6. POTENTIAL SEDIMENT SOURCES

The potential beach nourishment strategies outlined in Section 5.1 require sources of sediment. This section investigates and characterizes potential sources of sediment for beach nourishment including:

- areas of excess sediment such as harbors and wetlands, where sand must be removed to restore function
- flood control projects such as dams and reservoirs where sand may become available as a result of dredging or excavation to restore capacity or closure of the dam
- inland commercial sand sources and sand sources which may become available during new development projects
- dunes at Fort Ord
- offshore sand sources

Three main criteria are used as an initial basis for screening source locations; availability of large quantities of beach compatible sand, levels of contamination, and the location of the source relative to the potential southern Monterey Bay receiver site. Potential sources are then targeted, using Tier I evaluation criteria of the Sand Compatibility and Opportunistic Use Program Plan (SCOUP) (Moffatt and Nichol Engineers, 2006), for more detailed compatibility studies. The locations of potential sediment sources are available as GIS data files in CSMWs GIS database.

The characteristics of the available source sediment are important in the design of beach nourishment strategies (CDBW and SCC, 2002). Sediment to be placed on the beach should contain only a small mud fraction. Sediment with a higher percentage of fines or smaller sand particle sizes may be appropriate for placement in the nearshore. The source sediment should be similar in particle size (or larger) than the receiver site, so as to behave in a similar way to the natural beach sediment. To evaluate source-receiver site compatibility, it is important to determine two parameters; the littoral cell cut-off diameter of the receiver site (LCD) (Limber et al., 2008) and the composite particle size envelopes of source and receiver (Moffatt and Nichol Engineers, 2006).

The littoral cut-off diameter is the particle size diameter of the sediment below which it is generally removed from the beach to leave only the sediment with particle sizes greater than the cut-off diameter. The littoral cut-off diameter is strongly controlled by wave energy. Typically, fine-grained sand in the particle size range 0.063 to 0.125 mm does not remain on the exposed beaches of central California because they are high-energy wave environments. For potential beach nourishment projects the LCD is important because any sediment finer than the cut-off that is placed on the dry or subaerial beach will likely move offshore of the beach, driven by wave processes. In northern Santa Cruz County where wave energy is high, the littoral cut-off diameter

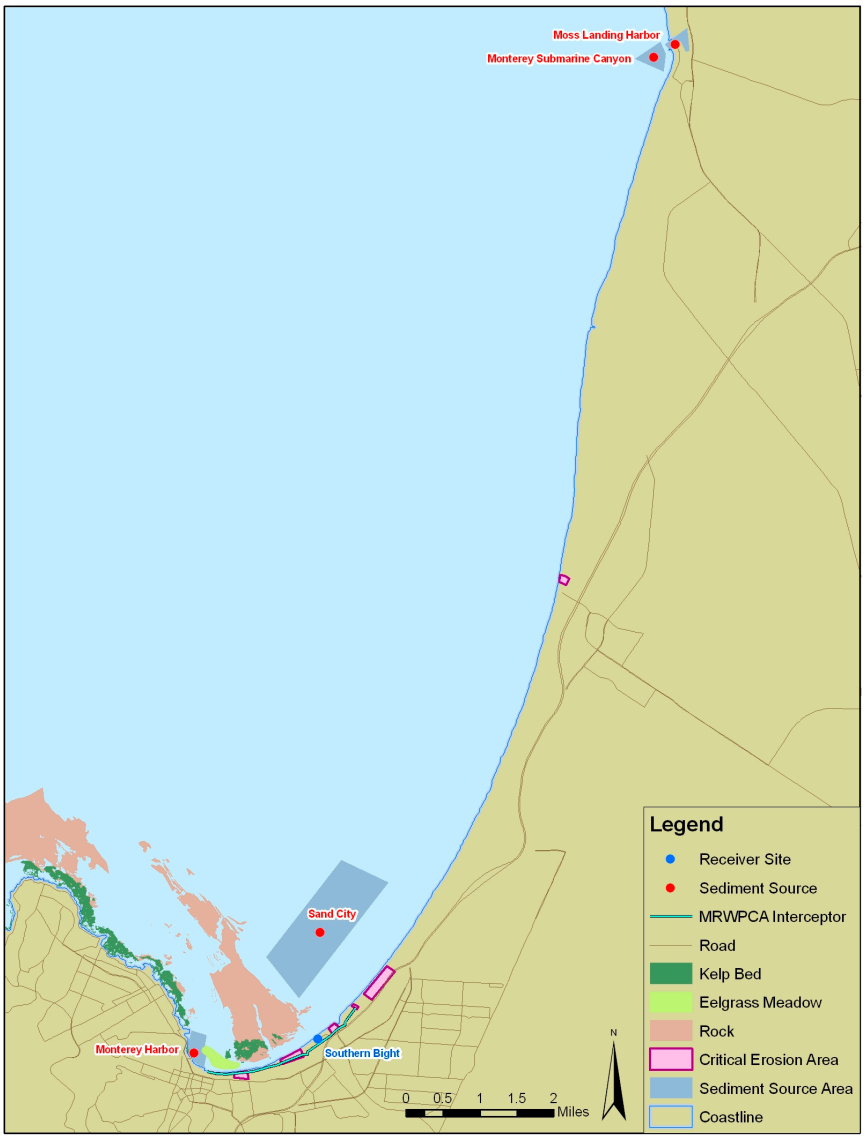
is approximately 0.18 mm (Patsch and Griggs, 2006). However, finer sands could be placed in the nearshore, where they would support the overall receiver site profile.

Moffatt and Nichol Engineers (2006) recommended determination of a 'composite particle size envelope' for the surface sediment at each receiver site. This brackets the range of particle sizes, from the coarsest to finest fractions (LCD) that characterizes the receiver site. They also recommended characterization of the wider littoral zone around the footprint of placement in order to understand how the sediment may disperse once placed. If the source's sand gradation falls within the receiver site composite grain size envelope, then the source and receiver sites are compatible with respect to particle size.

In addition, source materials must be free of harmful chemical and biological contamination. Sediment is appropriate for placement on the subaerial beach if it is sand or possibly gravel, and is found in areas of high energy. Testing protocols for contamination are set out in the Inland Testing Manual (USEPA and Corps, 1998).

In this Coastal RSM Plan, available information was collated on the physical and chemical characteristics of the potential source sediments. The essential data include particle size, and chemical signatures (metals and other analytes). This is defined as a Tier I analysis in SCOUP. From these data, provisional recommendations are made regarding the suitability of the source sediments for placement at the potential receiver site, which should then be carried forward into Tier II analysis. Tier II analysis requires sampling and testing for particle size distribution, chemistry, and physical properties, at each of the source sites and comparison with the potential receiver site sediments to assess compatibility. Analysis of these Tier II data would provide a definitive statement regarding the suitability of the source materials for placement at the potential receiver sites. The Tier I analysis carried out for this Coastal RSM Plan targets five potential sources of sand for beach nourishment, which are described below (Figure 32).

Figure 32. Location of Potential Sediment Sources



6.1 HARBORS AND WETLANDS

Three coastal harbors are situated in Monterey Bay; Santa Cruz, Moss Landing, and Monterey. Each harbor dredges sediment to keep their navigation channels and berths open for safe passage of commercial fishermen, recreational fishermen, and boaters. Moss Landing Harbor and Monterey Harbor are within the southern Monterey Bay littoral cell and considered potential opportunistic sources of sand. Santa Cruz Harbor was not considered further because it is within

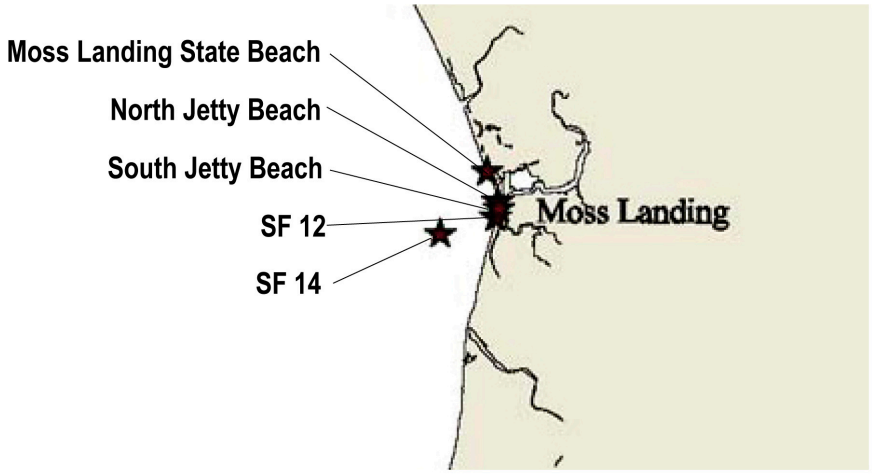
another littoral cell and the vast majority of the sand is being used to successfully nourish beaches immediately down coast in the same cell. No surplus sediment would be available for nourishment of southern Monterey Bay beaches without negatively impacting Santa Cruz beaches. No wetlands with compatible sediments for beach nourishment are identified in this Coastal RSM Plan.

6.1.1 Moss Landing Harbor Entrance Channel

The Corps and Moss Landing Harbor District have conducted maintenance dredging of Moss Landing Harbor since it opened in 1947. Sediment samples collected for the Environmental Assessment for maintenance dredging of the harbor in 2007 (Corps, 2007) showed that sediments in the entrance channel are greater than 90% (medium) sand and free of contaminants. Sediments further into the harbor are predominantly fine-grained (83-98% silt and clay), approximately 90% of which were contaminant-free in 2007. The primary sediment contamination issue for Moss Landing is chemical contamination from erosion of agricultural soils in the watershed. Soil loss from the surrounding land results in sediment deposition on roads, drainage channels, and ultimately into the harbor. In addition, Moss Landing Harbor provides haven to over 600 vessels year round, some of which may dispose wastewater into the harbor, or be subject to minor accidental oil spills during routine maintenance. However, chemical testing by Corps (2007) for metals, pesticides (including DDT), and PAHs, showed that the majority of the samples were below the threshold limit for aquatic disposal suitability.

Uncontaminated dredged materials are disposed at two offshore unconfined discharge sites (SF-12 and SF-14) and at three beach nourishment sites located north and south of the harbor (Figure 33). Finer-grained sediments (greater than 20% mud) are disposed at the offshore sites. When the dredged sediment contains less than 20% fines, it is placed at up to three beach disposal sites (Moss Landing State Beach, North Jetty Beach, and South Jetty Beach). Moss Landing Harbor has typically dredged approximately 50,000 yd^3 of sediment every three years, although the present permit (California Coastal Commission Permit 3-01-049) allows up to 100,000 yd^3/year to be removed. Sand in Moss Landing Harbor not abundant and would for beach nourishment purposes would need to be supplemented with sand from other sources.

Figure 33. Moss Landing Harbor Dredge Disposal Sites



Source: MBNMS

Having determined that the Moss Landing Harbor entrance channel sediments meet the particle size and contamination requirements, the only constraint on their use to nourish southern Monterey Bay beaches is that they are already placed on beaches adjacent to the harbor. With additional transportation costs, this sediment could be placed elsewhere in the southern Monterey Bay littoral cell. Therefore, Moss Landing Harbor entrance channel has the potential to be a source of sediment and is recommended as a target for more detailed Tier II compatibility analysis. It should be noted that Elkhorn Slough is rapidly eroding and therefore may also be targeted for receipt of dredged sediments.

6.1.2 Monterey Harbor

Historically, Monterey Harbor has been dredged approximately every 7-8 years with removal of around 4,000-10,000 yd^3 of sediment from the main channels. Most of the sediment has been placed either in shallow water immediately adjacent to Wharf II or on the beach above MHW (Steve Scheiblauer, Monterey Harbormaster, personal communication). Approximately 2,000-3,000 yd^3 of the sediment was placed inland. In the near future there is the possibility of a dredging operation to remove approximately 75,000 yd^3 from the entire harbor basin. The intention would be a complete

dredge of the berths and main channels to last for 40 years. Because of its complexity, particularly in obtaining permits to dispose of the sand, this dredging is unlikely to take place before 2010-2011.

Monterey Harbor is a potential source of sand for nourishment of the southern Monterey Bay beaches south of Sand City. The sediment infilling the harbor is locally derived through the pervious Coast Guard Pier breakwater, from three runoff outfalls within the harbor, and from an overflow runoff pipe just inside Wharf II. Little sand in the harbor appears to be derived from Del Monte Beach to the east. Monterey Harbor may have potential for minor contamination including agricultural chemicals from runoff, and wastewater and oil discharge from vessel operations.

Sand from Monterey Harbor is not plentiful and would provide only a very small portion of the necessary volume and would need to be supplemented with sand from other sources. However, Monterey Harbor is recommended as a target for more detailed Tier II compatibility analysis. AMBAG would need to coordinate with Monterey Harbor harbormaster about near-term (possibly 2010-2011) future dredging activities and the potential use of the sand for beach nourishment.

6.2 FLOOD CONTROL PROJECTS

6.2.1 Sediment Impounded by Dams

There are three dams along the main tributaries of the Salinas River that have sediment accumulated in the reservoirs behind them (Salinas, Nacimiento and San Antonio). Two more dams (San Clemente and Los Padres) are located along the nearby Carmel River but in a different watershed. None of the sediment bodies impounded behind these dams are considered potential sources of sand, for several reasons:

- the reservoirs on the Salinas River and behind Los Padres Dam contain sediment with a high percentage of mud, and so are unsuitable for beach nourishment purposes
- the Salinas Dam is approximately 120 miles from southern Monterey Bay, and the Nacimiento and San Antonio Dams are approximately 80 miles, so transportation of sand would likely be uneconomical
- although the particle size characteristics of the San Clemente Reservoir sediment may be compatible they are derived from granite rocks in a different watershed and would be unsuitable in terms of mineralogy and/or color
- although the San Clemente Dam is only 20 miles by road from southern Monterey Bay it is remote and access to the source sediment would be difficult, and transporting the sand by truck to southern Monterey Bay would be expensive (approximately \$20-\$30 per yd^3). This cost is approximately two to three times higher per yd^3 than the most expensive offshore source (see Section 7 for results of economic analysis for offshore sources)

6.2.2 Salinas River Sand Bar Breaching

In order to prevent flood damage to the surrounding floodplain areas, Monterey County Water Resources Agency periodically removes part of the sand bar fronting the Salinas River mouth. A ten-foot wide notch is cut through the bar to allow water at high tide to pass over the bar and begin a process of scour which eventually creates a breach 150-200 feet wide. The notch is cut with an excavator which disposes of the sediment adjacent to the notch. No sediment is removed from the littoral cell during excavation and hence no new sediment becomes available for nourishment purposes.

6.3 INLAND COMMERCIAL SITES

The SCOUP Plan (Moffatt and Nichol Engineers, 2006) provides a generic list of potential inland sources of beach quality sediment, including:

- road and railway construction
- landslides
- quarries

Currently there are no future major roads or railway construction projects identified in proximity to southern Monterey, and in general most of the materials yielded through these construction activities would not be suitable for beach nourishment purposes. However, there is a small chance that routes cut through coastal terrain comprised of marine sedimentary deposits may yield some beach-compatible sediment. In addition, landslides wouldn't in all likelihood provide beach compatible material nor large enough volumes to consider. However, slides in uplifted marine deposits in coastal regions may prove to be possible sources. Quarried sand and gravel may be appropriate for smaller nourishment projects in close proximity to the quarry. These sources would become available opportunistically and possibly not at a time suitable for immediate use. Hence, for these opportunistic sources, the sediment would require relatively rapid identification and characterization to determine compatibility with receiver sites, and then stockpiled for future nourishment needs.

6.3.1 Stockpiling

In order to temporarily store beach compatible sand from opportunistic inland sources (and potentially from offshore if the nourishment is phased) requires a stockpiling site. This Coastal RSM Plan suggests two potential stockpile sites (Figure 32):

- the former Fort Ord where there are many acres of unused land (recommended)
- a large pit (approximately 600 feet by 450 feet by 90 feet deep at the north end of Sand City.

For the Fort Ord recommended option, AMBAG would need to approach the Fort Ord Reuse Authority (FORA) and the County of Monterey to receive permission. The Fort Ord site is large, accessible, and local to the southern bight (the southern end of Fort Ord is adjacent to Sand City), and hence transportation by truck of the stockpiled sand along established routes (Highway 1 and access roads) from the stockpile to the placement area should be relatively straightforward.

The alternative pit location at north Sand City is between Highway 1 and the shoreline and is a former sand mining pit. This site could accommodate approximately 1,000,000 yd^3.

Although no inland commercial sites with compatible sediments for beach nourishment are identified in this Coastal RSM Plan, it is recommended that part of the SCOUP process secures part of Fort Ord as a stockpile site where sediment can be stored to the appropriate volumes for nourishment projects.

6.4 DUNES AT FORD ORD

There are 40.4 square miles of sand dunes in the southern Monterey Bay dune field south of the Salinas River that extend inland as far as five miles in the Fort Ord area. The dunes north of the Salinas River mouth are less extensive, and narrower, and consist of several smaller complexes that total 8.8 square miles. Thus, the total southern Monterey Bay dune area is about 51 square miles with nearly 80% of this lying south of the Salinas River mouth (Cooper, 1967).

The particle size characteristics of the dune sand is important because it provides information on what volume of sediment eroded from the dunes is large enough to remain on the beaches and shoreface. Using the methods of Dean (1974) shows that approximately 25% of the dune sand has particle sizes equivalent to those that would reside on the beach. However, according to Dingler et al. (1985), who based his statement of the work of Dorman (1968), the eroded dune sand contains on average 76% medium-to-coarse sand (>0.25mm) that can remain within the beach and shoreface, leaving 24%, which is lost offshore. The finer dune sands may also result in a wider, flatter shoreface and increased shore recession until the widening is complete.

Although the particle size of the dunes is finer than the beach, the data suggest a potential 76% retention on the beach and shoreface of sediment eroded from the dune bluffs. With over 40 square miles of sand dunes adjacent to the bay, derived originally from the beach, the southern Monterey Bay dune field is a large potential source of sediment for nourishment of the southern Monterey Bay beaches. There are some significant areas of dune sand within Fort Ord that have been disturbed and do not contain endangered species that would provide large quantities of

compatible sand. Hence, the sand dunes within the Fort Ord complex are recommended as a target for more detailed Tier II compatibility analysis.

6.5 OFFSHORE LOCATIONS

Large volumes of sand exist offshore in southern Monterey Bay (Figure 12) (Combellick and Osborne, 1977; Reid et al., 2006). This sand is a potential source that could be dredged and placed either on the beach or in the nearshore, where it can become part of the littoral cell. The main opportunities with offshore sources include relatively low cost, high placement rates on the receiver beach, and minimal disturbance onshore while the project is underway. One main constraint is that the offshore zone of southern Monterey Bay is part of the MBNMS, and dredging of the sand may be a complex issue due to a sanctuary prohibition on alteration of the seafloor. These activities can however be permitted if it can be determined that the impacts from these activities are neither significant nor long term.

Textural analyses of the offshore surface sediments in southern Monterey Bay reveal major sandy environments based on mean particle size. The delineation of particle size variations in the bay is critical for identifying appropriate source sands for potential beach nourishment. The offshore sand environments of southern Monterey Bay that are potential sources are:

- Monterey Submarine Canyon
- a zone of sand offshore from Sand City
- a nearshore relict sand corridor

6.5.1 Monterey Submarine Canyon

The upper 2.5 miles of the Monterey Submarine Canyon experiences both local deposition due to supply from adjacent littoral cells and erosion due to slope failure and landslides (Smith et al., 2007). Frequent episodes of sediment build-up and subsequent down-slope failure transport littoral sediments from the canyon rim to deeper in the canyon, where sediment is stored. Hence, the upper canyon is a temporary storage site for sediment.

A study is being undertaken by the Corps to examine the feasibility of capturing littoral sediments adjacent to canyons (Moffatt and Nichol Engineers, 2008). In the examination of all the canyons along the California coast, the two identified with the most potential were Monterey and Mugu Canyons. Monterey Submarine Canyon meets three critical criteria used in the analysis:

- it meets the minimum critical capture rate (greater than 10,000 yd^3/year), determined to be economically worth pursuing
- the location of the sand to be captured is relatively near a critical coastal erosion area as identified by CSMW (southern Monterey Bay)
- there is an additional benefit that the nearby and eroding Elkhorn Slough, a federal reserve, is in need of sediment.

Several means to recover sediment from Monterey Submarine Canyon were considered in the feasibility study. First, the sand that has already been lost down the canyon could be extracted. Second, it may be possible to intercept the sediment as it moves toward the canyon head and redirect it back into the littoral system. Interception would prevent the sand from being lost into the canyon. Several interception alternatives were considered by Moffatt and Nichol Engineers (2008):

- use the north jetty to intercept sediments with an array of stationary jet pumps attached to the breakwater
- a jet pump on a moveable crane on the breakwater
- an offshore breakwater on the south side to impound sediments and provide shelter for a dredge
- use a hopper dredge to create an offshore pit south of the canyon to serve as a sand trap for future mining of sand

The latter approach (although only the utilizing the south side of the canyon) was suggested as having the least environmental impact with the best cost-benefit ratio.

Monterey Submarine Canyon is a large potential source of sediment for nourishment of the southern Monterey Bay beaches. Given the proximity of the canyon head to the nearshore zone, sediment in the vicinity of the canyon head should match the characteristics of the adjacent littoral cell, and be a suitable source with respect to particle size and chemistry. The volumes available are probably sufficient to nourish all the critical areas of erosion south of Sand City. The Monterey Submarine Canyon is recommended as a target for more detailed Tier II compatibility analysis. Identifying an appropriate offshore pit area closer to the critical erosion areas, between the Salinas River Mouth and the submarine canyon head, could reduce transport costs.

6.5.2 Zone of Sand Offshore from Sand City

It is likely that offshore transport of sediment from the southern Monterey Bay beaches is taking place. This repository for sediment could be a potential zone for obtaining sand for beach nourishment purposes. In particular, the possibility that sand is moving offshore from a probable alongshore convergence zone in the vicinity of Sand City should be investigated in more detail. The analyses of Combellick and Osborne (1977) describe a zone of medium sand (particle size 0.25-0.5 mm) offshore from Sand City (Figure 12). These sands are potentially the offshore extension of a zone of convergence of alongshore sediment transport in the vicinity of Sand City.

Reid et al. (2006) compiled particle size data for the Pacific coast including southern Monterey Bay. Their data offshore from the southern bight shows a grouping of surface samples in the 0.3 to 0.5 mm particle size range in a similar location to the medium sand zone of Dorman (1968)

and Combellick and Osborne (1977). Particle size data from the offshore zone is presented in Table 13 (Reid et al., 2006), and describes sediments with mean/median particle sizes between 0.3 and 0.5 mm (medium sand).

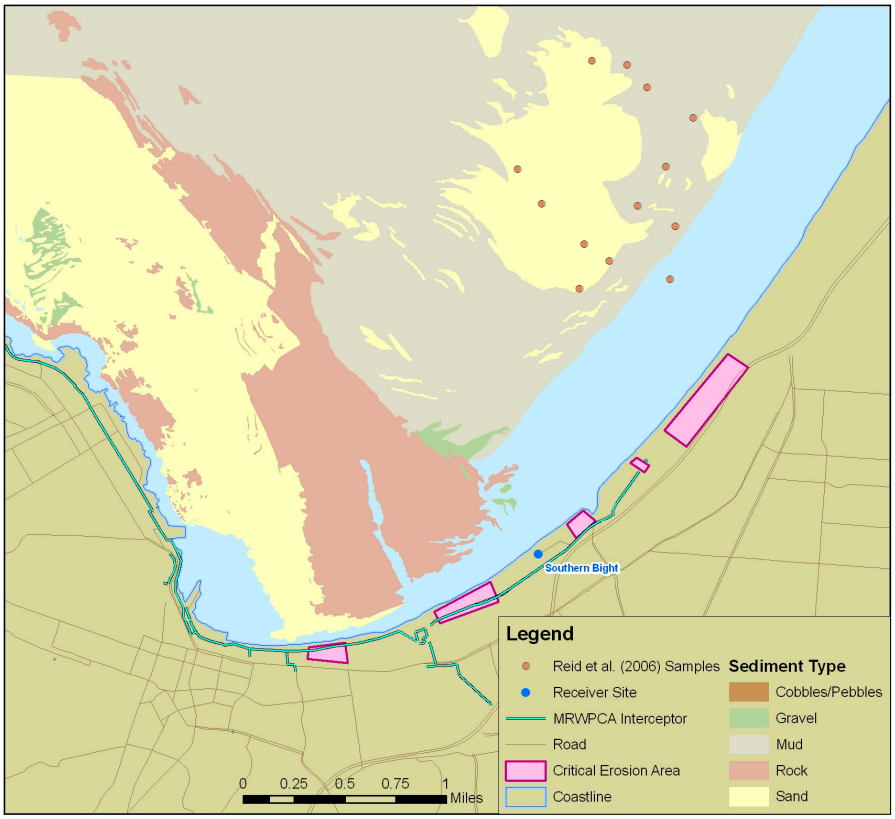
Table 13. Particle Size of Sand Offshore from Sand City (Reid et al., 2006)

Latitude	Longitude	% sand	Particle size[1] (mm)
36.64240	121.85500	100	0.38
36.64040	121.85080	100	0.31
36.63683	121.85300	100	0.27
36.63610	121.86610	99	0.31
36.63370	121.86380	100	0.35
36.62780	121.86010	100	0.31
36.63100	121.85990	100	0.33
36.64410	121.86000	99	0.50
36.64390	121.85690	100	0.33
36.63390	121.85530	100	0.47
36.63260	121.85190	100	0.47
36.62880	121.85210	100	0.33
36.62990	121.85760	100	0.33

[1]Particle size reported as either mean or median.

Data compiled by the NOAAs National Coastal Data Development Center presented as part of the Sanctuary Interactive Monitoring Network (SIMoN) interactive map series also shows a large patch of sand in a similar location to the Combellick and Osborne (1977) and Reid et al. (2006) data sets (Figure 34). The locations of sediment samples taken by Reid et al. (2006) are also shown on Figure 34.

Figure 34. Offshore Sediment Types



The particle size of these sands appears compatible with the southern Monterey Bay beach sands and therefore they are a potential source of sand for beach nourishment. The zone of sand offshore from Sand City is therefore recommended as a target for more detailed Tier II compatibility analysis.

6.5.3 Nearshore Relict Sand Corridor

Relict medium to coarse sand occurs on the inner shelf of southern Monterey Bay as irregularly shaped depressions, approximately three feet deep out to water depths of 200 feet. In shallower water depths of 30-60 feet, these medium-coarse-sand deposits trend parallel to the shoreline as bands 60-300 feet wide, and alternate with bands of fine-medium sand that are of similar width (Hunter et al., 1988). The medium-coarse sands have a mean particle size of 0.35-1.0 mm, and the fine-medium sands have a mean particle size of 0.125-0.35 mm. Further offshore, patches of the medium-coarse sand are exposed through an overlying mud layer. The source of the sand may be a pre-Flandrian transgressive lag deposit underlying much of the shelf (Chin et al., 1988). It

would appear that these coarse sands do not move onshore and contribute to the sand budget, so they may be a potential source of sand for beach nourishment.

6.6 SEDIMENT SOURCE SHORT-LIST

The Tier I screening of potential sediment sources for beach nourishment shows that currently considered opportunistic inland sources are unsuitable. A regional stockpile area somewhere on Fort Ord lands close to the southern bight receiver site is recommended to allow accumulation of appropriate sediment of opportunity to a volume sufficient for a nourishment project. Also, the dunes at Fort Ord may themselves provide a suitable source. Of the three harbors in Monterey Bay, Moss Landing Harbor entrance channel and Monterey Harbor contain sediment that could potentially be beneficially re-used. Potential offshore sand sources include the area between the Salinas river mouth and head region of Monterey Submarine Canyon, and the shelf offshore of the transport convergence zone at Sand City.

In this Plan, the following five potential sources of sand are recommended for more detailed Tier II compatibility studies.

- **Monterey Submarine Canyon**
- **Shelf offshore from Sand City**
- **Fort Ord dune field**
- **Moss Landing Harbor entrance channel**
- **Monterey Harbor**

All of the potential sediment sources for nourishment of the beaches in southern Monterey Bay are in coastal and nearshore locations. It is anticipated that the feasibility of the use of sand sources from much further inland to nourish the southern Monterey Bay shoreline may change. Feasibility may increase due to the need to restore dam capacity by removing sediment, the need to decommission the dam, and the increased value of sand for nourishment if future erosion is great enough. Consequently, the feasibility assessments in this Coastal RSM Plan should be updated, as appropriate, in the future.

6.7 ENVIRONMENTAL IMPACTS AT POTENTIAL SOURCE AREAS

Dredging in subtidal sandy habitats to obtain sediment for beach nourishment disturbs and removes benthic habitat and results in elevated turbidity (NRC, 1995; Green, 2002) with potential impacts to invertebrates and fish in nearshore and offshore environments. Borrow site dredging removes sediment and associated benthic organisms and has the potential to entrain organisms as a result of near-bottom water being withdrawn by suction dredgers. Generally, complete mortality is assumed for dredge-removed and/or entrained organisms, although a small percentage may survive depending on discharge location (LaSalle et al., 1991).

Recovery of benthic communities following borrow site dredging varies depending on sediment infill rates, hydrodynamics, and dredging method but can be protracted (SAIC, 2007). In Monterey Bay, Oliver and Slattery (1976) found dredging in channel areas removed 60% of the benthic animals. Abundance remained low 1.5 years after dredging, but indexes of species diversity and evenness were higher than before dredging. They suggested that the timing of dredging in relation to the reproductive cycles and distributive abilities of the benthic organisms in the area affects recovery.

6.7.1 Mitigation Measures

Recovery may be facilitated by shallow dredging over a larger area rather than creation of deep pits covering a limited area. Dredging shifting sands rather than more stable bottoms, retaining similar surface sediment type, and leaving undisturbed areas within the larger dredged area may also reduce disturbance (Thompson, 1973; Oliver and Slattery, 1976; Hurme and Pullen, 1988; Jutte, 2002; Diaz et al., 2004).