismically induced displacement (U) can then be estimated using Fig. 11.

Site effects are apparent in Fig. 12. For both the Pacoima Dam Downstream and Synthetic Magnitude 8 rock motions scaled to MHAs of 0.2, 0.4, 0.6, and 0.8g, the upper bound, median, and lower bound calculated seismically induced permanent displacements are shown for all landfill configurations sited on rock, sand, and deep soft clay. For these input motions, the median and upper bound displacements are significantly higher for cases where the MSWLF is situated atop a deep soft clay foundation. Even the sand site produces significantly larger displacements than the rock site at low k_y/k_{max} values. Hence, site conditions are important in evaluating seismically induced permanent base displacements. Note, however, that the larger displacements calculated at soft soil sites for a specified k_y/k_{max} ratio are offset by the results shown in Fig. 7(b), indicating that deep soft clay sites produce lower k_{max} values for identical rock motions and landfill configurations. Thus, for identical landfill configurations and rock motions, the base sliding displacement calculated at soft sites is comparable to that calculated at stiff sites (i.e., only slightly higher when $k_y < 0.1$, but slightly lower at higher k_y values).

Calculated earthquake-induced cover displacements for the

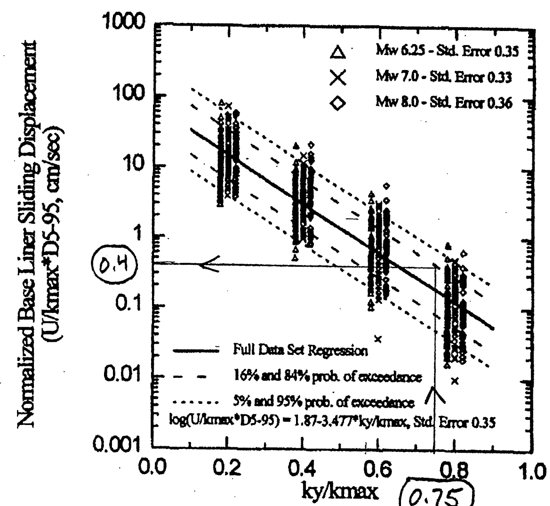

FIG. 11. Normalized Base Liner Displacements

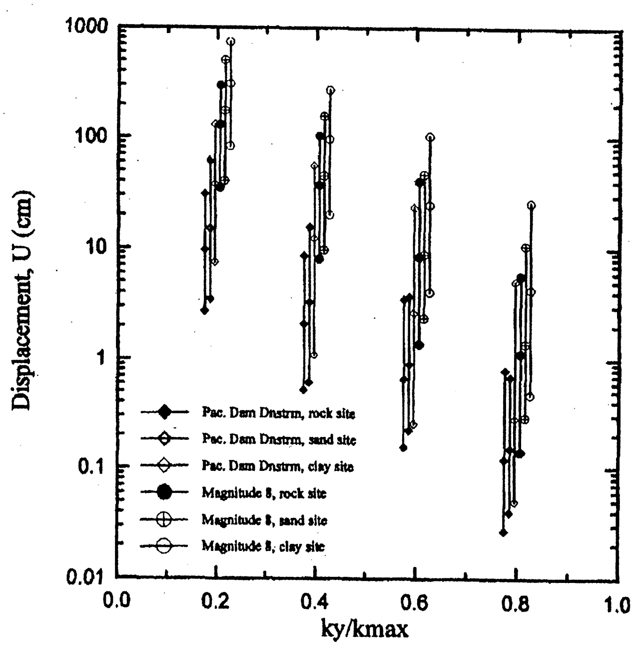

FIG. 12. Site Condition Effects on Base Liner Displacements