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Coastal Monitoring of the May 2005 Dredge Disposal Offshore of Ocean Beach, San Francisco, Calif.

By Patrick L. Barnard and Daniel M. Hanes

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By Patrick L. Barnard[1] and Daniel M. Hanes[2]

Introduction

Ocean Beach, California, contains an erosion hot spot in the shadow of the San Francisco ebb tidal delta south of Sloat Boulevard that threatens valuable public infrastructure as well as the safe recreational use of the beach. In an effort to reduce the erosion at this location and avoid hazardous navigation conditions at the current disposal site (SF-8), a new plan for the management of sediment dredged annually from the main shipping channel at the mouth of Francisco Bay was implemented in May 2005 by the United States Army Corps of Engineers, San Francisco District (COE). The objective for COE was to perform a test dredge disposal of ~230,000 m^3 (300,000 yd^3) of sand just offshore of the erosion hot spot, in depths between approximately 9 and 14 m. This disposal site was chosen because it is in a location where the strong tidal currents associated with the mouth of San Francisco Bay and waves can potentially feed sediment toward the littoral zone in the reach of the beach that is experiencing critical erosion (Fig. 1). The onshore migration of sediment from the target disposal location might feed the primary longshore bar or the nearshore zone, and provide a buffer to erosion that peaks during winter months when large waves impact the region. The United States Geological Survey (USGS), in collaboration with the Sea Floor Mapping Lab (SFML) of California State University, Monterey Bay, monitored the initial bathymetric evolution of the test dredge disposal site and the adjacent coastal region from May 2005 to November 2005. This paper reports on this monitoring effort and assesses the short-term coastal response.

Background

The USGS has been conducting field research at the mouth of San Francisco Bay (Barnard, 2005; Barnard and others, under review), with emphasis on Ocean Beach (Barnard and Hanes, in press) since April 2004. Much of this work complements the coastal monitoring research described in this report. The Ocean Beach Coastal Processes Study (website: http://walrus.wr.usgs.gov/coastal_processes/) includes monthly topographic beach surveys, quarterly cross-shore bathymetric profiles, grain size analysis, numerical modeling, video monitoring, wave and current measurements, and a multibeam/side scan bathymetric survey in collaboration with SFML and COE. The goal of this project is to define the dominant sediment transport pathways at the mouth of San Francisco Bay and, in so doing, determine the cause of erosion at Ocean Beach. Our initial work describes a highly energetic coastal system that has evolved considerably over the last century and shows significant short-term fluctuations in the nearshore zone.

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Mapping at the mouth of San Francisco Bay

Fifty days of multibeam mapping were conducted during the fall of 2004/05 through a USGS-COE-SFML collaboration. One of the primary goals of this survey was to evaluate bathymetric change at the mouth of San Francisco Bay since the last comprehensive bathymetric survey was completed in 1956 by the National Ocean Service. Fig. 2 shows the change in depth from 1956 to 2005. The large scale morphological trend is ebb tidal delta constriction and sediment loss. The average depth change in the entire region was -70 cm (erosion), which amounts to ~105 million m^3 of sediment loss in the region common to both surveys (Fig. 2). Even with a conservative vertical error bar of +/-30 cm this is a significant trend. The outer lobe of the ebb tidal delta is completely dominated by erosion. Several likely causes include a reduction in tidal prism/currents due to San Francisco Bay development and a decrease in sediment supply due to both removal by sand mining inside the bay (Chin and others, 1998; 2004) and reduced influx of hydraulic mining debris from the Sacramento River (Gilbert, 1917). There are two distinct accretionary mounds in the SF-8 disposal site, presumably the result of dredge disposal in this area that has totaled ~18 million m^3 since disposal commenced on this site in 1971 (United States Army Corps of Engineers, 1996). This accretion has increased navigational hazards for COE dredging operations. Note also the nearshore erosion seaward of the erosion hot spot at Ocean Beach near Sloat Boulevard (Fig. 2), leaving this reach of the beach more susceptible to wave attack.

The Southwest Ocean Outfall Pipe near the southern end of Ocean Beach carries approximately one-third of San Francisco's treated sewage out to sea. It was constructed in the late 1970's (Woodward Clyde Consultants, 1978). The fall 2004-05 multibeam survey indicates extensive scour associated with the pipe (Figs. 3-4).

The multibeam bathymetry shows the large-scale bedform morphology, primarily sand waves with wavelengths > 5-10 m, along Ocean Beach. The bedform orientation indicates dominance by tidal forcing outside the surf zone (Jordan, 1962; Bouma and others, 1977; Dalrypmple and others, 1978; Briggs and Southard, 1980; Ashley, 1990) (Fig. 5). Most bedforms in the northern half of Ocean Beach are oriented with their crests nearly perpendicular to the shoreline, while toward the middle of the beach, approximately 1 km north of the erosion hot spot, there are indications of onshore directed transport (Fig. 5, Inset A). The only bedforms observable offshore of the erosion hot spot are scour ripples associated with the Outfall Pipe and ripple scour depressions oriented east-west (Fig. 5, Inset B). Any bedforms < 5 m are not resolved with the multibeam system.

In summary, three important management issues were highlighted by the multibeam survey:

1. The SF-8 disposal site is accreting and a new site for disposing of ship channel sediment may soon be essential.
2. The Southwest Ocean Outfall Pipe is exposed and is causing severe scour in the immediate vicinity. The ramifications for the structural integrity of the outfall pipe and the influence of this scour on the adjacent coastline are unknown.
3. Most of the region offshore of the erosion hot spot at Ocean Beach has lost > 1m of sediment since 1956, reducing the wave protection these shoals formerly provided to the adjacent beach, and indicating a general reduction in sediment supply to this reach of the ebb tidal delta.

Beach and nearshore studies

Work to date by the USGS suggests strong seasonal fluctuations in beach and nearshore sand volumes, high cross-shore sediment transport rates, and large short-term changes in beach morphology (Barnard and Hanes, in press). Intrannual shoreline positions can exceed 80 m, as measured during the 1997-98 El Niño period. USGS Personal Watercraft (PWC) surveys show seasonal cross-shore transport rates that can exceed 1000 m^3 per m of shoreline (Fig. 6). Monthly all terrain vehicle surveys have logged instances of dramatic changes in beach morphology, particularly during the winter months, when powerful storms can temporarily remove large volumes of beach sediment, leaving the beach and associated infrastructure more vulnerable to further wave attack (Fig. 7). The winter beach is typically narrower and flatter, while the summer beach is wider and steeper. The region of beach near Sloat Boulevard is the most vulnerable, historically narrow and often the first to lose significant sediment when the winter storm season begins (Fig. 8). Grain size surveys along Ocean Beach using both settling tube results and a digital bed sediment camera (Chezar and Rubin, 2004; Rubin, 2004) show that the grain size is quite consistent alongshore with a median grain size of 0.29 mm, with some coarser gravel lags occasionally occurring in the southern half of the beach.

Methods

The USGS monitored and evaluated the initial bathymetric evolution of the test dredge disposal site and the adjacent coastal region from May 2005 to November 2005. Four multibeam surveys (performed by SFML) were conducted: pre-dredge (May 2005), post dredge (June 2005), 1 month post-dredge (July 2005) and 4 months post–dredge (October 2005). The USGS performed PWC surveys in May 2005 and November 2005. The beach was mapped using all-terrain vehicles in May, June, July, August and November, 2005. In June 2005, at the onset of the dredge disposal, the USGS deployed 4 tripods offshore of Ocean Beach, each equipped with a current profiler, to make calculations of the directional wave spectrum, water levels and tidal currents from *in situ* measurements (Fig. 9). The USGS conducted eight days of sediment sampling in June and July 2005. A total of 191 stations were sampled by collecting grab samples or employing a digital bed sediment camera (eyeball) at the mouth of San Francisco Bay, with emphasis immediately on and around the Ocean Beach disposal site (Fig. 9). The subsequent sediment analysis will serve to track the dredge disposal (if the grain size is different from the surrounding sediment), to determine if the grain size of the dredge disposal is suitable for bed load transport under the prevailing hydrodynamic conditions of the area, and as input for use in future sediment transport models at Ocean Beach.

Results and Discussion

Multibeam surveys

Fig. 10 shows the bathymetric change in June and October 2005, associated with the dredge disposal, relative to the bathymetry measured in May 2005. The peak of the asymmetric disposal mound in June is ~1.75 m high, with some secondary mounds scattered throughout the site. By October the peak location is largely unchanged, but the mound has greatly dissipated and the overall volume within the survey area (indicated by the survey extent in Fig. 10) has been reduced by ~50%. Much of this volume loss is likely attributed to the summer seasonal cross-shore sediment flux, that is, the natural cross-shore sediment transport trend toward the beach. A large portion of the dredge volume was placed in the vicinity of the exposed outfall pipe (Figs. 3-4), and

cross sections show that some accretion has occurred around severely exposed portions of the pipe, reducing the exposure and thus the scour potential (Fig. 11). However, much of the pipe remains exposed.

These repeated multibeam surveys confirm from the fall 2004/05 multibeam survey that no hard bottom exposure exists anywhere in the vicinity of the dredge disposal region. These surveys, coupled with the numerous grab samples and digital camera drops in this region, further confirm that the bottom is almost continuously sand covered, broken up only by occasional sand dollar colonies and coarse sand and gravel filled ripple scour depressions. Sand thickness is unknown.

PWC nearshore surveys

Between May and November 2005 the PWC surveys indicate a high rate of cross-shore sediment transport. The dredge disposal mound is identifiable along survey line #16 (Fig. 12). PWC surveys at Ocean Beach indicate that wave-induced cross-shore sediment transport (i.e. depth of closure) exists out to ~10 m of water depth, encompassing portions of the disposal area.

Beach surveys

A comparison of topographic beach surveys during the May-August period in both 2004 and 2005 indicate a higher rate of beach accretion during the initial disposal period in summer 2005, particularly along the northern half of Ocean Beach (Fig. 13). However, this higher rate of accretion could be attributed to a number of variables (e.g. dominant wave direction), and without a longer term data set it is not possible to isolate the dredge disposal as the direct cause of this accretion.

In situ instruments

Currents and waves measured at all sites (Fig. 9) are indicative of a highly dynamic coastal system, where waves and tidal currents both play important roles in sediment transport and the resulting morphology. Preliminary measurement analysis from the current profiler placed at the disposal site in June 2005 (Site 3) clearly show the potential for sand transport with summer waves approaching 2.5 m (offshore > 4 m) and currents peaking at 60 to 80 cm/s (Fig. 14).

Grain size analysis

Preliminary grain size analysis shows a highly spatially variable sedimentological character at the mouth of San Francisco Bay. Median grain size varies from coarse sand and gravel in the inlet throat to a massive ebb tidal delta dominated by fine to medium sand, with occasional sand dollar colonies and mud traces along the outer reaches. Intense sampling about the dredge disposal region confirms that the sediment offshore consists of fine to medium sand, broadly consistent with beach and dune sediment found along Ocean Beach.

Conclusions

The response of the beach and nearshore region to the June 2005 test dredge disposal thus far is largely inconclusive. The mound peak has not moved, but only ~50% of the initial increase in sediment volume associated with dredge disposal remained in the survey area after 4 months. Current measurements indicate the potential for high rates of sediment transport, and PWC profiles show very high rates of cross-shore sediment transport in this region. The beach did accrete at a higher rate during the dredge disposal monitoring period than it did during the prior year, but this

correlation may be coincidental due to the common seasonal changes. The major directly observable benefit of the dredge disposal thus far is reducing the exposure of the outfall pipe, and thus the scour associated with the pipe exposure. It will likely take at least several more years of disposals of similar magnitude in this new location and careful monitoring to determine if the beach and nearshore region will benefit from the artificial increase in offshore sediment supply to this area.

Future and ongoing related work

In January 2006, a current profiler was also placed at SF-8 giving direct measurements of current velocities and wave conditions at the existing disposal site. Two additional profilers were deployed offshore and six Aquadopp profilers were deployed in the surf zone at Ocean Beach. More tightly spaced topographic beach surveys have been conducted since December 2005 in an effort to document the very short term changes in beach response to the winter storm season. A Deflt3D hydrodynamic and sediment transport model continues to be developed, benefiting greatly from this *in situ* instrumentation. Over 1.5 years of images taken from a web camera at the Cliff House (http://www.evsboca.com/usgs/default.htm) are being analyzed to track short term changes in shoreline position, run-up statistics, and nearshore rip and bar evolution.

Acknowledgements

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Appendix

Field Activity IDs and Web Links

ATV Survey List

Survey #	FACS ID	Survey Date
1	OB104CA	4/7/2004
2	OB204CA	5/7/2004
3	OB304CA	6/7/2004
4	OB404CA	7/6/2004
5	OB504CA	10/13/2004
6	OB604CA	11/15/2004
7	OB704CA	12/10/2004
8	OB105CA	1/11/2005
9	OB205CA	2/7/2005
10	OB305CA	3/8/2005
11	OB405CA	3/11/2005
12	OB505CA	5/2/2005
13	OB605CA	6/10/2005
14	OB705CA	6/27/2005
15	OB805CA	7/12/2005
16	OB905CA	7/22/2005
17	OBA05CA	8/22/2005
18	OBB05CA	11/17/2005

PWC Survey List

Survey #	FACS ID	Survey Date
1	OB204CA	5/4/2004
2	OB404CA	7/20/2004
3	OB604CA	11/12/2004
4	OB505CA	5/5/2005
5	OB805CA	7/5/2005
6	OBB05CA	11/17/2005

Beach Eyeball Survey List

Survey #	FACS ID	Survey Date
1	OB104CA	4/7/2004
2	OB204CA	5/7/2004
3	OB404CA	8/3/2004
4	OB305CA	3/7/2005

5	OBB05CA	11/17/2005

Sediment Sampling Offshore

Survey #	FACS ID	Survey Date
1	S105NC	6/21/2005
2	S105NC	6/22/2005
3	S105NC	6/23/2005
4	S205NC	7/25/2005
5	S205NC	7/27/2005

Instrument Deployments/Recovery

Survey #	FACS ID	Survey Date
1	S105NC	6/21/2005
2	S205NC	7/26/2005

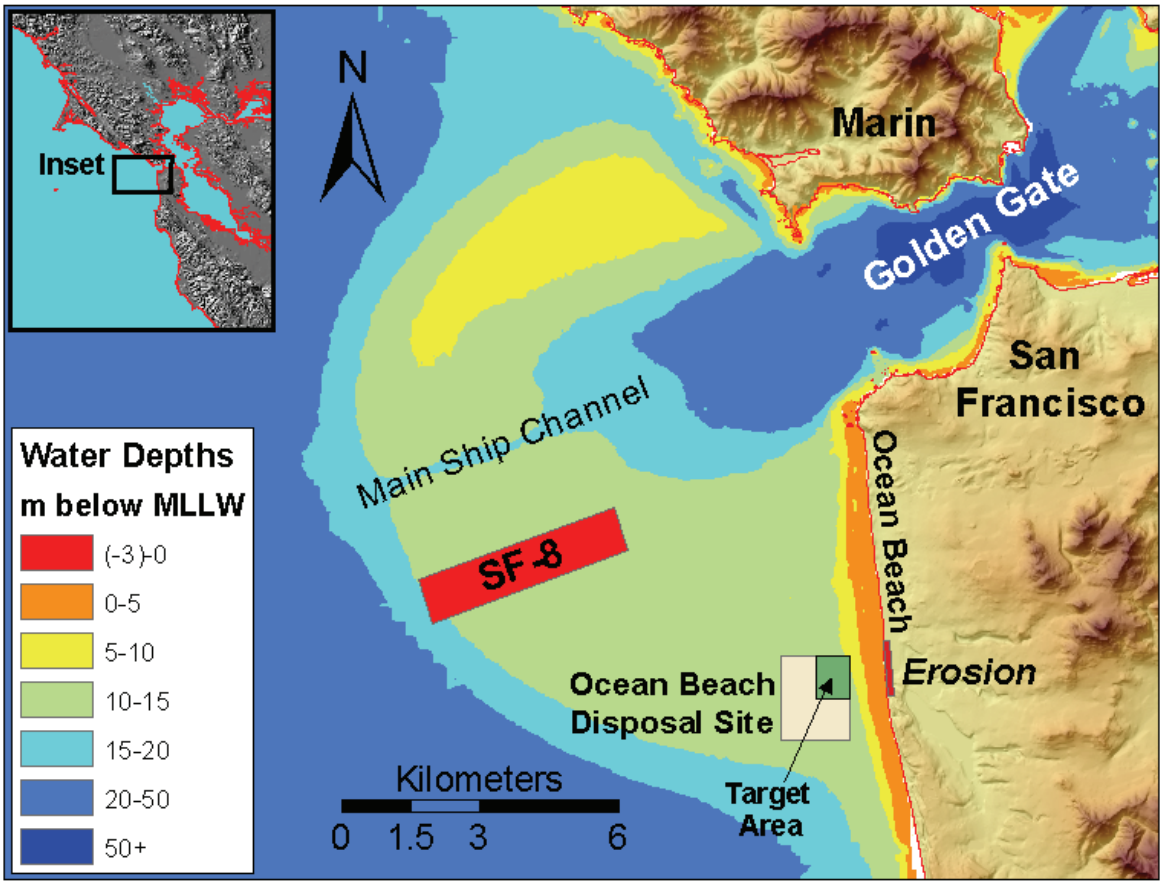


Figure 1. Map of the study area showing the location of the existing dredge disposal site (SF-8) and the test dredge disposal site (Ocean Beach Disposal Site). Bathymetry is from a 1956 National Ocean Service (NOS) survey.

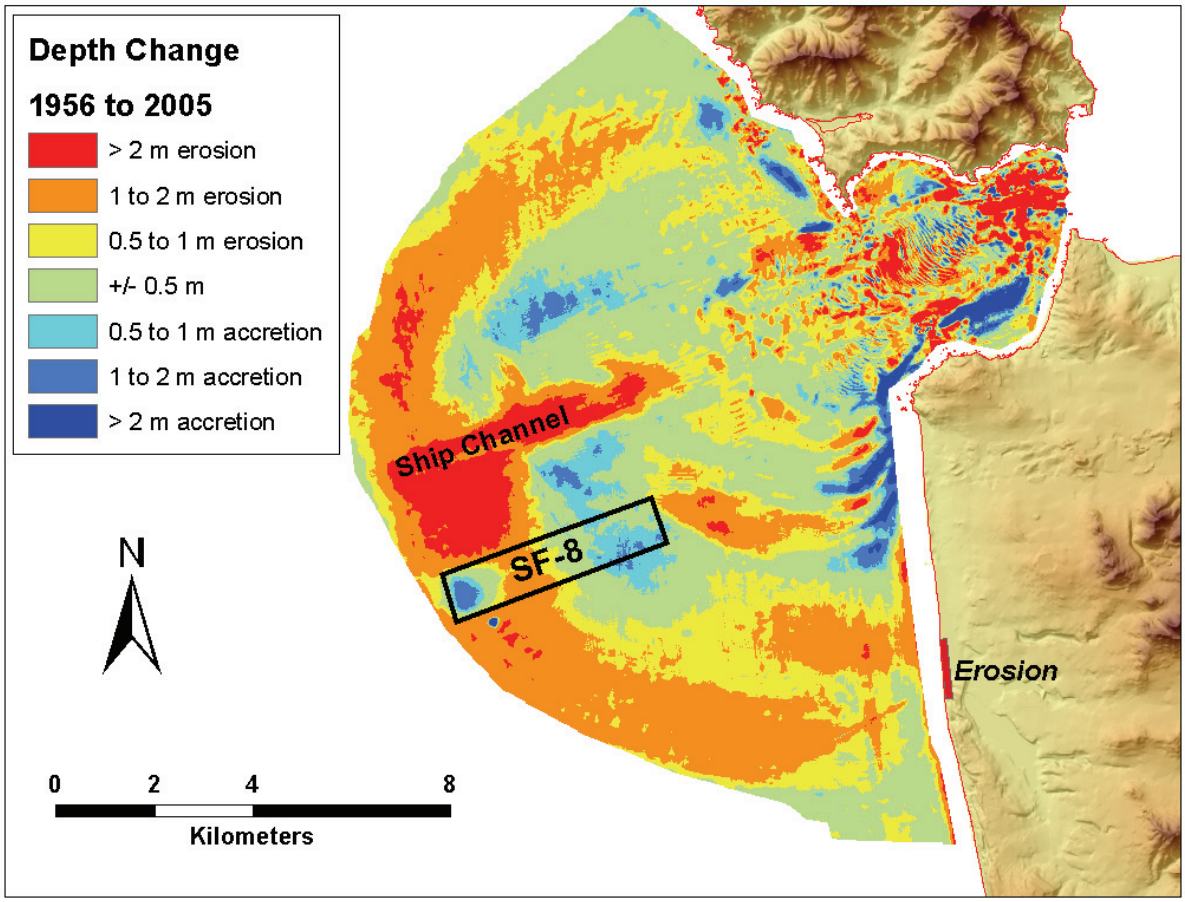


Figure 2. Map of bathymetric change at the mouth of San Francisco Bay between the 1956 NOS survey and fall 2004-05 multibeam survey conducted by SFML.

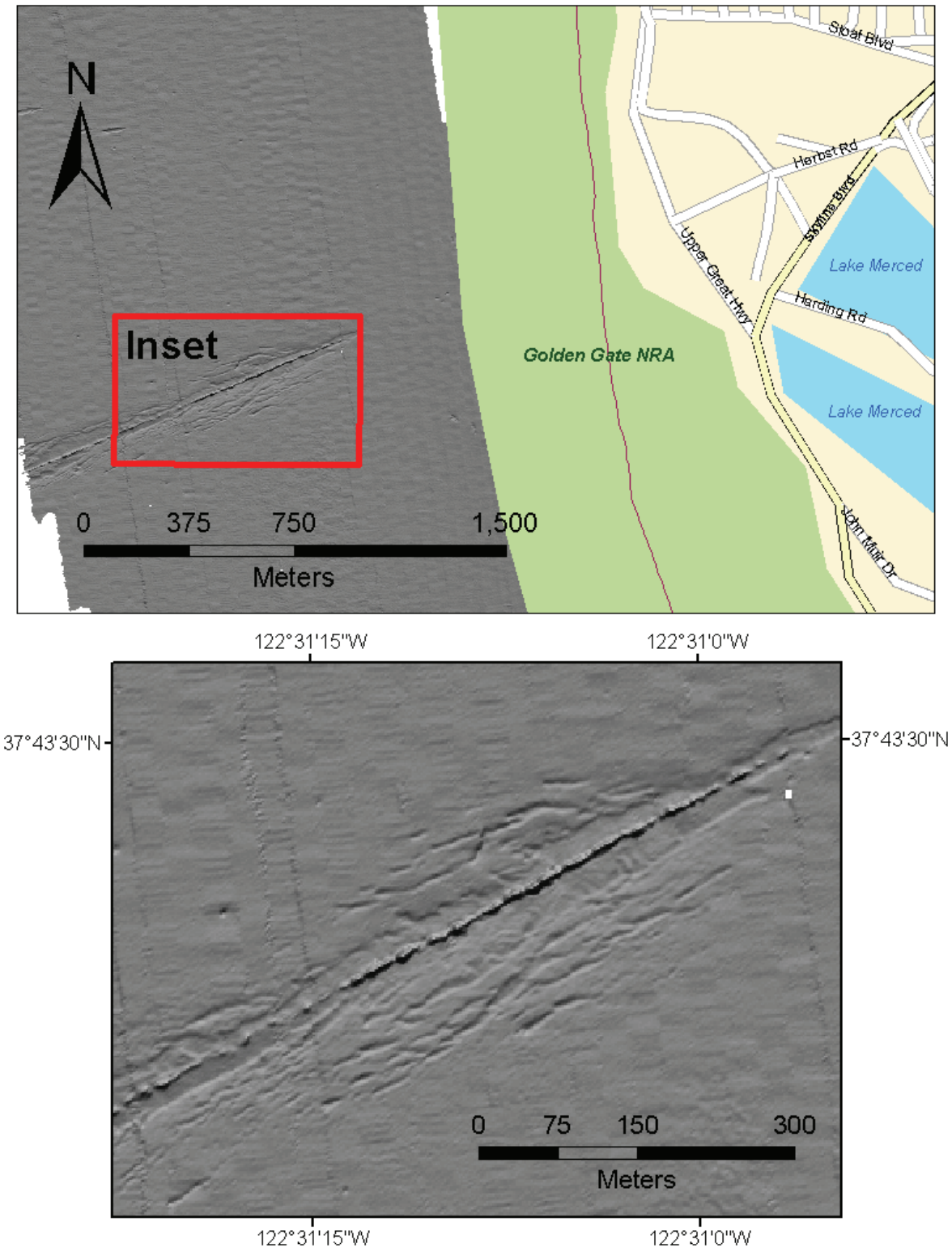


Figure 3. Shaded relief image of the bathymetry around the Southwest Ocean Outfall pipe offshore of Ocean Beach from the fall 2004 multibeam survey.

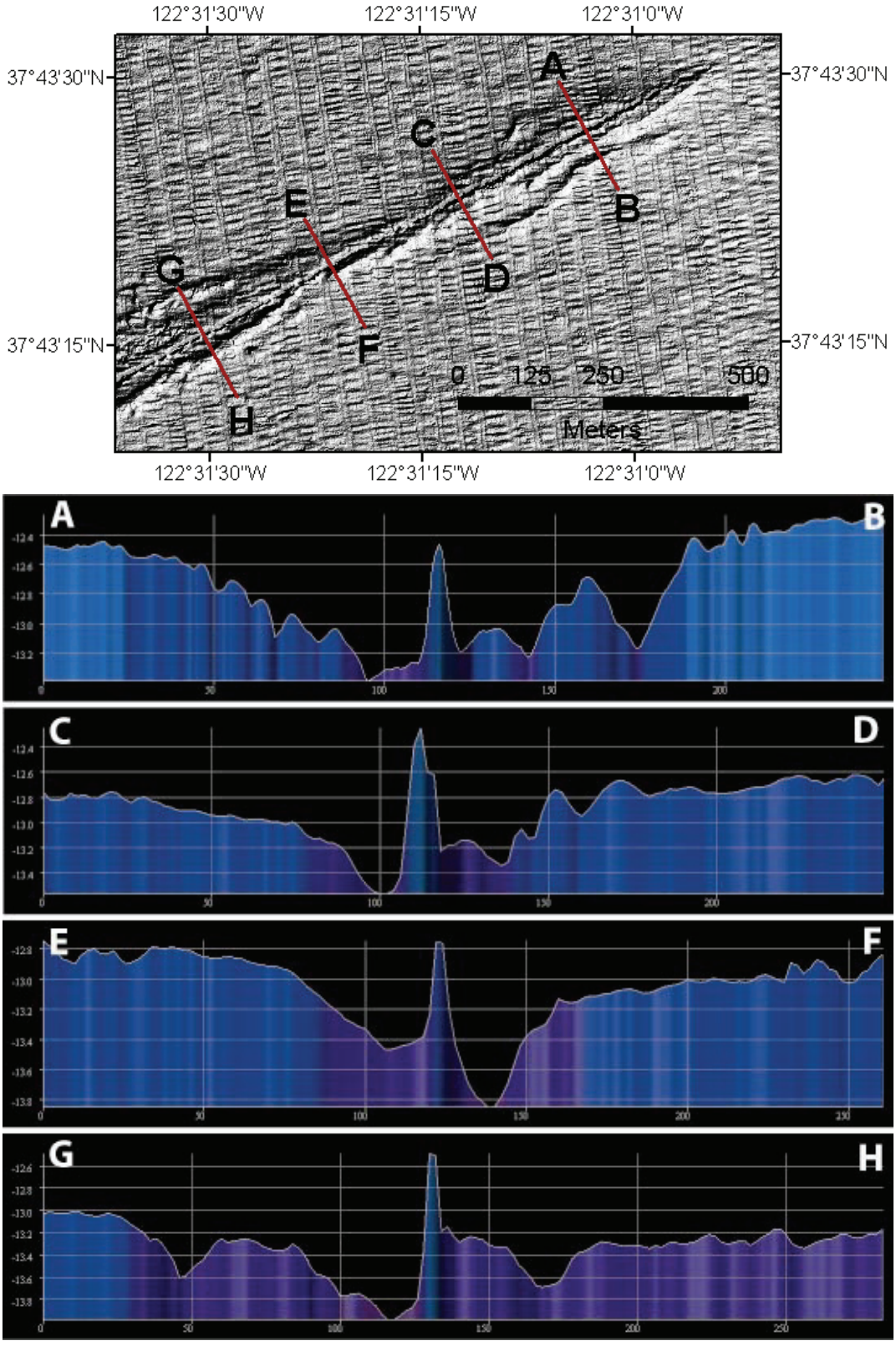


Figure 4. Cross-sections over the outfall pipe from the May 2005 pre-dredge disposal survey, indicating > 1 m of vertical scour adjacent to the exposed pipe.

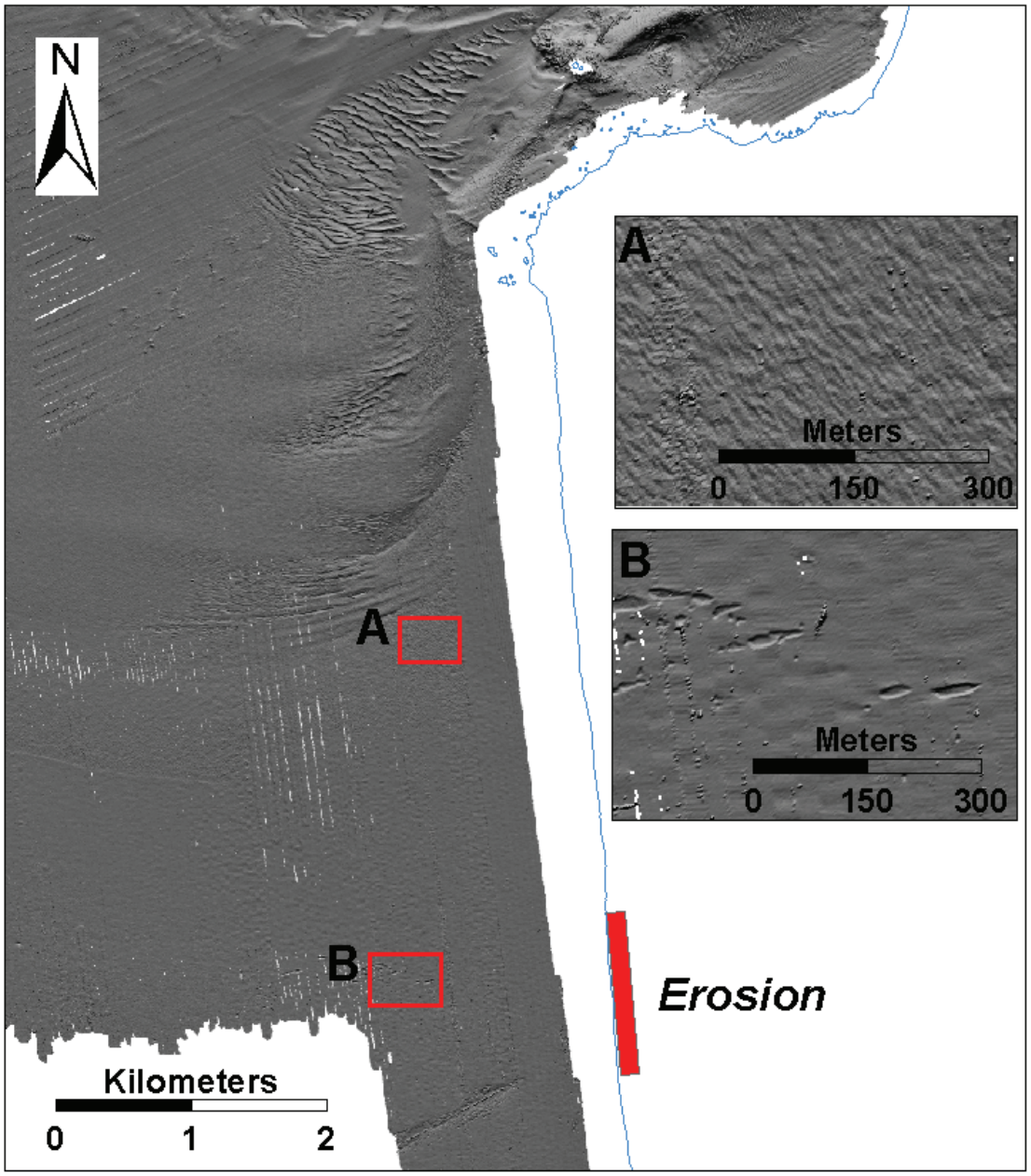


Figure 5. Shaded relief image from the fall 2004 multibeam surveys showing bottom features along Ocean Beach.

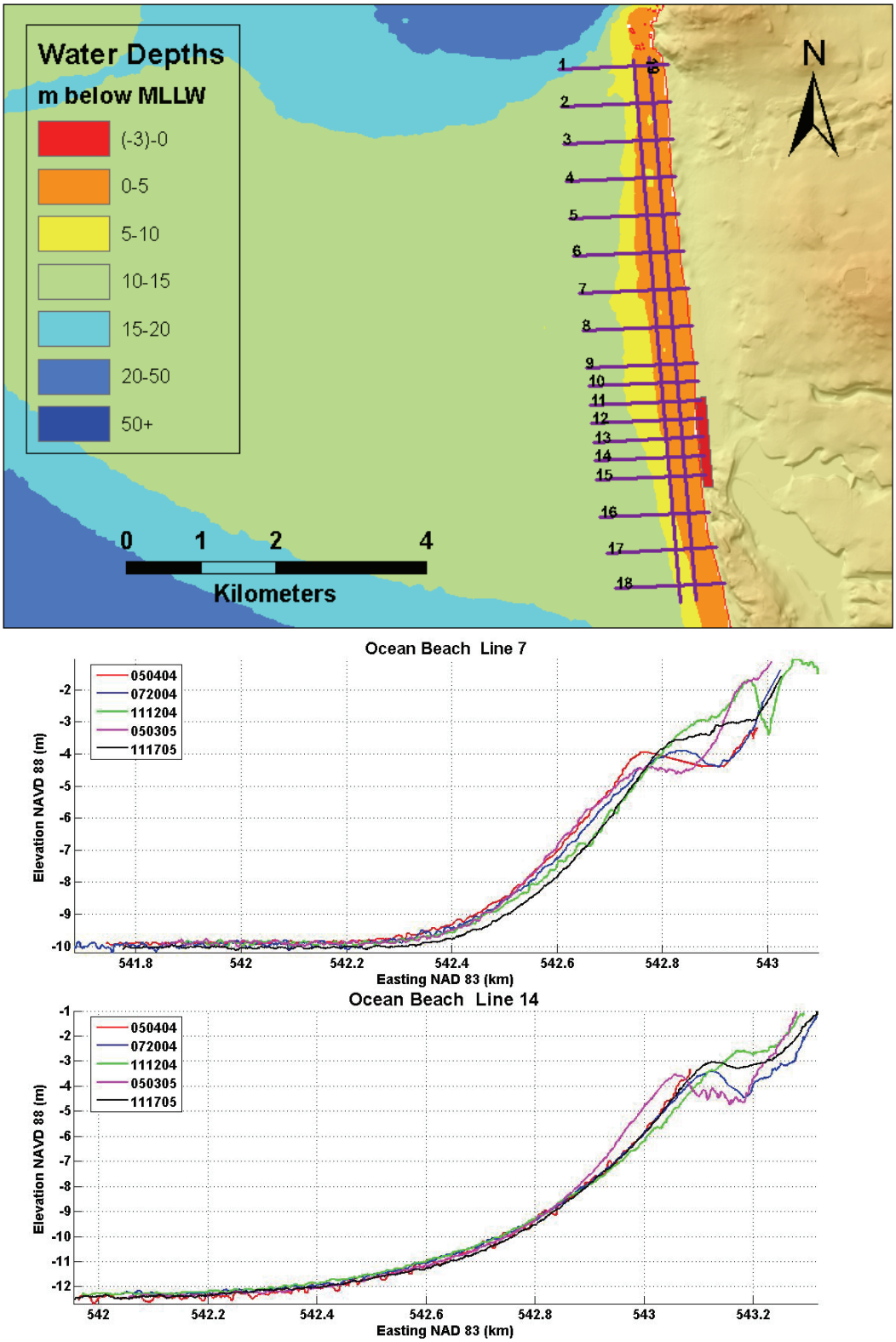
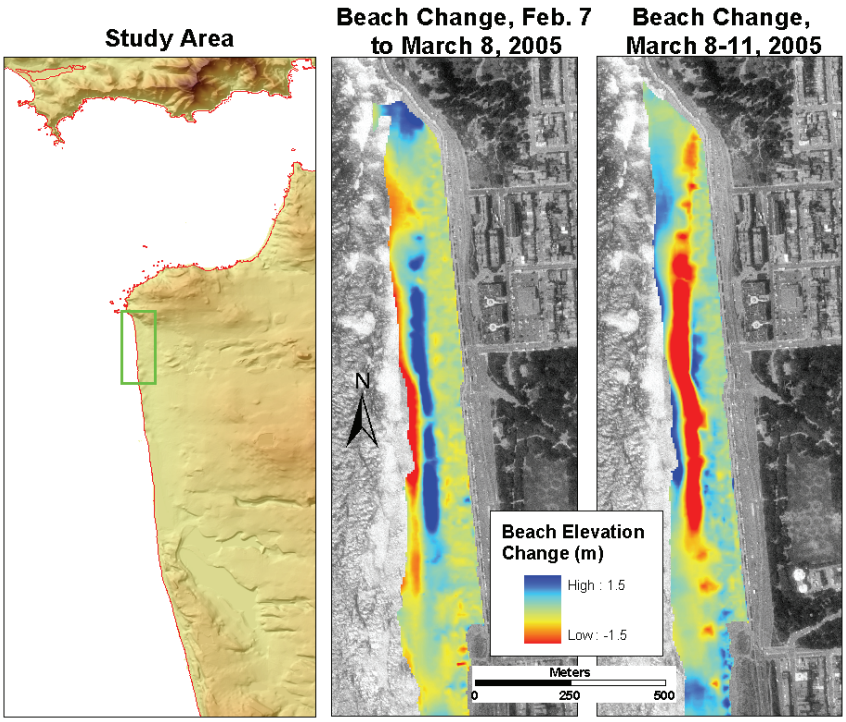


Figure 6. Two transects from PWC surveys along Ocean Beach indicating seasonally high rates of cross shore sediment transport. The labels in the top panel are the survey lines numbers.

A



B

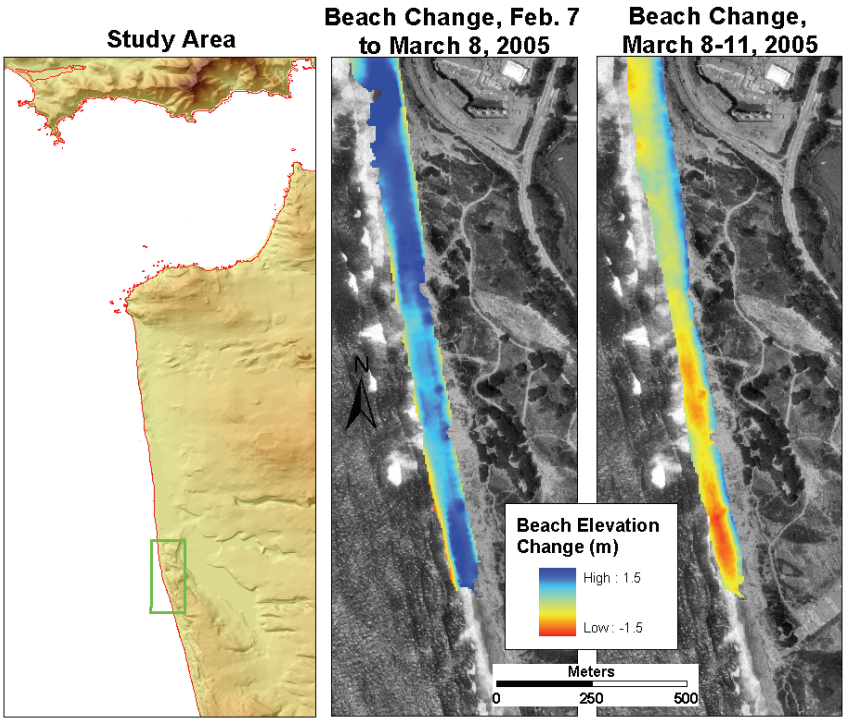


Figure 7. Short-term beach change associated with a significant wave event (offshore wave heights reached 6 m) at Ocean Beach in March 2005 as compared to the month prior. A) Northern Ocean Beach. B) Southern Ocean Beach.

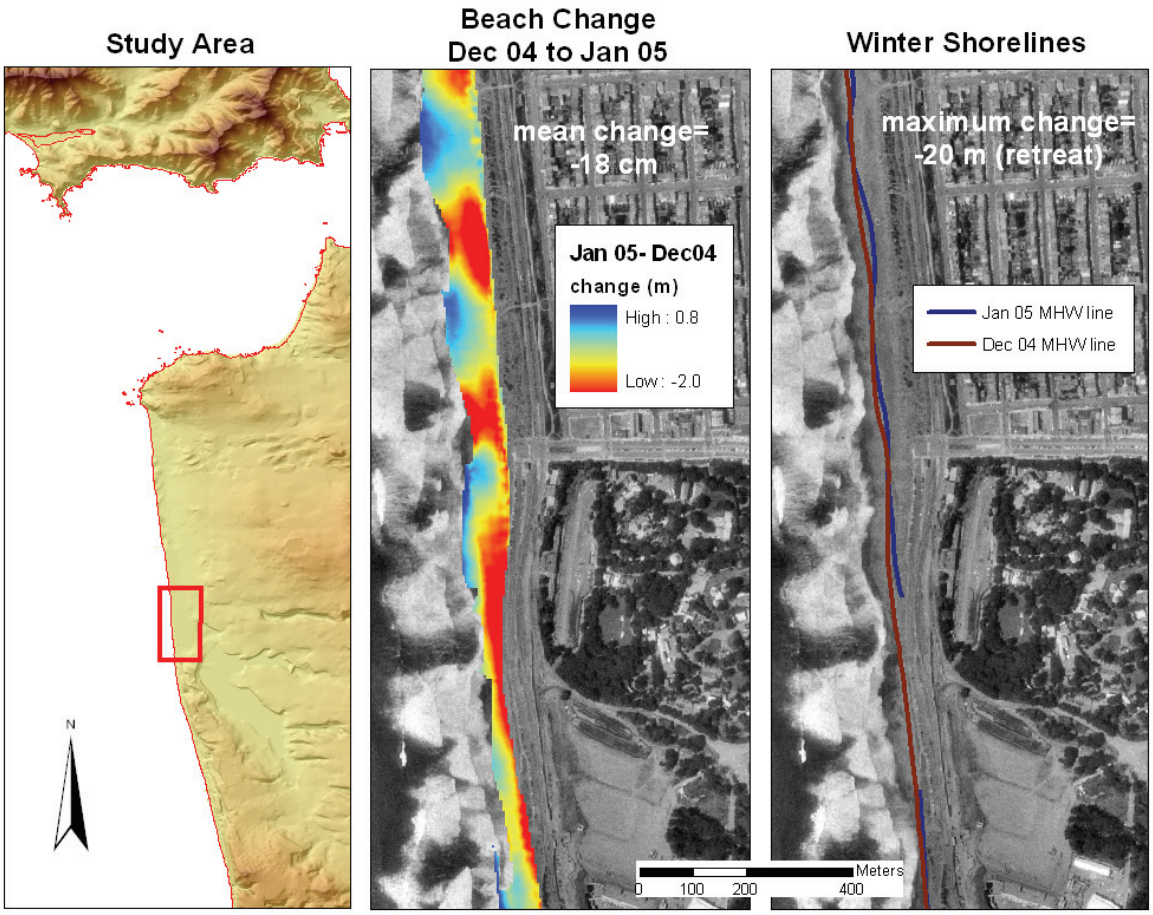


Figure 8. Winter storm change in the location of the erosion hot spot. Note the narrow beach width- the Mean High Water (MHW) line no longer exists on the beach in January 2005 at the pinch point.

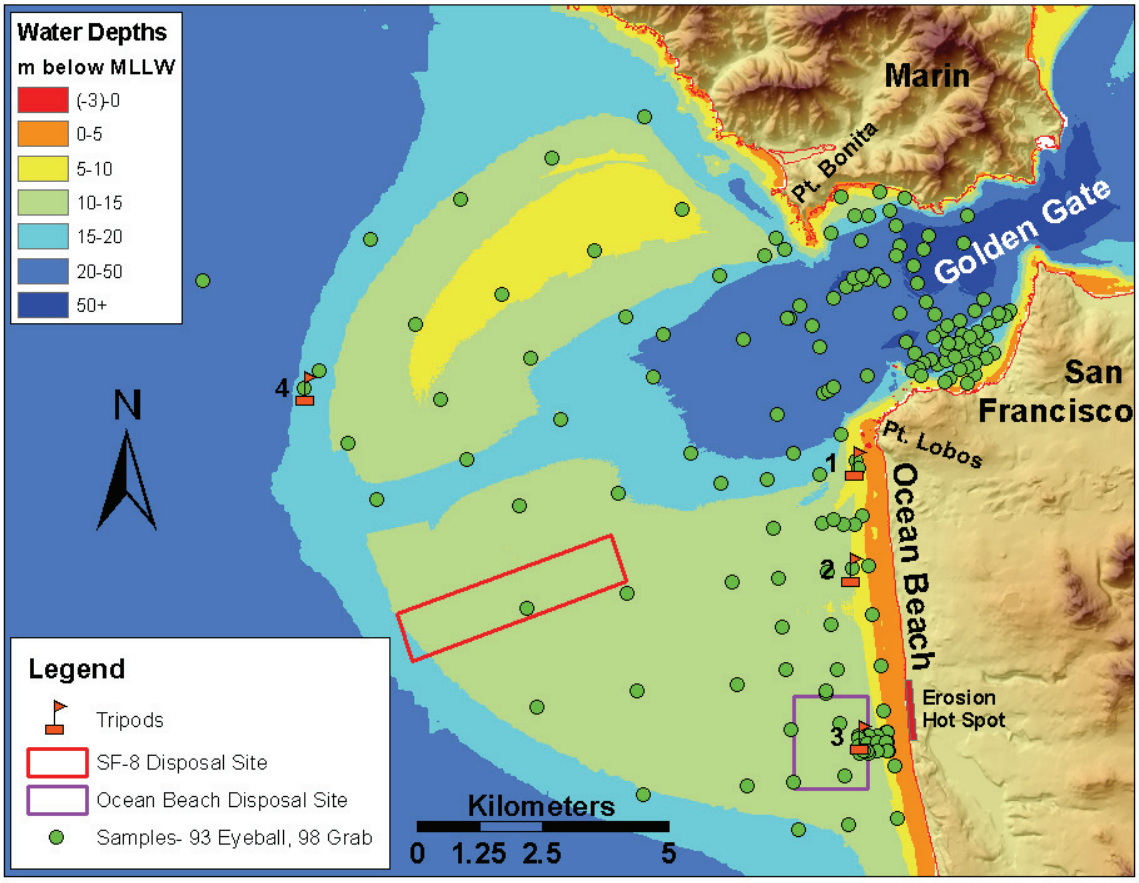


Figure 9. Location of instrument deployments and sediment sampling in summer 2005.

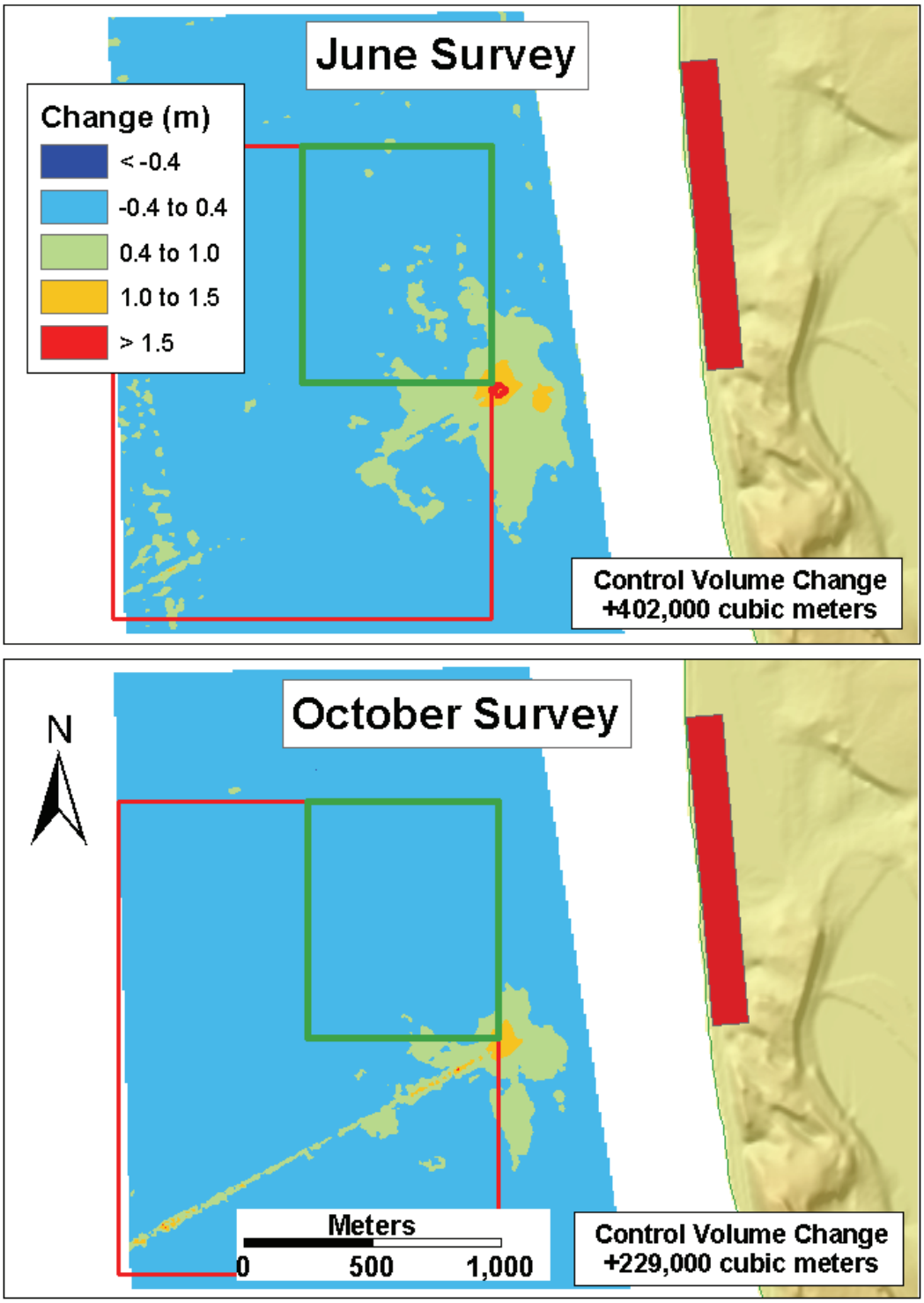


Figure 10. Difference plot showing bathymetric change associated with the initial dredge disposal (June 2005) and change 4 months after the dredge disposal (October 2005). All changes are measured relative to the pre-dredge disposal survey in May 2005.

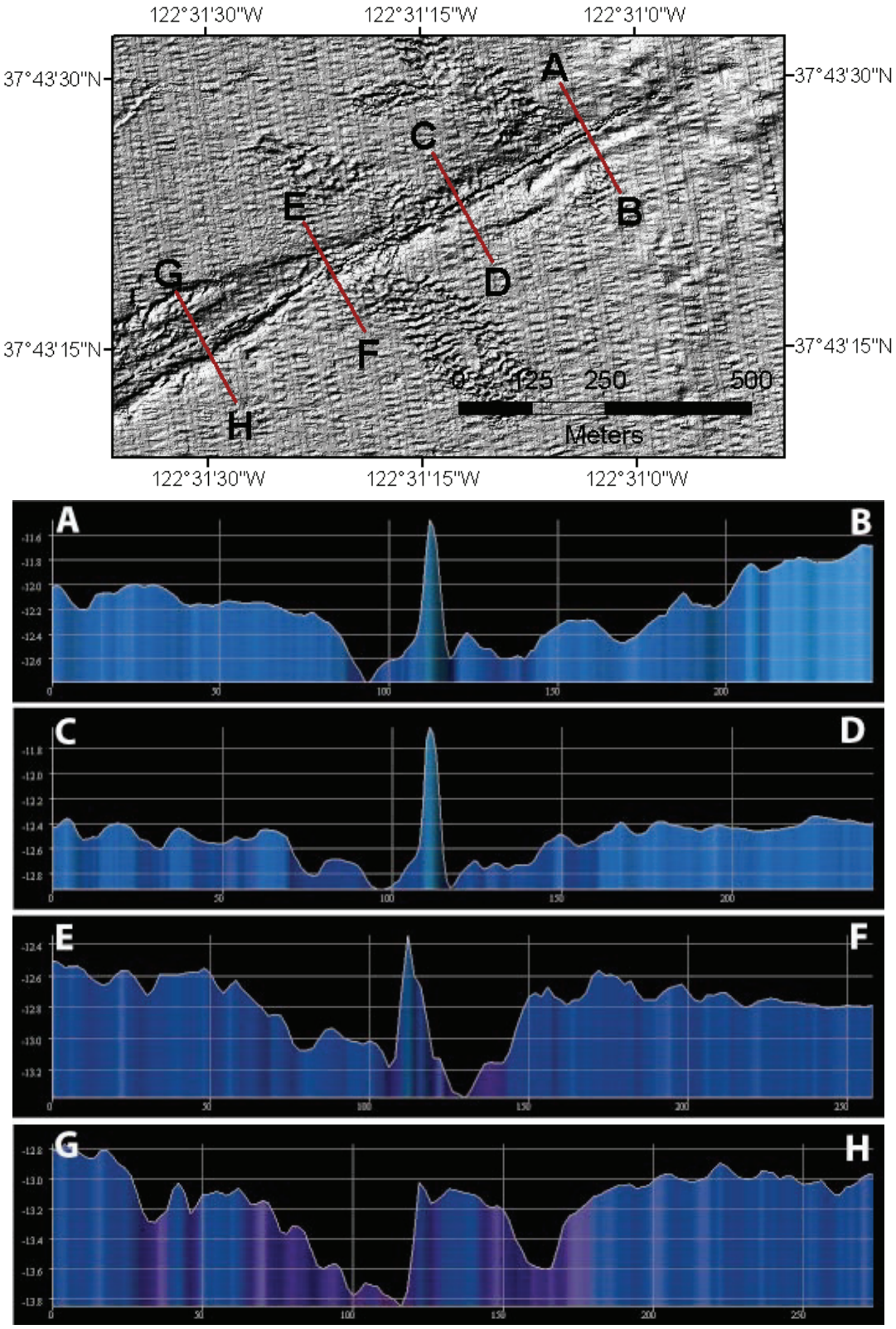


Figure 11. Cross sections over the outfall pipe immediately after dredge disposal. See Figs. 3-4 for pre-dredge conditions.

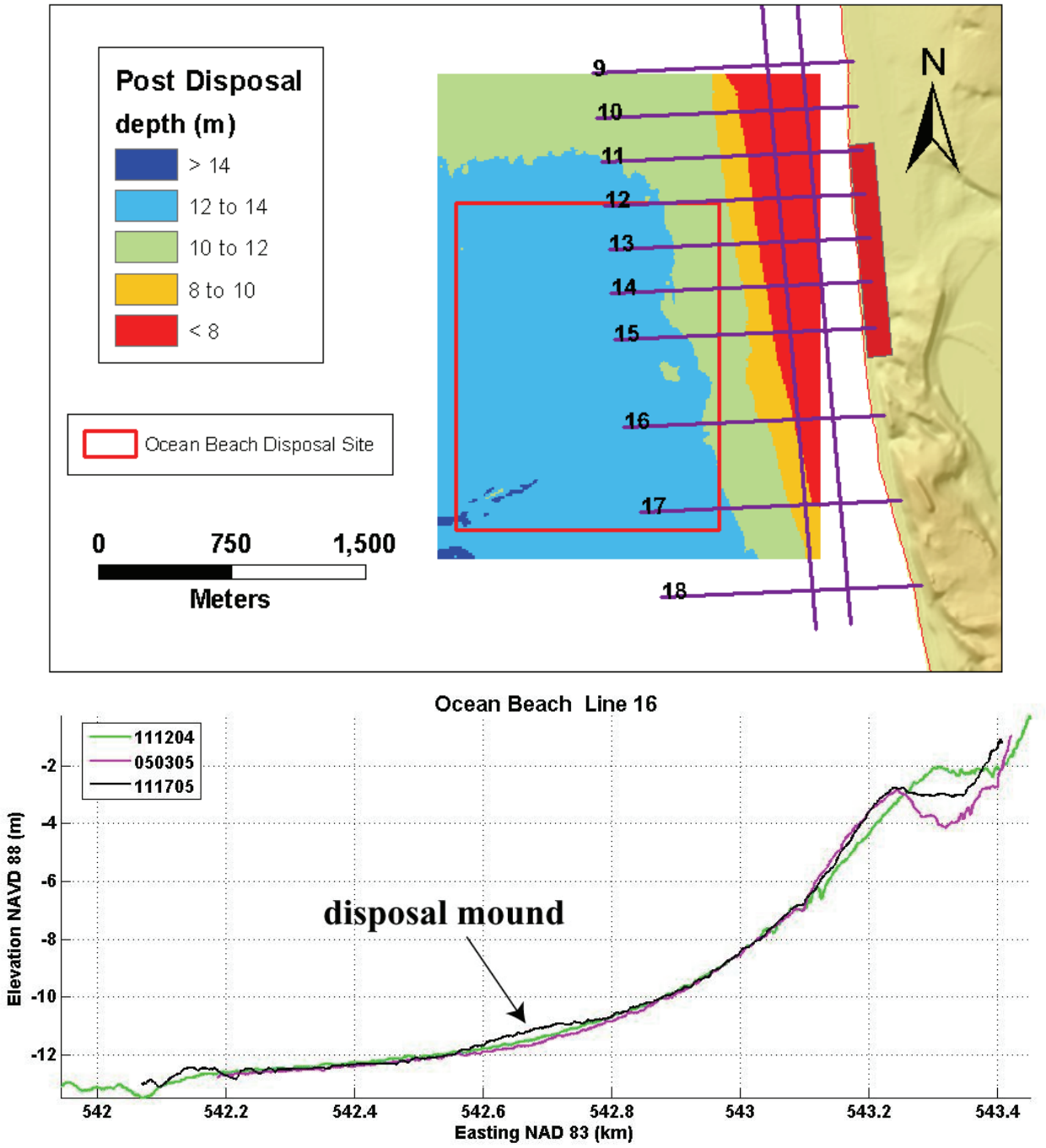
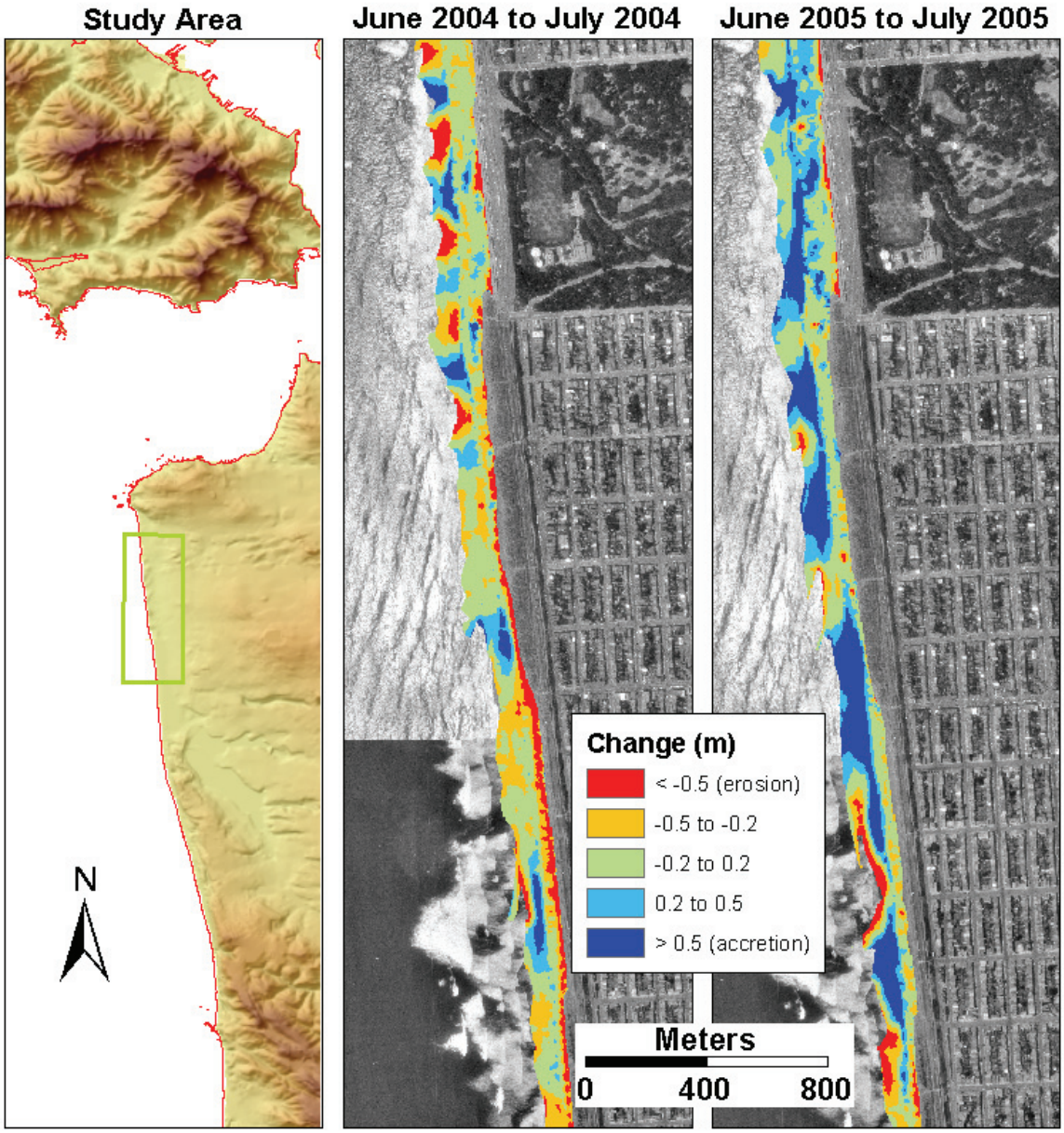
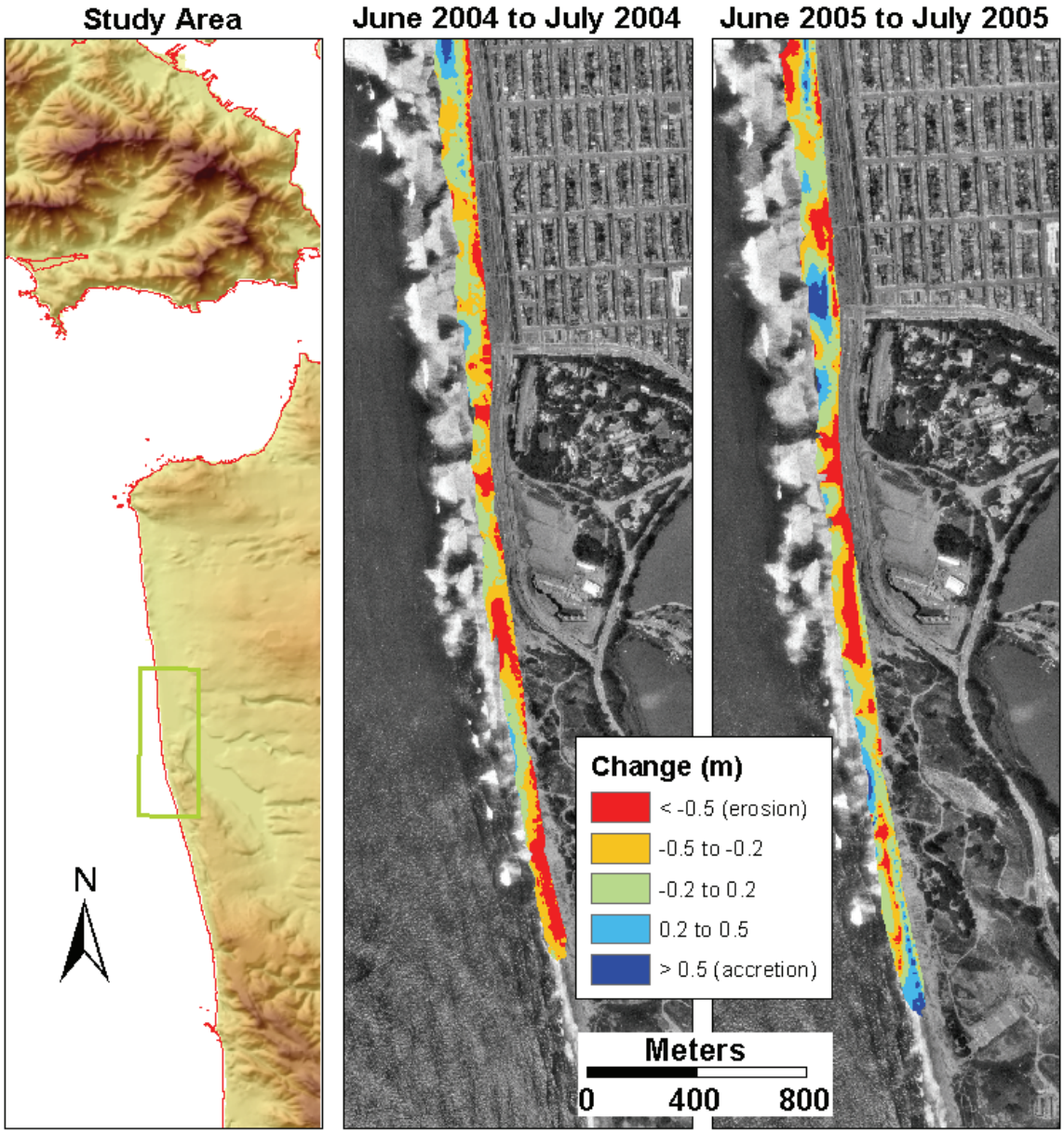


Figure 12. Detection of the dredge disposal mound in the November 2005 PWC survey along PWC survey line #16.

A


Study Area
June 2004 to July 2004
June 2005 to July 2005
N
Change (m)
< -0.5 (erosion)
-0.5 to -0.2
-0.2 to 0.2
0.2 to 0.5
> 0.5 (accretion)
Meters
0
400
800

B



Beach vertical change (cm)

	2004	2005
May - June	18	4
June - July	-18	12
July - August	NA	24

Figure 13. Beach change during the dredge disposal monitoring period, as compared to 2004. A) Northern Ocean Beach. B) Southern Ocean Beach and average vertical change totals for entire beach study area.

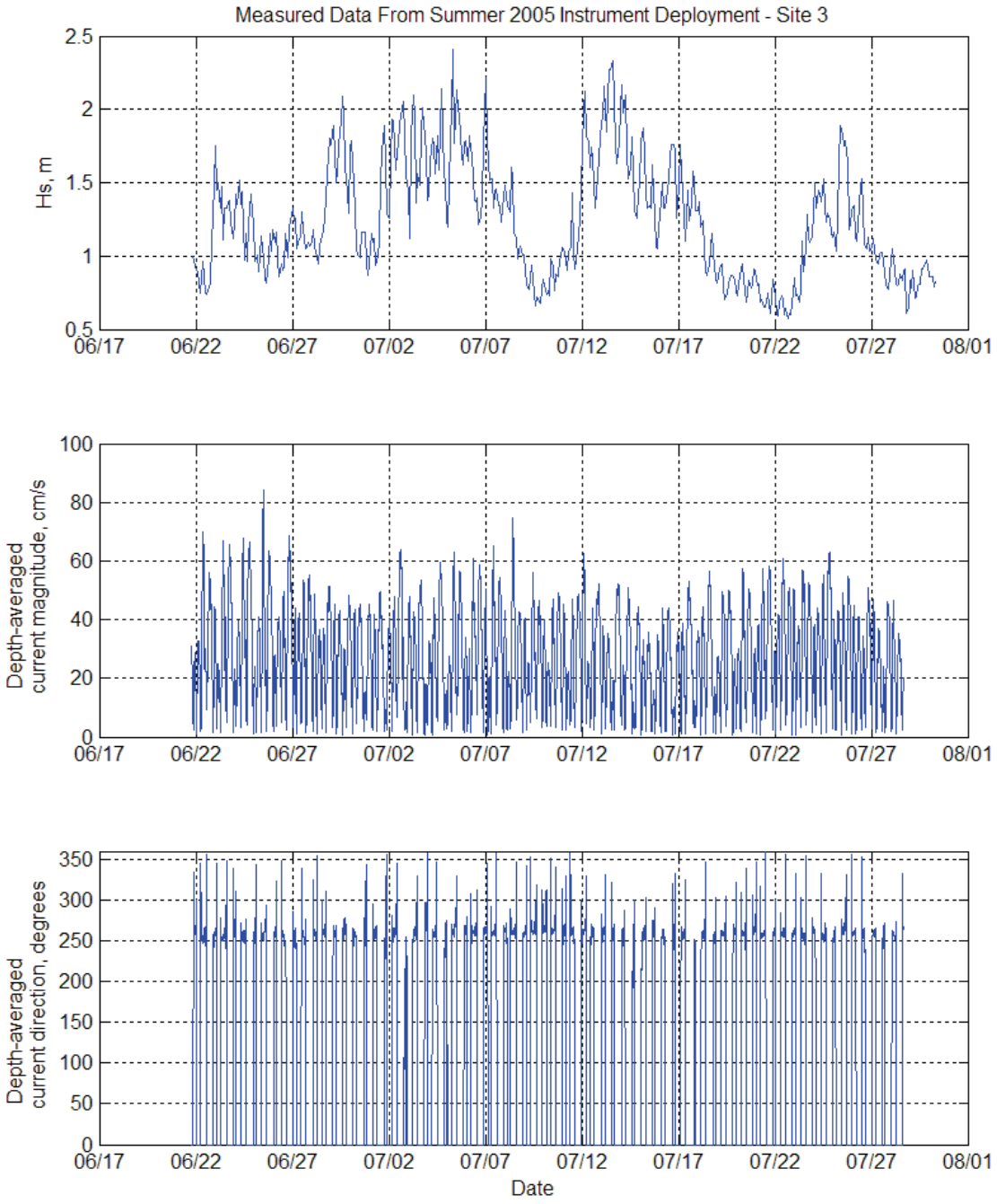


Figure 14. Current and wave plots from site #3 (see Fig. 9) at the disposal site. Currents are more than adequate (peaking at 80 cm/sec) to move sediment from the disposal site.