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PRINCIPAL SOURCES AND DISPERSAL PATTERNS OF SUSPENDED PARTICULATE MATTER IN NEARSHORE SURFACE WATERS OF THE NORTHEAST PACIFIC OCEAN

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Abstract of ERTS Significant Results

Release-recovery paths of drift cards released in conjunction with ERTS overflight show that nearshore surface currents along the central and northern California coast flowed southward at an average rate in excess of 10 cm/sec. (8.5 km/day) during August and September 1973 (California Current). By the middle of October 1973, the nearshore surface currents had reversed and the dominant flow velocity was northward at an average rate in excess of 20 cm/sec. (17 km/day) (Davidson Current). The August-September data also suggested the presence of counterclockwise gyres in Monterey Bay and the Gulf of the Farallones, but by the middle of October, the gyres were no longer evident.

ERTS imagery of April 1973 showed well developed plumes of suspended sediment in Monterey Bay from the Salinas River and in the Gulf of the Farallones from San Francisco Bay. Depths at which a Secchi disc was no longer visible ranged from 3 to 6 meters in Monterey Bay and from 2 to 4 meters in the Gulf of the Farallones, compared to .5 to 1 meter in South San Francisco Bay.

ERTS imagery provides an effective means of monitoring timber harvest in the redwood forest along the northern California coast. The multispectral imagery shows recent clearcuts and new timber access roads, thus providing information needed by land managers on initiation, rate of cutting, and final size of the timber harvest units.

ERTS imagery also clearly portrays contrasting topographic belts characterized by fluvial erosion and by mass movement. The most visually apparent and most persistent river mouth suspended sediment plumes are associated with those rivers that drain belts of topography that appear to have been eroded primarily by mass movement.

Type II Progress Report

ERTS -1

a. PRINCIPAL SOURCES AND DISPERSAL PATTERNS OF SUSPENDED PARTICULATE MATTER IN NEARSHORE SURFACE WATERS OF THE NORTHEAST PACIFIC OCEAN
ERTS-1 Proposal No: SR209 Subdisciplines: 5B, H, K, 4A, 3I, 1B,

b. GSFC ID No. of P. I.: IN 011

c. Statement and explanation of any problems that are impeding the progress of the investigation:

The largest problem we continually encounter is the capriciousness of Mother Nature. In the past three months, three water sampling cruises were made concurrent with ERTS passes and clouds obscured the test sites each time. The cloud cover of the ERTS imagery received for the various geographic areas of our proposal is shown on table 1. This list includes only those images with less than 70% cloud cover.

Table 1. Numbers of Images and Coastal Zone Cloud Cover (thru Aug. '73)

Location	Relatively cloud free	Partly Cloudy (of limited use)	Cloudy (not useful)	Total
Central Calif.	37 (45%)	37 (37%)	15 (18%)	83
No. Calif.	22 (30%)	25 (35%)	25 (35%)	72
Oregon	12 (20%)	22 (37%)	26 (43%)	60
Washington	14 (17%)	24 (30%)	43 (53%)	81
Mexico	58 (35%)	46 (28%)	63 (37%)	167
S. E. Alaska	19 (18%)	35 (48%)	50 (48%)	104
Hawaii	0 (0%)	5 (37%)	8 (63%)	13

The lack of tonal contrast in water scenes continues to be a major problem. In order to utilize fully all of the information on the ERTS imagery, we must usually reprocess the positives using a photographic density enhancement process; this added enhancement requires additional time and project funds.

d. Discussion of the accomplishments during the reporting period and those planned for the next reporting period:

In order to compensate for the lack of ERTS coverage of the coastal zone during cloudy weather and to document the nearshore current directions interpreted from the ERTS imagery, drift cards have been dropped at 2 month intervals off the mouths of rivers of central and northern California and southern Oregon. In addition to documenting current direction, the drift cards indicate minimum velocity of the coastal currents. The date the card is found on a given beach is not necessarily the same date that the card drifted onto the beach, but could be a day or more later; thus the computed current velocity is a minimum value. A total of 1900 drift cards were released during each drop period, and the return has been between 10 and 15 percent. The cards were air-dropped in packets of 50 at distance of 1.6 and 8.1 km (1 and 5 mi.) seaward of the river mouths. The drift cards were dropped in April, June, August, and October at the times of ERTS overpasses. The next release is planned for the middle of December.

Cruises to obtain water measurements concurrently with satellite passes were made in San Francisco Bay and the Gulf of the Farallones on five separate occasions during the report period. The dates of the cruises were April 4-5, May 30, Aug. 8-9, Oct. 4, and Nov. 6-7, 1973. Water measurements of salinity, temperature and turbidity were made, and samples were collected for sediment concentration, particle size, and composition. Water measurements also were made in Monterey Bay 3 days before an ERTS overpass in mid-April 1973 (Broenkow and Benz, 1973).

Concurrent with the satellite passes of November 27 and 28, 1973, water measurements will be made off the mouths of several northern California rivers. One boat based in Humboldt Bay will collect water samples and make in situ measurements off the Eel and Mad Rivers. A second boat based at Crescent City will sample and measure the water off the Klamath and Smith Rivers. A third cruise is planned for San Francisco Bay and the Gulf of the Farallones in mid-December coincident with satellite passes. High-altitude photographic coverage of San Francisco Bay and the central and northern California coastal zones will be provided during this high-rainfall period by U-2 aircraft from NASA, Ames.

Field studies of coastal river drainage basins of northern California and southern Oregon were conducted throughout the summer and early fall months. These studies provide information about the sources of the sediment in the plumes of turbid water visible on the green and red bands of ERTS imagery.

Measurements included: river cross-section and profiles, river discharge, sediment transport (suspended and bed load), sediment texture and composition, and water chemistry. In addition to these ongoing studies, synoptic measurements will be made during major storms as part of a U.S. Geological Survey - National Park Service cooperative environmental surveillance program. One such synoptic study was made November 7-9, 1973, in which 6 stations along the main channel of Redwood Creek and 7 tributary streams were occupied by teams of hydrologists and geologists. Another synoptic study is planned for

early December 1973.

Broenkow, W. W. and Benz, R. S., 1973, Oceanographic observations in Monterey Bay, California, January 1972 to April 1973; Tech. Publ. 73-3, Moss Landing Marine Laboratories, California State University, 336 p.

e. Discussion of significant scientific results and their relationship to practical applications or operational problems.

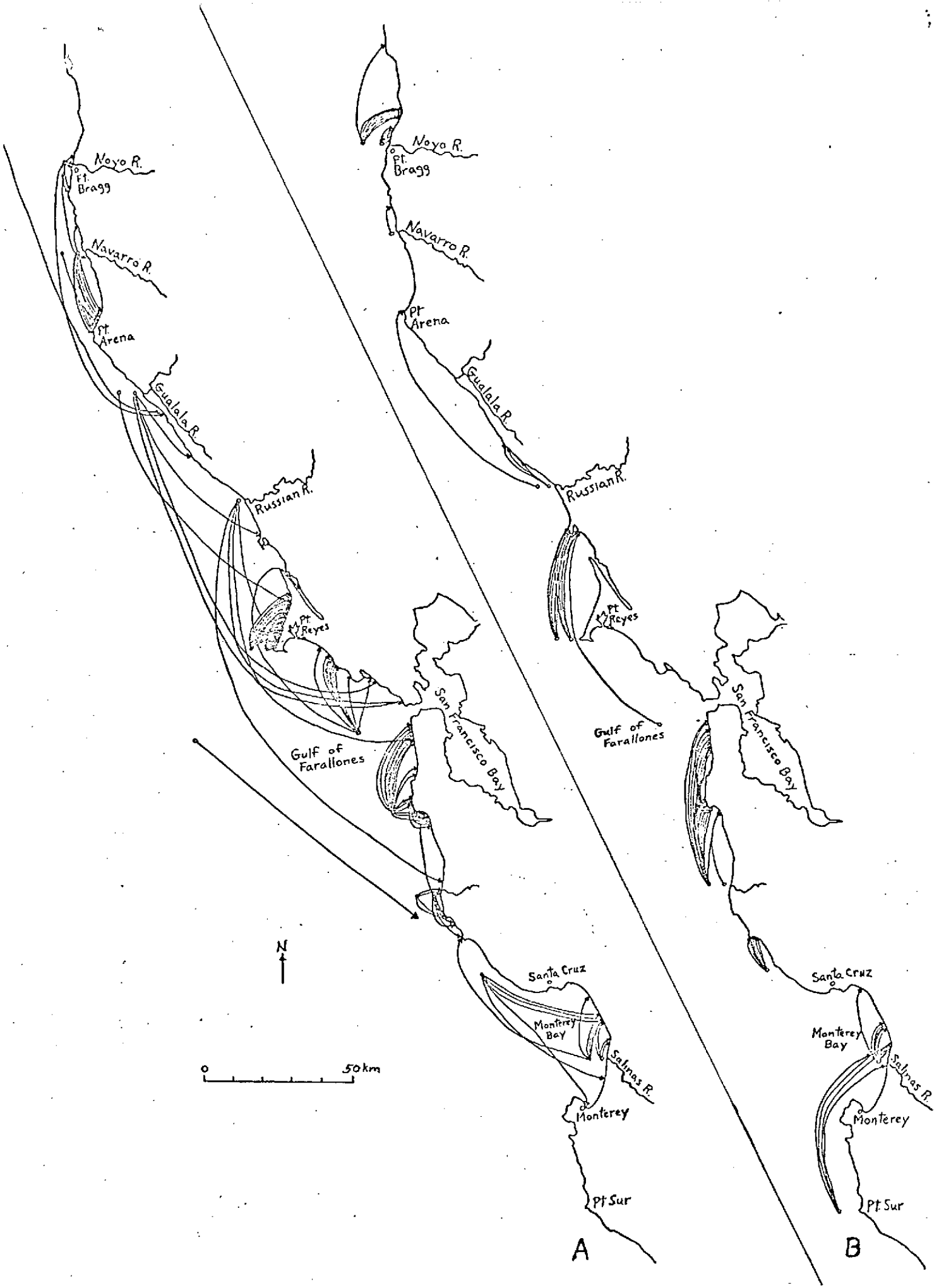
Surface Current Directions-
California Coastal Zone

Comparison of current directions indicated by drift cards dropped in mid-June 1973 with those interpreted from the suspended sediment patterns visible on the June 17, 1973, ERTS imagery show good agreement (Carlson and Harden, 1973). Although clouds have obscured much of the coastal zone during the satellite passes of August and October, the drift card data (Fig. 1) show the changes in current direction from southward flow in late August and September (California Current) to northward flow in mid-October to November (Davidson Current). There also was a difference in current speeds noted during the two different times. The average speed during the August-September period was in excess of 10 cm/sec. (8.5 km/day), but in the October-November time frame when the current changed direction the average speed was in excess of 20 cm/sec. (17 km/day). The counterclockwise gyres in Monterey Bay and the Gulf of the Farallones suggested by the drift card return from the August drop (fig. 1) are not evident at the time of the October drop. It appears that the northward-flowing Davidson Current is beginning to dominate the nearshore current flow. The surfacing of the Davidson Current appears to be earlier this year than last year when current directions interpreted from the ERTS imagery of late October 1972 indicated that southward flow predominated (Carlson et. al., 1973).

Carlson, Paul R. and Harden, Deborah R., 1973, Principal sources and dispersal patterns of suspended particulate matter in nearshore surface waters of the northeast Pacific Ocean and seasonal variation in snow cover in the Sierra Nevada. 20 August 1973, 13 p., NASA Type I progress report, Natl. Tech. Info. Service.

Carlson, Paul R., Conomos, T. John, Janda, Richard J., and Peterson, David H., 1973, Principal sources and dispersal patterns of suspended particulate matter in nearshore surface waters of the northeast Pacific Ocean and the Hawaiian Islands. 2 April 1973, 9 p., NASA-CR-131307, Natl. Tech. Info. Service E 73-10487.

Figure 1. Surface current directions along the central California coast based on drift-card returns. The drift cards were released coincident with satellite passes on August 27, 1973, panel A and October 19, 1973, panel B. The circles indicate release points and the arrowheads show the location of the drift-card recovery.


Noyo R.
Ft. Bragg
Navarro R.
Pt Arena
Gualala R.
Russian R.
Pt Reyes
San Francisco Bay
Gulf of Farallones
N
0
50km
Santa Cruz
Monterey Bay
Salinas R.
Monterey
Pt Sur
A
B

Patterns of suspended sediment - Gulf of the Farallones, San Francisco Bay and Monterey Bay

Preliminary comparisons of suspended sediment concentrations and turbidity measurement in San Francisco Bay, the Gulf of the Farallones, and Monterey Bay show good agreement with the patterns of suspended sediment visible on ERTS-MSS bands 4 and 5 of April 4, 1973. Well-defined plumes were present off the Salinas River mouth in Monterey Bay and off the Golden Gate in the Gulf of the Farallones. Comparable depths of Secchi disc visibility were measured in these plumes (fig. 2). For comparison note the Secchi depths measured in south San Francisco Bay. These values ranged from 60 to 105 cm, as compared to 2 to 4 meters depth in the Gulf of the Farallones and 3 to 6 meters in Monterey Bay. Table 2 shows the changes of suspended sediment concentration and percent light transmission as compared to the Secchi disc readings for south San Francisco Bay and the Gulf of the Farallones. The lines of traverse are shown on Figure 2.

Table 2. Water turbidity measurements.

	San Francisco Bay (4/4/73)				Gulf of Farallones (4/5/73)		
	Secchi Depth (cm)	Suspended Sediment (mg/ℓ)	Transmitted Light (10 cm path) (% T)		Secchi Depth (m)	Suspended Sediment (mg/ℓ)	Transmitted Light (1m path) (% T)
g.	60	40	25	c.	4.0	8.8	27
	105	18	42		2.8	8.4	16
	75	28	25	d.	2.0	22.0	7
h.	65	31	24				

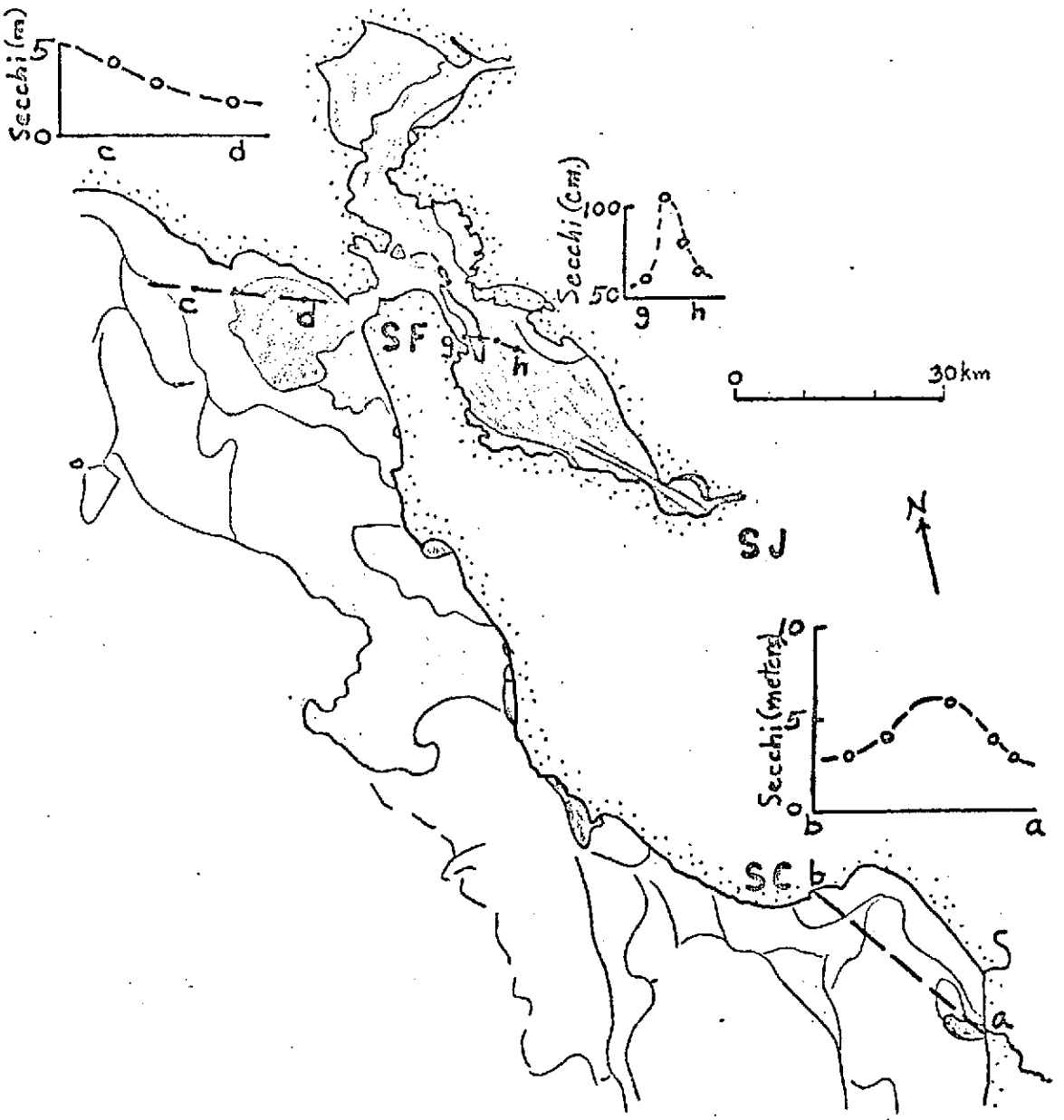


Figure 2. Suspended sediment patterns in San Francisco Bay, Monterey Bay, and the adjacent ocean as seen on ERTS, MSS-4 imagery of April 4, 1973 (1255-18183-4). The dotted pattern represents the shoreline, and the lines offshore indicate the changes in tonal contrast between masses of water bearing different concentrations of suspended sediment. The more turbid water is shaded. The dashed lines a-b (Monterey Bay), c-d (Gulf of the Farallones), and g-h (south San Francisco Bay) indicate positions of water cruise profiles made April 19, 5, and 4, 1973, respectively.

Sediment sources -
no. California and so. Oregon coastal zone

ERTS-1 MSS imagery has been used in our northern California and southern Oregon test area to investigate sediment sources as well as sediment-dispersal patterns in nearshore Pacific Ocean water. Interpretations of low-altitude aerial photographs and ground transverses suggest that the two principal sources of the suspended sediment transported by northern California rivers are areas of active mass movement and areas of recent tractor-yarded clearcut timber harvest. Streams draining these areas have river mouth plumes that are more persistent and are more clearly visible on ERTS-1 images than streams draining less rapidly eroding areas.

North-northwest trending linear belts of topography, characterized by broadly rounded hillslopes and relatively low drainage densities, appear to have been eroded primarily by mass movement processes. These topographic belts stand in marked contrast to adjacent belts of more intricately dissected topography, characterized by linear hill slope profiles and eroded primarily by fluvial processes. Inspection of multispectral U-2 photography and standard (1:10,000 and 1:40,000) low altitude black and white aerial photograph suggests that the belts of mass movement eroded topography are in general more actively eroding than the topographic belts sculptured primarily by fluvial processes. These distinctive topographic belts are clearly visible on bands 6 and 7 of ERTS-1 MSS imagery. Many small individual landslides that have profound impacts upon land-use patterns, transportation routes, and stream sediment loads can not be resolved on ERTS images. Thus, these images appear to have greater utility for regional planners charged with defining broad areas characterized by certain types of erosion problems, than for engineers working on specific construction or remedial activities.

In areas of recent detailed geologic mapping, the N-NW trending linear topographic belts appear to be lithologically controlled. However, on a regional basis the topographic unconformities discernible on ERTS-1 MSS imagery do not always correspond to the geologic contacts portrayed on existing regional geologic reconnaissance maps. Additional study is needed to assess further the usefulness of ERTS imagery for modifying existing reconnaissance maps of the geologically complex terrane of northwestern California and southwestern Oregon.

The contrast in spectral reflectance between recently cut-over land and old growth (virgin) or advanced second growth redwood (Sequoia sempervirens) and Douglas-fir (Pseudotsuga menziesii) is extreme. These two types of areas can be distinguished on all four spectral bands of ERTS MSS imagery, but the contrast is most obvious on band 5. The difference between old growth and second growth forest is clearest on band 6. The extreme spectral contrast at the margins of recent clearcut blocks and new timber access roads has enabled us to effectively monitor rates and practices of timber harvest in the environs of Redwood National Park as part of the U.S. Geological Survey - National Park Service environmental surveillance program. The initiation, rate of cutting, and final size of harvesting units can be determined directly from ERTS images; yarding procedures can be inferred from the size of the harvesting units and their relation to timber access roads.

f. A listing of published articles, and/or papers, pre-prints, in-house reports, abstracts of talks, that were released during the reporting period:

Broenkow, W. W. and Benz, S. R., 1973, Oceanographic observations in Monterey Bay, California, January 1973: Tech. Publ. 73-3, Moss Landing Marine Laboratories, California State University, 336 p.

Carlson, Paul, Janda, Richard, and Conomos, T. John, 1973, Observations of suspended particle patterns in nearshore northeastern Pacific Ocean waters by ERTS-1 imagery: Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1, NASA/Goddard, v. 1, p. 1305.

Conomos, T. J. and Peterson, D. H., 1973, Seasonal circulation and suspended particle distribution patterns, San Francisco Bay, California: Symposium International, Relations Sedimentaires Entre Estuaires Et Plateaux Continentaux, Bordeaux, France, p. 26-27.

Nelson, C. Hans, 1973, Sediment and mercury dispersal through estuary, shoreline, and epicontinental shelf environments of the northeast Bering Sea: Symposium International, Relations Sedimentaires Entre Estuaires Et Plateaux Continentaux, Bordeaux, France, p. 65.

Peterson, David, 1973, Silica cycle in San Francisco Bay: Talk given at Estuarine Research Conference, Myrtle Beach, So. Carolina, Am. Soc. Limnol. and Oceanog.

g. Recommendation concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system:
NONE

h. A listing by date of any changes is Standing Order Forms:
NONE

i. ERTS Image Descriptor forms: NONE

j. Listing by date of any change Data Request forms submitted to Goddard Space Flight Center/NDPF during the reporting period:
NONE

k. Status of Data Collection Platforms (if applicable): N/A