CITY OF
RANCHO PALOS VERDES
U.S. ARMY CORPS OF
ENGINEERS
PORTUGUESE BEND SHORE
PROTECTION FEASIBILITY STUDY
ANALYSIS OF
LANDSLIDE
MATERIAL LOSS

Prepared by:
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Torrance CA 90501
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The Portuguese Bend Landslide has moved continuously over the past forty years. Vonder Linden (1972), attributes this continued movement partly to a notable rise in the ground water table between 1957 and 1968 and the continued erosion of the toe by wave action. The rate of movement varies considerably in response to variation in ground water levels (Vonder Linden, 1972). In 1978, above average rainfall caused a large increase in the rate of movement in the Portuguese Bend Landslide. The high rates of movement continued until 1986 when the Rancho Palos Verdes Redevelopment Agency performed remedial grading. For example, one survey monument, R-1, (see Figure 1) which is located in the east central part of the landslide, moved 382 feet horizontally in the ten year period from October 1976 to October 1986 whereas it had moved 237 feet during the twenty year period from October 1956 to October 1976 (Ehlig 1991). Near the coast, the correlation of offset features indicates displacements of more than 800 feet since the start of landsliding.

A sediment plume has been visible in the ocean since the start of movement in 1956. Landslide sediments have been identified 2.5 nautical miles to the south of the landslide and 1.5 nautical miles off-shore.
(Stevens, 1990). It is estimated that sediment from the Portuguese Bend Landslide affects the marine environment in an area of approximately 771 hectares in size (Stevens, 1990). The photograph on the previous page shows the sediment plume from the Portuguese Bend Landslide in 1980.

ANALYSIS

In determining the amount of landslide material that has been lost, cross-sections were drawn using topographic maps of the area from 1955, 1976, 1984, 1987, 1988 and 1995. By comparing the area between cross-sections on the first map, dated August 1955 (prior to the start of landsliding), and cross sections taken at the same location on subsequent topographic maps, a difference of the upslope removal and the downslope fill can be computed. However, in this situation where the entire landslide mass is translating downslope in a non-uniform manner, the typical approach to calculating the difference between removals and fills does not explain how parts of a mass can translate up to 800 feet without that part of the entire mass being dispersed into the ocean. Therefore, the difference in density of the material in slide mass before landsliding began, and in 1995, must be taken into account after the typical difference between removals and fills are calculated.

In order to calculate the difference between the removals and fills created by the landslide, a total of eight (8) cross-sections were computed between the easterly edge of the landslide and Inspiration Point for each topographic map. The location of the cross-sections are shown on Figure 2. The various cross-sections are included in Attachment A. Adequate maps are not available to determine the amount of land movement in the area between Inspiration Point and Portuguese Point. Therefore we did not take cross-sections in this area.

Volume of displaced earth was determined by using the average end area method. Volume calculations were broken down into three portions. Portion 1, the removal, included the material between the location of the bluff in 1955 or limit of landslide and the top of the landslide. Portion 2 included the material between the 1955 shoreline and the location of the bluff in 1955 which is part of the fill area. Portion 3 included the material between the 1955 shoreline and the shoreline in later years and represents the part that the landslide has encroached into the ocean. Figure 3 shows the general location of the three portions used in our calculations.

Based on this volume analysis, we estimate that the amount of material that has entered the ocean due to landsliding is approximately 3,584,000 cubic yards.

However, as stated earlier, this does not account for the total amount of material dispersed into the ocean. Because of the loss of density of the moving material in the slide mass, another significant amount of material has been moved into the ocean. Once the
CROSS-SECTION
E 4,178,000

PORTION 1

1955 Cross-Section

PORTION 2

Bluff Point In 1955

1955 Cross-Section

PORTION 3

1995 Shore Line

1995 Shore Line

Top of Landslide

1995 Cross-Section

Figure 3
mass began moving downslope, a number of factors have affected the speed of the landslide mass. These factors include: 1) the height of ground water above the slide plane, 2) the depth of the slide mass, 3) the slope of the slide plane, 4) the friction of the material at the slide plane, 5) the amount of support, particularly at the bluff and 6) the rate at which the ocean removes material along the shoreline. These factors vary throughout the landslide. Survey data indicates that the most rapid movement has occurred within the oceanward part of the landslide south of Palos Verdes Drive South. Because the downslope portion of the landslide has a higher rate of movement than other sections of the landslide, grabens and voids are created within the landslide mass causing a significant reduction in the density of the original slide mass. For the purposes of this report, we have assumed that the loss in density is 10%. This assumption is based on our experience in mass earthwork construction where materials such as soils and rock that are loosened, typically show a 10%-15% decrease in density. The translation of the material occurs at a much faster rate in the coastal zone (Palos Verdes Drive South to the ocean) than in the inland areas. Therefore, pull apart, grabens, and fissures are commonplace in the areas moving. Thus, the faster moving areas separate from the slower moving areas creating these void spaces and less dense material.

From our cross-sections and calculations, we estimate the mass of the original landslide to be 22,480,000 cubic yards. Assuming a loss of 10% in density, the additional dispersion of material into the ocean is 2,250,000 cubic yards. This brings the total amount of material loss due to landsliding to 5,834,000 cubic yards since the landslide began moving in 1956.

Figures 4 and 5 on the following page show the cumulative amount of material loss and the average yearly loss for various periods between 1956 and 1995. As shown in Figure 5, the average yearly loss of material was 85,633 cubic yards for the period from 1955 through 1976 and 207,795 cubic yards for the period from 1987 through 1995.

**CONCLUSION**

Two factors must be considered in determining the amount of landslide material loss; 1) the actual amount of earth that has moved into the ocean which can be verified using photographs and topographic maps, and 2) the estimated loss of density that has occurred as a result of land movement. Our calculations using verifiable information indicate that approximately 3,589,000 cubic yards of earth entered into the ocean as a result of landsliding. In addition, based on our experience, we have estimated that the landslide mass has experienced a minimum 10% reduction in density as a result of land movement. This translates into an additional 2,250,000 cubic yards of earth that has been dispersed in the ocean. Therefore, the total landslide material loss is estimated to be 5,834,000 cubic yards.
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CROSS-SECTION
E 4,177,100
08/55 and 01/87
CROSS-SECTION
E 4,177,100
08/55 and 03/88

Horizontal Distance In Feet

Elevation In Feet

1988 Shore Line
1955 Shore Line
Bluff Point In 1955

1988 Cross-Section
1955 Cross-Section

1988 Cross-section above 1955 cross-section
1955 Cross-section above 1988 cross-section
CROSS-SECTION
E 4,177,100
08/55 and 08/95

Elevation In Feet

1995 Shore Line
1955 Shore Line
Bluff Point In 1955

1955 Cross-Section
1955 Cross-Section
1995 Cross-Section

Horizontal Distance In Feet

1995 Cross-section above 1955 cross-section
1955 Cross-section above 1995 cross-section
CROSS-SECTION
E 4,177,400
08/55 and 03/76

1976 Cross-Section above 1955 cross-section
1955 Cross-section above 1976 cross-section
CROSS-SECTION
E 4,177,400
08/55 and 01/87

1987 Shore Line
1955 Shore Line
Bluff Point In 1955

1987 Cross-Section
1955 Cross-Section

1987 Cross-section above 1955 cross-section
1955 Cross-section above 1987 cross-section

Elevation In Feet

Horizontal Distance In Feet
CROSS-SECTION

E 4,177,400

08/55 and 03/88

1988 Cross-Section above 1955 cross-section
1955 Cross-section above 1988 cross-section
CROSS-SECTION
E 4,177,700
08/55 and 03/76

[Diagram showing horizontal distance in feet and elevation in feet with annotations for 1955 and 1976 cross-sections.]
CROSS-SECTION
E 4,177,700
08/55 and 08/95

Horizontal Distance In Feet

- 1995 Cross-section above 1955 cross-section
- 1955 Cross-section above 1995 cross-section
CROSS-SECTION
E 4,178,000
08/55 and 03/76

Horizontal Distance In Feet

Elevation In Feet
1976 Shore Line
1955 Shore Line
Bluff Point In 1955

1976 Cross-Section
1955 Cross-Section
1976 Cross-Section above 1955 cross-section
1955 Cross-section above 1976 cross-section
CROSS-SECTION
E 4,178,000
08/55 and 09/84

[Diagram showing a cross-section with annotations for 1955 and 1984 cross-sections, elevation in feet, and horizontal distance in feet.]
CROSS-SECTION
E 4,178,300
08/55 and 03/88

- 1988 Shore Line
- 1955 Shore Line
- Bluff Point In 1955
- Top of Landslide

- 1988 Cross-Section
- 1955 Cross-Section
- Slip Plane
- 1988 Cross-Section

Horizontal Distance In Feet
Elevation In Feet

1988 Cross-section above 1955 cross-section
1955 Cross-section above 1988 cross-section
CROSS-SECTION
E 4,178,300
08/55 and 08/95

Horizontal Distance In Feet

Elevation In Feet

1995 Shore Line 1955 Shore Line

Bluff Point In 1955

6'-1'

1995 Cross-Section

1955 Cross-Section

Slip Plane

1995 Cross-Section above 1955 cross-section
1955 Cross-section above 1995 cross-section

Top of Landslide

500 1000 1500 2000 2500 3000 3500 4000 4500
CROSS-SECTION
E 4,178,600
08/55 and 08/84

1984 Cross-Section
1955 Cross-Section
1984 Cross-section above 1955 cross-section
1955 Cross-section above 1984 cross-section
CROSS-SECTION
E 4,178,600
08/55 and 08/87
CROSS-SECTION

E 4,178,600

08/55 and 08/95

[Diagram showing cross-sections and elevations]
CROSS-SECTION
E 4,178,900
08/55 and 03/76
CROSS-SECTION

E 4,178,900

08/55 and 09/84

The diagram illustrates a cross-section with the following features:

- Elevation in Feet
- 1984 Shore Line
- 1955 Shore Line
- Bluff Point in 1955
- Top of Landslide

Two cross-sections are depicted:

- 1955 Cross-Section
- 1984 Cross-Section

Legend:

- Light blue: 1984 Cross-section above 1955 cross-section
- Red: 1955 Cross-section above 1984 cross-section

Horizontal Distance in Feet

Vertical Distance in Feet
CROSS-SECTION

E 4,178,900

08/55 and 01/87

Horizontal Distance In Feet

1987 Shore Line
1955 Shore Line
Bluff Point In 1955
Top of Landslide

Elevation In Feet

1955 Cross-Section
1987 Cross-Section

1987 Cross-section above 1955 cross-section
1955 Cross-section above 1987 cross-section