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COASTAL EROSION IN SAN DIEGO COUNTY, CALIFORNIA

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Introduction

During the past two decades there has been a tremendous boom of land development along the cliffs at the seaward margins of the coastal terraces of San Diego, particularly to the north of La Jolla. Until enactment of the California Coastal Zone Conservation initiative in late 1972, local agencies frequently permitted construction of single-family residences and multiple-unit residential structures within only a few feet of bluffs and on the beaches. Developers justified this practice by stating that none of these sea cliffs were retreating at an appreciable rate. What was overlooked was that the cited low retreat rates were usually based on only the experience of the last 25 or 30 years, an unusually benign and quiescent time, characterized by low rainfall and few local storms capable of producing heavy surf. Earlier studies of coastal erosion in the area which provided a far less optimistic picture of the stability of sea cliffs were ignored or discounted.

In 1889, during a wet, stormy period which lasted from 1884 to approximately 1893, the United States Coast and Geodetic Survey (U.S.C.G.S.) was conducting topographic and bathymetric surveys along the coast of San Diego County. The U.S.C.G.S. (1889) topographic notes indicate the bluffs showed ". . . new erosion during each winter storm as the characteristic feature of this coast." Additionally, Hanna (1926, p. 233) noted that the cliffs north of La Jolla were actively retreating during the wet and stormy years of the 1920's. Vaughan (1932) also reported that alluvial bluffs near Scripps Institution of Oceanography in La Jolla retreated 10 to 20 feet between 1923 and 1930. Shepard and Grant (1947) found erosion of the same area occurring at a rate of about 1 ft/yr during the stormy periods that preceded 1947.

From various sources summarized in Shepard and Wanless (1971, p. 265), there are indications that cliffs of Eocene and Cretaceous slightly dipping strata have retreated episodically due to large rock falls, although the rock cliffs in many places showed no indication of having had appreciable retreat since photographic records began some half century earlier.

The stormy period with unusually high rainfall that began in early 1978 has considerably changed the picture, especially on the beaches

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and along the bluffs north of Del Mar (Figure 1), extending to Oceanside where much building has been done on the low terrace close to the bluff edge in recent years. Also, the alluvial cliffs near Scripps Institution in La Jolla, which had appeared to stabilize after 1947, became active areas of erosion once again during this same period.

Beginning in 1973 Kuhn (1977) has made extensive and continuing studies of the coastal erosion in the area from La Jolla to San Onofre State Park, including repeated measurements and photographic coverage of critical points. Kuhn has also investigated the erosion history through a search of old maps and land ownership records, and interviews with long-time residents whose families have inhabited these coastal areas for long periods of time. Some of these personal stories of erosion have been verified by examination of old newspaper files, historical maps and old weather bureau reports of storms reported by the residents.

Erosion of the sea cliffs, bluffs and canyon heads is episodic, site specific, directly related to prevailing meteorological conditions and, in recent years, to man's altering of natural drainage patterns.

Historical Aspect

In evaluating the danger of building on the beaches and near the bluff margins, we should not overlook evidence of erosion during the entire century or more that the coast has been occupied by California residents. Examination of old maps, road, railroad and topographical surveys dating back to 1876 indicates that the beaches and the bluffs were markedly different than those of the present day. Perusal of these maps has shown that in the area north of San Diego city limits there are tax assessor records of property that has since ceased to exist. In 1883 Encinitas was the only surveyed town in San Diego County between San Juan Capistrano in the north and the city of San Diego in the south. An extremely stormy wet period began in 1884, following the eruption in August 1883 of the volcano Krakatoa; this wet period lasted until 1893 (Ganus, 1976). During this period entire surveyed blocks of real estate were annually devalued and disappeared at Encinitas. As the seaward block property value decreased, the land parcels directly inland increased. The seaward blocks decreased in value until they were removed from the tax rolls by 1895. Streets were then legally closed by the County Board of Supervisors after the turn of the century.

Since 1884, the Santa Fe Railroad maps and records indicate that tracks have had to be relocated on repeated occasions at several sites due to collapse of the bluffs along the coastline as well as along the river valleys. In particular, the Sorrento valley between Del Mar and Torrey Pines Mesa was hard-hit during February and March of 1884. The San Diego Union of March 2, 1884 states that at that time all telegraph lines were down, the railroad through that area was completely impassable, and that two trains were ". . . hemmed in on one side by landslides in the big Soledad cut, and on the other by the unsafe condition of the track, which is mostly underwater through the whole of Soledad flats." This same valley presently contains not only the same railroad

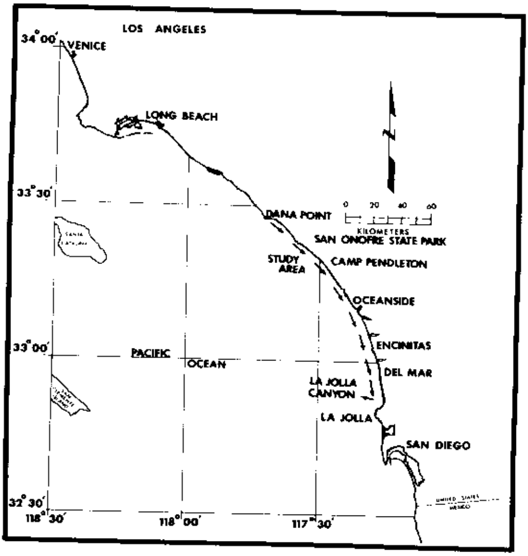

Figure 1. Location map. Arrows indicate predominant longshore sand transport current direction.

line, but portions of major freeways and an extensive industrial development, all in the flood-plain area.

A particularly bad place is in the southern portion of Del Mar where trains have been derailed on various occasions and even fallen over the cliffs. During an extremely stormy period in the winter of 1940-41, the tracks were undermined and a freight train went off the cliff on New Year's Eve, 1940; the cause was a series of heavy rains, large waves and unusually high tides (Kuhn and Shepard, 1979a). Beach cottages were damaged or destroyed along the shore (Figure 2) during the storm, and some additional delayed damage took place at Encinitas. In 1938 the Self-Realization Fellowship temple was built at least 30 feet from the sea-bluff edge. Following the storm period of 1941, the bluff had been weakened by a combination of rain-saturated soil and erosion by wave action, and it collapsed. The temple building was destroyed (Figure 3).

Artificial Coastal Protection

Construction intended to protect the coast, such as groins, jetties, concrete and wooden sea walls, riprap and rock debris, as well as concrete lifeguard towers and buildings, are located along the cliffed shoreline of San Diego County. The erosive effects of improperly located artificial protection, and other structures have not been fully understood, especially during periods of large storms and high tides. It has been observed that where such protective measures project or extend seaward beyond adjacent unprotected lots, there is immediate erosion and notching of the unprotected lots. As beach sand levels fall, storm waves tend to converge on projecting structures and the waves refract toward unprotected lots. Recent examples were seen along the La Jolla Shores, Carlsbad and Oceanside areas (Kuhn and Shepard, 1979b). During the storms of January through April 1978, beach sand levels dipped to a very low point, storm waves and high tides undercut the slope toe, and unprotected lots which were located adjacent to artificial projections were eroded landward in a short period of time (Figure 4). Since 1978 the sandy beach continues to decrease in width and at many locations has been replaced by extensive cobble beaches. The cobbles in turn have greatly accelerated erosion by moving over, and abrading behind existing seawalls, riprap and other structures located along the shore, even during summer months (Figures 5, 6 and 7).

Beach Condition Prior to 1978

Prior to 1900 the sandy beach served as the most heavily traveled "highway" along the California coast. During the 1880's the coastal sand beaches varied in width from 100 to 300 feet (Figure 8). The U. S. Coast and Geodetic Survey (1889) noted that " . . . from Mussel Rocks [Bathtub Rock at Torrey Pines] there is an unbroken sand beach for forty or fifty miles or as far north as the valley of San Juan Capistrano and in former times this stretch of beach was used whenever specially fast time [was] to be made on the route Los Angeles, via Capistrano, to San Diego." Wide, sandy beaches existed along this shore until the early 1940's.

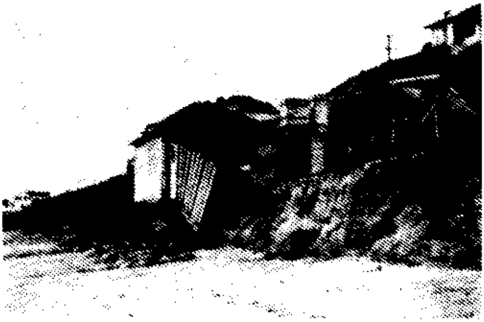

Figure 2. Beach cottage was damaged at Carlsbad during a severe sea storm in 1941. Note: In recent years apartments and homes have been constructed at this site. Photo courtesy of Shore Processes Lab, Scripps Institution of Oceanography; January 5, 1941.

Figure 3. Collapse of Self Realization Fellowship temple along bluff at Encinitas following stormy period in the winter of 1940-41. Photo courtesy of Self Realization Fellowship; 1941.

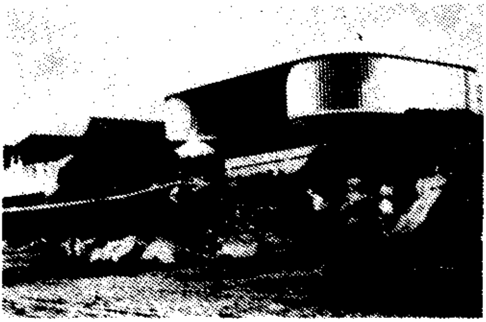

Figure 4. March 1978 view of the eroded beach at Del Mar, California. The wooden seawall collapsed and the adjacent unprotected lots were eroded. Photo courtesy of Sea Grant; March 5, 1978.

Figure 5. 1980 view of a site in Carlsbad eroding even during the summer. Beach cobbles have eroded behind and around seawalls and riprap and adjacent to building along the shore. Photo courtesy of Sea Grant; July 25, 1980.

Figure 6. (Before.) Beach cobble abrasion along the shore at South Oceanside. The cobbles moved up the beach 18 to 20 ft and covered riprap seawall in places, and eroded the lawns directly behind. Photo courtesy of Sea Grant; January 1978.

Figure 7. (After.) Same view at South Oceanside in June 1978. Only remnant pockets of cobbles remain. Photo courtesy of Sea Grant; June 1978.

The sandy beaches which still exist along the cliffs north of Oceanside at San Onofre State Park and Camp Pendleton, are the result of both man-induced and natural causes (Kuhn, Baker and Campen, 1980). During the recent wet years of 1978-80, erosion has accelerated at canyon heads. Placement of storm drains and culverts beneath the railroad bed and highways have increased erosional rates by concentrating surface water runoff along pre-existing drainage avenues. Also, landslides and blockfalls have occurred during this period, contributing sediment to the beaches.

Today the formerly wide sandy beaches south of Oceanside have, for the most part, been replaced by beach cobbles resting on exposed bedrock outcrops. This is the result of numerous factors, both natural and man-induced. 1) Agricultural storage dams have been constructed on the principal rivers in San Diego County, thus cutting off the sand transport to the beaches (Inman, 1976). 2) No flood of any significance has occurred on the undammed segments of the river basins during the previous forty years, and consequently very little sediment has reached the coast. 3) In 1942 the Camp Pendleton Boat Basin was constructed directly north of Oceanside and began silting up immediately following construction (Figure 9).

Erosion from January 1978 through August 1980

Beach Cobble Abrasion:

Beach cobbles found along the shore in San Diego County are derived from both the rivers in flood and also directly from the bluffs at some localities (Emery, 1955, 1960, p. 184).

During the 1880's lenses of these rocks were so extensive that at one location across the mouth of Penasquitas Lagoon south of Del Mar, a "beach shingle railroad siding" was installed by the Santa Fe Railroad to mine the beach stones for street-paving material in the city of San Diego. During the early part of this century two other sites in northern San Diego County were "mined" to obtain abrasives.

In 1963 approximately 3000 x $10^3 m^3$ of sedimentary material (clay, sand and cobbles) was dredged from the Oceanside Harbor and placed on the beaches to the south. During the destructive winter storms of 1977-78 the buffering sand beach was rapidly removed at Oceanside as the result of wave action and high tides. Beach cobbles became exposed, were withdrawn by the waves and then thrown toward buildings located at the top of the former beach. Again in the winter of 1980 the cobbles were a destructive element, this time contributing to the undermining and collapse of the beach road, and damage to apartments and homes along the shore (Figures 10 and 11).

Another occurrence in 1978 and again in 1980 was that sea caves and weak shear zones and loosely-cemented bedding planes were seen to enlarge as cobbles abraded these weak sites during periods of high surf and high tides.

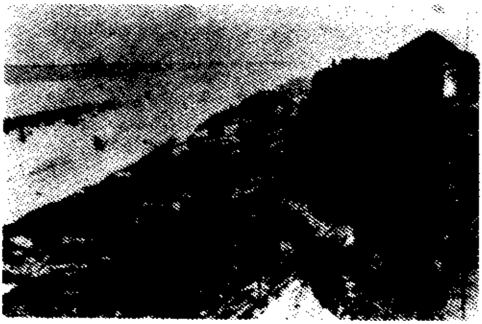

Figure 8. View in 1885 looking north along the eroding bluffs and the extremely wide sandy beach at Oceanside, California. Note: The Oceanside pier is presently located at the same location as the building seen in the photo. Photo courtesy of Scripps Institution of Oceanography; July 4, 1885.

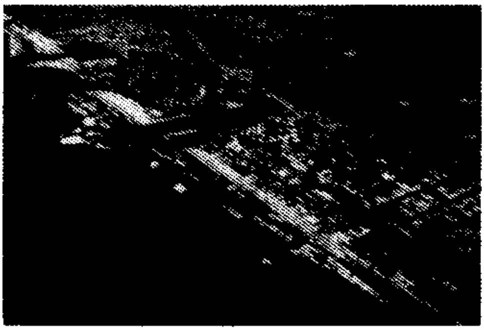

Figure 9. 1980 aerial view looking north across the City of Oceanside toward the Camp Pendleton Boat Basin and Oceanside Harbor. Note that the width of the beaches markedly decreases to the south of the harbor. Photo courtesy of Sea Grant; February 23, 1980.

Figure 10. (Before.) 1978 photo of beach cottages located south of Wisconsin Street in Oceanside. Photo courtesy of Sea Grant; January 4, 1978.

Figure 11. (After.) Same view in 1980 showing wave and beach cobble abrasion which damaged houses along the shore during the storms in February 1980. Property damage occurred with only 4-6 ft. swell. Photo courtesy of Sea Grant; February 17, 1980.

Erosion Due to Increased Ground Water:

As an indication of what can be found by careful study of areas where casual study had suggested that there was little or no coastal erosion, we cite the results of work north of Del Mar, where many sections of the cliffs collapsed between 1973 and 1977 (Kuhn and Shepard, 1979b). Failure involved both landslides and block falls. For the most part, collapse of the cliffs along this section occurred as instantaneous failures, where masses separated from the cliff face along fractures, joint sets and contact planes. During the dry years from May 1973 to December 1977, at least 25 block falls occurred along the cliffs at Encinitas. Measuring from the cliff face landward, these blocks varied in dimensions from 1 to 12 feet across, 5 to 110 feet in length, and a maximum of 32 feet in height.

These failures are partially related to the undercutting of the sea cliff, but more importantly to a recent steady rise in ground water levels along the sea cliffs. This rise is occurring commensurate with urbanization along, and inland of the sea cliff. It is a result of excessive watering of lawns, and the attempt to grow non-native vegetation; of agricultural irrigation, septic tanks, leach lines and cess pools. Sorben and Sherrod (1977) indicate that the over-irrigation of landscaping in residential subdivisions alone is the equivalent of 50 or 60 inches of precipitation per year.

This extensive watering in the coastal area has had at least three important effects: It has caused a slow but steady rise in the water table even during the dry period preceding the heavy rains of 1978, and this has added weight to the cliff material which contributes to development of landslides; it has lubricated surfaces along which slides and block falls are initiated; and in some cases it has greatly increased solution in the underlying rocks.

Specific sites which experienced erosion during the drought years prior to 1978 have continued to collapse. Along the cliffs at the Self-Realization Fellowship property in Encinitas a large section of the cliff face separated along parallel joint sets and collapsed on April 26, 1978 (Figures 12 & 13). This recent failure measured 12 to 16 feet landward, 112 feet in width, and a maximum of 40 feet in height. Following the collapse, springs were seen to flow from the cliff face. This is the same site where the cliff collapsed during the 1940's and the temple was lost. Saint and Turner (1980) investigated conditions at this site, including the 1941 and 1978 events, and indicated that the cliffs in this area are subject to collapse as the result of a combination of factors. They stated that ". . . the large blocks, bounded by weakened joints, fractures and bedding planes move out laterally following a build up of pore pressure under the attack of wave action."

Because of the heavy rains in early 1978, cliffs that had been relatively stable were again subject to considerable retreat. A notable example is the low Quaternary alluvial cliffs south of Scripps Institution of Oceanography, which seemed to have stabilized during the dry period from 1947 to 1977. The series of houses built along the edge of these

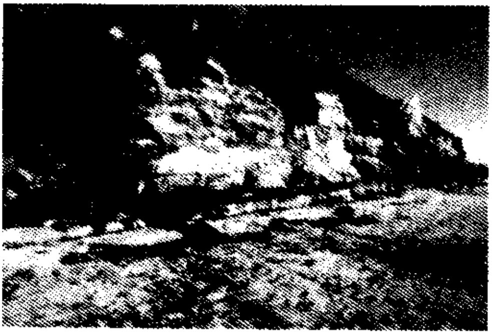

Figure 12. (Before.) 1978 photo looking southeast along the base of the cliff at the Self Realization Fellowship at Encinitas, California. Photo courtesy of Sea Grant; February 3, 1978.

Figure 13. (After.) Same location seen following the cliff collapse of April 26, 1978. Photo courtesy of Sea Grant; May 2, 1978.

low cliffs, mostly without sea walls or any adequate protection, were subjected to erosion in January, and again in February 1978. As the rains continued and the beaches were washed out by a combination of high waves and perigean spring high tides, as well as by the erosion of rain gullying, erosion again occurred along these cliffs. The residents were threatened with loss of their property and went to desperate measures to stop the erosion. Old car bodies were placed at the slope toe, and later riprap was placed at these sites and cemented in place; temporary sea walls were installed. This was only partially successful as the houses had to be reinforced in various places to prevent their collapse. Adjacent unprotected lots were more severely eroded during the storm period. In 1979 a concrete seawall was constructed along most of this area.

Man-Induced Erosion:

Accelerated headward erosion is taking place along existing paleo-drainage avenues where culverts have been constructed under the railroad track and highways at San Onofre State Park and Camp Pendleton (Kuhn, Baker and Campen, 1980). Between 1885 and 1980, normal erosional drainage avenues have been drastically altered by man. In 1885 the Atcheson-Topeka & Santa Fe Railroad Company constructed trestles across existing gullies and canyons. These structures were designed to span channels and did not appreciably alter the existing drainage patterns. During construction of California State Highway 101 in 1912-1918, culverts were installed under the highway in order to control surface runoff under the road and down the canyons during periods of heavy rainfall. In the wet years following installation of these drains, erosion of gullies accelerated where these structures concentrated flow.

During construction of Interstate 5 in the late 1960's, large culverts and storm drains were installed directly below the San Onofre watershed and east of old Highway 101. These drains concentrated the surface runoff from numerous adjacent drainage avenues, directing it parellel to the highway and then west into culverts under Highway 101. No severe wet years occurred after completion of Interstate 5 until 1978. During January through April 1978, however, rainfall was greater than normal and headward erosion along these altered drainage avenues accelerated greatly. At Horno Canyon the southbound lanes of Highway 101 collapsed, leaving a 75-ft deep vertical scarp.

At one location no canyon existed perpendicular to the shoreline prior to the 1969 storms (Figure 14). However, between 1968 and 1976 a new canyon began to cut headward, reaching headward about 60 feet. During January and February of 1978 approximately 160 feet of headward erosion occurred. On February 14, 1980, another 5 ft of headward erosion occurred, and on the 20th of February, during one day, the canyon actually eroded approximately 235 ft landward, 50-100 ft deep and 60-90 ft in width (Figure 15). This amounted to approximately 50,000 cubic yards of sedimentary material which moved immediately out onto the beach.

Figure 14. (Before.) 1968 vertical aerial photograph of a canyon along the bluffs at San Onofre State Park in northern San Diego County. Prior to this time only a notch existed perpendicular to the shoreline at this site. Photo courtesy of U. S. Navy; 1968.

Figure 15. (After.) March 1980 vertical aerial photograph showing development of 460 ft canyon perpendicular to the shoreline. It was actually cut 235 ft on February 20, 1980 alone. Photo courtesy of U. S. Navy; March 1, 1980.

Dead Dog Canyon, south of Horno Canyon on Camp Pendleton, experienced approximately 560 ft of headward erosion between 1932 and 1977. This same canyon eroded another 100 feet during a two-week period during January and February 1978 (Berggreen, 1979) and approximately 100 feet in February 1980.

These are but two examples of the man-induced rapid headward erosion during wet years that can occur in canyons located perpendicular to the shoreline. Rapid degradation of the bluffs also occurs wherever fences, stairways, lifeguard towers and storm drain pipes are located along former drainage avenues. Surface water tends to adhere and flow along the underside of such structures, thus eroding the bluff face. At Carlsbad State Park numerous beach stair accesses have been undermined and storm drains collapsed between 1978-1980 (Figures 16 and 17).

Bluff-Top Grading:

The grading of the bluff tops, in many cases to the edge of the slope, initiates slope failures in the sea bluff and creates drainage avenues along which further surface runoff erodes the bluff-top edge and the bluff face. It has been observed that where the existing terrace deposits and soil profile are left intact and surface drainage is diverted, the bluff edge appears to erode very slowly (Figure 18). In 1971-72 along south Solana Beach the bluff top was lowered by excavation by 15 to 18 ft and surface water was allowed to run over and down the bluff face. The upper slope continued to collapse during and following heavy rainfall. The base of the cliff along this site eroded 8-10 ft between 1972 and 1978 (Figure 19).

A condominium homeowner's association connected with the property threatened at this location has spent in excess of $1.5 million since 1978 in an attempt to forestall and retard future erosion. A concrete seawall was constructed along the slope toe and concrete "cribbing" was installed along specific sites in the unconsolidated bluff face (Figure 20). In early May 1979, the week that the concrete "crib wall" was expected to be finished, the entire structure rotated and collapsed, leaving the debris and sediment resting on the seawall below (Figure 21).

Another cliff collapse also occurred following extensive grading of the bluff top along the cliffs at Scripps Institution of Oceanography. The Quaternary cliffs in front of the Marine Biology building retreated 54 ft between 1912 and 1975 (Hannan, 1975). During extensive grading of the bluff top in 1975 the cliffs collapsed 5 to 8 ft landward.

The importance of grading in relation to construction and the removal of protective vegetation and case-hardened surface materials has also had an important effect and is clearly indicated where areas have been used for construction along bluff margins.

Conclusions

The popular concept of an average coastal-retreat rate for the evaluation of developmental projects is open to serious questioning, at

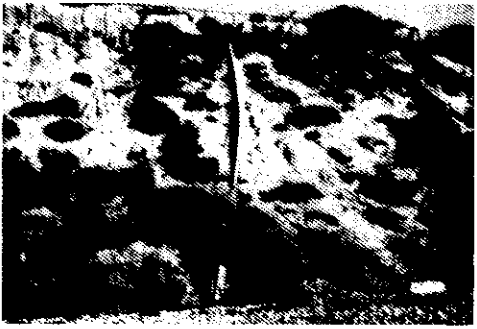

Figure 16. (Before.) 1977 view of storm drain designed to carry surface water down and away from slope face at Carlsbad State Park, California. Photo courtesy of Sea Grant; December 17, 1977.

Figure 17. (After.) 1979 view at the same location following the collapse of storm drain pipe, and severe gullying of bluff face. Photo courtesy of Sea Grant; February 11, 1979.

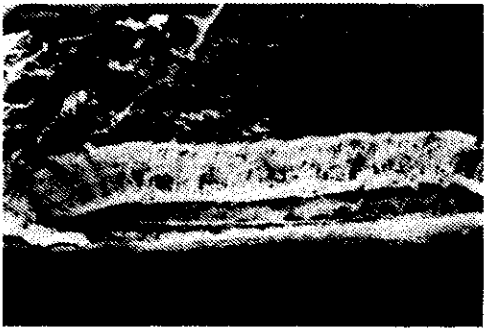

Figure 18. (Before.) 1954 oblique aerial view of a portion of South Solana Beach, California prior to bluff top development. Photo courtesy of Shore Processes Lab, Scripps Institution of Oceanography; 1954.

Figure 19. (After.) Same view in 1974 after development. Photo courtesy of B and A Engineering; June 1974.

Figure 20. (Before.) April 1979 view of concrete "cribwall" being installed on bluff face at Solana Beach, California. Photo courtesy of Sea Grant; April 23, 1979.

Figure 21. (After.) May 1979 view of same site following "cribwall" collapse. Photo courtesy of Sea Grant; May 4, 1979.

least in the San Diego region and probably elsewhere. Sea-cliff and bluff retreat is episodic, site-specific, and strongly related to the meteorological conditions, induration and stability of rock formations within a given area, and to a combination of erosive agents, both natural and man-induced, that may act upon them.

Both canyon head erosion and landslides are presently contributing significant quantities of sand to the beaches at San Onofre State Park and Camp Pendleton, north of Oceanside. It had previously been believed that most beach sand along the shore in San Diego County was supplied by rivers in flood, with only minor contributions from other sources.

A combination of continuing detailed observations in selected areas, detailed mapping on a large scale, careful review of historical records, and consideration of rock structures and competence along with hydrological considerations gives us the opinion that much of the coastal bluff area of San Diego County is a hazardous area for building, particularly near bluff edges.

Acknowledgments

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