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SHELF AND SLOPE CURRENTS OFF NEWPORT BEACH

The characteristics of the currents in the vicinity of an ocean outfall influence the initial and subsequent dilution of the wastewater, and the dispersion and sedimentation rates of effluent particulates to the ocean bottom.

During the past two years, we have been making current measurements on the shelf and slope area off Newport Beach. The purposes of these measurements are: (1) to obtain the information on the "mid-water" and "near-bottom" currents that is required by our sediment quality model, (following paper), (2) to determine the properties of the currents in deeper water so the feasibility and advisability of extending outfalls into deeper water can be explored, (3) to examine inter-annual variability in the properties of the currents, and (4) to add to the body of information on the characteristics of the currents within the Southern California Bight.

RESULTS

Current meter moorings were placed at three locations in water depths ranging from 55m to 351m. Measurements were collected at "mid-water" and "near-bottom" (1-2m from the bottom) depths.
Mid-water measurements, at depths from 40m to 300m, indicated many similarities between these flows. At each location, the net movement was upcoast, at speeds ranging from 4 to 9 cm/sec. The principal fluctuations about these mean flows had rms speeds of 6 to 12 cm/sec along the principal axis of variation. The orientation of this axis, like the net flow, was approximately parallel to the local isobaths. Most of the variation in this longshore direction was associated with fluctuations which changed more slowly than the tidal fluctuations. The strongest net flow, and the greatest longshore fluctuations, were observed at the middle station. The meter was at a depth of 50m in 150m of water.

Mid-water median speeds ranged from 7 to 11 cm/sec. The highest observed speeds, occurring at a depth of 40m in 55m of water, and at the 50m depth in 150m of water, were 48-49 cm/sec, or roughly one knot.

Near-bottom speeds were somewhat less. Median speeds in 55m and 350m of water were 6cm/sec. Substantially weaker currents, with a mean speed of 3 cm/sec, were measured in 150m of water. The maximum observed speed in 55m of water was 33 cm/sec; at the 150m and 350m depths, it was 21 cm/sec.

Cross-shore fluctuations, both at mid-water and near-bottom depths, were primarily associated with tidal, and shorter period fluctuations. Frequently the cross-shore rms values were greater near the bottom than they were in mid-water depths. This was particularly true at the station in 350m of water and is suggestive of internal waves or tides "shoaling" on the slope.

Simultaneous mid-water measurements at the two inner stations (55m and 150m of water) indicated that long-period fluctuations in the longshore direction were highly correlated. We have not yet made simultaneous mid-water measurements at the inshore and offshore station (55m and 350m).

Simultaneous measurements were also made at meter depths of 15m and 40m (in 60m of water) off Palos Verdes, and at a depth of 40m in 55m of water off Newport Beach. The net flow, and the fluctuations at the 40m depth, off Palos Verdes were substantially less than off Newport Beach. Surprisingly, the net flow and fluctuations at the 15m depth off Palos Verdes were much closer to the 40 m deep Newport Beach values. Some correlation was observed between the Newport Beach and the Palos Verdes fluctuations, but even between the two Palos Verdes meters, the correlation was not large.

Long-period fluctuations in the longshore direction in the near-bottom currents off Newport Beach were generally well correlated with the mid-water fluctuations at the same station, but are substantially weaker. Fluctuations of tidal, or shorter periodicity were generally comparable, or exceeded, the corresponding fluctuations at mid-water depths. This diminution of the long-period fluctuations is probably associated with the development of the benthic frictional boundary layer, and its dependence on the characteristic fluctuation times for unsteady flows.

These measurements indicate that the net flow, and the long-period fluctuations, tend to strengthen with increasing offshore distance, but slowly weaken with increased depth in the water column. As a result, the currents at a depth of 250m, in 350m of water, are comparable to those at a depth of 40m in 55m of water, but both are exceeded by the 50m deep flows in 150m of water. They also indicate that resuspension effects will probably be as important on the slope, in water depths of 350m, as they are on the shelf in 55m of water. There is however, also the suggestion that resuspension effects may be weaker near the shelf/slope break, in 150m of water.

EQUIPMENT

Tiltmeter-type current meters, of SCCWRP design, were deployed on taut-line moorings at all stations. These meters have a threshold speed of about 1 cm/sec, and an error of 1 cm/sec, or less (under steady-state conditions), in the speed range from 1 to 20 cm/sec. Measurements are collected at fifteen minute intervals, but analyzed at forty-five minute intervals, unless substantial short-period fluctuations are present in the record.

STATION LOCATIONS AND PERIODS OF OBSERVATION

The locations of the current meter moorings are shown in Figure 1. The associated water depth, meter depths, and the periods of record, are summarized in Table 1. The three Newport stations are situated on the nearshore shelf, near the shelf/slope break, and on the upper portion of the slope. The Palos Verdes station is on the nearshore shelf.

DISTRIBUTION OF SPEEDS

The distribution of current speeds observed at each meter location and mooring in the Newport

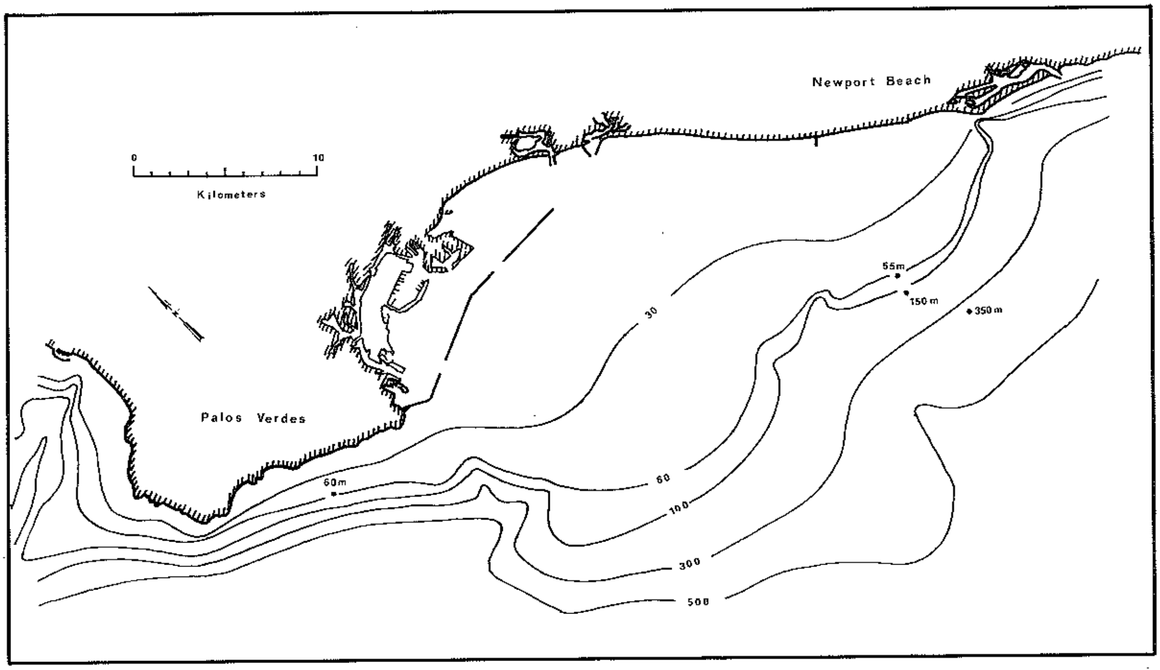

Figure 1. Location of the current meter stations in the Newport Beach and Palos Verdes areas. Depth contours are in meters.

Table 1. Characteristics of Newport Beach Current Meter Records

Location	LORAN Coord.	Meter Depth (m)	Water Depth (m)	Date(s) of Records
Shelf/Midwater	28215.4 40920.8	40 40920.8	55	10/7/80 - 11/4/80 3/2/81 - 3/9/81 3/10/81 - 7/27/81
Shelf/Bottom	28215.1 40920.7	53 40920.7	55	10/3/80 - 11/4/80 2/2/81 - 7/27/81
Break/Midwater	28213.6 40920.4	50 40920.4	150	10/3/80 - 11/7/80 2/2/81 - 4/13/81
Break/Bottom	28215.1 40921.0	148 40921.0	150	10/3/80 - 10/7/81 6/25/81 - 7/27/81
Slope/Midwater	28214.4 40911.3	250 40911.3	351	2/11/82 - 2/28/82 4/26/82 - 5/11/82
Slope/Midwater	28214.4 40910.2	300 40910.2	351	2/11/82 - 2/23/82 4/26/82 - 5/20/82
Slope/Bottom	28214.5 40910.7	300 40910.7	351	3/22/82 - 6/2/82

Beach area is illustrated in Figure 2. Table 2 summarizes various descriptions of these speed distributions in terms of the median speed, most probable speed, etc. Mid-water median speeds range from 7 to 11 cm/sec. Near-bottom median speeds vary from 3 to 6 cm/sec. Peak speeds tend to be higher on the shelf than in deeper water, but this may just reflect the longer record lengths available for the shelf area. A striking feature is that the current strengths at a depth of 250m (in 350m of water) are comparable with those at a depth of 40m in 55 m of water.

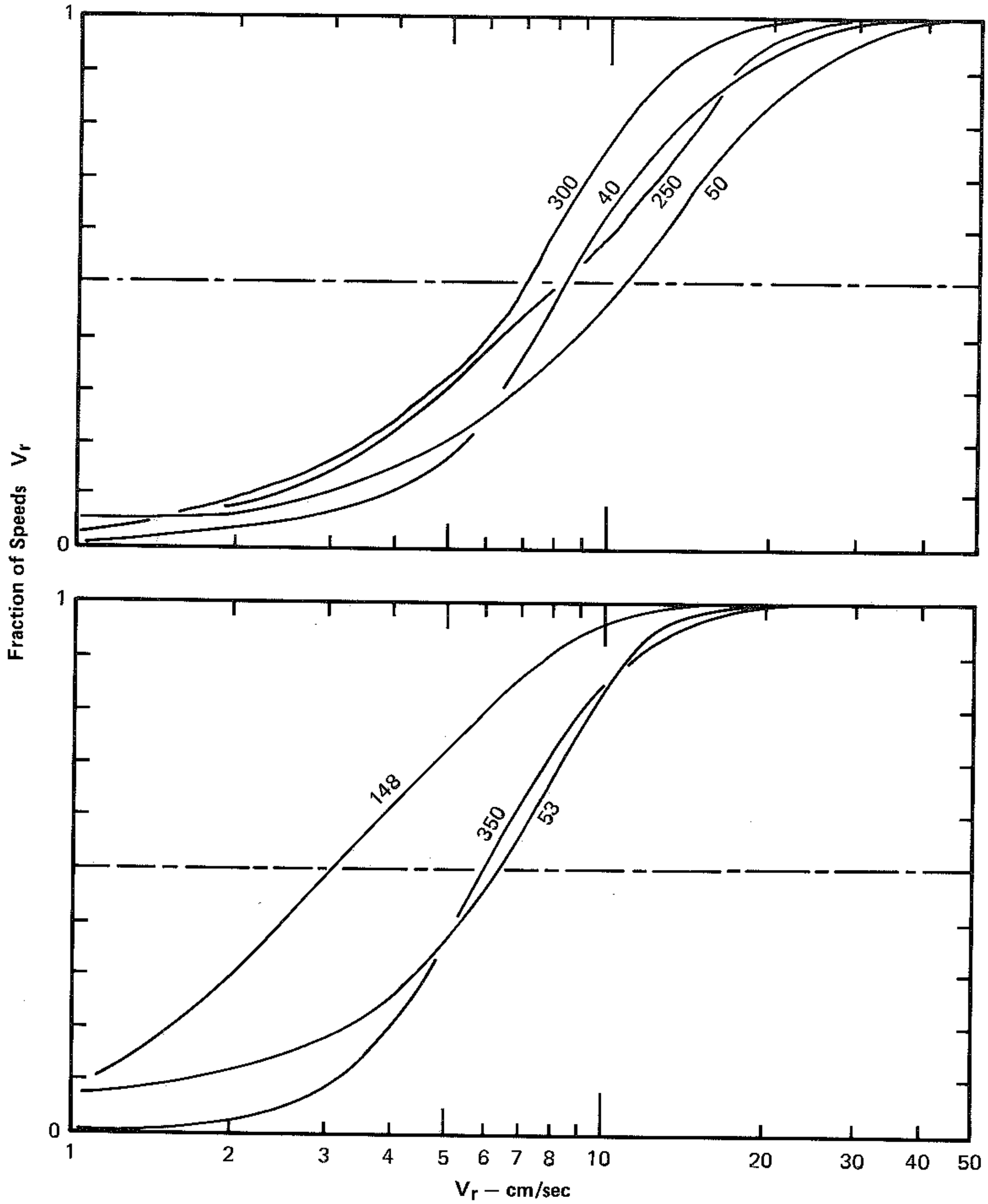

Figure 2. Distribution of observed current meter speeds. The upper portion is the distribution at the mid-water meter depths; the lower portion, the near-bottom speed distribution. The vertical axis is the fraction of the observations which have a speed less than some reference value, v_r; the horizontal axis indicates this reference speed. The numbers on each curve are the depths of the current meters (in meters).

Table 2. Statistical Properties of the Newport Beach Current Speeds

Meter Depth (m)	Water Depth (m)	Median Speed (cm/sec)	Most Prob.	Middle 50%	Greatest 10%	Max. Speed
40	55	8.5	7	5.8 - 12.7	>18	48
50	150	11.0	10	5.5 - 16.2	>22	49
250	351	7.9	5	4.3 - 13.5	>17	27
300	351	6.8	7	4.2 - 9.5	>13	25
53	55	6.3	6	3.9 - 9.1	>11	33
148	150	3.1	3	2.7 - 5.4	8	21
350	351	6.0	6	4.4 - 8.3	>11	21

NET SPEEDS AND VARIATIONS IN THE FLOW

Table 3 indicates the net flows, and the direction of these net flows, over the period of record available for each of the current meter locations. Off Newport Beach, the net speeds at mid-water depths ranged from 4 to 9 cm/sec, and generally increased with increasing distance offshore. At a depth of 50m, in 150m of water, the net speed of 8.7 cm/sec was slightly more than twice the net speed at a depth of 40m in 55m of water. The second highest net speed was at a depth of 250m in 350m of water, but this is based on a relatively short record length.

Near the bottom, the net speeds were in the range of 1-3 cm/sec. On the shelf, the net flow was upcoast and somewhat offshore. At the intermediate station, the net movement was offshore and slightly downcoast, while at the deeper station, the movement was upcoast along the local isobaths. This suggests complex long-term flows in this depth range, but this can not be conclusively demonstrated because of the (present) short record lengths at depths of 150m and 350m.

Table 3 also contains the rms speed values for the fluctuations along the principal axes of variation. At mid-water depths, the primary fluctuations generally occur along an axis that is approximately parallel to the mean flows and the direction of the local isobaths. These fluctuations are also stronger than the mean flows. More than half the variance associated with these longshore fluctuations is associated with time-scales longer than the tidal oscillations. Along the minor axis (perpendicular to the major axis), the fluctuations are weaker, with the cross-shore variance ranging from one-quarter to one-seventh the longshore values.

Near the bottom, the major principal axis of variation in water depths of 55m and 150m is parallel to the local isobaths. In a water depth 350m, it is almost perpendicular to the isobath, but there is little difference in the strengths along the major and minor axes. As at the mid-water depths, the magnitude of the variations exceeds the strength of the net flows, however, the ratio between the variances along the major and minor axes has been reduced to 1-3.

Mean flows and the rms fluctuations for the Palos Verdes mooring (meters 15m and 40m deep, in 60 m of water) are also summarized in Table 3. At both depths, the net flow is substantially weaker than those indicated for the mid-water Newport Beach stations, but this is somewhat misleading since the net flow at the 40m depth off Newport Beach for almost the same time period was only 1.6 cm/sec. In addition, the net flow is somewhat onshore during this period. This feature is probably associated with the weak net flow, since it is difficult to determine the net speed and direction when the variations are on the order of ten times greater than the net speed. The primary axis of variation is close to the direction of the local isobaths.

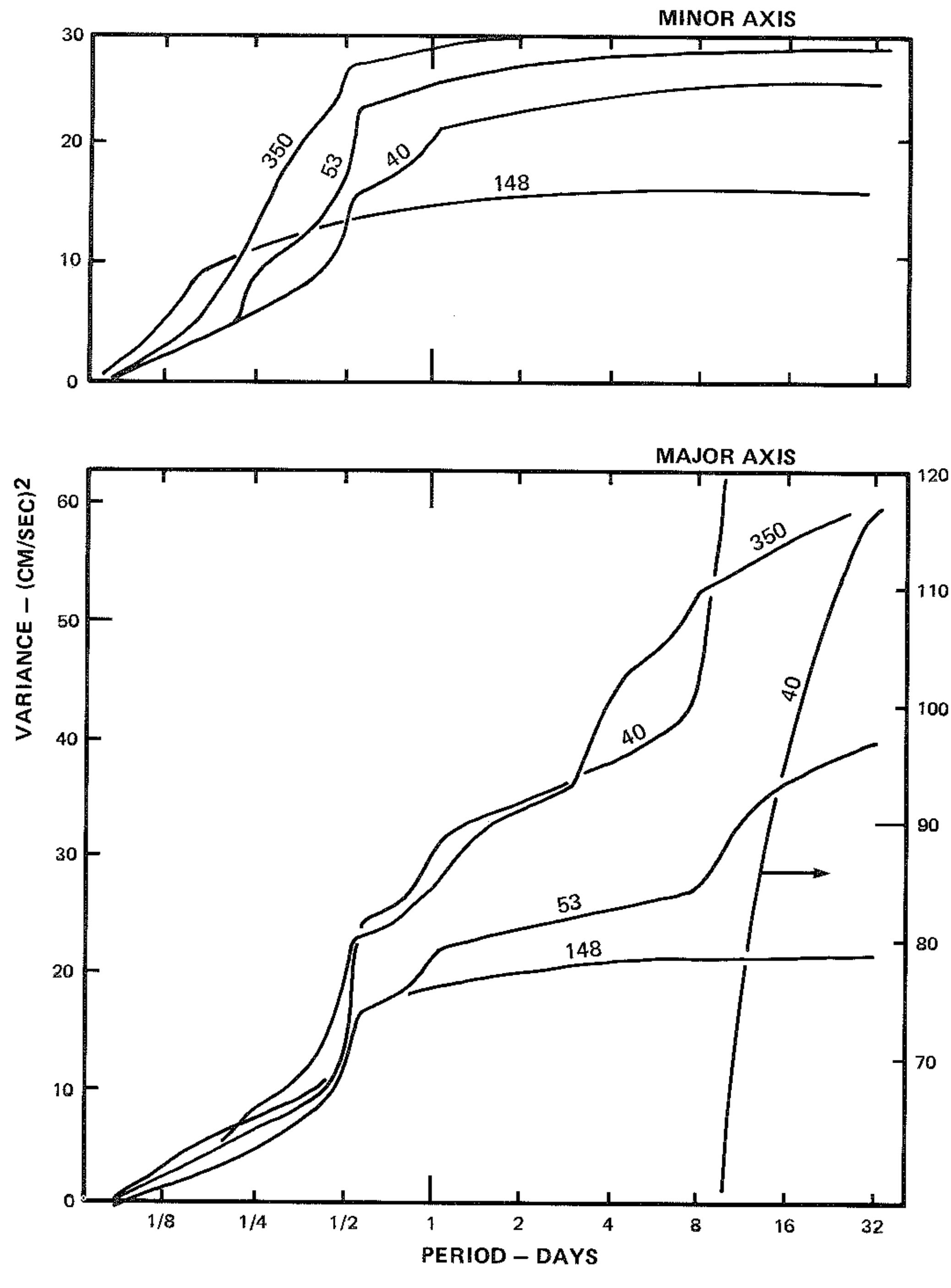

Figure 3. Cumulative variance of the fluctuating components of the flows as a function of the "characteristic fluctuation times." The upper figure corresponds to fluctuations along the minor principal axis of variation; the lower portion, along the major axis. The vertical axis represents the total variance associated with characteristic fluctuation times less than some reference time. The lower axis indicates this time, which corresponds to the "periodicities" of the Fourier components of the sequence of measurements. The numbers on each curve correspond to the depth of the current meter (in meters). Note that the 40m deep record in the longshore direction is continued on the right hand vertical axis.

Table 3. Net Flows and RMS Variability

Loc.	Depth (m)	Days Rec'd	Isobth Dirc.	Net Speed (cm/sec)/ Direction (deg. meg.)	RMS Speeds Major Axis	Minor Axis
PV	15/61	56	285	1.3 - 322	13.3 - 275	6.2 - 185
PV	40/61	56	285	0.6 - 323	5.8 - 270	3.7 - 180
NB	40/55	188	274	4.2 - 274	8.9 - 276	4.4 - 186
NB	53/55	192	274	2.5 - 235	5.7 - 265	5.1 - 175
NB	50/150	70	275	8.7 - 265	11.5 - 265	4.5 - 175
NB	148/150	71	275	1.0 - 166	4.0 - 274	3.7 - 184
NB	250/351	26	265	7.1 - 270	7.5 - 267	2.8 - 177
NB	300/351	36	265	4.7 - 273	6.2 - 273	3.2 - 183
NB	350/351	60	265	2.8 - 272	6.2 - 297	4.4 - 207

VARIABILITY OF THE CURRENTS IN TIME

Figure 3 shows the cumulative variance as a function of increasing characteristic time scales of the fluctuating portion of the currents for records collected at 40m, 53m, 148m, and 350m (in water depths of 55m, 55m, 150m, and 351m respectively). The upper part of the figure is along the minor axis of variation; the lower part, the major axis. The cumulative variances for the records at meter depths of 50m, 250m, and 300m (in water depths of 150m, 351m, and 351°m respectively) are not shown since they are similar to the 40m variance distribution (but with different total variances). It is evident from this figure, that at mid-water depths, most of the longshore variance is associated with fluctuations whose variation times are longer than one day. These long-period fluctuations are substantially suppressed, however, near the ocean bottom (53, 148, 350m). Since the thickness of the benthic boundary layer(s) for unsteady flows increases with increasing characteristic variation times, this suppression of the long-period components probably reflects the greater frictional effects on these variations.

Along the minor axis of variation (essentially cross-shore), almost all of the variance is associated with fluctuations with time-scales of variation comparable with, or shorter than, the tidal oscillations. In mid-water depths, noticeable contributions occur at both the semi-diurnal and diurnal tidal frequencies (0.52 and 1.0 day periods). Near the bottom, however, the situation is more complex. On the shelf, at a depth of 53m, there is virtually no contribution at the diurnal tidal frequency, but a substantial input at the first harmonic of the semi-diurnal tidal frequency. Near the shelf/slope break, at a depth of 148m, there is no noticeable contribution from the diurnal, semi-diurnal, or first harmonic of the semi-diurnal tidal frequencies. There is some indication, however, of the input from broad peaks around the third and fourth harmonics (periods of 0.17 and 0.13 days) of the tidal frequencies. In 351m of water, the near-bottom cross-shore variations appear to be predominately associated with broad peaks around the first and second harmonics of the semi-diurnal tidal frequency, with a smaller contribution from the semi-diurnal tides. These inputs from harmonics of the tidal oscillations suggest non-linear interactions between the internal tides and the ocean bottom. There is also the suggestion of a contribution of the first harmonic of the semi-diurnal tide at a depth of 350m along the major axis of variation, but this is probably related to the fact that the major axis of variation at this location includes a cross-shore component in its orientation.

Because most of the total variance (combined major and minor axes) in the near-bottom currents is associated with tidal and sub-tidal periods, the properties of the benthic boundary layer are likely to be similar in other ocean areas which have different characteristics for the long-period components of the flows, but contain tidal contributions (or areas driven predominantly by tidal oscillations). This suggests that the "fitted" value we obtain for the "characteristic dispersion length" parameter in the benthic processes sub-model (see following paper for the Palos Verdes area may be representative of a wider class of receiving water conditions or areas. Figure 4 shows the long-period portion of the flows along both the longshore and cross-shore axes. These daily values are obtained using a 24.75 hour running-average filter to suppress tidal and shorter period fluctuations. It is immediately obvious that after the short-period fluctuations are removed from the record, the variations along the major axis are substantially larger than along the minor (cross-shore) axis.

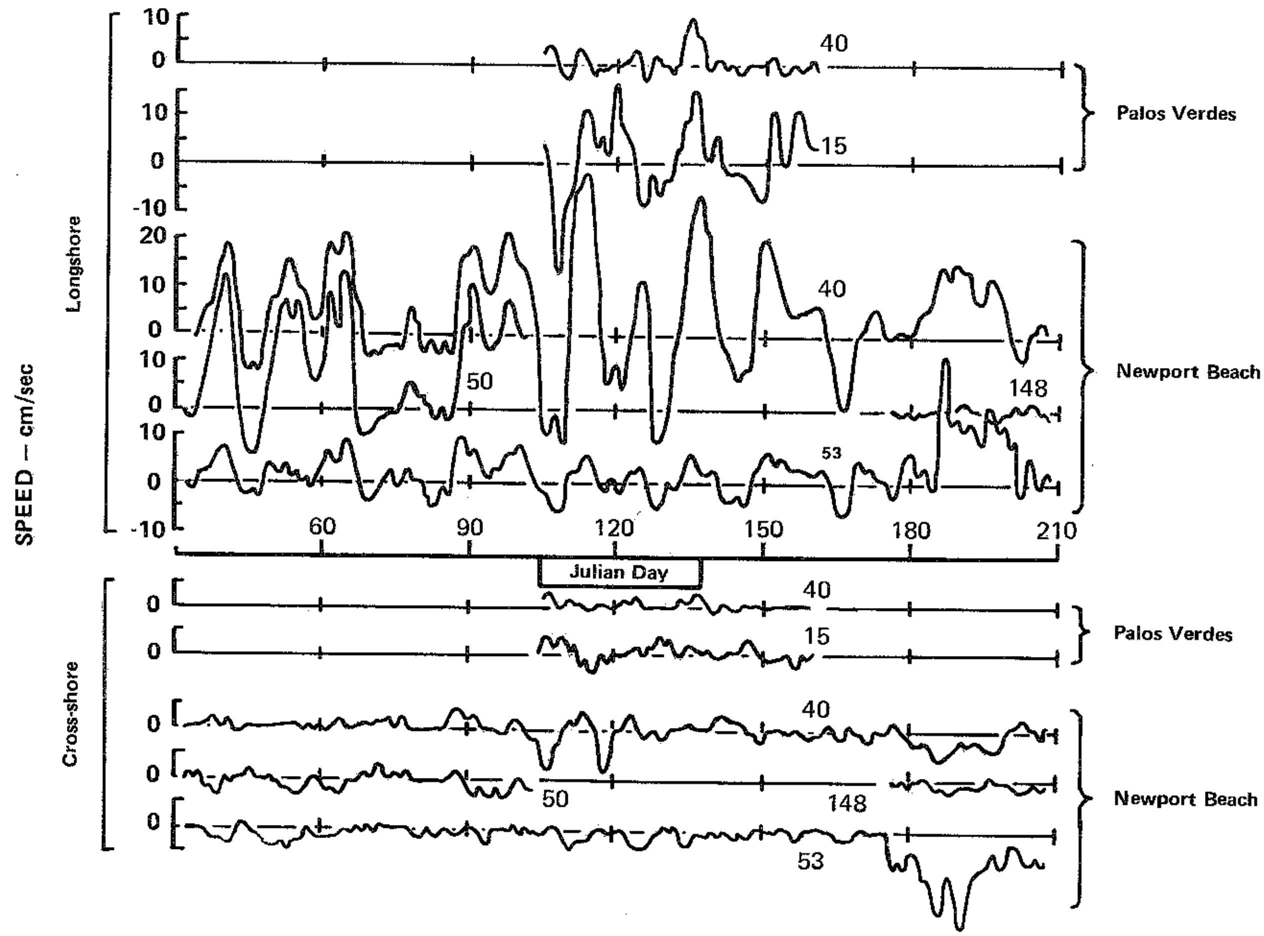

Figure 4. Longshore and cross-shore components of the "average daily currents." The longshore and cross-shore values are obtained by applying a 24.75 hour running-average filter to the original data. Note that the records from 50m and 148m, in 150m of water, share the same line but were collected at different times.

A comparison of the longshore components of the flow at water depths of 40m and 50m (in water depths of 55m and 150m, respectively) shows that the flows at these two stations are highly correlated. Similarly, the longshore fluctuations near the bottom at the 55m station, although weaker than the mid-water fluctuations at this station, are also well correlated.

In contrast, the longshore fluctuations in water depths of 15m and 40m (in 60m of water) at the Palos Verdes mooring are not nearly as well correlated. Some common variations are observed between the Palos Verdes fluctuations at both depths, and the 40m deep record off

Newport Beach (a separation of about 33km), but the correlation is not high. Similar correlations at comparable separations have previously been observed in the coastal area off San Diego County.

At the present time, we do not know why the longshore correlation between meters on the same mooring is so high at Newport Beach, but substantially lower off Palos Verdes. The low correlation between two depths at the same mooring implies substantial baroclinic flows (i.e. associated with the density stratification of the water column), and it may be that intensified baroclinic activity occurs over the narrower shelf area off the Palos Verdes area.

The long-period component of the flows, in combination with the net flow (infinite period), is generally the most important part of the currents in dispersing wastewater and particulates over length-scales in excess of 1-2 kilometers. By comparing the longshore fluctuations at depths of 40m off Palos Verdes and Newport Beach, it is evident that these fluctuations are a factor of two, or more, stronger at the Newport site. Therefore, even if the net flows are comparable, the Newport Beach currents should be much more effective at dispersing effluent particulates during periods characterized by this type of flow. Note that the rms values off Newport Beach were only about 50 percent stronger than those off Palos Verdes before removing the short-period fluctuations (see Table 3, indicating that the primary differences between these two flows is in the strength of the long-period fluctuations.

CONCLUSIONS

The mid-water, sub-thermocline currents on the nearshore shelf, near the shelf/slope break, and on the upper slope in water depths ranging from 40m to 300m are comparable, within a factor of two, in the Newport Beach area. In contrast, the currents at a depth of 40m in 55-60m of water off Newport Beach and Palos Verdes can differ by more than a factor of two if the short-period fluctuations are ignored. This suggests that the difference in the longshore transport of wastewater from outfalls in greater depths of water off Newport Beach are not likely to differ in effects related to this aspect of the currents than the differences that exist between the existing Newport Beach and Palos Verdes outfall areas.

The situation becomes more uncertain with respect to the settling of effluent particulates. Based on our model studies which compare the sedimentation rates of effluent particulates in the Newport Beach and Palos Verdes area (see following paper), we would expect that sedimentation rates could be enhanced at the slope station (given equal heights of rise for the effluent--which may not be the case) due to the reduced cross-shore fluctuations and the effect of the sloping bottom. There is also the indication that although the net speed of the mid-water flows at the 150m station are larger than on the shelf or lower on the slope, the near-bottom speeds are less than at the other two sites. This indicates that the "dilution" of effluent particulates by resuspended natural particulates may be less at this location.

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