# LITTORAL CELLS AND SAND BUDGETS ALONG THE COAST OF CALIFORNIA

## *Proposal to the California Coastal Sediment Management Working Group And California Department of Boating and Waterways*

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**STATEMENT OF NEED**

The California Sediment Management Working Group seeks to address the requests of coastal regulators for sediment budget information that would assist them in their efforts to make sediment management decisions. There is a need for sediment budget information for California's littoral cells including source inputs, littoral drift rates and losses or sinks along California's 1100 miles of coastline. The need is for both natural sediment budgets, prior to human intervention and alterations of these cells or compartments (e.g. prior to dams, debris basins, coastal armoring, etc.), and also the present-day or altered sediment budgets. This information is desired in a GIS base for ease of use.

An additional desired work product is a summary document that would provide the non-technical reader with a sense of littoral cells or beach compartments, how littoral budget components are determined, measured or approximated, and what assumptions or uncertainties are involved in littoral budget determinations. This document would be well illustrated in order to provide both written and graphical explanations of littoral cell functioning and budget determinations.

**INTRODUCTION**

The movement of sand along the coastline under the influence of waves has been observed for many years. In addition, the actual impacts and costs of interrupting or obstructing the littoral drift process have been painfully obvious along both the Atlantic and Pacific coasts of the United States since the 1930's. Construction of the Santa Barbara Harbor (initiated in 1927) and the consequent interruption of littoral drift was perhaps the first well-studied example along the California coast (Wiegel, 1965). Many of the immediate effects of breakwater construction at Santa Barbara including upcoast accretion, costly annual maintenance dredging, and downcoast beach loss and coastal erosion have been well documented at other California harbor locations as well (for example, Norris, 1964; Griggs and Johnson, 1976; Adams, 1976; Lajoie and others, 1979; Griggs and Savoy, 1985; and Griggs, 1985 and 1987).

Average annual dredging volumes at some southern California harbors now exceed 600,000 $m^3$/yr with dredging costs well in excess of $1,000,000 annually. In contrast, there are other harbors along the coast of California that have had very little impact on the shoreline and where no littoral drift obstruction, and therefore, dredging problems, have arisen. Griggs (1985, 1987) recognized that marinas or harbors built either between or at the upcoast ends of beach compartments or littoral cells in California have been relatively maintenance-free, because of a lack of significant littoral drift at these locations. On the other hand, those harbors built in the middle reaches or downcoast ends of littoral cells with high littoral drift rates have significant annual dredging requirements and high maintenance costs. Although engineers have labored for years on various breakwaters, jetty or entrance channel configurations, the actual design used is usually of secondary importance. The critical factors in California are harbor location within a littoral cell and annual littoral drift volume.

**BEACH COMPARTMENTS/LITTORAL CELLS**

Beach compartments or littoral cells form the framework for our understanding of the sources, transport, sinks, and storage of sand in the nearshore zone along the Pacific Coast. In a typical beach compartment, littoral transport begins at a rocky headland or section of coast where the upcoast supply of sand or littoral drift is restricted or minimal. Sediments enter the littoral cell primarily from coastal streams and bluff erosion, and are transported alongshore under the influence of the prevailing wave conditions (Inman and Frautschy, 1966). Ultimately the sand is lost from the system or cell through either a submarine canyon, a coastal dune field, or in some cases, directs removal through sand mining. In theory, each cell exists as a distinct entity with little or no transport of sediment between cells.

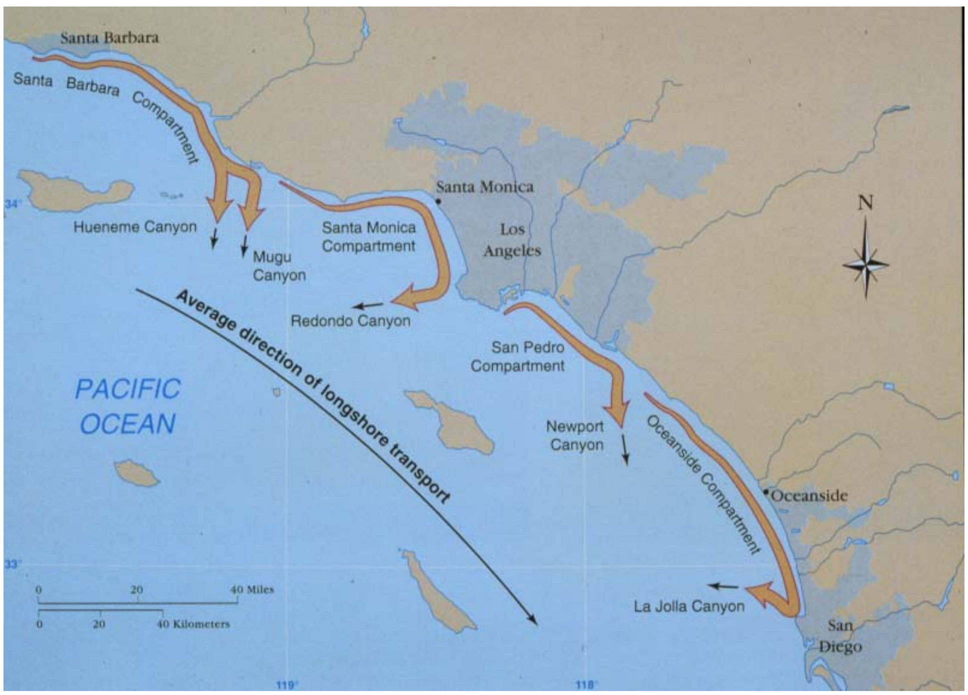


**Figure 1. Littoral cells of the southern California area (from Inman and Frautschy, 1966)**

Our lack of a quantitative understanding of littoral cells and sand budgets has become all too obvious along the California coast (Griggs, 1987). The problems and costs associated with harbor dredging where jetties or breakwaters have been constructed in the middle or downcoast ends of littoral cells with high drift rates, on one hand, and the reduction of sand delivery to beaches due to impoundment of sediment behind dams in the coastal watersheds (Norris, 1964; Brownlie and Taylor, 1981; Ewing, Magoon and Robertson, 1999), on the other, stem directly from the failure to incorporate this type of information early on in the decision making process in any large coastal engineering project. The application of a sediment budget to the nearshore zone is a useful tool in coastal land use management and coastal engineering, and is an essential step in understanding the importance of sediment routing along the coast. On the central and northern California coastline, a large gap exists in our present state of knowledge regarding littoral cell boundaries and production, transport, storage and loss of littoral sediment within these cells.

Along California's 1760 km of coast, there are four large harbors (Humboldt Bay, San Francisco Bay, Los Angeles/Long Beach, and San Diego) and 21 small craft harbors with some entrance channel or breakwater protection (Table 1). Additional entrance channels and small craft harbors have been proposed as well. Each of these existing harbors occupies a position in a littoral cell and has the potential to provide important information on the littoral drift rate or sand transport at that particular location. While sand inputs to littoral cells from coastal streams and from cliff erosion are difficult to quantify accurately (Griggs, 1987; Griggs, Runyan, Willis and Lockwood, 2001) due to both spatial and temporal variations in the key quantities that need to be measured, long term average annual dredging volumes can provide very useful data on littoral drift rates at specific locations within littoral cells. Many harbors provide very efficient littoral drift traps such that the average annual dredging volumes are among the most representative and reliable values we have for littoral drift rates within individual littoral cells.

Dredging data in some cases (Santa Barbara Harbor) extends back over 70 years such that the year-to-year variations can be averaged out and a long-term average calculated (Figure 2). Thirty or more years of dredging data are available for other harbors. Cumulatively, the long-term data on harbor dredging has the potential to provide a useful and valuable indicator of littoral drift rates at specific locations along California's 1760 km of coastline. These values can be used in sediment budgets to provide perspective and a cross-check on the other elements in a littoral budget, e.g. the particular input and output volumes from specific sources and sinks (rivers, cliff erosion, submarine canyons, for example, that are far more difficult to quantify). Littoral drift data are necessary to evaluate in the preliminary planning for any additional entrance channels or small craft harbors. Temporal variations and long term values and can also be used to estimate or predict future dredging costs.

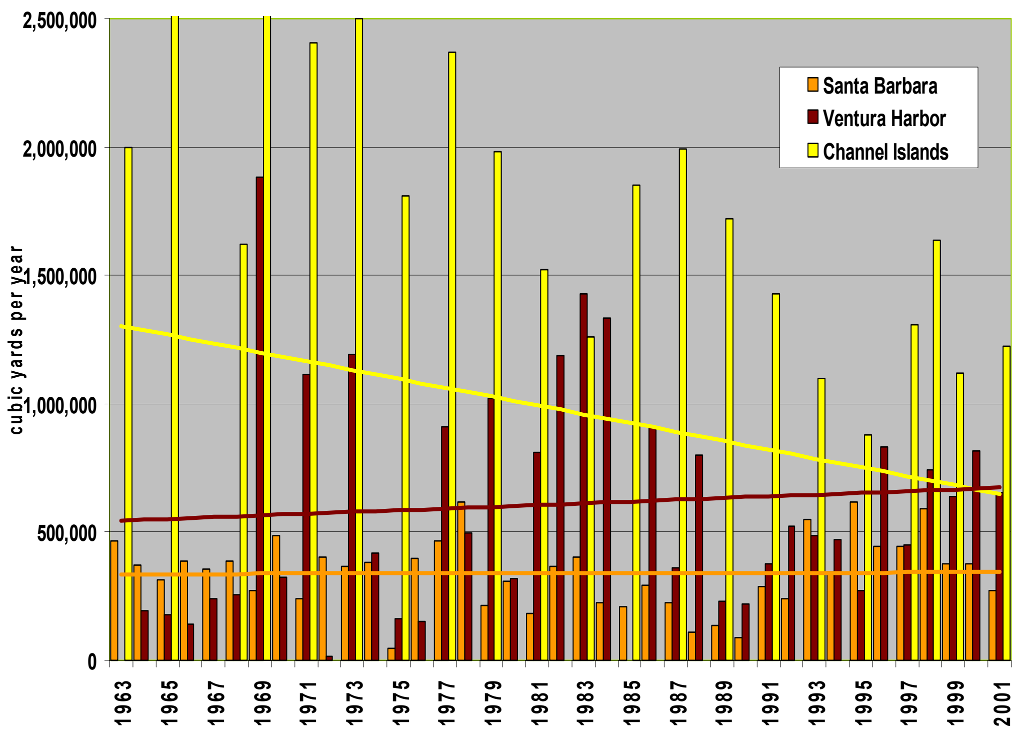


**Figure 2. Long-term dredging history for the Santa Barbara, Ventura and Channel Islands harbors.**

**PROPOSED DELIVERABLES**

A final report that would include the following:

1] a critical examination of the existing or often used littoral cell boundaries for the coast of California (Habel and Armstrong, 1978; Griggs, 1985, 1987) in light of more recent research (Griggs, Runyan, Willis and Lockwood, 2001) and confirmation or revision of these cell boundaries as well as possible with existing data..

2] An evaluation of the long term dredging volumes from each of California's coastal harbors and a determination of average annual rates as proxies for littoral drift rates at specific littoral cell locations.

3] A compilation and evaluation of existing data on sand sources/inputs to California's littoral cells (stream inputs, cliff and bluff erosion) and comparison with the calculated dredging/littoral drift rates in order to provide perspective and a cross-check on volume consistency in the individual littoral cell budgets.

4] A compilation of existing data and development of littoral budgets under pre-existing natural conditions of sediment input and littoral transport and also development of littoral budgets under present altered conditions.

5] Field and lab work needed to determine how much sand has been cut off from littoral cells throughout California from dams, debris basins, channelization projects, and seawalls and revetments. Data on sediment reductions from dams, debris basins and channelization projects will be compiled from recent studies incorporated into the *California Beach Replenishment Study*. The field work and subsequent sediment analysis effort required to quantify the amount of sand provided by cliff/bluff erosion to the shoreline under natural conditions and under the present armored conditions will be concentrated primarily along the coast from San Francisco south to Mexico. The contributions of sand from the coastline from San Francisco north to the Oregon border will be evaluated in a semi-quantitative manner using all available data.

6] A compilation all of the existing information on the components of individual littoral cells and littoral drift rates on a GIS base for the coast of California compatible with the CSMW's Master Plan GIS format and metadata needs, for the coast of California.

7] Preparation of a summary document that would provide the non-technical reader with a sense of the functioning and importance of littoral cells or beach compartments, how littoral budget components are determined, measured or approximated, and what assumptions or uncertainties are involved.

8] Preparation of a summary white paper (a component of 7] above) or non-technical discussion of spatial and temporal (seasonal and decadal) movement of sand within a littoral cell.

9] Preparation of a summary white paper (a component of 7] above) or non-technical discussion of the movement of sediment, within a littoral cell resulting from a beach nourishment project using a comprehensive beach and offshore morphology data set, i.e. SIO's at Torrey Pines State Beach .

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## APPENDIX 1. CALIFORNIA'S COASTAL HARBORS

Crescent City
Humboldt Bay
Bodega Bay/Harbor
San Francisco Bay
Half Moon Bay Harbor
Santa Cruz Small Craft Harbor
Moss Landing Harbor
Monterey Harbor
Morro Bay
San Luis Harbor
Santa Barbara Harbor
Venture Harbor
Channel Islands Harbor
Port Hueneme
Marina del Rey
Redondo-King Harbor
Los Angeles/Long Beach Harbor
Alamitos Bay
Anaheim Bay/Seal Beach Harbor
Newport Bay
Dana Point Harbor
Oceanside Harbor
Mission Bay
San Diego Bay

## APPENDIX 2. ORIGINALLY PROPOSED CALIFORNIA LITTORAL CELLS (Habel and Armstrong, 1978)

1. Smith River Cell- Oregon Border to Pt. St. George

2. Klamath River Cell-Pt. St. George to Rocky Pt.

3. Eureka Cell- Trinidad Head to False Cape

4. Mattole River Cell- Cape Mendocino to Punta Gorda

5. Spanish Flat Cell- Punta Gorda to Pt. Delgada

6. Ten Mile River Cell-Bruhel Point to Ft. Bragg

7. Navarro River Cell- Navarro Head to Pt. Arena

8. Russian River Cell-Northwest Cape to Bodega Head

9. Bodega Bay Cell- Bodega Head to Tomales Bay

10. Pt. Reyes Cell- Tomales Bay to Pt. Reyes

11. Drakes Bay Cell- Pt. Reyes to Duxbury Point

12. Bolinas Bay Cell- Duxbury Point to Golden Gate
13. San Francisco Cell- Golden Gate to Pt. San Pedro
14. Half Moon Bay Cell- Pillar Point south 5 miles
15. Santa Cruz Cell- Golden Gate to Moss Landing
16. Southern Monterey Bay- Moss Landing to Monterey
17. Carmel River Cell-Monterey to Pt. Lobos
18. Point Sur Cell- Pt. Sur to Partington Canyon
19. Morro Bay Cell-Ragged Point to Pt. Buchon
20. Santa Maria Cell- Pt. San Luis to Pt. Sal
21. Santa Ynez River Cell- Pt. Sal to Pt. Arguello
22. Santa Barbara Cell- Pt. Arguello to Mugu Canyon
23. Santa Monica Cell- Mugu Canyon to Palos Verdes
24. San Pedro Cell- Pt. Fermin to Newport Canyon
25. Oceanside Cell- Dana Point to Pt. La Jolla
26. Mission Bay Cell- Pacific Beach to Ocean Beach
27. Silver Strand Cell- Pt. Loma to Mexican border