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SYNOPSIS: Big Lagoon, located 30 miles north of Eureka, California is formed behind a bay barrier built across the mouth of a drowned river valley. To the south of the bay the beach follows rising wave cut slightly cemented sand and gravel sea cliffs and terminates at the south end of Agate Beach. The retreat of these sea cliffs and its effect on property development along the top of the cliff is the focus of the paper. Measurements of bluff retreat in this area have been documented extensively from November 1941 to March 1986 through ground surveys and air photos. Review of the data indicates that the retreat rate is not constant along the cliff but has either been decreasing or remaining the same over the last 45 years. Using information on the rate of retreat, a method is developed to predict the cliff erosion in the future.

INTRODUCTION

As far back as geological records can be traced, there is evidence that the shorelines of the world are dynamic, subject to rises and falls in sea level, and elevations and depressions in land masses. Looking eastward from the town of Trinidad, California marine terraces and old beach lines can be seen rising step by step to an elevation of 1400 ft. There is clear evidence of the successive elevations in land masses along this coast. Coupled with these two geological phenomena is the fluctuating sea level, which has been rising since the beginning of the last ice age. Presently the sea level is rising along the north coast (Russell, 1957). The result of the rise of sea level with respect to the land is coastal erosion.

Big Lagoon, located 30 miles north of Eureka, California and 7 miles north of Trinidad, California is formed behind a bay barrier built across the mouth of a drowned river valley. The bay barrier is part of a sandy-beach section of coastline that extends from a cliffed headland at the north end of the lagoon to a low sandy bluff at the southern end. This beach then follows rising wave-cut sea cliffs and terminates at the south end of Agate Beach (Martinez, 1978). The sea cliffs are composed of a slightly cemented sand and gravel that form a soft sandstone. This sandstone is presently tilted downward to the north. Some of the layered structure extends along the floor of the lagoon until at the north end of the lagoon, it abruptly stops where it meets a rocky bluff. This change from a soft sandstone to rocky bluff marks a line of a fault. The erosion of the soft sandstone sea cliffs will be the focus of this study. A map of the area is shown in Figure 1. Also shown in Fig. 1 are numbered section lines which will be utilized to discuss historic erosion.

The bathymetry along the coast at this location does not exhibit any substantial change. There is a headland immediately south of the study area which does result in a focusing of waves.

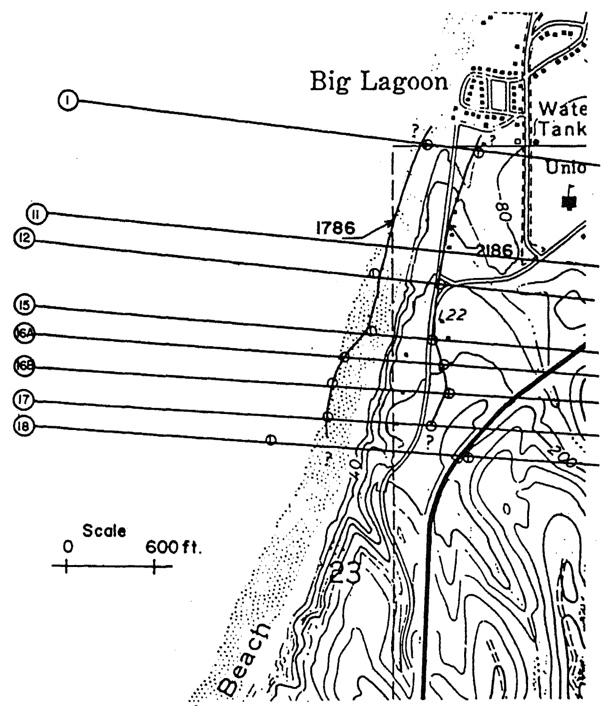

Fig. 1 Location of Coastal Bluffs at Big Lagoon

The erosion potential of a coast varies greatly from point to point and is dependent on a number of factors which may be listed as follows: (Adapted from King, 1959) (1) exposure of coastline to wave attack, (2) tide, (3) coastal type, (4) type of geologic material comprising coast, (5) offshore relief, (6) effect of man-made structures, (7) longshore movement of beach material, (8) tectonic changes, and (9) proximity of rivers carrying sediment to the ocean. The basic premise is that if the beaches below a coastal bluff are subject to sand depletion due to a lack of material transport by the longshore current then wave action will be able to actively attack the coastal bluffs. Conversly, if the beaches are aggraded, then the wave action will not effect the coastal bluff.

WAVE AND TIDES

Incoming wave power is distributed among three recognizable "families" of waves, each with a particular season of effect and average angle of approach (Johnson et al., 1971; Scripps Institution of Oceanography,]947). From April to November, the dominant wave energy component at the study area is the "prevailing swell". These waves are generated by storms in the north-central and north eastern Pacific. These waves are low energy wave forms, generally not higher than 9.8 ft. and averaging under 3.3 ft. high, and dominate the total wave power as a result of their long season of effect. The winter months, November through March, are characterized by very high energy "seas" which arrive from the south. These southerly waves average about 9.8 ft. high and range over 26 ft. high. They are associated with storm fronts passing through the study area during winter. A third group of waves arriving at the study area are seas generated by NNW winds which occur most strongly in the months of May to August. This family of waves has an average deep water approach direction of NW to NNW and an average height of 3.2 ft. to 6.4 ft. with a maximum height of 16.4 ft. Southward drift during the late spring and summer months is a result of the arrival of this group of waves. The total wave-power of this northerly group is about equal to the total wave-power of the winter southerly waves.

Tides in the study area are mixed semi-diurnal, with a mean tide range of about 5 ft., and a maximum tide range of about 11.2 ft. (N.O.A.A., 1980).

HISTORIC EROSION

Measurements from the centerline of Roundhouse Creek Drive/ Ocean View Drive to the top of the coastal bluffs are presented in Table 1 for the period of time from November 1941 to March 1986. Plots of cumulative time versus distance from the top of coastal bluffs to center of the road is presented in Figure 2. An inspection of Figure 2 shows that along a number of section lines a substantially linear relationship exists between coastal bluff erosion and time. An interpretation of this phenomenon would be that the rate of coastal bluff retreat has been fairly constant over the period of time that measurements have been taken. An implication of a relatively constant rate (ER) of coastal bluff erosion is that a constant amount of sediment is being transported along the coast by the littoral current.

EVALUATION OF EROSION RATE

The erosion rate (ER) is defined as the change in distance from a known point to the edge of the coastal bluffs as a function of time as shown in Figure 3 and as given in equation 1.

$$ER = \frac{D_1 - D_2}{Y_2} \qquad (1)$$

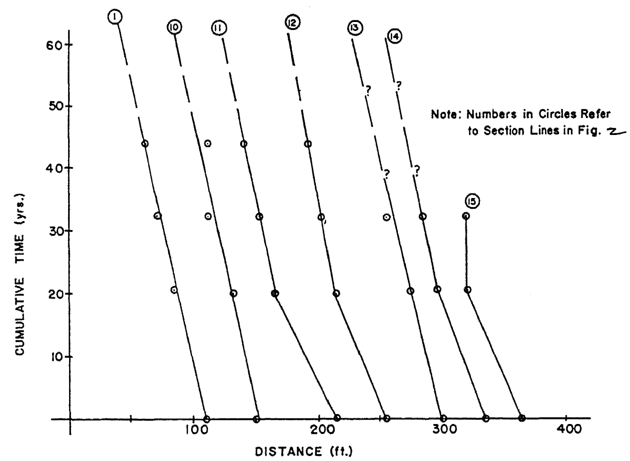

Fig. 2a Distance From Fixed Point To Coastal Bluff Versus Time

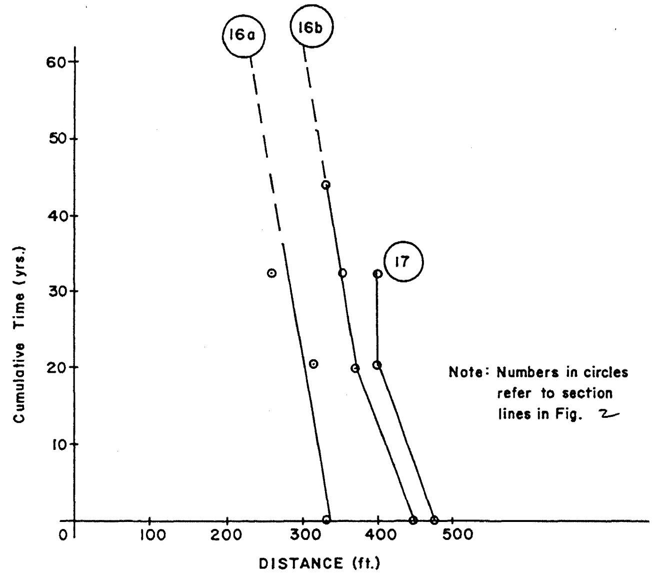

Fig. 2b Distance From Fixed Point To Coastal Bluff Versus Time

where:
- ER - Erosion Rate (ft./yr.)
- D_1 - Initial distance from edge of coastal bluff to reference point(ft.)
- D_2 - Distance from edge of coastal bluff to reference point at time T_2 (ft.)
- Y - Number of years that have occurred since initial measurement

Plotting the calculated erosion rate versus time in years for section 11 and 16b are shown in Figures 4 and 5. A review of these figures indicates that the erosion rate (ER) has been decreasing from 1941 to the present (1986) for these specific location in contrast to other sections where the erosion rate is relatively constant.

Line	Distance From Centerline of Ocean View Drive (feet) Nov. 1941	Aug. 1962	Aug. 1974	March 1986	Retreat (feet) 1941-1962	1941-1974	1941-1986	Average Erosion Rate (ft./yr.)
1	110	85	72	62.5	25	38	47.5	1.06
10	150	132	113	112.5	18	37	37.5	0.83
11	215	165	153	140	50	62	75	1.67
12	255	215	202	192	40	53	63	1.40
13	300	275	255	--	25	45	--	1.36
14	335	295	285	--	40	50	--	1.52
15	365	320	320	--	45	45	--	1.36
16a	330	315	260	--	15	70	--	2.12
16b	445	385	355	330	60	90	115	2.56
17	476	400	400	--	76	76	--	2.30
18	467	--	315	--	--	152	--	4.61 (1)

Note: (1) Site of drainage culvert.

Table 1 Measurements From Centerline of Ocean View Drive To Top of Coastal Bluffs at Big Lagoon Subdivision (Adopted from Tuttle, 1981)

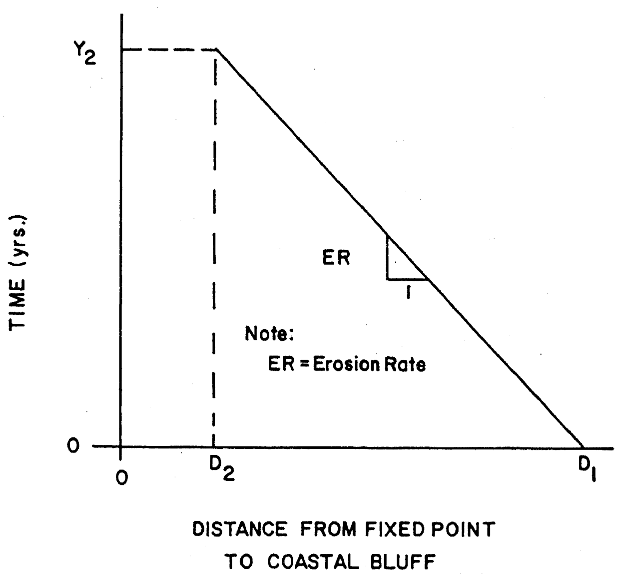

Fig. 3 Schematic Illustration of Distance from Fixed Point to Coastal Bluff Versus Time

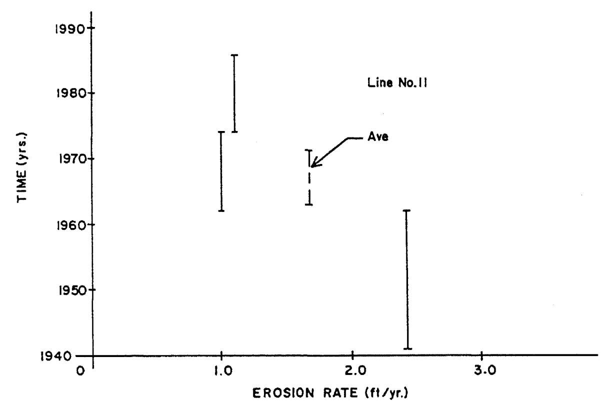

Fig. 4 Erosion Rate Versus Time, Line No. 11

HINDCASTING AND FORECASTING COASTAL BLUFF LOCATIONS

The coastal bluff location in the past or in the future can be estimated by rearranging equation 1 as follows:

$$D_2 = D_1 - (ER)\, Y_2 \qquad (2)$$

Using equation 2 and assuming an average ER of 2 ft./yr. the location of the coastal bluff in 1786 and 2186 was estimated as shown in Figure 1. A review of the estimated coastal bluff locations as shown in Figure 1 indicates that a larger

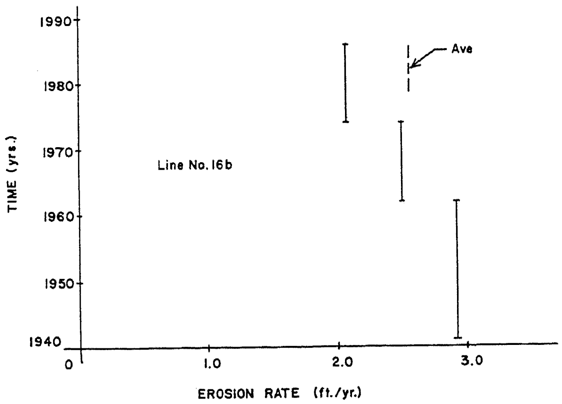

Fig. 5 Erosion Rate Versus Time, Line No. 16b

amount of movement occurs in the southern portion of the cliffs as opposed to the north.

CONCLUSIONS

(1) The coastal bluff erosion rate along each line has been relatively uniform over the last 45 years as shown by linear time versus distance plots.

(2) Erosion rates vary from 0.8 to 2.6 ft./yr. along the section investigated. Line 18 indicated an erosion rate of 4.6 ft./yr. but was probably influenced by the presence of a drainage culvert.

(3) Erosion rates seem to be decreasing with time along specific section lines. Reason for this decrease is unknown at the present time.

(4) Hindcasting and forecasting coastal bluff retreats based on average erosion rates indicates that the bluff has retreated from 170 to 500 ft. in the last 200 years and will probably experience an equal amount in the next 200 years.

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