Chapter 5

THE SIGNIFICANCE OF SAND DISTRIBUTION PATTERNS FOR A PERMANENT BERKELEY BEACH

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Introduction

Though there are over 300 miles of shoreline around San Francisco Bay, there are only a few miles of recreational beach in this expanse. Thus, to many Berkeley residents a seven-acre stretch of beach along the Berkeley Waterfront is an appealing prospect. Berkeley, perhaps more than other cities, is concerned with rapidly diminishing open space. A permanent public beach could both preserve precious open space and alleviate the pressures of urban living. The purpose of this report is to address the question, "How feasible is a permanent beach at the Berkeley Waterfront?"

Due to both the complexity of beach dynamics and time constraints, this analysis encompasses only four selected sites (Figure 1) along the Berkeley Waterfront. Sediment samples were collected for each of the study sites on three different occasions throughout the winter. The characteristics of the sediment samples for each site will be compared with "typical" beach characteristics, and the reasons for deviations from these typical characteristics will be examined. The impact that such deviations may have on a reconstructed beach will also be examined. For instance, storm drains which empty into the

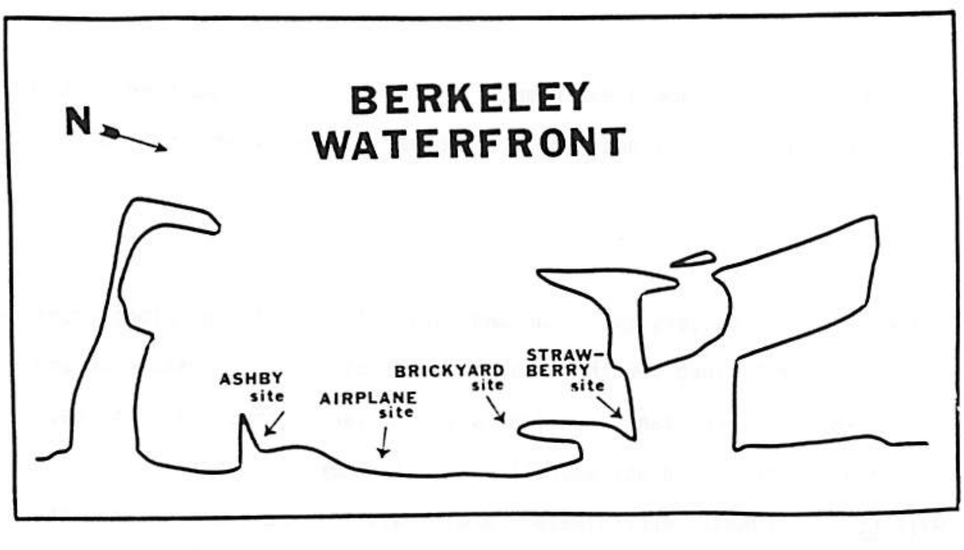

Figure 1. Study Site Locations Along the Proposed Berkeley Beach.

beach and bay may carry sediments from or deposit sediments onto a reconstructed beach. Although this analysis is too limited both spatially and temporally to determine the absolute feasibility of a reconstructed beach, such an analysis does reveal factors (e.g., storm drains) which may affect the stability of a reconstructed beach.

There has been a previous grain size analysis conducted at the beach (see Hall et al., 1983). To my knowledge, however, there has been no published sedimentation analysis which studied fluctuations over time. A study was conducted in 1982 to determine the average grain size at the present beach (Bachman, 1982). After sampling transects along the beach, D. Bachman determined the mean grain size of the average shore profile. The results obtained in this study will be compared with Bachman's results.

Background

Nearly all the development plans which address the shoreline between Ashby and University Avenues call for a public beach, and many of these plans propose some form of beach restoration (e.g., Planning and Community Development Department, 1984; CHNMB Associates, 1982). As it appears now, the area proposed for a public beach is barren and limited to fishing and windsurfing. Other than at the Brickyard (Figure 1), there are only two places where sand is regularly exposed; at high tide, nearly all the beach is inundated.

The plans to improve and restore the present beach have rational basis; it does little good to have a public beach that cannot be used by the public. Before creating a sandy beach, however, Berkeley must ensure that fill materials will remain in place. The City of Alameda, in response to similar demands for a public beach, created a beach in 1959. Between 1959 and 1979, the shoreline eroded 250 feet and Shoreline Drive is eroding an average of five feet per year (U.S. Army Corps of Engineers, 1979). A public beach came with a much more expensive price tag to Alameda than was ever anticipated, and this bill has yet to be fully paid.

The lesson to be learned from the Alameda experience is clear: Berkeley must be certain that money invested in a beach restoration project will not merely disappear to the bay during the first winter storm.

Site Description

The present beach lies south of University Avenue and north of Ashby Avenue along Frontage Road (Figure 1). Rip-rap extends the mile-long length of the beach, protecting Interstate-80 and Frontage Road from erosion and also protecting Frontage Road from wave and sand intrusions. The beach sand is very fine to medium-grained along the immediate shoreline, and farther from shore the sediments are composed of bay mud (Hall et al., 1983). Approximately a mile west of the beach between the Brickyard and the Ashby Spit lies the Ashby Shoal, an offshore sandbar.

Three storm drains from the City of Berkeley, Strawberry Creek, Potter Creek, and the Aquatic Park drain, empty into the beach and bay. These drains carry great amounts of runoff during high rain periods, and are relatively dry during the summer months. Water flowing from these outlets may deposit sediments from the city onto the beach.

Beach Dynamics

On a stable beach, the annual patterns of sand inflow and outflow are balanced. There is a cyclic flow of sediments from bar to berm in the summer months, and from berm to bar in the winter months (Bascom, 1980). A berm is the flat above-water portion of sediment, commonly thought of as "the beach". Bars are under-water ridges, situated parallel to the berm. The uneven exchange of sediments between berms and bars determines beach formation or beach erosion.

In the winter, when waves carry more energy, sand is lost from the berm (Bascom, 1980) and the median grain size on the beach is coarser (Bird, 1984). In the summer, the opposite occurs. The waves carry less energy, and more sand is deposited on the berm face. The berm becomes flatter as more fine sediments accumulate. Therefore, the net flow of sand is seaward in winter and landward in summer.

Most beach sediments are well-sorted, with the bulk of material falling within a certain size grade (Bird, 1984). Further, the grain size distribution is usually asymmetrical and negatively skewed, with the average grain size coarser than the median. Deviations from these standard beach characteristics may indicate that the beach is unstable or that there are factors interfering in "normal" beach processes.

What do these patterns imply about the present beach and about a reconstructed Berkeley Beach? If the beach demonstrates "typical" beach patterns, sediments will become coarser through the winter, and the grain size distribution will be asymmetrical and negatively skewed. If the patterns demonstrated at the study sites do not follow these "typical" beach patterns, the causes for these differences will be examined. Such deviations could affect the stability of the reconstructed beach.

Methodology

Sediment samples were collected at four sites along the beach (Figure 1). These four sites were chosen because they are approximately equidistant from each other and because they are affected by converging currents. It is important to note that the sample site was not precisely relocated at successive collection times and may have varied by as much as one meter; thus, samples were not taken in exactly the same location for each period. This fact alone can account for some of the grain size variability between each period.

The under-water samples were scooped, with the aid of a "sand grabber", from the top ten centimeters of sediments on the bay floor. A "sand grabber" is a fifteen-foot pole with a coffee can attached at the end. Approximately 200 grams of sand were collected from each site.

The samples were collected on November 20, 1984 (Period One), January 14, 1985 (Period Two), and February 28, 1985 (Period Three). The Period One samples were taken at high tide, and all of the sites were submerged in water. Although the day was clear, there had been 4.94" of rainfall in the two week period preceding the sampling (National Cooperative Weather Station, 1984-1985). The Period Two samples were collected at low tide, and all the sample sites except the Strawberry Site were again under-water. There was relatively little rainfall before the second sampling; only .41" of rainfall was recorded in Berkeley for the two weeks before sampling. The third and final sampling occurred at low tide. For the three weeks before this sampling period, the weather had been unusually warm and dry. The daytime temperatures had ranged from 65^{o}F to 75^{o}F, and there was no recorded rainfall in Berkeley during this period. Once more, all of the samples except the Strawberry sample were submerged.

To determine grain size, each sample was oven-dried at low temperature (175^{o}F), and 50 grams were removed from each for wet sieve analysis. The 50 gram samples were soaked in water for two hours and then wet-sieved on a 230-mesh, 120-mesh and 20-mesh screens. The material retained on the 120-mesh screen was re-sieved one month later on 35-mesh and 60-mesh screens. The sediments retained on the sieves were dried overnight and then weighted. The sediments were classified according to a logarithmic transformation of the Wentworth scale (Table 1).

Classification	Diameter (mm)	Phi
Very Coarse Sand	Greater than .833	Less than 0
Coarse Sand	.500 - .833	0 - 1
Medium Sand	.250 - .500	1 - 2
Fine Sand	.125 - .250	2 - 3
Very Fine Sand	.063 - .125	3 - 4
Silt and Clay	Less than .063	Greater than 4

Table 1. Logarithmic Transformation of the Wentworth Scale (after Blatt and others, 1972).

On this scale, the coarse materials have negative phi values, and the finer sediments have positive phi values. A cumulative-frequency curve (based on the phi scale) was calculated for each sample. Values for the mean (M), sorting (S), and skewness (SK) were calculated from the cumulative-frequency curve as follows (see Bird, 1980):

$$M = .5(\emptyset_{16} + \emptyset_{84})$$

$$S = .5(\emptyset_{84} - \emptyset_{16})$$

$$SK = (M - \emptyset_{50})/S$$

For more information regarding mean, sorting, and skewness, see Bird, 1980.

The data were classified according to the percent composition in each grain size class. Comparisons between the sample site and the "average" beach will be made once the descriptions for sorting, skewness and mean are obtained from the data.

General Trends

The data (Table 2) show that there are a few characteristics common to all the study sites. The median grain size of all the samples became coarser as winter progressed, as is the trend for most beaches. At no time were all the "typical" beach characteristics demonstrated by any one sample; there were no well-sorted, negatively-skewed samples.

Characteristics were similar at sites affected by similar environmental factors. For instance, both the Brickyard and the Strawberry sites are located in or near a cove. These samples showed both the most variability in grain size and the greatest percentage of sediments in the coarse or the silt and clay range; the sediments were often too coarse or too fine for measurements of median, sorting, and skewness. Further, the Ashby and the Airplane sites, which are not located near coves, had similar skewness and sorting values.

The average mean for all the sites was 1.6 phi (medium sand). In 1982, D. Bachman measured an average mean of 2.4 phi which is in the fine sand range (Bachman, 1982). The discrepancy between these numbers suggests that the mean is not a constant value. Instead, the mean along the beach changes as the environment changes.

Phi Range	0	0 - 1	1 - 2	2 - 3	3 - 4	4
ASHBY SITE						
Period One	16.7%	6.3%	8.6%	35.0%	28.6%	4.8%
Period Two	4.2%	11.6%	21.8%	42.3%	15.2%	4.9%
Period Three	2.5%	4.6%	37.6%	38.2%	16.0%	1.2%
AIRPLANE SITE						
Period One	15.6%	5.7%	12.2%	24.4%	24.4%	17.7%
Period Two	3.8%	12.1%	42.0%	30.1%	7.3%	4.7%
Period Three	4.2%	13.6%	62.7%	16.5%	2.2%	0.8%
STRAWBERRY SITE						
Period One	4.4%	2.0%	5.1%	26.0%	32.8%	29.6%
Period Two	1.2%	0.7%	0.6%	1.5%	20.0%	76.0%
Period Three	18.7%	7.4%	18.3%	39.6%	11.4%	4.6%
BRICKYARD SITE						
Period One	0.2%	0.5%	0.5%	4.0%	24.8%	70.0%
Period Two	1.0%	4.2%	9.8%	28.0%	40.7%	16.2%
Period Three	27.5%	1.2%	12.6%	29.4%	22.8%	6.5%

Table 2. Grain Size Distributions Along the Berkeley Beach.

Strawberry Site

PERIOD	ONE	TWO	THREE
Mean	•	•	1.2
Median	2.9	Greater Than 3.5	1.7
Sorting	•	•	Poor (1.5)
Skewness	•	•	Strongly Negative (-0.3)

() The numbers in parenthesis are the numerical values calculated from the sorting and skewness equations

• Data are insufficient to calculate mean, sorting and skewness

TABLE 3. Grain Size Characteristics of the Strawberry Site in Phi Units

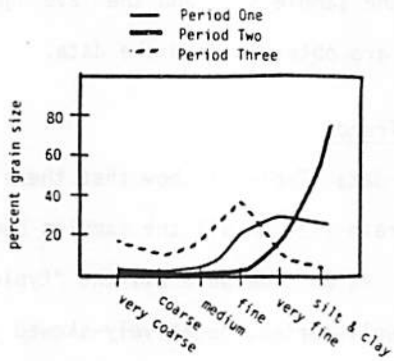

FIGURE 2. Grain Size Distribution Curves at the Strawberry Site

The most dramatic and the most unusual grain size fluctuations occurred at Strawberry Creek. There was such a high percentage of silt and clay during the first two periods that mean, sorting, and skew measurements could not be derived. It is possible that the study site was in a protected pocket along the beach. Because the site is generally exposed, I could not determine whether or not the site was in a sheltered location. If the site was in a protected pocket, the sediments would not be subjected to back-and-forth wave motions, and the fine particles would settle on the bay bottom. The increased deposits from Strawberry Creek during a rainy period may explain the high silt and clay content in Periods One and Two.

Sample Period Three demonstrated more typical beach characteristics, with the average grain size coarser than the median. However, this sample was also poorly sorted. There are several factors, acting alone or in combination, that can explain the Period Three results. First, a slight change in the study site location could greatly alter grain size composition, indicated in the methodology. A slight change in the study site location could place the sample site out of the protected pocket and into the direct flow of Strawberry Creek. Second, instead of a change in the location of the site, the flow of Strawberry Creek itself may have changed. The altered pathway may have exposed the protected pocket and subjected the site to more intense water motion. Coarser sediments from Strawberry Creek could then have settled at the study site. Finally, the sediment flows from Strawberry Creek may have been so variable that "typical" beach patterns were not displayed.

What do the grain size patterns indicate regarding a permanent beach at the Strawberry Site? Most importantly, the patterns indicate that Strawberry Creek will affect a reconstructed beach. The very high silt content in the First and Second Periods suggests that Strawberry Creek may have a direct impact on sedimentation dynamics. Determination of whether the net balance of sand is positive (sediment deposition through creek outflow) or negative (sand removal through strong creek currents) is beyond the scope of this paper.

Brickyard Site

PERIOD	ONE	TWO	THREE
Mean	*	2.5	*
Median	Less than 3.5	2.7	1.8
Sorting	*	Moderately Well/ Poor (1.0)	*
Skewness	*	Negative (-1.5)	*

() The numbers in parenthesis are the numerical values calculated from the sorting and skewness equations

* Data are insufficient to calculate mean, sorting and skewness

TABLE 4. Grain Size Characteristics of the Brickyard Site in Phi Units

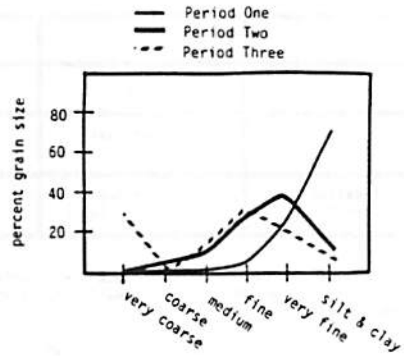

FIGURE 3. Grain Size Distribution Curves at the Brickyard Site

As is typical for beaches, the median grain size became coarser through the winter. What was unusual, howver, was the degree of change from fine to coarse. The Period One sample was 70% silt and clay, and the Period Three sample was only 6.5% silt and clay (see Table 2). Mean, sorting and skewness values could not be calculated due to the high silt content of the Period One sample and due to the high percentage of coarse sediments in the Period Three sample. The reason for the high silt content in Period One is inexplicable; it suggests there are many factors which determine sediment sizes, and this simple analysis is inadequate to list all of these complicating factors. The coarseness of the Period Three sample is more easily explained. Converging cove and bay currents could be responsible for this characteristic. Particles from the cove and particles from the bay could be deposited on the Brickyard Site. The sorting of sediments in Period Two might be poor as a result of these two different sand sources converging on the same point.

What do the data indicate regarding a permanent beach at the Brickyard site? First, the very high silt concentration in Period One suggests that the patterns of sand movement and the reasons for grain size distributions are very complex. On a reconstructed beach, these complexities must be well understood for engineering strategies to be successful in maintaining a sandy beach. Second, the currents converging on this single point may alter typical beach patterns and may require special technologies to ensure beach stability. However, the overriding impact of weather may serve to remove sand from the beach despite man's technologies. Thus, the reconstruction of a beach at this site must take both weather extremes and cove and bay tides into account.

Airplane Site

PERIOD	ONE	TWO	THREE
Mean	1.7	1.5	1.1
Median	2.2	1.4	1.0
Sorting	Poor (1.8)	Moderately Well/ Poor (1.0)	Moderately Well (0.7)
Skewness	Negative (-2.8)	Positive/Nearly Symmetrical (0.1)	Positive (0.14)

() The numbers in parenthesis are the numerical values calculated from the sorting and skewness equations

* Data are insufficient to calculate mean, sorting and skewness

TABLE 5. Grain Size Characteristics of the Airplane Site in Phi Units

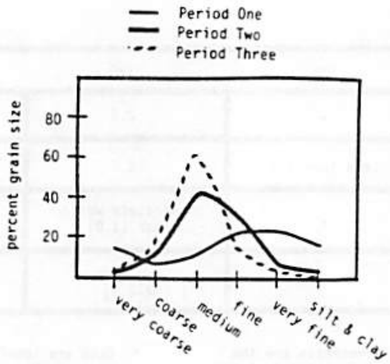

FIGURE 4. Grain Size Distribution Curves at the Airplane Site

About 200 feet from shore, between the Ashby Spit and the Birckyard, rests a "Snoopy and the Red Baron" model airplane. The Airplane Site is situated perpendicular to this airplane and is approximately 250 feet between two storm drains. Perhaps as a result of storm drain run-off, the values for sorting and skewness at this site varied greatly through winter. The mean and the median grain size became coarser through winter, while the samples became progressively better sorted and positively skewed. At no time were "typical" beach patterns demonstrated. As with the Strawberry samples, the drains could have influenced sand distribution patterns. For instance, the poor sorting of sediments in Period One could have resulted from high storm drain run-off. The incrased run-off from the intense rains could have interfered in the back-and-forth wave motion which normally sorts the sediments into grain size categories. The Period Three sample, which was taken after an unusually warm and dry period, was moderately well sorted. The decreased run-off from the storm drains may have subjected the sediments to more wave motions, and thus, may have resulted in the better sorting of sediments.

What do the grain size analyses indicate regarding a permanent beach at the Airplane Site? The storm drains adjacent to the Airplane Site probably directly impact sedimentation dynamics. During intense rains, the drains may have more of an effect than the tide does on sand distributions. On a reconstructed beach, the two drains may deposit or remove sediments in winter, and have relatively little effect in summer. However, a study of sediment flows from the drains should be conducted in both the winter and the summer to test the validity of this hypothesis.

Ashby Site

PERIOD	ONE	TWO	THREE
Mean	1.4	1.7	1.7
Median	2.5	1.8	1.6
Sorting	Poor (1.6)	Poor (1.1)	Moderately Well (0.9)
Skewness	Strongly Negative (-0.7)	Negative/Nearly Symmetrical (-0.1)	Positive (0.11)

() The numbers in parenthesis are the numerical values calculated from the sorting and skewness equations

* Data are insufficient to calculate mean, sorting and skewness

TABLE 6. Grain Size Characteristics of the Ashby Site in Phi Units

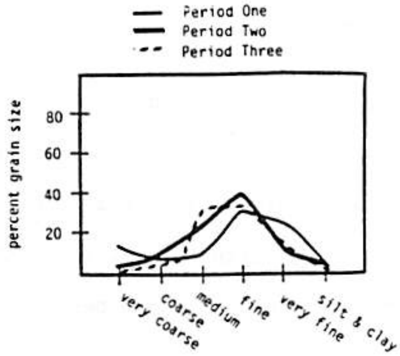

FIGURE 5. Grain Size Distribution Curves at the Ashby Site

At the Ashby Site the results for sorting and skewness for all the samples were different from the "typical" beach characteristics. First, the median grain size became finer through winter, though the general trend of beaches is to a coarser grain size in winter. The Period One and Two samples were poorly sorted, and the Period Three sample was only moderately well sorted. It could be that the spit protects the Ashby Site from full wave action. The sand is thus not subject to sorting from strong tidal influences, resulting in the poor sorting of sediments. For Period Three, the skewness could be positive due to the summer-like weather preceding sampling. The waves would carry less energy, and finer sediments could then accumulate. The winter-to-summer transition from a coarse to a fine median grain size could result in positive skewness.

The Ashby Spit is probably protecting the Ashby Site from full wave action. Thus, a reconstructed beach may be stable at this site. Furthermore, since there is presently exposed beach at the site, it is likely that a reconstructed beach will also be stable.

Conclusion

Even between sites a quarter of a mile apart, there were large variations in grain size distributions. For each site there was a unique set of factors governing sediment sizes. Climatic factors were of particular significance, as were the effects of run-off through the storm drains. Despite the differences between each site, however, several conclusions for the beach as a whole can be drawn:

1. Grain sizes changed dramatically through the winter.
2. The average and the median grain size changed with each measurement taken; the concept of "average" grain size across an entire transect of beach is probably as subject to change as the weather.
3. Drains emptying into the beach and bay have an impact on sedimentation dynamics.
4. The sites located in or near coves experienced the most variability in grain sizes; currents converging on these sites affect sedimentation dynamics.

These four conclusions should be incorporated in a feasibility study before a reconstructed beach at the Berkeley Waterfront is further considered. Although a reconstructed beach at the Berkeley Waterfront is desirable to almost all, no one would enjoy seeing the beach consumed by the bay through erosion. Hopefully, further investigations into beach dynamics will prevent the recurrence in Berkeley of the disastrous Alameda beach experience.

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