U.S. Department of the Interior
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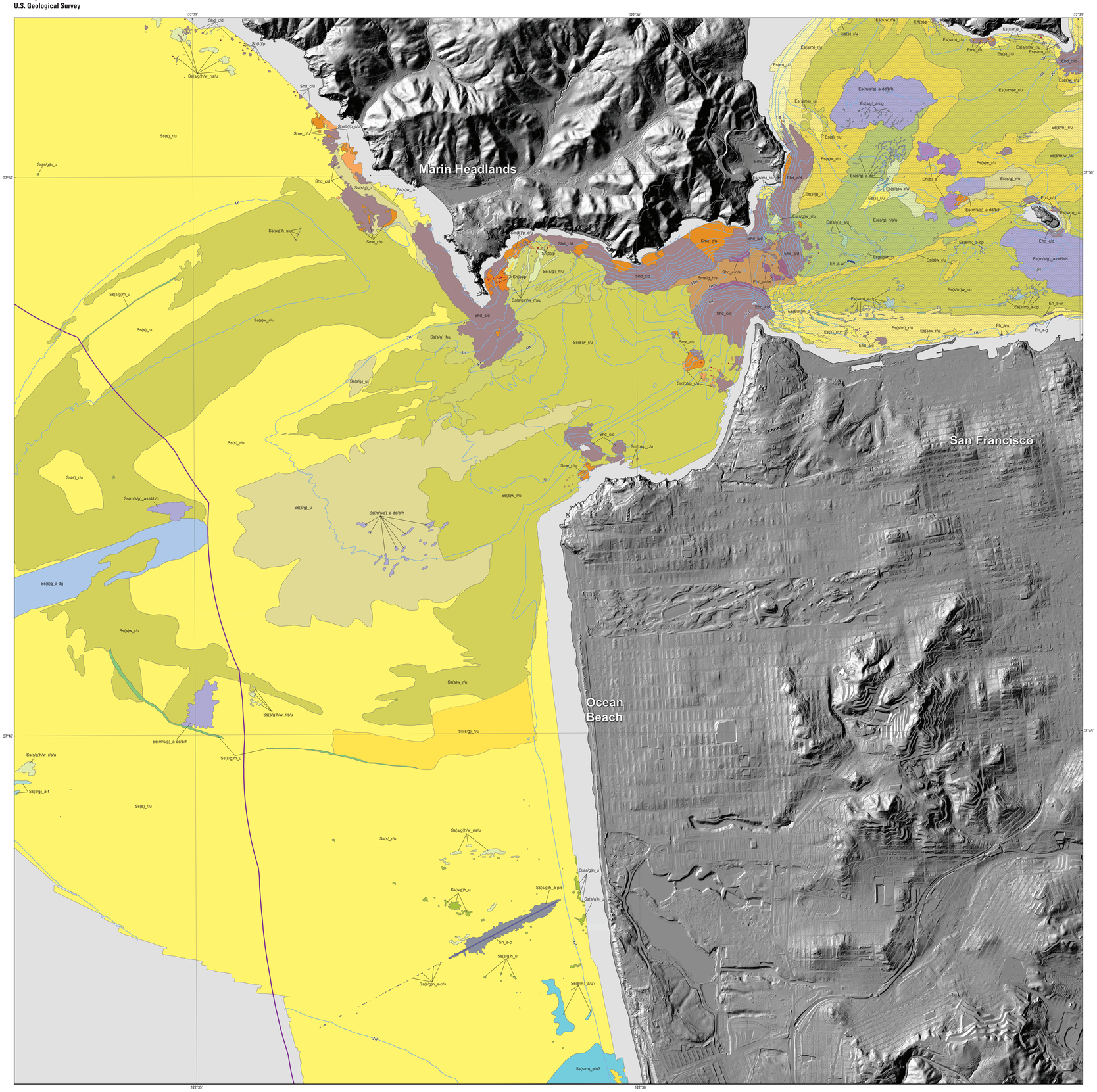
Open-File Report 2015–1068
Sheet 7 of 10
Pamphlet accompanies map



Onshore elevation data collected by Earth Eye in 2010 for San Francisco State University and the U.S. Geological Survey.
California's State Waters limit from NOAA Office of Coast Survey
Universal Transverse Mercator projection, Zone 10N
NOT INTENDED FOR NAVIGATIONAL USE

APPROXIMATE MEAN DECLINATION, 2015

SCALE 1:24 000

1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0 1 KILOMETER

BATHYMETRIC CONTOUR INTERVAL 10 METERS
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Bathymetric contours by Mercedes D. Erdey, 2012
GIS database and digital cartography by Mercedes D. Erdey and Charles A. Endris
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Potential Marine Benthic Habitats, Offshore of San Francisco Map Area, California

By
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DESCRIPTION OF MAP UNITS

UNCONSOLIDATED CONTINENTAL SHELF SEDIMENTS

- Ss(s)_r/u — Soft, unconsolidated sediment (sand), predominantly rippled
- Ss(s)w_r/u — Sediment waves in soft, unconsolidated rippled sediment (sand)
- Ss(s/g)_u — Soft, unconsolidated sediment (sand and gravel)
- Ss(s/g)m_u — Current-scoured depression in soft, unconsolidated sediment (sand and gravel)
- Ss(s/g)_h/u — Linear ridge in soft, unconsolidated sediment (sand and gravel)
- Ss(s/g)h/w_r/s/u — Soft, unconsolidated, hummocky sediment (sand and gravel)
- Ss(s/g)h/w_r/s/u — Soft, mobile sediment window that has unconsolidated and rippled sediment waves, overlying scoured lag pavement of sand and gravel (sorted bedforms)

MIXED SUBSTRATE ON CONTINENTAL SHELF

- Sme_c/u — Mixed habitat of soft, unconsolidated sediment, locally overlying hard, consolidated sedimentary bedrock
- Sme/g_b/s — Current-scoured bedrock with local cover of bimodal, coarse-grained sediment within high-energy channel
- Sm(b)/p_c/u — Mixed habitat of boulders or pinnacles and cobbles with soft, unconsolidated sediment

HARD SUBSTRATE ON CONTINENTAL SHELF

- Shd_c/d — Hard, deformed, and differentially eroded sedimentary-bedrock outcrop
- Shd_c/d/s — Hard, deformed, and differentially eroded sedimentary-bedrock outcrop, current-scoured
- Sh(b)/p — Hard boulder, boulder field, or pinnacle

ANTHROPOGENIC FEATURES ON CONTINENTAL SHELF

- Ss(s/m)_a/u? — Unconsolidated sediment (sand and mud) with possible anthropogenic deposits; inferred
- Ss(s)g_a-dg — Grooves or linear depressions formed by extractive dredging activity in unconsolidated sediment (sand)
- Ss(s/g)_a-f — Parallel linear or sinuous scars in soft, unconsolidated sediment (sand and gravel); likely caused by vessel propeller thrust or turbulence scouring
- Ss(s/g)h_a-p/s — Current-scoured depression in soft, unconsolidated sediment (sand and gravel) adjacent to a hard, anthropogenic feature (pipeline)
- Ss(m/s/g)_a-dd/b/h — Irregular relief and hummocky bimodal, unconsolidated sediment created by disposal of dredge deposits (mud, sand, and gravel)
- Sh_a-p — Hard, anthropogenic feature (pipeline)

UNCONSOLIDATED ESTUARY SEDIMENTS

- Es(m)_r/u — Soft, unconsolidated sediment, predominantly rippled (mud)
- Es(s/m)_r/u — Soft, unconsolidated sediment, predominantly rippled (sand and mud)
- Es(s/m)s_u — Scarp or linear ridge composed of unconsolidated sediment (sand and mud)
- Es(s/m)w_r/u — Sediment waves in soft, unconsolidated rippled sediment (sand and mud)
- Es(s/m)m_u — Mound or linear ridge comprised of soft, unconsolidated sediment (sand and mud)
- Es(s/m)h_s/u — Current-scoured depression in unconsolidated sediment (sand and mud)
- Es(s)_r/u — Soft, unconsolidated sediment (sand), predominantly rippled
- Es(s)w_r/u — Sediment waves in soft, unconsolidated rippled sediment (sand)
- Es(s)h_s/u — Current-scoured depression in unconsolidated sediment (sand)
- Es(s/g)_u — Soft, unconsolidated sediment (sand and gravel)
- Es(s/g)m_u — Mound or linear ridge comprised of soft, unconsolidated sediment (sand and gravel)
- Es(s/g)w_r/u — Sediment waves in soft, unconsolidated rippled sediment (sand and gravel)
- Es(s/g)s_s/u — Current-scoured scarp in soft, unconsolidated sediment (sand and gravel)
- Es(s/g)h_s/u — Current-scoured depression in soft, unconsolidated sediment (sand and gravel)
- Es(s/g)_h/s/u — Hummocky and current-scoured soft, unconsolidated sediment (sand/gravel)

MIXED SUBSTRATE IN ESTUARY

- Eme_c/u — Mixed habitat of soft, unconsolidated sediment locally covering hard, consolidated sedimentary bedrock
- Eme/g_b/s — Current-scoured bedrock with local cover of bimodal, coarse-grained sediment within a high-energy channel

HARD SUBSTRATE IN ESTUARY

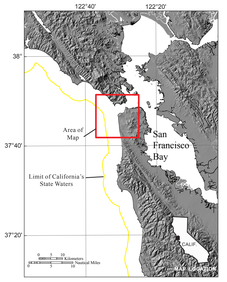
- Ehd_c/d — Deformed and differentially eroded sedimentary bedrock outcrop
- Ehd_c/d/s — Deformed and differentially eroded sedimentary bedrock outcrop, current-scoured
- Eh(b)/p — Hard boulder, boulder field, or pinnacle

ANTHROPOGENIC FEATURES IN ESTUARY

- Es(s/m)_a-dg — Grooves or linear depressions formed by extractive dredging activity in soft, unconsolidated sediment (sand and mud)
- Es(s/m)_a-dp — Anthropogenically formed depressions, pits, or potholes; created by extractive dredging or gravel mining in soft unconsolidated sediment (sand and mud)
- Es(s/g)_a-dg — Grooves or linear depressions formed by extractive dredging activity in unconsolidated sediment (sand and gravel)
- Es(s/g)_a-dp — Anthropogenically formed depressions, pits, or potholes; created by extractive dredging or gravel mining in soft, unconsolidated sediment (sand and gravel)
- Es(s)_a-dg — Grooves or linear depressions formed by extractive dredging activity in unconsolidated sediment (sand)
- Es(s)_a-dp — Anthropogenically formed depressions, pits, or potholes; created by extractive dredging or gravel mining in soft, unconsolidated sediment (sand)
- Es(m/s/g)_a-dd/b/h — Irregular relief and hummocky bimodal unconsolidated sediment created by disposal of dredge deposits (mud, sand, and gravel)
- Eh(b)_a — Hard, anthropogenically modified outcrops; dynamited to remove hazards to shipping
- Eh_a-g — Hard, anthropogenic feature (groin or jetty) (breakwater)
- Eh_a-s — Hard, anthropogenic feature; supports, pilings, dolphins
- Eh_a-w — Hard, anthropogenic feature (shipwreck)

EXPLANATION OF MAP SYMBOLS

- **Contact**
- **Area of "no data"**—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data; areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program
- **3-nautical-mile limit of California's State Waters**
- **Bathymetric contour (in meters)**—Derived from 2-m-resolution bathymetry grids



DISCUSSION

This map shows "potential" marine benthic habitats in the Offshore of San Francisco map area. Marine benthic habitats represent a particular type of substrate, geomorphology, seafloor process, or any other attribute that may provide a habitat for a specific species or an assemblage of organisms. Such maps are based largely on seafloor geology, and this map integrates seafloor geology (sheet 10) with information depicted on several other thematic maps of the Offshore of San Francisco map area: high-resolution bathymetry (sheet 1); shaded-relief imagery (sheet 2); backscatter (sheet 3); seafloor character (sheet 5); and ground-truth information (sheet 6). This map also uses information from the usSEABED bottom sampling compilation by Reid and others (2006). The combination of remotely observed data (for example, multibeam bathymetry and backscatter, seismic-reflection profiles) and directly observed data (for example, camera transects, sediment samples) translates to higher confidence in the ability to interpret broad areas of the seafloor (fig. 1).

To avoid any possible misunderstanding of the term "habitat," the term "potential habitat" (as defined by Greene and others, 2005) is used herein to describe a set of distinct seafloor conditions that in the future may qualify as an "actual habitat." Once habitat associations of a species are determined, they can be used to create maps that depict actual habitats, which then need to be confirmed by "ground-truth" surveying using in situ observations, video, and (or) photographic documentation.

Marine benthic habitats are classified using the Benthic Marine Potential Habitat Classification Scheme, a mapping-attribute code developed by Greene and others (1999, 2007). In this map series, habitat-classification codes are based on the deepwater habitat-characterization scheme developed by Greene and others (1999), which was created to not only easily distinguish marine benthic habitats but also to facilitate ease of use and queries within GIS and database programs. The code, which is summarized in chapter 6 in the accompanying pamphlet, is derived from several categories of the Benthic Marine Potential Habitat Classification Scheme (Greene and others, 1999, 2007), and it can be subdivided on the basis of the spatial scale of the data.

High-resolution, multibeam-sonar data, converted to bathymetric depth grids (seafloor digital elevation models; sheet 1), are essential to development of the habitat map, as is shaded-relief imagery (sheet 2), which allows for visualization of seafloor terrain and provides a foundation for interpretation of submarine landforms. Areas of seafloor bedrock exposures are identified by their common sharp edges and high relative relief; these may be contiguous outcrops, isolated parts of outcrop protruding through sediment cover (pinnacles or knobs), or isolated boulders.

Backscatter maps (sheet 3) also are essential for developing potential benthic habitat maps. High backscatter is further indication of "hard" bottom, consistent with interpretation as rock or coarse sediment. In many locations, areas within or around a rocky feature appear to be covered by a thin veneer of sediment, identified on the habitat map as "mixed" induration (in other words, containing both rock and sediment). Broad, generally smooth areas of seafloor that lack sharp and angular edge characteristics are mapped as "sediment" and are further defined by various sedimentary features such as erosional scours and depressions, as well as depositional features such as dunes, mounds, or sand waves. Low backscatter, indicative of a "soft" bottom, also significantly aids identification and classification of sedimentary habitats.

The Offshore of San Francisco map area includes the San Francisco Bay estuary and the offshore inner continental shelf. Delineated on the map are 50 potential marine benthic habitat types: 19 are found on the continental shelf ("Shelf" megahabitat), and 31 are identified in San Francisco Bay estuary ("Estuary" megahabitat).

The meso- and macrohabitats on the continental shelf include soft unconsolidated sediment (7 habitat types) such as sand and gravel, a large sediment (sand) bar (the horseshoe-shaped bar offshore of the Golden Gate), and dynamic features such as mobile sand sheets, sediment waves and ripples, sediment depressions; mixed substrate (3 habitat types) such as soft sand and gravels overlying consolidated sedimentary bedrock and gravel pavement; hard substrate (3 habitat types) such as deformed and differentially eroded bedrock, pinnacles and boulders; anthropogenic features (6 habitat types) such as dredge spoil fields, dredged channels, and pipelines with hard rock ballast.

The meso- and macrohabitats in San Francisco Bay include soft unconsolidated sediment (15 habitat types) such as sediment waves, rippled sand, gravel and mud; mixed substrate of soft unconsolidated sediment covering hard rock (2 habitat types); hard substrate (3 habitat types) such as deformed consolidated bedrock, pinnacles and boulders; and anthropogenic features (11 habitat types) such as dredged areas, sand and gravel mining, and dynamited rocks for navigation purposes.

Backscatter data show that most of the area is underlain by "soft" materials, consistent with the interpretation that unconsolidated sediments dominate habitat in the mapped area. Sedimentary processes are quite active and, thus, habitats are highly dynamic. On the continental shelf sediment transport is primarily to the southeast and westward out through the Golden Gate. In addition, erosion through shelf sediments down to a coarser lag has produced "ripple scour depressions" (see, for example, Cacchione and others, 1984) on the shelf and deep scour depressions are found in the central part of San Francisco Bay.

Of the 173.45 km^2 of mapped area, 146.66 km^2 (84.6 percent) was mapped on the continental shelf and 26.79 km^2 (15.4 percent) was mapped in the estuary. Unconsolidated sediment is the dominant habitat type with a total coverage of 159.94 km^2, representing 92.2 percent of the mapped area. Hard rock covers 5.78 km^2 (3.3 percent) while 1.76 km^2 (1 percent) includes mixed hard and soft substrate. Anthropogenic features inside and outside the bay make up 5.97 km^2 (3.4 percent of the total mapped area).

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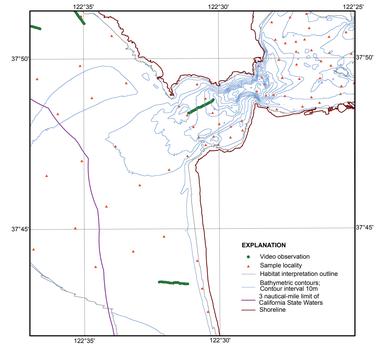

Figure 1. Map showing video-observation locations and sample localities for Offshore of San Francisco map area.

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