CHAPTER 362

San Gabriel River to Newport Bay Erosion Control Project
Orange County, California
30 Years of Periodic Beach Replenishment

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Abstract: Monitoring of a Beach Erosion Control project consisting of a protective and feeder beach with periodic beach nourishment in Orange County, California is assisted with Computer Aided Design and Drafting technology. Time series of depth changes and profile volumes are analyzed, and predicted renourishment requirements compared to 31 years of project history.

Introduction

The U.S. Congress authorized an erosion control project in 1962, recognizing the impacts of flood works, coastal harbors and other factors in causing beach erosion along the northern Orange County, California shoreline. With legislatively established cost-sharing between the State and federal government, an initial beachfill was constructed in 1964, with periodic nourishment in 1971, 1979, 1984, 1989-90 and 1996-97. Future beachfills are projected to be needed on a 5 year cycle, indefinitely.

The construction of the project was modified from the originally formulated plan with the use of sand sources of opportunity, the addition of a groin field, and deferring a detached breakwater/sand trap feature. A comprehensive analysis was performed of available profile data to compute the shoreline and volumetric history from pre- and post project to the present. This analysis was compiled by meticulously reconstructing historic data from the 1960's to the present to create controlled digital terrain maps which can easily be analyzed with CADD software.

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Project History

The erosion control project formulated in the 1960's consisted of a protective and feeder beach to be located at the updrift end of the littoral cell at Surfside and Sunset Beach, with periodic beach nourishment by back-passing from the downdrift end of the cell near the Santa Ana River. The project area of approximately 20 km alongshore had a planned fill volume of three million cubic yards (mcy) for the initial protective beach, and a projected periodic renourishment rate of 1.75 mcy every five years. A detached offshore breakwater was also planned as a sand trap to be located at the downdrift location. The overall project plan is shown on Figure 1.

The initial protective and feeder beach was built in 1964 with four mcy of material from the adjacent Anaheim Bay/Seal Beach Naval Weapons Station (NWS). Between the initial fill and 1995, four renourishment cycles and three dredging projects of the NWS placed 8.6 mcy of dredge material - measured at the dredge site - at the feeder beach, as listed in Table 1. Of dredge material, 5.0 mcy were borrowed from offshore dredge pits. Photos 1 and 2 show typical pre and post beachfill conditions.

Construction of the detached breakwater/sand trap is deferred pending a demonstration of need, and no backpassing from the downdrift beach area has been performed. A groin field and beachfill at west Newport Beach was added to the project and constructed between 1969 and 1973. Eight groins were constructed and their cells filled with about 1.5 mcy of beachfill from the Santa Ana River or the adjacent Balboa peninsula.

Table 1 Surfside-Sunset Beach Fills (1963-90)

Completion Date	Dredge Volume (cy)	Cumulative Volume (cy)	Description /Borrow Sit
June 1964	4,000,000	4,000,000	Stage 1/Seal Beach NWS
May 1971	2,260,000	6,260,000	Stage 4A/Seal Beach NWS
June 1979	1,644,000	7,904,000	Stage 7/Offshore Borrow Pit
May 1983	400,000	8,304,000	Deepening NWS Channel
April 1984	1,500,000	9,804,000	Stage 8/Offshore Borrow Pit
April 1984	783,000	10,587,000	Seal Beach NWS
March 1989	180,000	10,767,000	Deepening NWS Channel
June 1990	1,300,000	12,067,000	Stage 9/Offshore Borrow Pit
Sep 1990	522,000	12,589,000	Stage 9/Offshore Borrow Pit

Analysis Methodology

Commercial Computer Aided Drafting and Design (CADD) software, MicroStation and InXpress from Bentley Systems, Inc., were utilized in creating digital terrain models (DTM) of the beach and nearshore hydrography. The CADD design files (.dgn) and digital terrain models (.dtm) are full scale models referenced to the California State Plane Coordinate System (SPCS27, Zone 6) as described in Stem(1989). The coordinate system was chosen for compatibility with an existing Geographic Information System (GIS) database made

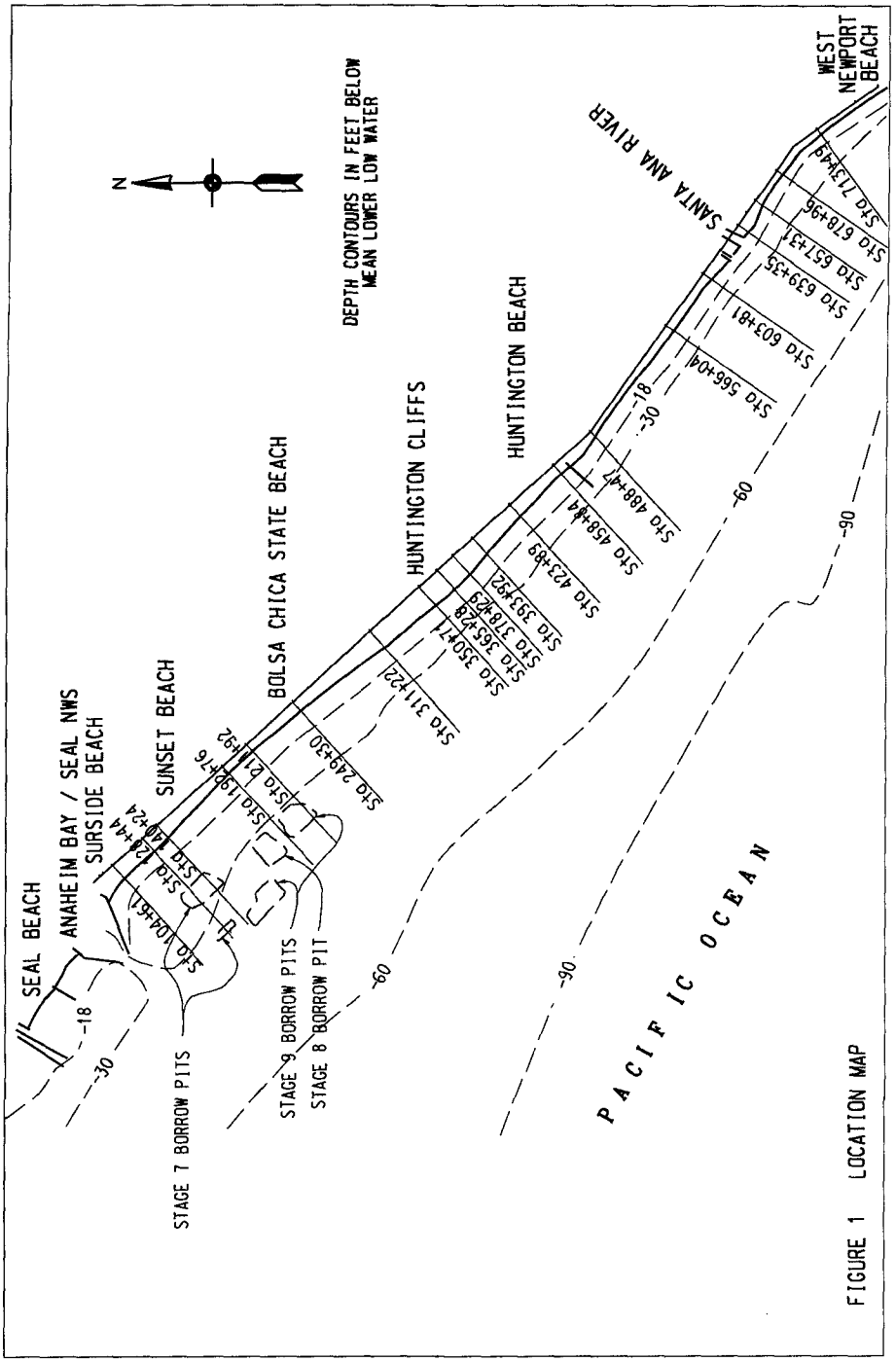

FIGURE 1 LOCATION MAP

PHOTO 1 Feeder Beach Area - Post Stage 7 Beachfill (Oct 31, 1979)

PHOTO 2 Feeder Beach Area - Pre Stage 8 Beachfill (April 16, 1982)

available by Orange County, California, allowing overlays of the beach profile data to map data having property line resolution and orthogonally rectified aerial photography. Programs, such as CORPSCON developed by the U.S. Army Corps of Engineers Topographic Engineering Center, are available for conversion to any of the common horizontal datums with an accuracy as good as the original positioning data. The vertical datum used for all of the analysis is mean lower low water.

Available surveys used to construct DTM models, also referred to as Triangulated Irregular Network (TIN) models, include condition surveys, and pre- and post construction surveys of the San Gabriel River to Newport Bay Beach Erosion Control project; dredging of the Seal Beach NWS; the Santa Ana River Mainstem (SAR) project; the Coast of California Storm and Tidal Wave Study (CCSTWS); and surveys of the National Ocean Survey (NOS) conducted along the coasts in 1934 and 1975-77. Surveys were performed with varying degrees of spatial coverage and resolution, as well as duration. The recent profile surveys (1990's) were collected in time periods as short as a week while the 1960's surveys were collected over several months and the NOS surveys collected over multiple years. A tabulation of surveys utilized are listed in Tables 2 and 3.

After the tedium of reconstructing survey notes to the SPCS27 datum and data input into the DTM models, analysis alignments or baselines and control volumes were established. Volume estimates can be made with three different computational methods: 1) surface to surface comparisons between each facet of TIN models, 2) comparison of gridded surfaces fit to the TIN models, and 3) the traditional average-end area method applied to cross-sections of an alongshore alignment. The surface to surface approach provides the most numerically precise computation of the available data, however, the most useable volumetric comparisons were provided by the average-end area method with carefully selected sections located near surveyed profile lines. The reason that the surface to surface or gridded model computed erroneous results were due to differences in alongshore spacing of profiles between the different surveys resulting in the comparison of measured to interpolated surfaces. Interpolation of the beach profile across even slight embayments can result in large errors. The location of the selected sections used are shown on Figure 1. Sample cross-sections generated from the TIN model are shown on Figure 2.

Closure Depth and Profile Control Volume

The depth of closure, "pinch-out" depth, or location where measurable depth changes do not occur could not be readily found in the profile comparisons. Some reasons why the profiles have significant depth changes in deeper than typical depth of closure water depths are the dredge borrow pits, nearshore dredge material disposal, and subsidence associated with mineral extraction, besides natural sediment transport occurring on the nearshore shelf. The depth of closure concept defined as the seaward limit of significant sediment transport is a misnomer since near-bottom wave induced currents do mobilize large volumes of sediment, and small depth changes on the nearshore shelf result in large volume changes in comparison to the volumes contained on the beach and within the limits of the surf zone. Utilizing a depth of closure concept as a control volume boundary in plan, with its location determined from an abrupt change in the standard deviation of a time series of elevation is a more useful definition along this coastline. This boundary approximates the seaward limit of "significant" wave generated longshore currents and is numerically more consistent with

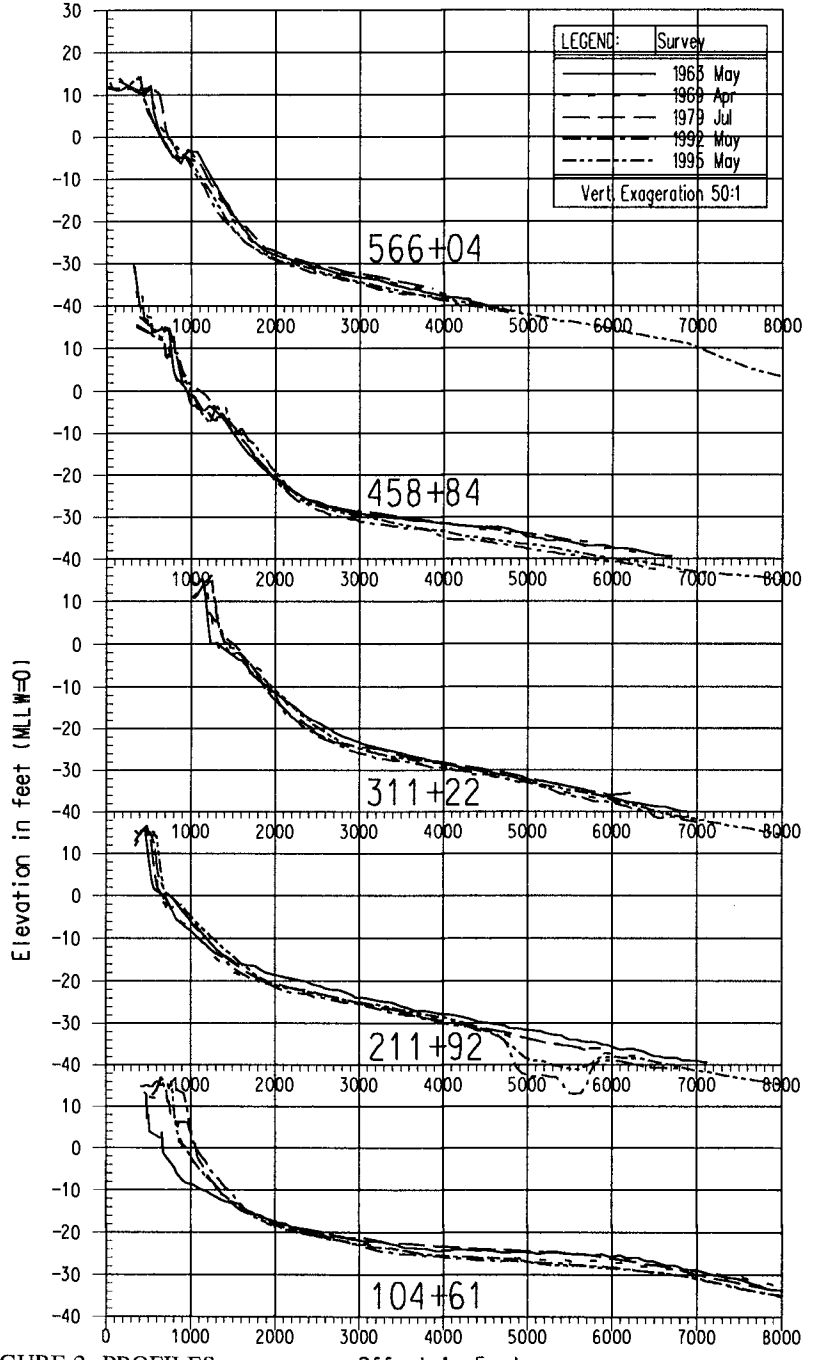

FIGURE 2 PROFILES

values estimated from formulae and wave statistics, ie. the 12-hour annual wave at Huntington Beach of 233 cm based on four years of observation results in a computed depth of closure of 16 feet (Hallermeir, 1981). It also does not have to assume a priori insignificant sediment transport across the boundary.

Table 2 Surveys between 1963 and 1993

Date of Survey	Construction Activity and Survey Coverage
1963 May-August	Pre-Stage 1. Seal Beach to Newport Bay.
1964 July	Post Stage 1. Surfside to Bolsa Chica.
1966 October	Condition Survey. Seal Beach to Newport Bay.
1969 April	Condition Survey. Seal Beach to Newport Bay.
1971 June	Post Stage 4A. Surfside to Bolsa Chica.
1973 May	Post Stage 5. Bolsa Chica St. Beach to Newport Bay.
1978-79 Dec-Jan	Pre-Stage 7. Surfside to Newport Bay.
1979 June	Post-Stage 7. Surfside to Newport Bay.
1982 April	Condition Survey. Seal Beach to Newport Bay.
1982-83 Dec-Jan	Condition Survey. Seal Beach to Newport Bay.
1987 December	Condition surveys and
1988 October	pre- and post-dredge
1989 March	surveys of Anaheim Bay and the
1993 October	approach channel to Anaheim Bay
1990 January	Stage 9 Borrow Pit pre-dredge.
1990 June	Stage 9 Borrow Pit interim post-dredge.
1990 July	Stage 9 interim pre-dredge and beachfill.
1990 September	Stage 9 Borrow Pit post-dredge.
1993 October	Surfside nearshore condition survey.

Table 3 CCSTWS and SAR Survey Dates

Coast of California Surveys	Santa Ana River Surveys
1992 February	1991 December
1992 May	1992 May
1992 November	1992 July
1993 May	1992 November
1993 October	1993 Mar
1994 April	1993 May
1994 November	1994 January
1995 May	1994 November

Figure 3 shows the mean, range and standard deviation of elevation along a profile through the feeder beach at Surfside Beach. Elevation statistics were computed separately for the Feb 1992 to May 1995 time period and the 1963 to 1983 time period because of the differences in collection methodology and sampling interval between the two data sequences

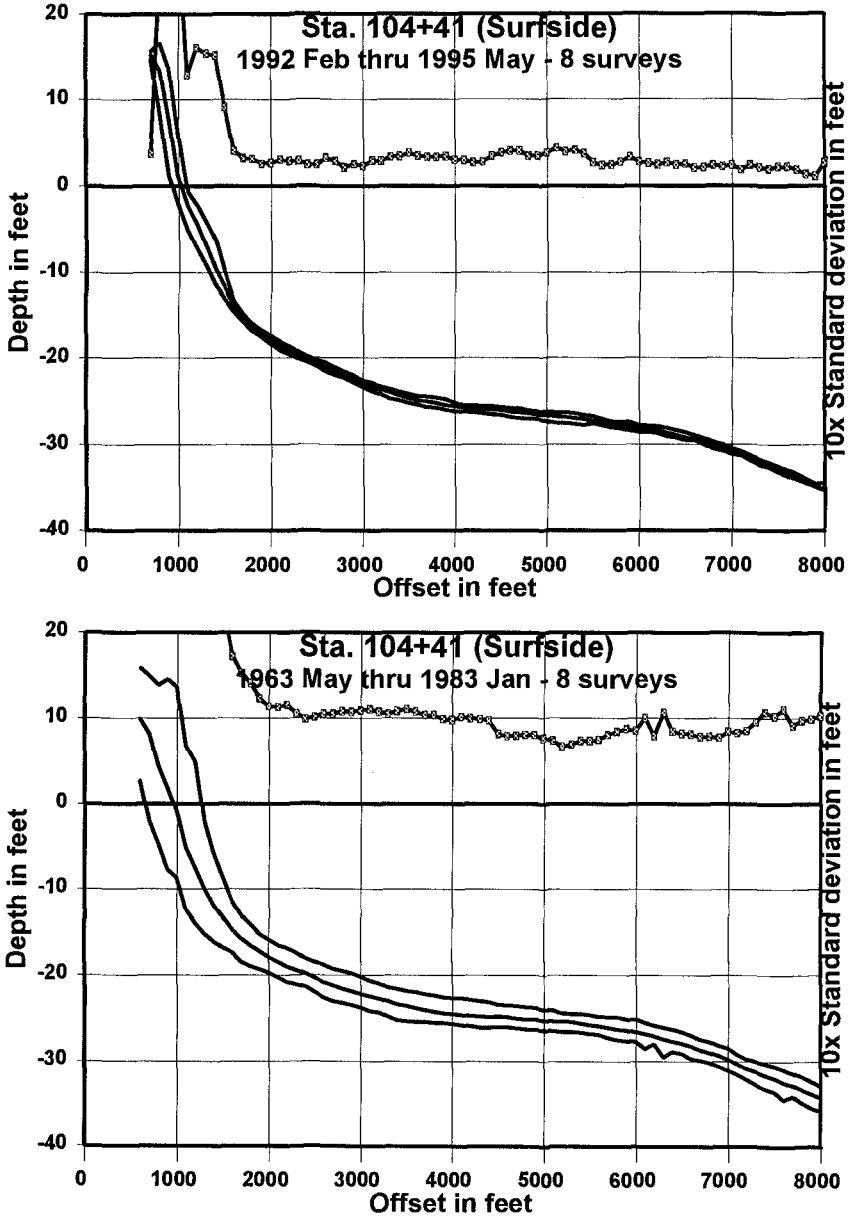

FIGURE 3 MEAN, RANGE and STANDARD DEVIATION of PROFILE DEPTH

-- ie. multiple surveys per year compared to multiple years per survey. For the recent 3-year period, a depth of closure boundary is at approximately -16 feet, while for the 20-year period it is at approximately -20 feet. This depth of closure also coincides with the boundary between the shoreface and nearshore shelf. Alongshore variation of depth of closure ranges from about -16 to -28 feet, the deepest being located offshore of Huntington Cliffs and Huntington Beach.

A control plan area was defined for profile volume computation. This area is bounded by the landward limit of overlapping survey coverage on the back beach, but below the toe of the coastal cliffs, and the location of the 20-foot depth contour of the 1963 survey -- although a seaward boundary that varies with depth by alongshore location could have also been applied.

Profile Volume and Volumetric Changes

Profile volumes, contained within the control volume plan limits defined by the survey limit along the beach backshore and the -20 foot contour, are averaged with ranges and deviations computed as shown on Figure 4 by alongshore stationing. These profile volumes, in cubic yards per alongshore foot of beach, have a zero mean over the available surveys. Relatively large standard deviations in profile volume occurs for sections through the Surfside-Sunset feeder beach (Sta 100 to Sta 140) and south of the Santa Ana River Mouth (Sta 630) with values of about 190 cy/ft and 110 cy/ft, respectively. These large variations are due primarily to beach nourishment, groin field and nearshore berm construction (see Mesa, Paper No. 330). Along the remainder of the shoreline, where natural transport processes predominate, the standard deviation of profile volume averages approximately 60 cy/ft.

End-area volumes contained in the control volume described above and relative to the 1963 survey are shown in the format of a mass-haul diagram in Figure 5. Volumes, by date, are cumulative alongshore starting at Anaheim Bay (Sta 97+71) progressing southeasterly to West Newport Beach and the Newport submarine canyon (Sta 757+74). A positive, flat or negative slope of the diagram indicates an accreted, stable or eroded profile volume, respectively, relative to pre-project condition in 1963. The effects of the initial 4 mcy beachfill can be seen in the July 1964 survey, which shows a profile volume gain of about 3 mcy along Surfside-Sunset Beach (Sta 100 to Sta 200). Other general observations from this diagram are that the total profile volume accreted between Anaheim Bay and the Santa Ana River (Sta 100 to 630) for all surveys compared to 1963; a slight erosional trend is observed in the Huntington Cliffs area (Sta 350 to 410); and with the exception of Dec 78 and Jan 83, both abnormally severe storm years in addition to being surveys before renourishment stages, the profile volume along most of the shoreline has been stable or accretional. The sharp increase in alongshore volume at the Santa Ana River mouth in 1969 is the result of a broad delta created by the flood flows earlier that year. A similar increase shown in the 1992 through 1995 surveys are due to construction of a 1.3 mcy nearshore berm (1992), and groin field and beachfill (1970's) at West Newport Beach.

Other control volumes were defined such as the area bounded by the back beach and the MLLW datum plane (dry beach volume), and the nearshore shelf area bound by the -20 and -30 foot contour in 1963. The dry beach volume follows similar trends to that of the profile

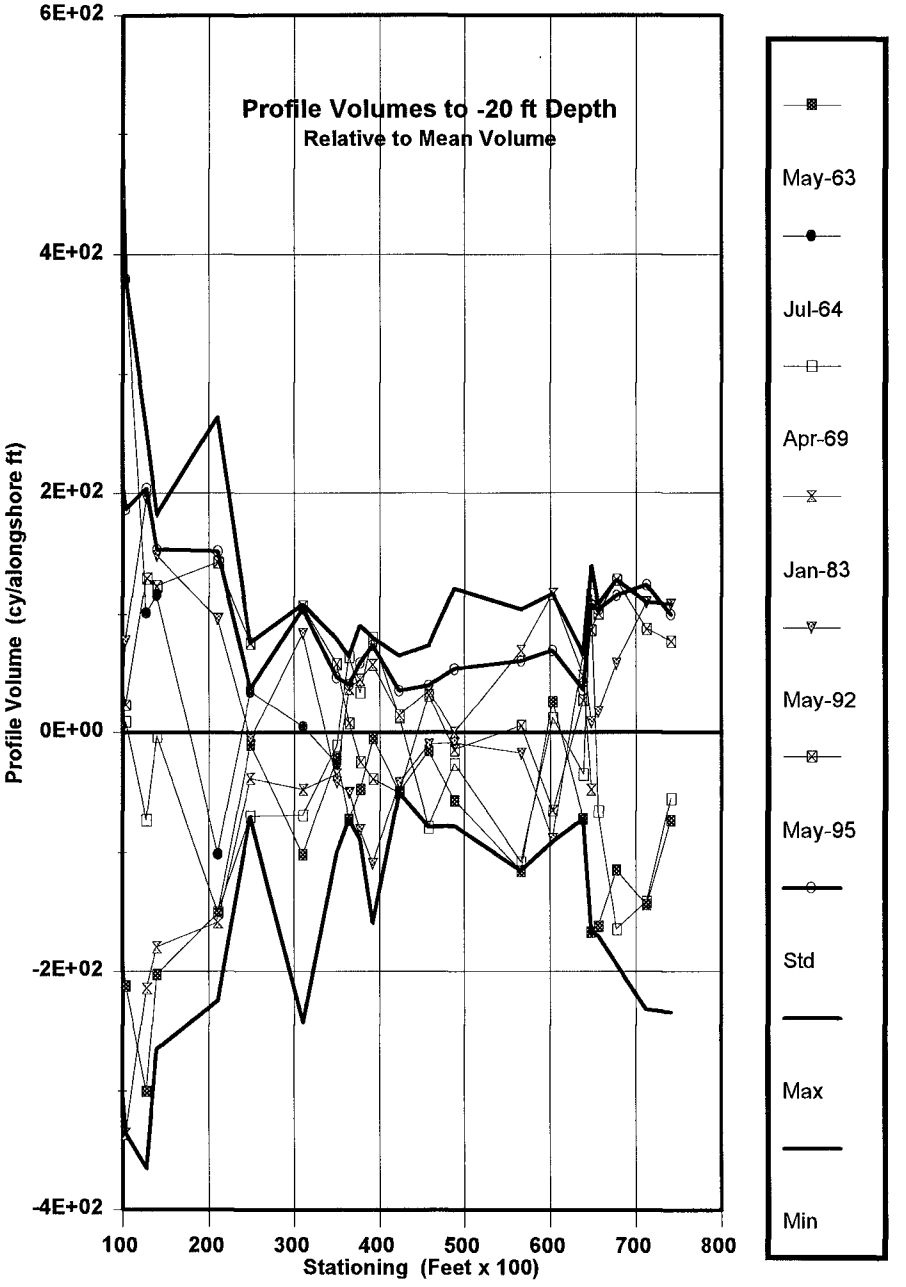

FIGURE 4 PROFILE VOLUMES

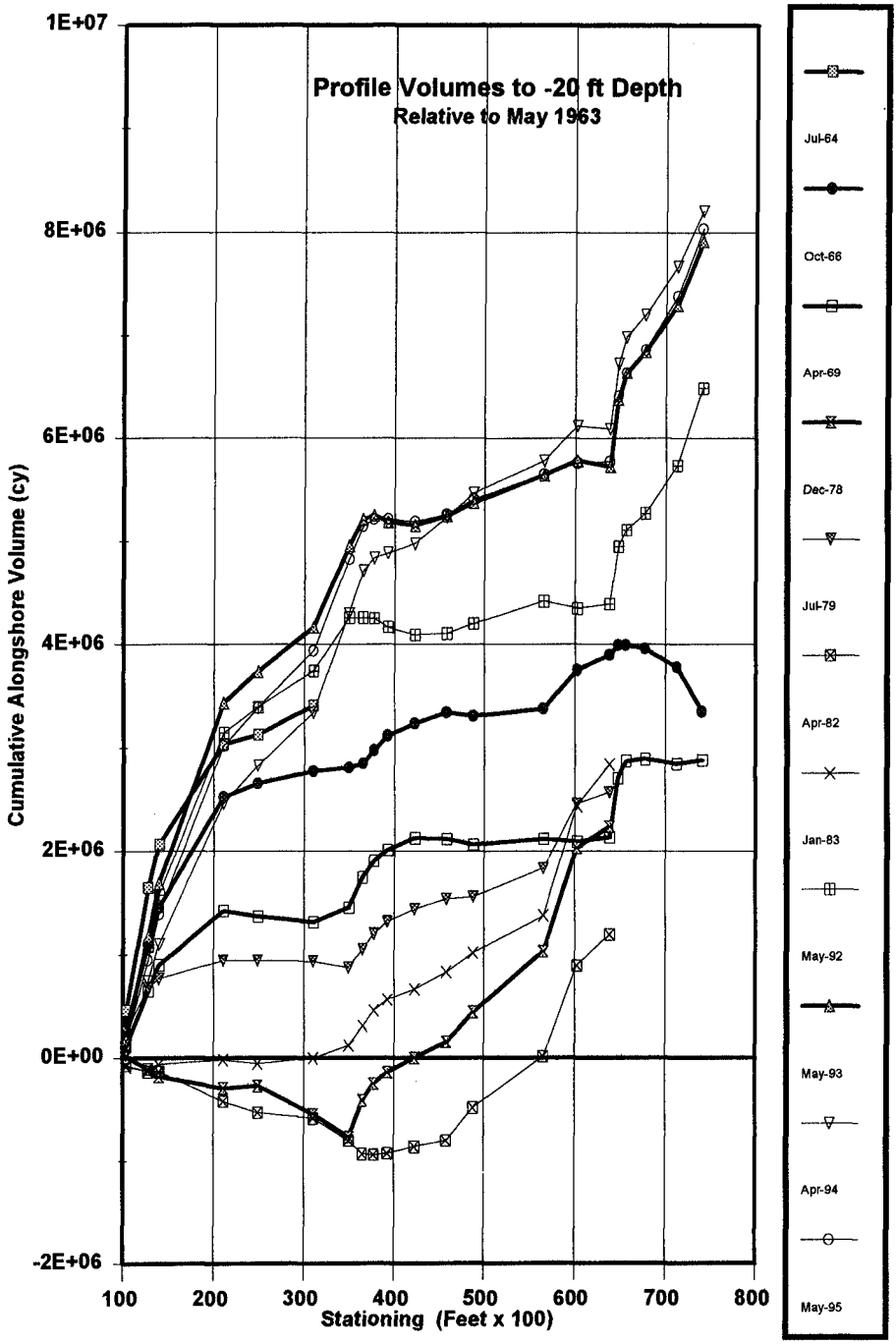

FIGURE 5 CUMULATIVE PROFILE VOLUMES

volume of the -20 foot depth, whereas, the nearshore shelf (-20 to -30 ft) has experienced deepening over a large portion of this coastal segment. Some of this deepening is the direct result of sand mining for beach replenishment while other deepened areas appear to be directly related to subsidence associated with mineral extraction. The latter has been documented through differential leveling along the coast highway and is most evident in comparison of the 1934 to 1975 NOS nearshore hydrography.

Conclusions

Available surveys for the northern Orange County coastal segment have been analyzed with the use of CADD and triangulated irregular network models. Historic surveys with U.S. Coast and Geodetic Survey control can be reduced and used to build a shoreline and profile history database accessible to GIS systems. State Plane Coordinate Systems can be easily related to geodetic coordinates allowing utilization of data from multiple historic sources. Once the TIN models are created, time series of depths, volumes and shoreline positions can be queried for analysis.

As for the San Gabriel River to Newport Bay Erosion Control Project, monitoring over 30 years of beach nourishment has shown a transport rate from the feeder beach to be remarkably close to the originally projected beachfill requirements published by the U.S. Army Engineer District, Los Angeles(1962). Comparison of profiles generally show wider beaches and a deepening of the nearshore. By comparison to the pre-project condition, artificial beach fills have created a protective and feeder beach such that the profile volume has always been above that which existed in 1963, except during the severe winter seasons of 1978 and 1982-83. At the feeder beach location, 772,000 more cubic yards existed on the beach above MLLW datum in May 1995 than in 1963, and 1.39 million cubic yards more existed within the profile volume bound by the beach and historic -20 foot contour. The initial beach construction, NWS channel deepening and four nourishment cycles placed dredge material totaling 12.6 mcy on the feeder beach. Assuming 15 percent of the dredge prism to be composed of fine grain sediments which would quickly wash away, a beach nourishment volume of 10.8 mcy can be estimated. Only 1.4 mcy remain within the profile volume of the feeder beach after 31 years, yielding an average loss rate of 303,000 cy/year. The predicted periodic renourishment volume of 1.75 mcy about every five years in the 1962 study was based on an annual loss of 350,000 cy/year, consisting of 300,000 cy/yr loss from the littoral cell and 50,000 cy/yr loss to the offshore, wind and other causes.

While periodic beach nourishment has maintained profile volumes above pre-project levels, protective beach widths are not always provided for all locations. This is particularly true for about 3,000 feet adjacent to the Anaheim Bay East Jetty (sta 100+00 to 130+00) which appears to have a component of southeasterly directed longshore transport from westerly swells and reflected southerly swell as can be seen in the approaching wave fronts of Photos 3 and 4.

PHOTO 3 Surfside Beach with a South Swell Wave Pattern (June 7 , 1980)

PHOTO 4 Surfside Beach with a West Swell Wave Pattern (April 17, 1981) Sunset Gage: 0904, Hs=110.3 cm; Tp=13s.

Acknowledgements

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