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CORRELATION OF OCEAN TRUTH DATA WITH ERTS-1 IMAGERY

California Coastal Sites in Monterey Bay, Santa Barbara Channel, and Santa Monica Bay

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16. Abstract

Oceanographic data was gathered synchronously with 4 ERTS overflights over Monterey Bay, 4 over the Santa Barbara Channel, and 2 over Santa Monica Bay, California in 1973. ERTS digital and photo images obtained on the overflights were examined, processed, and interpreted for oceanic features using relative radiance evaluation and pattern recognition techniques. Oceanographic data was compared to digital scene data to extract the degree of correlation between MSS band radiance and the values of the following oceanic parameters: turbidity, Secchi depth, concentrations of dinoflagellates, chain diatoms and sediment particles suspended in the surface water, water color, ocean reflectance, wind speed, surface water temperature, sun elevation, underwater light transmission, light extinction, underwater light scattering, and aerosol concentration just above the water surface. Turbidity correlates with radiance the best. Specular radiance effects correlate with high wind speeds and define the synoptic regional surface wind field. Digital processing and ERTS system artifacts are discussed extensively.

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Preface

a. Project Objective

The objective of this project is to gather oceanographic data for developing techniques using ERTS-1 remote sensing data to solve problems in coastal oceanography related to population growth in coastal sectors and the development of offshore resources.

Specifically, the objective involves correlating ground truth oceanographic data with synchronous ERTS-1 MSS data to discover methods of interpreting ERTS-1 products and extracting information of use to municipal, state, and federal agencies responsible for planning, monitoring, and surveillance and to industries involved in development of coastal resources.

b. Scope of Work

The project involved 10 cruises into 3 areas on the California coast; Monterey Bay, the Santa Barbara Channel, and Santa Monica Bay. The cruises were synchronized with ERTS-1 satellite overflights and featured a data-gathering program including: 1) visual observations of oceanographic conditions and marine weather, 2) photographic recording of sea state, 3) characterization of surface water appearance by visual observation and color measurement and by color aerial photography, 4) assessment of visibility in air by atmospheric nephelometry and radiometry, 5) determination of optical properties of sea water using a Secchi disk, light attenuation meter, underwater transmissometer/nephelometer, 6) measurement of sea water temperatures, and 7) water sampling.

Laboratory analyses performed on sea water samples were designed to determine those properties that produce the observed turbidity. The analyses included: 1) measurement of turbidity, 2) reflectance colorimetry, and 3) examination of filtered suspended matter with optical microscopy and scanning electron microscopy.

Correlation of ground truth data with ERTS-1 scene data involved several subsidiary investigations. Scene data were studied to determine the format and degree of enhancement required to optimize correlation. CCT data proved to be more suitable than photo-imagery so enhancement algorithms were designed to remove system noise, compare radiance levels in each band, pixel by pixel, and perform density slice displays of the results. Pattern recognition analyses were performed upon density slice maps and on ERTS-1 photo imagery.

Actual correlation of scene data and ground truth data was made on computer-generated radiance profiles bearing corresponding ground truth parameter values. An analysis of the results of the correlations yielded conclusions regarding user applications and recommendations for future satellite remote sensing of the ocean.

c. Conclusions

1. ERTS Photo imagery can be interpreted for oceanic features by combining a systematic examination of all 4 MSS bands with a confirmatory pattern recognition.

2. Film negatives of MSS bands 6 and 7 show more oceanic detail than the corresponding film positives.

3. There are two classes of oceanic features evident on ERTS photo imagery; those present in all bands and related to

clouds and wind effects, and those present only in certain bands and related to seawater turbidity.

4. Wind effects are quite pronounced when the local wind velocity exceeds 10 knots. These effects can be predominant in marine scenes.

5. Parallel, linear bands of low radiance associated with broad areas of higher radiance produced by wind roughening are probably caused by regular undulations in the wind field near the sea surface. It is unlikely that vertical circulation of surface water produces these features.

6. It is possible to identify areal distribution and trajectories of severe winds at the sea surface, shoreline, clouds, fog or low stratus, beach sands, dunes, suspended sediment plumes, tidal circulation events, outfall plumes, plankton, kelp beds, harbor configuration, and possibly oil slicks in the ERTS imagery examined during this investigation.

7. Although much marine intelligence is present in ERTS photo imagery, marine radiance values are limited to the 4 lowest gray scale steps on the photos. Corresponding CCT's contain 10 digital levels so they are more suitable for data correlation purposes.

8. Digital density slice maps prepared from CCT data provide a better resolution of patterns discerned in ERTS marine scenes because of the higher resolution of radiance inherent in the CCT's. However, noise in the form of 6-cycle radiometric striping and gross banding detract from the areal definition of the patterns because only a part of

all available scan lines can be used without sacrificing confidence in the relative precision of radiance data.

9. Automated production of graphic displays from CCT data is extremely difficult. It is necessary that an oceanographer interact during production so that subjective corrections of radiometric striping and banding can be made on each marine scene.

10. Test areas for ocean truth measurements and correlation should be larger than approximately 10 miles X 10 miles to avoid spurious results from the inherent patchiness in the distribution of turbidity-producing particles.

11. Of the several methods investigated for the color enhancement of MSS data, photographic methods were least satisfactory because of the difficulty in controlling exposure and development conditions and because of the non-linear D log E characteristics of the photo materials. The best enhancement was obtained by using CCT digital scene data to drive a color printing press. This system produced exactly reproducible hard copy products directly with each digital level represented by a discrete color. Spectral signatures can be color coded by combining digital levels from each MSS band into a single, diagnostic digital code word.

12. ERTS digital data contain system artifacts that produce visible effects in images of marine scenes where broad fields of uniform radiance prevail. Examples are vertical banding apparently produced by mechanical vibration in the satellite, gross horizontal banding caused by an abrupt change in the calibration coefficient during processing,

and 6-cycle radiometric striping caused by the imperfect inter-detector calibration.

13. Conversion of scene data and calibration data from 6-bit binary format to 7-bit format introduces"forbidden numbers" into each type of data. The calibration procedure introduces a different discontinuous number system into scene data each time it is applied. As a result, levels from adjacent scan lines cannot be averaged without introducing severe distortion in radiance values. Smoothing along a scan line is subject to similar error but to a lesser extent because only one discontinuous number system is involved.

14. The range of radiance levels in marine scenes is so small that system artifact errors tend to obscure oceanic features. This problem was overcome by using only every sixth scan line thereby avoiding striping caused by imperfect-inter-detector calibration. The choice of lines is made interactively in order to choose those lines corresponding to the detector with maximum sensitivity.

15. Once the effects of radiometric 6-cycle striping have been removed from scene data, interpretation of the scene is possible provided that the remaining system errors are taken into account.

16. Interpretation must be made on a scene-by-scene basis because absolute scene radiance was not measured. For the same reason, interpretation and correlation must be made using relative radiance differences within each scene.

17. The MSS system records two major effects in marine scenes. If the wind speed exceeds about 10 mph, specular reflections from the roughened water surface predominate and are registered congruently in all MSS bands. In the absence of wind effects, water turbidity variations are recorded in bands 4 and 5.

18. The strongest correlation with radiance is obtained from measurements of turbidity by in-situ or laboratory nephelometry (90° light scattering) and by the measurement of the concentration of non-living debris (mainly suspended sediment) filtered from seawater.

19. Indirect measures of turbidity or optical properties of seawater correlate poorly with scene radiance. Water color correlates with radiance only if turbidity contrasts are high.

20. Spectral radiance comparison (band ratioing) is a potentially useful technique for assessing the composition of suspended particles in seawater by using ERTS digital imagery if laboratory data on the spectral reflectance of filtered suspensoids is available.

21. Ocean reflectance measurements are dominated by glare which correlates strongly with sun elevation.

22. Surface water temperatures do not correlate directly with scene radiance.

23. Much interpretation of marine scenes is possible in the absence of ground truth data. The turbidity pattern in coastal water can be determined directly from digital or photo imagery once specular effects are determined to be absent or minor.

24. Information on surface water circulation and sources of turbidity can be extracted from ERTS imagery by an oceanographer once the turbidity pattern is defined. No ground truth is required for this operation.

25. Meteorologists are able to derive a pattern of regional surface winds after specular effects are identified on ERTS imagery. Ground truth is not required for this operation.

d. Summary of Recommendations

Recommendations derived from this study are as follows:

1. Increase the gain of the MSS system when scanning marine areas.

2. Maintain a wide dynamic range in sensor response.

3. Minimize data manipulations and conversions in the data acquisition system.

4. MSS band 6 should be replaced with a band in the blue region.

5. Restrict band width of each MSS band and reposition them to be more diagnostic of marine features.

6. Adjust satellite schedule to achieve early afternoon overflights in coastal areas.

7. Original compressed CCT data should be made available to marine users on a routine basis.

8. A new version of the ERTS Data Users Handbook using actual cases of data manipulation and processing should be prepared.

9. The spectral reflectance of plankton species and suspended debris should be cataloged in detail to permit application of band ratioing techniques to ERTS marine scenes.

10. Large-scale offshore currents should be mapped from composite images consisting of several ERTS frames.

Table of Contents

List of Figures

List of Figures

Continued
Page 2

List of Figures

Continued
Page 3

List of Figures

Continued
Page 4

Figure		Page*

List of Figures

Continued
Page 5

List of Figures

Continued
Page 6

List of Figures

Continued
Page 7

List of Figures
Continued
Page 8

List of Figures

Continued
Page 9

* Appendix figures bound in serial order by figure number

List of Tables

List of Plates

CORRELATION OF OCEAN TRUTH DATA
WITH ERTS-1 IMAGERY
CALIFORNIA COASTAL SITES IN
MONTEREY BAY, SANTA BARBARA CHANNEL,
AND SANTA MONICA BAY

CONTRACT NAS5-21877

Part 1

INTRODUCTION

PROJECT OBJECTIVES:

The principal objective of this study is the application of the long-sought, synoptic view of large areas of the ocean to the problems in coastal oceanography. ERTS-1 radiance measurements afford a multi-spectral portrayal of the instantaneous appearance of surface water of thousands of square meters of the ocean. It remains to interpret the radiance data in terms of oceanographic events and conditions that are of use to persons solving problems in coastal oceanography. To accomplish that, means for relating observations of ERTS-1 sensors to causative factors in the ocean must be found. Examining correlations between radiance and those ocean parameters that control ocean radiance appears to be a promising way to develop requisite techniques for useful interpretation of ERTS-1 data.

A specific objective of this study is the acquisition of oceanographic data, called coastal ground truth data, for correlating with ERTS-1 radiance data obtained simultaneously. Parameters governing water clarity, water color, and the nature of the ocean surface were selected for measurement because of their known relationship to ocean radiance.

Secondary objectives involve the actual correlation of obtained coastal ground truth data with ERTS-1 radiance data. The selection of the format for radiance data and its adaption for correlation proved to be a significant objective of this study. The correlation and extraction of interpretation techniques is the ultimate objective.

PROJECT SCHEDULE:

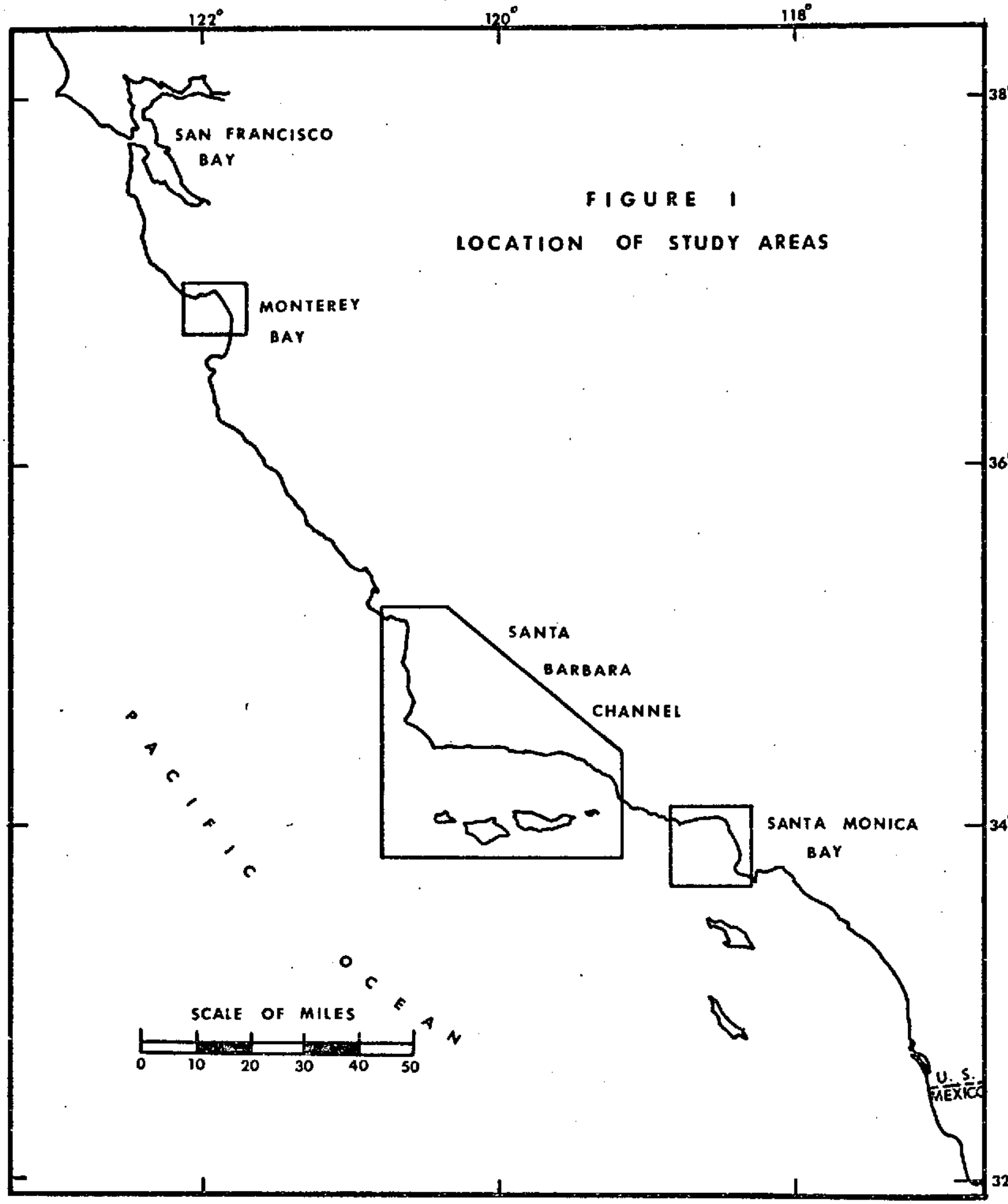
The realization of project objectives was approached in three phases:

Phase I - Data Analysis Preparation

Starting 2 January 1973, arrangements for securing ocean truth vessels and equipment were initiated. Within 30 days, vessels were chartered and all outstanding field gear and image viewing equipment was obtained or placed on order.

Phase II - Preliminary Data Analysis

Shortly after the initiation of Phase I, a concurrent Phase II effort was begun. ERTS-1 imagery received starting late December 1972 was examined and analyzed. Two scenes of Monterey Bay, 1021-18172 on 13 August 1972, and 1002-18134 on 25 July 1972 were studied most intensively. It was ascertained that, for ocean scenes, CCT data bear more radiance intelligence so arrangements were made to secure CCT coverage of scenes taken synchronously with ocean truth cruises. Also, it became apparent that the 20 square miles test sites originally specified for the project were too small to contain significant ocean features. The test sites were enlarged to include the northern half of Monterey Bay, the entire width of the Santa Barbara Channel off Santa Barbara, and the northern half of Santa Monica Bay (Figure 1). Phase II culminated with a Data Analysis Plan which was submitted at the end of January 1973.


122°
120°
118°
38°
36°
34°
32°
SAN FRANCISCO BAY
FIGURE I
LOCATION OF STUDY AREAS
MONTEREY BAY
SANTA BARBARA CHANNEL
SANTA MONICA BAY
PACIFIC OCEAN
SCALE OF MILES
0 10 20 30 40 50
U. S.
MEXICO

Phase III - Continuing Data Analysis

This phase began with the approval of the Data Analysis Plan on 23 February 1973. Shortly thereafter, ocean truth cruises were begun in the newly redefined test areas. Twelve cruises, four in each of the test areas, Santa Monica Bay, Santa Barbara Channel, and Monterey Bay were to be synchronized with ERTS-1 overflights. Weather contingencies limited executed cruises to those listed in the following table.

Table 1

LIST OF GROUND TRUTH CRUISES

Date	Scene I.D.	Location
25 Feb 73	1217-18074	Santa Barbara Channel
15 Mar 73	1235-18075	Santa Barbara Channel
17 Mar 73	1237-18183	Monterey Bay
1 Apr 73	1252-18021	Santa Monica Bay
2 Apr 73	1253-18075	Santa Barbara Channel
4 Apr 73	1255-18183	Monterey Bay
15 Jun 73	1327-18182	Monterey Bay
3 Jul 73	1345-18174	Monterey Bay
23 Aug 73	1396-18004	Santa Monica Bay
24 Aug 73	1397-18062	Santa Barbara Channel

Overcast weather occurring May through August prevented many ocean truth cruises from being conducted during scheduled ERTS overflights. Government furnished data in support of this study was not supplied after the termination date, 18 September 1973, so cruises were not scheduled after the 13 September overflight of Monterey Bay. The complete list of ERTS-1 overflights during Phase III is listed in Table 2.

Table 2

ERTS-1 OVERFLIGHTS, 24 FEB 73 to 18 SEPT 73

Overflight Date	Location	Weather Conditions
24 Feb 73	Santa Monica Bay	Fair, No Cruise Planned
25 Feb 73	Santa Barbara Channel	Fair, Cruise Executed
27 Feb 73	Monterey Bay	Fair, No Cruise Planned
14 Mar 73	Santa Monica Bay	Fair, No Cruise Planned
15 Mar 73	Santa Barbara Channel	Fair, Cruise Executed
17 Mar 73	Monterey Bay	Fair, Cruise Executed
1 Apr 73	Santa Monica Bay	Clear With Strong Winds, Cruise Aborted After 4 Sta.
2 Apr 73	Santa Barbara Channel	Fair, Cruise Executed
4 Apr 73	Monterey Bay	Fair, Cruise Executed
19 Apr 73	Santa Monica Bay	No Cruise Planned
20 Apr 73	Santa Barbara Channel	No Cruise Planned
22 Apr 73	Monterey Bay	No Cruise Planned
7 May 73	Santa Monica Bay	Overcast
8 May 73	Santa Barbara Channel	Overcast
10 May 73	Monterey Bay	No Cruise Planned
25 May 73	Santa Monica Bay	Overcast
26 May 73	Santa Barbara Channel	Overcast
28 May 73	Monterey Bay	Overcast
12 Jun 73	Santa Monica Bay	Overcast
13 Jun 73	Santa Barbara Channel	Overcast
15 Jun 73	Monterey Bay	Fair, Cruise Executed
30 Jun 73	Santa Monica Bay	Overcast
1 Jul 73	Santa Barbara Channel	Overcast
3 Jul 73	Monterey Bay	Fair, Cruise Executed
18 Jul 73	Santa Monica Bay	Overcast
19 Jul 73	Santa Barbara Channel	Overcast
21 Jul 73	Monterey Bay	Overcast
5 Aug 73	Santa Monica Bay	Overcast

Table 2 (Continued)

Overflight Date	Location	Weather Conditions
6 Aug 73	Santa Barbara Channel	Overcast
8 Aug 73	Monterey Bay	Overcast
23 Aug 73	Santa Monica Bay	Fair, Cruise Executed
24 Aug 73	Santa Barbara Channel	Fair, Cruise Executed
26 Aug 73	Monterey Bay	Overcast
10 Sep 73	Santa Monica Bay	Overcast
11 Sep 73	Santa Barbara Channel	Overcast
13 Sep 73	Monterey Bay	Overcast
18 Sep 73	END OF GOV'T SUPPLIED	DATA

Examination of ERTS-1 photo-imagery proceeded as material arrived and the development and refinement of digital techniques for processing CCT's continued throughout Phase III.

Part 2

DATA COLLECTION

FIELD METHODS:

General Description of Survey Areas

The three areas chosen for the collection of ground truth data; Santa Monica Bay, Santa Barbara Channel, and Monterey Bay, are located in accessible regions of central and southern California. Their locations are illustrated in Figure 1. Santa Monica Bay is an open, southwesterly-facing embayment bordering the western margin of the Los Angeles Basin. It encompasses approximately 130 square miles of ocean from Point Dume to Palos Verdes. The northerly boundary is formed by an arcuate, east-west shoreline extending from Point Dume to Santa Monica. The shoreline is composed of intermittent beaches and rocky headlands. From Santa Monica, the shoreline turns southeastward along continuous sandy beaches to Palos Verdes, the southern limit of the Bay. A detailed configuration of the Bay is presented in Figure 2.

Weather conditions in Santa Monica Bay are seasonal and readily affect the outcome of field work. The period December through March is characterized by frequent, and at times almost rhythmic, passages of frontal systems which generate southeast storms and northwest winds. One to three days of relative calm may exist between these events. The Bay is only mildly exposed to these conditions due to its southwest orientation, however, during southeasters or northwesters, the severity of sea states will normally curtail oceanographic work from vessels less than 75 feet in length. The cost of operating larger vessels for this type of work is prohibitive. When scheduling field trips during this

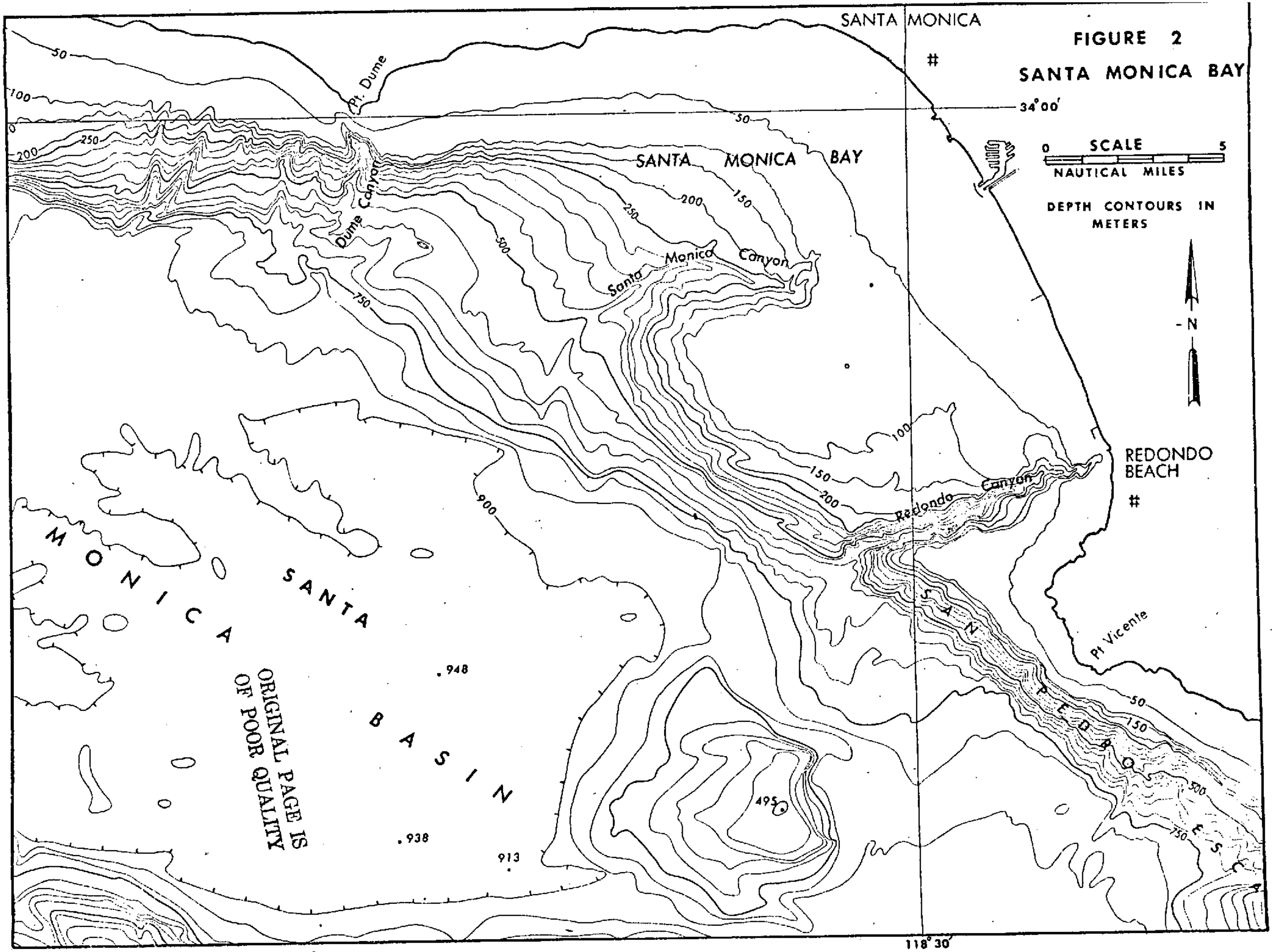


FIGURE 2
SANTA MONICA BAY

period, it was necessary to avoid these conditions. The weather from May to September is dominated by overcast skies and calm seas during the morning hours. This situation changes to clear skies and fresh onshore winds by early afternoon. The morning overcast conditions made summer scheduling difficult in order to avoid the expense of mobilizing field trips; only to have the skies overcast at the time of the overflight. An extensive program of correlating pre-survey weather observations with the forecasts was initiated to minimize aborted field trips.

Two large harbor facilities exist within Santa Monica Bay, Marina del Rey and Redondo Beach Harbor. Each facility maintains berthing accommodations for large numbers of sport and a few commercial vessels. The two surveys in Santa Monica Bay originated in Marina del Rey. Its central location (illustrated in Figure 2) was convenient for deployment to areas of special interest within the Bay.

The second area selected for ground truth data acquisition is the Santa Barbara Channel. The Channel covers 1300 square miles of ocean from Point Conception to Port Hueneme and south to the Channel Islands. The Channel width averages 25 miles, but it narrows to 11 miles at its eastern end. The Channel Islands, Anacapa, Santa Cruz, Santa Rosa, and San Miguel form the southern boundary of the Channel. Their irregular sizes and shapes range from four to twenty miles in length and from 800 to 2400 feet in elevation. Figure 3 illustrates the configuration of the Channel.

Weather in the Santa Barbara Channel is similar to that in Santa Monica Bay. However, the exposure is such that west to northwest winds are funneled into the Channel from the west. Strong winds from these directions during winter and spring months make it difficult to work and field trips must be scheduled around them.

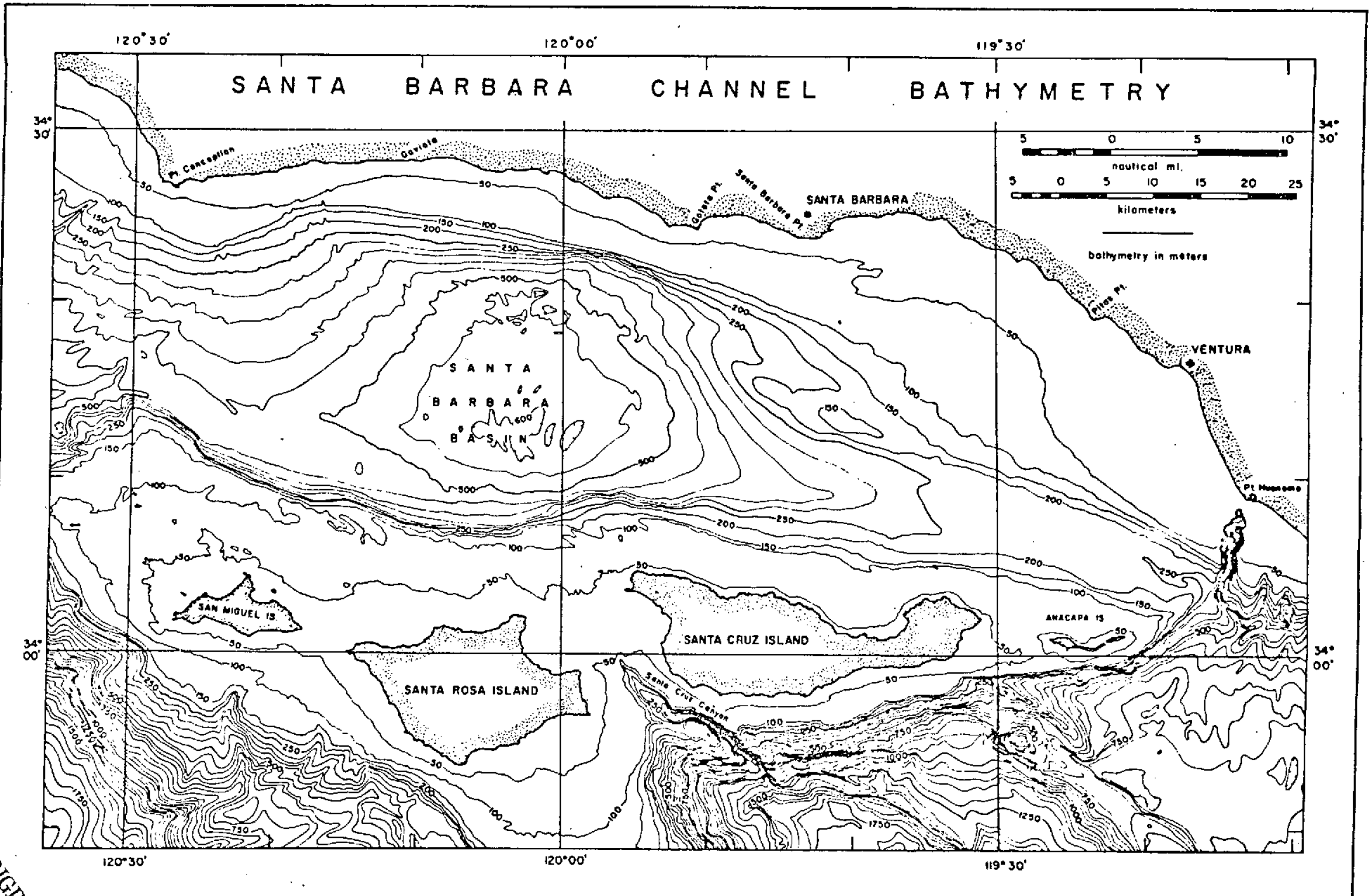


Figure 3
SANTA BARBARA CHANNEL

The same applies to southeasters which generate severely choppy seas and are commonly accompanied by rain. During the summer, afternoon onshore westerly winds normally are not severe enough to hamper field work.

Channel field trips were conducted from Santa Barbara Harbor because of the location of OSI's home office and the central location of the harbor with respect to the Channel.

The third area selected for ground truth data acquisition is Monterey Bay. It is a semicircular open embayment, approximately 70 miles south of San Francisco. The Bay covers nearly 200 square miles. Its eastern boundary is a broad river valley formed by the juncture of the Pajaro and Salinas Rivers. The shoreline consists of smooth, sandy beaches extending from Capitola to Monterey. The Bay is bisected by the Monterey submarine canyon which deepens to as much as 2600 feet below the floor of the Bay. Figure 4 presents a detailed configuration of the Bay.

Weather conditions in Monterey Bay are very similar to those in Southern California coastal regions. However, the intensity of these conditions is somewhat increased. Winter storms occur with greater frequency and severity. The only areas protected from southeast storms lie at the southern end of the Bay near Monterey. During northwest blows, Santa Cruz and Capitola areas offer the only protection. Overcast skies during the summer months are more persistent and afternoon onshore winds of 15 to 20 knots make field work difficult.

Field trips were conducted from each of the three harbors in Monterey Bay; Santa Cruz, Moss Landing, and Monterey. The availability of boats for field work fluctuated seasonally,

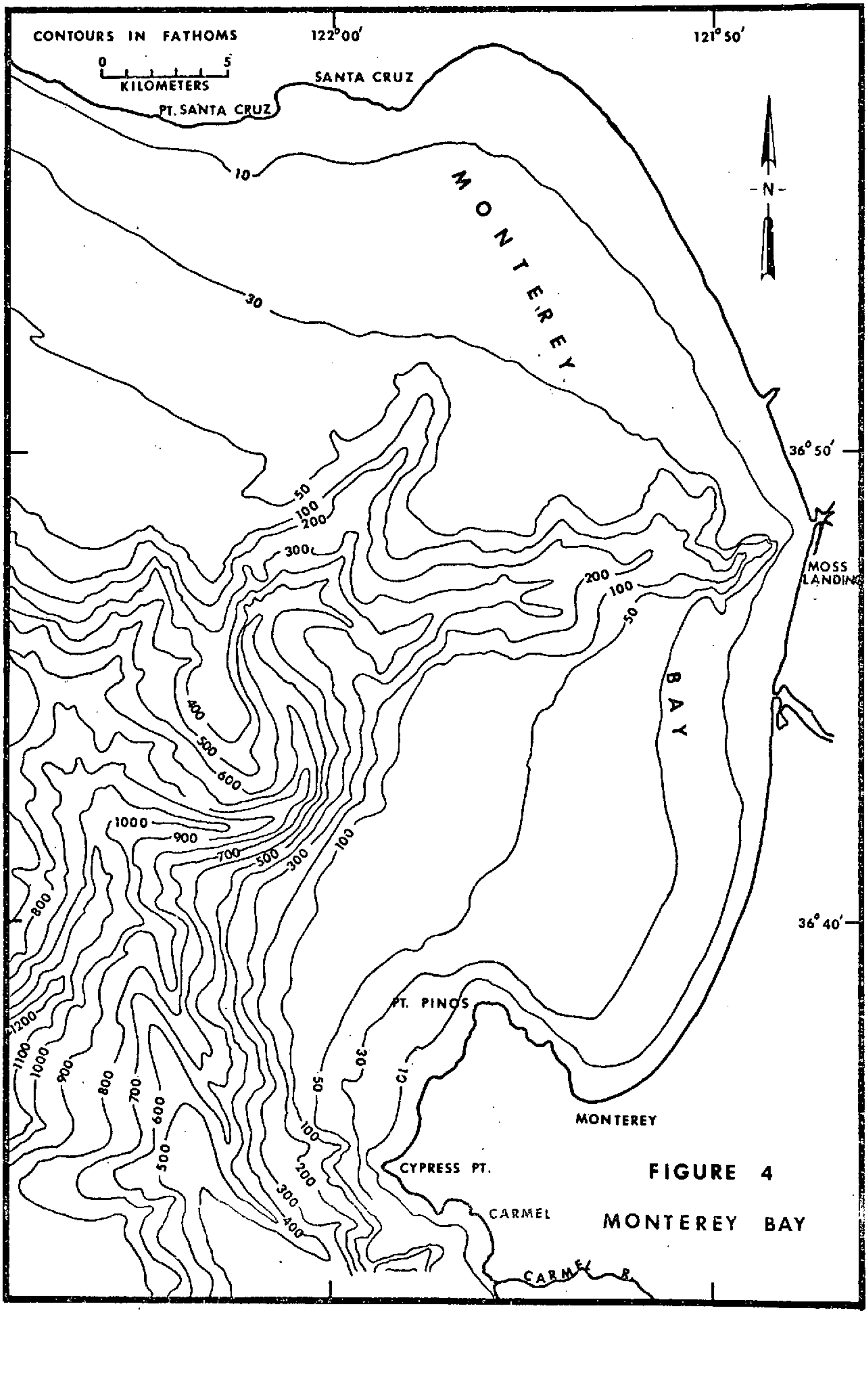


FIGURE 4

MONTEREY BAY

since the owners had commercial or sport fishing businesses to attend to. It proved necessary to operate from any harbor where vessels were available.

Cruise Design and Track Layout

The philosophy of ground truth data collection was to maximize the amount of useful data collected at the time of the overflight. Optimumly, this would require an armada of boats on location at the time of the overflight. Since this approach is unreasonable, every attempt was made to maximize vessel speed when planning surveys. Previous to the employment of the towed Mark 14 submarine optics package, vessels were chosen for their speed and navigational equipment. Navigational equipment (radar) took priority in Monterey and Santa Monica Bays where relatively featureless shorelines made line-of-sight navigation difficult. In the Santa Barbara Channel, where petroleum platforms, islands, and familiarity increased the accuracy of line-of-sight navigation, vessel speed took priority. After the Mark 14 was employed (June 15), vessel speed was reduced to 10 knots, maximum towing speed of the underwater instrument package. Thereafter, emphasis in boat selection was placed on navigational equipment.

In designing cruise tracks, every attempt was made to direct sampling to areas where high concentrations of image contrasts were expected to exist. Features or phenomena that were expected to generate such image contrasts in the ocean are:

. . . Sediment discharge from rivers, especially during rainy seasons.
. . . Shallow bathymetry subjected to wave base agitation.
. . . Sewage plant outfalls.
. . . Stagnant circulatory conditions.
. . . High current velocities, tidal or wind driven.
. . . Natural hydrocarbon seeps.

. . . Petroleum production platforms.

. . . Upwelling regions where plankton blooms occur.

Consideration was also given to avoiding areas where wind and seas were expected to hamper field work. This became especially important after employment of the Mark 14 instrument. Towing the instrument in rough seas was especially critical because pitching of the vessel put excessive strain on the towing hardware.

Figures illustrating the cruise patterns for all field surveys are presented in the Appendix, Figures A-1 to A-10. The cruise tracks for Santa Monica Bay were designed to cover both the offshore and nearshore areas since strong image features were not observed in previous ERTS data for particular areas within the Bay. The first survey was conducted on April 1st, and was called off because of high seas. The second field trip, and the only one completed in Santa Monica Bay, occurred on August 23, 1973. Figure A-9 illustrates the cruise track.

Cruise tracks for the Santa Barbara Channel are shown in Figures A-1, A-2, A-5, and A-10. The cruise pattern was designed after data received from ERTS during the spring rains indicated strong image features along the coastline and weaker features in the form of plumes between the islands. The same cruise pattern was maintained throughout consecutive field trips because the initial track yielded good coverage of these features. Besides examining previous ERTS data for areas in which to concentrate the cruise, every effort was made to sample sharp gradients in water color observed during the field trips. The cruise pattern for the final field trip in the Santa Barbara Channel on August 24 was modified for two reasons:

1. Considerable time had been lost attempting to repair the Mark 14 underwater optics package.

2. 20 to 30-knot winds were expected in the Santa Barbara Channel.

Cruise tracks for Monterey Bay are presented in Figures A-3, A-6, A-7, and A-8. The tracks were extended from the original test site area (Figure A-3) into the north end of the Bay where stagnant circulatory conditions are known to exist (AMBAG Final Report, 1973). This area has been of concern to adjacent municipalities planning waste treatment facilities. The first field survey was conducted from Santa Cruz Harbor on March 17th and had to be terminated early due to rough seas. The April 4 survey was operated out of Moss Landing. Twenty stations were occupied with intermediate water sampling locations added. The June 15 survey was conducted from Monterey Harbor. This was the first survey in which the Mark 14 underwater optics package was towed. Slower cruising speeds required that the number of sampling stations be reduced. The final survey was conducted on July 3 from Moss Landing; sixteen sampling stations were occupied.

Ship Specifications and Equipment

As previously mentioned, the choice of vessels for field work was governed by ship speed because it was important to maximize the number of stations occupied on each cruise. Prior to the employment of the Mark 14 underwater optics package (June 15), vessel speed between stations was limited only by the hull design and soundness of the vessel. A second critical factor was the availability of radar for station location, especially in Santa Monica and Monterey Bays. Twin-screwed, gasoline-engined, sport boats with radar were readily available in Santa Monica Bay. In Monterey Bay, this type of vessel was not common, so slower, commercial vessels equipped with radar had to be used. The only exception to this was the March 17th trip in Monterey Bay when a fast, 23-foot commercial fishing skiff was used. In the Santa Barbara Channel, 29 to 36-foot commercial abalone skiffs were chartered on all but one field trip. They were not equipped with radar. The March 15th survey was conducted aboard a 137-foot oil supply boat because extremely rough seas were anticipated.

Navigational Facilities and Methods

Objectives of the navigational procedures were to locate sampling stations and cruise tracks to within a mile radius. To accomplish this, several techniques were employed: radar ranges and bearings, sextant angles, compass bearings, and dead reckoning. When radar was available, ranges and bearings were taken from prominent landmarks, and this method provided positioning well within the one-mile radius. In areas where radar targets were weak, sextant angles and dead reckoning were used as backup navigational methods. On several field trips they were used as primary methods of navigation in addition to compass bearings to known landmarks. Table 3 lists surveys and navigational procedures used.

Table 3

NAVIGATIONAL METHODS USED ON OCEAN TRUTH CRUISES

Date	Location	Vessel	Navigational Procedures
25 Feb	Santa Barbara	29' Commercial Skiff	Sextant, Compass Bearings
15 Mar	Santa Barbara	137' Oil Supply Boat	Radar
17 Mar	Monterey	23' Commercial Skiff	Sextant, Compass Bearings
1 Apr	Santa Monica	32' Cabin Cruiser	Radar
2 Apr	Santa Barbara	29' Commercial Skiff	Sextant, Compass Bearings

Table 3 (Continued)

Date	Location	Vessel	Navigational Procedures
4 Apr	Monterey	90' Oceanographic Research Vessel	Radar
15 Jun	Monterey	65' Commercial Party Boat	Radar
3 Jul	Monterey	55' Oceanographic Research Vessel	Radar
23 Aug	Santa Monica	36' Cabin Cruiser	Sextant, Compass Bearings
24 Aug	Santa Barbara	36' Commercial Fishing Boat	Sextant, Compass Bearings

Position fixes obtained with sextant angles and compass bearings were accurate to within the one-mile radius approximately 80% of the time. Station locations of questionable accuracy occurred at no more than 20% of the positions located at maximum distance from land.

DESCRIPTION OF INSTRUMENTATION AND CALIBRATION:

Underwater Transmissometer/Nephelometer

A towed instrumentation package was made for this program by Montedoro-Whitney Corporation of San Luis Obispo, California. It is called the "Mark 14," and consists of a sensor package which mounts inside a towed "fish" and is connected to a deck unit. Sensors and preamplifiers are contained in a pressure housing fastened to an aluminum channel designed to provide a firm support for a mirror mount.

A beam of light from an incandescent lamp travels from the pressure housing to the mirror and back to the pressure housing, where it is sensed by a transmissometer sensor. The path length in the water is 1 m. A prism is located next to the exit port.

Light scattered at 90° from the beam enters the prism and impinges on a nephelometer sensor.

The transmissometer is calibrated by taking the reading with the instrument dry to be 100% transmittance. The nephelometer is calibrated by comparison with turbidity measurements made in the laboratory on water samples collected in the field. On each survey, many water samples were taken (for studying suspended particles). These were kept cold in ice chests until returned to the laboratory, where they were refrigerated. The turbidity of each sample was measured on a Hach Model 2100A Turbidimeter.

Temperature Probe

The towed "fish" also includes a glass probe thermistor protruding into the water through a seal. The thermal coupling depends on the water flow rate, but in all cases, the thermal response time is less than 5 seconds. This sensor is factory calibrated against mercury-in-glass thermometers traceable to the National Bureau of Standards. The calibration tolerance specified by Montedoro-Whitney is ±0.1°C.

Radiometer

A Montedoro-Whitney Model LMD-2S light meter was outfitted by OSI with two sensor assemblies and a switch to select one or the other. One sensor assembly was used for measuring ocean reflectance, and the other was used for measuring atmospheric parameters.

The sensor assembly for measuring reflectance was mounted on an arm and suspended 8 to 10 feet over the water at least 6 feet in front of the boat. A gimbal kept the sensor body vertical, so that one cell faced up, sensing global irradiance, while the other looked down through a tube, sensing upward radiance from the ocean. The readout unit contained electronics that provided the ratio of the two signals. This ratio is proportional to the reflectance of the ocean.

The calibration of this instrument consisted of directing both sensors at the same uniformly illuminated wall and noting the reading on each range.

The other sensor assembly was required for the purpose of obtaining absolute target reflectance by correcting ERTS radiance measurements for variable target irradiance, atmospheric attenuation, and atmospheric backscatter. Corrections were obtained from measurements of solar irradiance, global irradiance, and atmospheric backscatter.

OSI designed and assembled a radiometer for obtaining correction data. It contained four photovoltaic cells, each provided with a band-pass filter for a different ERTS MSS band. The four cells were coplanar and were directed at an elevation angle which could be adjusted from 0° to 90°. Since shipboard measurements were required, the angle-adjusting mechanism was mounted on a gimbal.

The instrument was designed to make both narrow-angle and wide-angle measurements. The former were made by placing a tube in front of each cell to restrict the field of view to about 6°. For making global irradiance measurements, these tubes were removed, giving the sensors an approximate cosine response.

The ERTS filters were produced by the same manufacturer* and to the same performance specifications as the filters in the satellite. In addition to these, three of the bands used

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* Optical Coating Laboratory, Inc., Santa Rosa, California 95403

correction filters to flatten the response of the silicon cell:

Band 4: Corning 1-58

Band 5: Corning 1-58

Band 6: No Correction Filter

Band 7: Corning 4-79

Each cell also had a neutral density filter consisting of flashed opal disc and four thicknesses of Wratten N. D. 0.30 gelatin filter. The purpose of this was to keep the cell in its linear operating range when the sensor was exposed to direct solar radiation.

The filters, cells, and readout were calibrated together as a system, using the sun as a reference. The attenuation caused by the atmosphere was determined by the use of an atmospheric extinction curve, obtained from several measurements made between noon and sundown. Solar irradiance readings were plotted vs. air mass, and the curve was extrapolated to zero air mass. The solar irradiance for zero air mass has been determined by NASA* as a function of wavelength (See Table 5).

The balance of this section is devoted to the detailed procedures for performing this calibration, making measurements, and correcting ERTS data for atmospheric parameters. These procedures are based on a paper by Rogers and Peacock (1973) who have shown that a solar irradiance meter can be calibrated against the sun on a clear day anywhere in the world, without additional instruments or standards. The measurements should be taken throughout a morning, or a whole day as a double check, but once they have been taken, they need not be repeated unless stability is questioned.

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* NASA SP 8005, Solar Electromagnetic Radiation

All of the nomenclature to be used is presented in Table 4.

Table 4

SYMBOLS USED IN CALIBRATION FORMULAE

Symbol	Definition
H	Global irradiance on the target, in a given band.
H_o	Solar irradiance outside the atmosphere, in a given band.
H_{sky}	Skylight on the target, in a given band.
H_{sun}	Direct solar irradiance on the target, in a given band.
L	Total radiance recorded by ERTS, in a given band.
L_{atm}	Foreground radiance seen by ERTS due to backscatter.
L_{meas}	Backscattered radiance measured on the ground at a different scattering angle from that seen by ERTS. (Elevation angle always specified)
m	Air mass causing beam attenuation, measured in atmospheres. $m = 1$ at ERTS, looking down. $m = 0$ outside the atmosphere, looking at the sun.
t	Beam transmittance of the air mass along a given path.
e	Solar elevation angle, measured directly by OSI, using a sextant.
ρ	Target reflectance, in a given band.

The following calibration procedure was used in this program.

1. Fit the sensor with a tube to block skylight, restricting the field of view to 6°.
2. Direct the sensor toward the sun. There must be no clouds or haze within the field of view.
3. Set the sensitivity so that full scale will accommodate the highest sun elevation angle of the day. Record setting.
4. Record the reading H_{sun} for each filter which is to be used, starting with a sun elevation angle e of at least 15° and no more than 30°. Measure e with a sextant and record it within

±1° for each H_{sun} reading. Record ambient (instrument) temperature and note any time it changes by 5°F or more from previous recording.

5. Repeat every 30 to 60 minutes until maximum e or until within 30 to 15° of sundown.

6. For each measurement, calculate the air mass m = csc e = 1/sin e.

7. Plot log H_{sun} vs. m and draw in the best fit straight line for each band.

8. If it is desired to know the atmospheric attenuation for a given band for the day on which the calibration was made, this is measured in terms of beam transmittance t, which is equal to the slope of the line plotted for that band, expressed in fractional absorption per air mass of one vertical atmosphere:

$$t = \frac{H_{sun} \ (m = 0)}{H_{sun} \ (m = 1)}$$

9. The value of H_{sun} at m = 0 is H_o, the solar irradiance outside the atmosphere, given in absolute units in Table 5.

Table 5

SOLAR IRRADIANCE FOR ZERO AIR MASS

ERTS MSS Band No.	Spectral Band (nm)	H_o (w/m^2)
4	500-600	177
5	600-700	151
6	700-800	124
7	800-1100	83

These are annual mean values. The maximum seasonal effects are +3% in the summer and -3% in the winter, according to NASA*.

* NASA SP 8005, "Solar Electromagnetic Radiation."

10. Calibration consists of determining for each band the scale factor by dividing the known value of H_o (w/m^2) by the extrapolation measurement of H_o.

Measurements of atmospheric parameters were made according to the following procedure:

1. Global Irradiance, H

   Direct the wide-angle sensors upward at the time of overflight.

2. Total Sky Irradiance, H_{sky}

   Same, but shadow the sun.

3. Solar Irradiance, H_{sun}

   Direct the narrow-angle sensors at the sun at the time of overflight.

4. Atmospheric Backscatter, L_{meas}

   If the solar elevation angle e is less than 45°, then it is possible to observe backscatter from the ground at the same scattering angle as it is seen by ERTS; direct the narrow-angle sensor away from the sun (180° in azimuth) at an elevation angle of 90-2e.

   If e is greater than 45° at the time of the overflights, as it was in this program, than this elevation angle is negative, and it is necessary to extrapolate from available angles and make this measurement when the sun is lower. At the time of the overflight, direct the sensor away from the sun at elevation angles of 10, 20, 30° within ±1°.

Having taken field measurements on the day of an overflight, and having calibrated the instrument (before and/or after field measurements), the parameters H, t, and L_{atm} can be calculated.

1. Global Irradiance H

Although H is measured directly, it can be determined more accurately by combining other direct measurements. At the time of overflight, calculate:

$$H = H_{sun} \sin e + H_{sky}$$

2. Atmospheric Transmittance t

Calibration stability was checked on each overflight. Having prepared a graph for the extrapolation to H_o, t can be obtained from:

$$t = \frac{H_{sun}\ (m = 1)}{H_{sun}\ (m = 0)}$$

3. Path Radiance L_{atm}

If L_{meas} has been measured at 90-2e at the time of the overflight, then L_{atm} can be calculated from:

$$L_{atm} = L_{meas}\ (1-t)/(1-t^m)$$

If L_{meas} has not been measured at 90-2e at the time of the overflight, then the values measured at 90-2e at other times during the day should be used in the above formula, together with corresponding values of m = csc e.

The above measurement procedure provides H, t, and L_{atm}. These are used to transform ERTS radiance measurements L into spectral signatures of absolute target reflectance ρ, using the formula

$$\rho = \frac{\rho}{Ht}\ (L-L_{atm})$$

Air Nephelometer

In order to help determine whether certain subtle features seen in ERTS images were of atmospheric or oceanic origin, measurements were made of the scattering of light by airborne particles on two surveys.

The Meteorology Research Inc. Model 2050 integrating nephelometer was used. In this instrument, air is drawn continuously through a chamber where it is illuminated by a pulsed flash lamp. The scattered light is detected by a photomultiplier tube looking at the illuminated air sample. The signal produced by the photomultiplier tube is averaged and compared with a reference voltage obtained from another phototube looking at the flash lamp.

The instrument is called an integrating nephelometer because the photomultiplier averages optically over virtually all scattering angles. The instrument was factory calibrated, using clean, filtered air and Freon-12 as calibration references.

Secchi Disk

A 30 cm diameter, white plastic Secchi disk made by CM^2 of Menlo Park, California was used in this program.

A Secchi disk is a white disk which can be lowered into the water by means of a line with a 3-point harness which orients the disk normal to the line when the line is taut. The depth at which the Secchi disk becomes visible as it is raised by a vertical taut line is called the "Secchi disk depth."

According to Holmes (1970), the use of a Secchi disk viewer had very little influence on the results so none was used in this program. Tests by Holmes of 30-cm and 50-cm disks showed negligible size influence at Secchi disk depth on the order of 5 m.

Observations were made on the sunny side of the boat, except in cases where this was prevented by a strong current which would carry the disk under the boat. In these cases, observations were made off the bow.

If the observation is made in the presence of a current which prevents the line from being vertical, then the actual Secchi disk depth is somewhere between the depth of the disk and the inclined optical pathlength in the water. This can be seen from the Duntley-Preisendorfer (Duntley, 1963) equation:

$$C_r = C_o e^{-(\alpha + k \cos \theta) R}$$

which describes the attenuation of contrast of a submerged object along an inclined path of sight. C_r is the apparent contrast of an object against its background; R is the optical pathlength in water; α and k are the attenuation coefficients for collimated and diffuse water, respectively; and C_o is the inherent contrast of the object against its background.

The equation reflects the fact that the (diffuse) illumination of the disk decreases according to the depth $R\cos\theta$ while the (collimated) image decreases in contrast according to the inclined pathlength R. Fortunately, α is usually several times larger than k, so that, for the angles encountered in this program, the submerged length of the line can be taken as the Secchi disk depth.

Light Attenuation Meter

As sunlight passes through seawater, it is attenuated by scattering and absorption. If the seawater composition is uniform along the path, the irradiance (I) on an upward-facing sensor lowered into the ocean decreases exponentially with depth (z) according to:

$$I = I_o e^{-kz}$$

where the attenuation coefficient (k) depends on the nature and concentration of particles in the water. Under these conditions, log I plotted against z produces a straight line with slope -k.

In practice, seawater stratification usually produces a curved line. The attenuation coefficient is nevertheless given by the local slope, which is then a function of depth.

Since the attenuation coefficient is found from a slope rather than a magnitude, the instrument does not require absolute calibration. Therefore, the instrument is not provided with a sensitivity adjustment; it reads out in arbitrary units.

This instrument was built by OSI prior to this program. It consists of a 3 1/2" photovoltaic sensor assembly suspended 2 feet below the end of a cable by a C-shaped arm. This arrangement minimizes shadowing from the cable and the arm.

SAMPLING AND FIELD OPERATIONS:

Description of Parameters Observed

Data collected during the field surveys included information on features that would affect an image created by the sea surface. The data included weather observations, sea surface conditions, sun orientation, and visible sea water characteristics. Weather parameters measured during field surveys include wind speed and direction, air temperature, relative humidity, and atmospheric visibility. The parameters were measured at each station on all field surveys and recorded on respective log sheets. Wind speed measurements were taken with a Dwyer, hand-held, wind meter and directions were measured with a hand-held compass. A Webster sling psychrometer was used to obtain wet and dry bulb temperature readings for determining relative humidity. The dry bulb reading is synonymous with air temperature. Atmospheric visibility was recorded by taking 35 mm color slide photographs in a direction that viewed distant visible objects. Vertical measurements were made by estimating the elevation of any broken or unbroken ceiling.

Sea surface roughness exerts considerable control upon the reflective properties of the ocean. Roughness was assessed by measuring sea or swell height and direction. Surface roughness was documented by taking 35 mm color photographs of the sea state at each location. A complete set of 35 mm slides are on file at OSI, Santa Barbara, California. Sea or swell heights were estimated to the nearest 0.5 m. Direction of approach was measured with the hand-held compass.

The orientation of the sun with respect to the sea surface greatly affects the amount of light entering the water column. To document this property, the sun elevation and azimuth were recorded at each station. A Plath sextant was used to measure sun elevations while the azimuth was recorded with the hand-held compass.

Visible characteristics of the sea water recorded included color and transparency. Color was recorded by comparison with the Forel-Ule color scale. Transparency was measured with a 0.30 m diameter Secchi disc. When the wind was light or calm, the disc was lowered over the side of the vessel not shaded from the sun. When the wind and/or sea state was sufficient to cause the vessel to drift, the disc was lowered over the windward side of the vessel to keep it from drifting under the boat. Every effort was made to keep the line vertical, and when this was not possible, the error due to deflection of the line from the vertical was estimated. Accuracy of the readings decreased with increasing sea states.

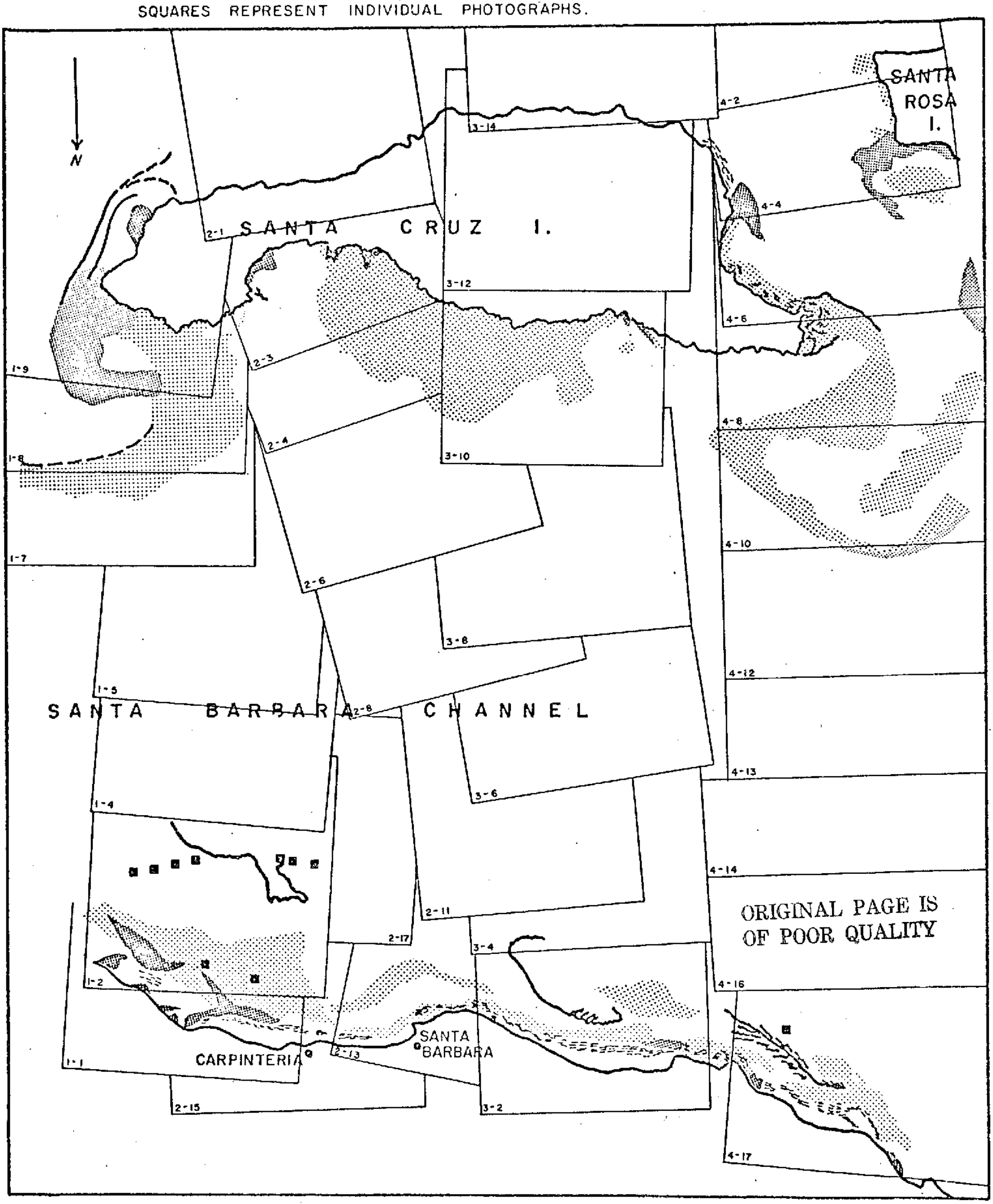
Water samples were collected in 500 ml opaque plastic bottles at the surface. The bottles were held just below the sea surface for filling during calm weather. Under rough conditions, a plastic pail was used to bring surface water aboard from which the bottles were filled. The samples were stored in an ice chest while in the field to inhibit the decay of organic materials.

Supplementary Image Data

In conjunction with the March 15th survey in the Santa Barbara Channel, a low altitude aerial photographic survey was flown over the proposed cruise track to supplement the satellite imagery. The photographs were taken at 27,000 feet from a single engine airplane. A Wild aerial camera was used with Kodak Aerocolor negative film. The flight pattern consisted of four transects across the Channel. The first transect originated over Summerland and continued across the Channel to San Pedro Point, Santa Cruz Island. The final track started seaward of the Santa Cruz Channel and ended over the Ellwood pier. Dead reckoning navigation was used. Linear overlap of the photos is approximately 100%. Lateral track overlap varied from 9% to 50%. The scale of the photographs is approximately 1" = 4500 feet. The photo coverage and photo interpretation is shown in Figure 5. Negatives and one copy of 9" x 9" color prints are on file at OSI, Santa Barbara, California.

The color aerial photographs were used to establish a moderate-range, synoptic record of the appearance of the cruise area in Santa Barbara Channel. Comparison with ERTS-1 imagery was

INTERPRETATION OF AERIAL PHOTO-COVERAGE ON 15 MARCH 1973, USING COLOR FILM AT 27,000 FEET. OVERLAPPING NUMBERED SQUARES REPRESENT INDIVIDUAL PHOTOGRAPHS.



SUSPENDED SOLID MATERIAL, INTENSITY OF SHADING PROPORTIONAL TO TURBIDITY OBSERVED ON PHOTO

SURFACE DEBRIS, NORMALLY HYDROCARBON FILMS NEAR COAST LINE, FOAM LINES AT ISLANDS

FEATURES DELINIATED BY CHANGES IN SEA SURFACE SMOOTHNESS

KELP

OFFSHORE OIL PLATFORM

APPROX. SCALE

0 1 2 3 4 5 N.MI.

Figure 5

AERIAL PHOTO COVERAGE AND INTERPRETATION
SANTA BARBARA CHANNEL - 15 MARCH 1973

performed visually to assess the degree to which turbidity patterns could be resolved in ERTS images. It was learned that small scale details of turbidity patterns were missed by the ERTS MSS, however the large scale aspects of those patterns were recorded better (with better definition and apparent contrast) on ERTS imagery, particularly after digital density slice enhancement. This finding is a subjective one and is difficult to demonstrate numerically; it remains for each observer to make the evaluation for himself.

LABORATORY PROCEDURES:

Water samples obtained on the ocean truth cruises were kept under refrigeration, at 4°C, until they could be processed in the laboratory. There was usually no more than a two-day storage period.

Turbidity

Turbidity of water samples collected during the cruises was measured in the laboratory using a HACH turbidometer, Model 2100A. Collection bottles were allowed to come to room temperature and thoroughly shaken. A sample was immediately poured into the sample cell, about 30 ml, and turbidity was read from the instrument directly in Formazin turbidity units (FTU). Turbidity values ranged from 0.1 to 3.8 FTU.

Suspensoids

Each sample bottle was again thoroughly shaken and 500 ml or less, depending on amount collected, was filtered with a Millipore vacuum filtration apparatus. Membrane filters having a pore size of 0.8 μ were found to be satisfactory for retaining plankton. Smaller pore size made filtration time too long without retaining appreciably more organisms.

Material retained on the filter was washed with distilled water to remove salts, and then air-dried. Some filters were treated with fixing solutions (1% gluteraldehyde in 0.1M phosphate buffer, pH 7.4, and 1% osmium tetroxide in 0.1M phosphate buffer, pH 7.4) but because the plankton are mostly diatoms, dinflagellates, and other shell-encased organisms, there was no apparent advantage to fixing the samples. Further, there was the disadvantage that the fixed filters and retained material were stained darkly, making optical microscopy extremely difficult.

Optical Microscopy

After air drying the filters were examined by optical microscopy (125 to 500X magnification) and tabulations were made of the planktonic organisms (by genus) and debris (by size) retained on the filter. Using the microscope's field of view as a grid system, estimates of the number of organisms or debris particles per liter were made by the following formula:

$$\text{Organisms/Liter} = \frac{\text{area used on filter (number of organisms counted)} \times 1000 \text{ ml}}{\text{area in field of view (number of fields counted)} \times \text{ml sample filtered}}$$

Scanning Electronic Microscopy

Based on the optical microscope study, selected filters were submitted to scanning electron microscope examination and micrographs were made of representative organisms, using Polaroid 4 X 5, type 55, positive-negative film. Small squares of filter, about 1 cm by 1 cm, were attached to the mounting stub with a conducting cement. A solution of glycerin saturated with potassium chloride was found to provide an effective anti-charging coating. A thin layer of solution was applied to the mounted filter from a thin pipette and allowed to dry for one half hour. Excess glycerin was then gently blotted away and the specimen put in an ETEL scanning electron microscope for examination.

Reflective Colorimeter

Freshly filtered and dried samples from two cruises were submitted to examination by reflective colorimetry with a color analyzer reflectance attachment on a Bausch and Lomb Spectronic 20. A percentage reflectance, based on 100% reflectance by a clean white filter and zero for a flat black surface, at specific lengths gave a reflectance spectrum for each filter.

Peaks in the resulting curves are considered to indicate the predominate color (most reflected wavelength) of the sample. Because the amount of filtrate varied from sample to sample and thus varying amounts of the white filter were covered or exposed, the absolute value of the spectral curves was varied.

Several filters were moistened with water to see if there was any change in the reflectance spectrum. The curve is displaced downward (less reflectance) when the sample is dampened but the shape remains constant.

Several filters from earlier cruises were also studied by reflectance colorimetry, but experiments have shown that the shape of the curve and the peak reflectance wavelength often vary with age.

Comparison of Field Water Nephelometer Readings and Laboratory Turbidity Measurements

Laboratory turbidity measurements were made on water samples collected when the boat stopped on station for observations and measurements. Water nephelometer readings were recorded continuously on strip charts as the boat traveled between stations. Readings from the strip chart directly before stopping on station were used as the nephelometry values for that station. Plotting those values against the corresponding laboratory turbidity measurements yielded no consistent relationship. Either different water was sampled, or one of the instruments was erratic in its readings. The water nephelometer was not calibrated before each use with commercially prepared standards. Therefore, data from the field nephelometer is presented in uncalibrated, arbitrary units.

Part 3

IMAGERY

PHOTOGRAPHIC IMAGE ENHANCEMENT EXPERIMENTS:

Prior to the receipt of CCT digital data, several attempts were made to enhance ERTS-1 photo imagery to accentuate ocean features in marine scenes. The first attempt was additive color rendition on colored transparent foils. Initially, a false color infra-red composite was sought by printing 9" x 9" MSS band positive transparencies on primary color diazo process transparent foils. MSS band 4 was printed on yellow (KYL), band 5 on red (KRD), and band 7 on blue (KBL) diazochrome* foils. Printing was performed on local commercial blueprinting equipment.

Extreme difficulty was experienced in securing a proper color balance because the foils were too dense when prepared by exposing MSS transparencies for normal lengths of time. Experimentation showed that exposures as long as 200 seconds were necessary to produce thin foils. At such long exposures, foil latitude and contrast were diminished and foil density could not be controlled sufficiently. Further, densitometer scans of the gray scale step wedges on several ERTS-1 marine scenes showed that, band for band, the film density characteristics varied considerably from scene to scene. This indicated excessive experimentation, hence cost, for each scene rendition.

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*These foils are manufactured by Technofax, a subsidiary of Scott Graphics, Inc., 847 South Monterey Pass Road, Monterey Park, California 91754.

The color additive approach was abandoned after considerable funds had been spent on processing without producing acceptable additive color transparencies. The possibility of generating photographically rectified positive transparencies from 70 mm MSS chips was investigated briefly. It was decided that the added cost plus the image degradation caused by using commercial equipment to generate second generation enlarged positive transparencies warranted pursuing this approach no further.

The technique of posterization was tried next. Both the positive and negative 70 mm chips of MSS band 4 were printed on photographic film having ultra-high contrast.* The method described in O'Neill (1973) produced a series of black and white transparencies, one for each density interval on the gray scale step wedge. Each of these transparencies was printed in a different color on diazo process transparent foils and the foils sandwiched in register to produce a color-enhanced, density slice composite (Figure 6). The result is pleasing to the eye; for the 15 March 1973 scene of Santa Barbara Channel (1235-18075), 7 colors were used. This amounts to separating 6 density slices plus one for all levels greater than the highest level in the ocean. Each slice does not represent a single density level on the step wedge however, because it is difficult to adjust the exposure and development of the high contrast film to produce a sharp cut off at each density level. As a result, each density slice overlaps the next to varying degrees. This produces additive color gradations in the composite that add to the aesthetic effect but detract from the definition of features. The technique also suffers the disadvantages of variable density characteristics in the ERTS photo imagery and is expensive.

*Eastman Kodak Kodalith film was used in this experiment.

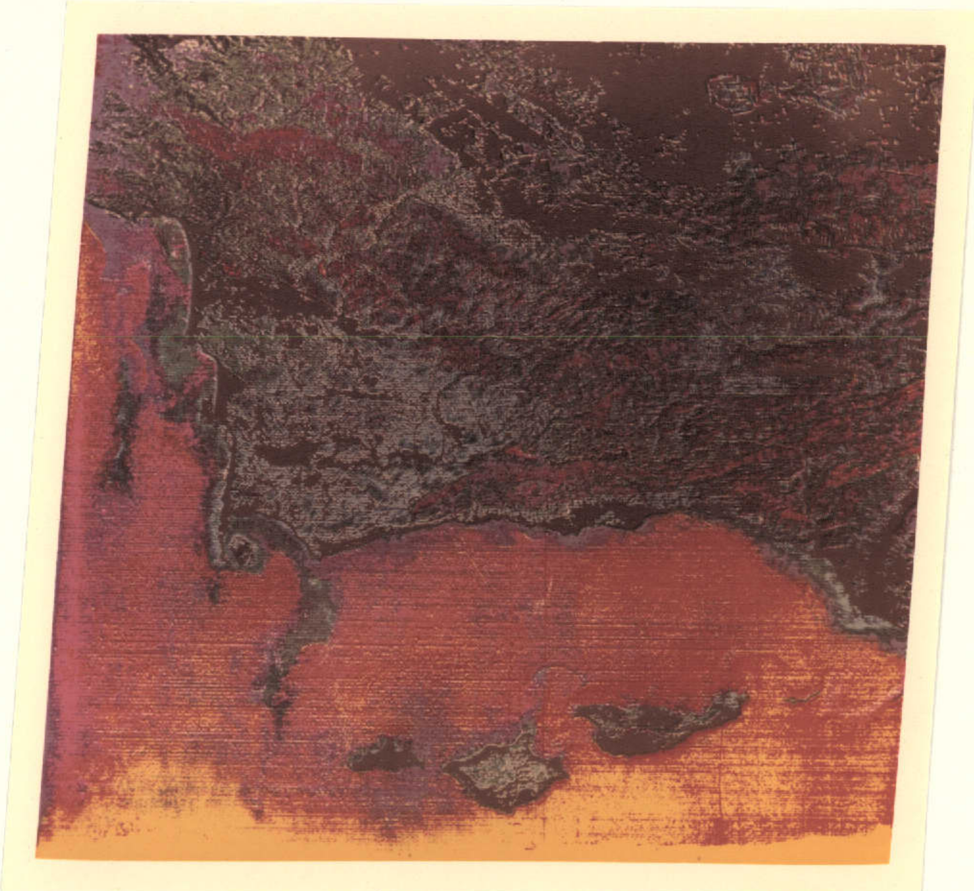

Figure 6

POSTERIZATION OF ERTS IMAGE
MSS BAND 4, SCENE 1235-18075, 15 MARCH 1973
SANTA BARBARA CHANNEL

Note: The color scale is arbitrary; yellow & red tones are relatively clean ocean water, while blue and violet tones represent turbid coastal water.

Mass production of composites is not likely to reduce costs because each band of each scene must be considered individually; proper exposures must be found by testing each piece of ERTS photo imagery. Nevertheless, the posterization technique is a promising one, meriting further investigation of applications elsewhere. The technique was abandoned in the present study only because it was discovered that CCT data contained more information than photo imagery and because digital density slices could be prepared interactively giving the oceanographer more control over the enhancement.

CCT DATA PROCESSING:

Introduction

Early in the project, it was decided that much of the ERTS image reduction and analysis would be performed on the computer and ground truth correlations would be made primarily in the digital domain. For this digital processing, two local computer systems were available, a CDC 6400 and an IBM 360-75. Considerations of cost, accessibility and turn-around time dictated that the CDC 6400 computer be the primary system. To that end, most of the processing discussed in this section pertains to the CDC system. IBM usage was restricted to a few test runs, some tape conversion (9-track to 7-track) and occasional associated small tasks.

The number of people involved in the processing and analyses was small and the programs generated were not designed for wide dissemination. Documentation for a program was limited to the extent that would allow program utilization by those people involved in the project. Nominal additional effort was expended to keep documentation of minor program changes up to date. In actual operation, programs were tailored to achieve the sub-task goals and never attained the status of true production-run programs.

The remainder of this section will concern itself with:

. . . the general program descriptions
. . . sample outputs
. . . data reduction problems

No program listings will be included as it would be misleading to imply these programs are easily adapted to other systems. Program documentation is available to those users who feel they would benefit from such documents. We feel however, that our main contribution to digital image users would be the discussion of problems encountered and their possible solution. A review of nearly all available ERTS reports on digital processing has failed to explain fully and document the often mentioned problems in the ERTS digital imagery. In fact, many of the solutions offered illustrate a lack of understanding of the origin of the problems in the first place. Much of our time and effort has gone toward investigations of banding, "forbidden numbers", and data calibrations. This was necessitated because the narrow range of the oceans radiance caused extreme sensitivity to the problems mentioned above.

Computer System

The primary computer system utilized was a CDC 6400. This computer has a high speed (100 ns cycle time) and large memory (96K central memory words of 60 bits each plus 125K words of extended core storage). It accommodates 10 peripheral processes of 4096-16 bit words each. The complete system includes a card reader, printers, card punch, disks, drums, 7-track tapes, console, and a 30 inch Calcomp drum plotter. The major shortcomings of the system with regard to the project are the absence of 9-track tape drives and its 60-bit word, 6-bit byte internal code structure.

The operating system used was the GOLETA Operating System, a multi-processing, document-oriented system developed by General Research Corporation. Some of the features available under GOLETA are not available under SCOPE (CDC Operating System) and vise-versa. Many of GOLETA's unique features were utilized in the programs developed for the project. The unique features further limit program utilization at other installations. In all programming, an attempt was made to reduce costs on the system used. This in turn may have produced programs that might be incompatible with other systems.

Computer Language

In general, all programs were written in FORTRAN (the exact version was a function of the computer system used). Special bit and byte manipulating sub-routines were written in CDC 6400 COMPASS where speed and efficiency of processing were considered important. This was true of those bit and byte operations which had extensive use.

Tape Conversion

The CCT tapes requested from NDPF were 7-track for use on the CDC 6400. On occasion we received 9-track tapes which we converted to 7-track on an IBM 360-75 for subsequent use on the CDC 6400. The time lapse between order and product received was such that we found it more expedient to convert the tapes received rather than resubmit the order. No serious problems were encountered during the conversion. It should be noted, however, that computer conversion costs were approximately $75.00 per scene.

Occasional problems were encountered in the tape handling process. These included both record parity errors and wrong record counts and lengths. An investigation made into the nature of these errors indicated they were most probably associated with the write parity error recovery software at NDPF. In conjunction with read parity errors on our computer system were incorrect data record lengths and extraneous short records. These short records appeared to contain the same scan lines as the following correct length no parity record. These problems were treated on an individual basis as no obvious pattern to all errors was found.

The 7-track, eight bit byte, 2342 record tape from NDPF is generally incompatible with the CDC 6400. The 6400 is word oriented (60 bits) with 6-bit bytes. In addition the billing algorithm is such that a large number of physical records is much more costly than the added memory required for large blocked data. An added economy arose upon discovering that our range of interest on all bands was limited to intensity values of 63 or less. This permitted us to drop the 7th bit (64-127) from each intensity value by setting all intensity values of 64 or greater to 63. Initially a record was kept of the number of 7-bit bytes (64-127) in the data. This provided the following observations:

1. Less than 1 percent of the data fell in the range of 64-127 on cloudless days in the scenes of interest.

2. MSS band 7 had no 7-bit data values because the data range was only 0-63 (not compressed in the spacecraft).

3. Of the remaining 3 bands (MSS 4 - MSS 6) band 4 had the fewest number of 7-bit values while band 6 had the largest number. Band 5 was intermediate between the two.

It should be emphasized that our interest was with the oceans and their inherently narrow range of intensities. The tabulation did confirm we were not degrading data in our interest area by restricting our intensity range from 0-63.

The billing algorithm problem was reduced somewhat by reblocking the ERTS data and extracting only that portion of the tape which covered our area of interest. In some scenes this represented 70% of the total. In others it only represented 10% of a scene. The new blocking factor was set at 9. This generated a physical record of 3960 words (39,600 bytes) equivalent to nine scan lines of information. This was the largest multiple of scan lines that was consistent with the GOLETA Operating System.

The record format also was changed to be more compatible with the characteristics of the 6400. The interleaved 2-byte channel information was converted to interleaved word (10 byte channel) information. For a given scan line and sample within a scan line, each computer word contained 10 bytes of data for a single channel. In this way 10 bytes of information for a single channel is accessed in one memory fetch and easily manipulated. Pixel by pixel comparison from band to band is easily done. The same pixel in each band is in the same byte position in an adjacent record.

In summary, the following changes take place during the conversion from a NDPF 7-track tape to a CDC 6400 7-track tape.

a. The ID record and annotation record are copied retaining all EBCDIC and Binary code.

b. The image area (scan lines) of interest is selected from the NDPF tape.

c. The output tape (CDC) is blocked 9 logical records to a physical record.

d. All intensity values in the range of 64-123 are set to 63.

e. All 7-bit bytes are converted to 6-bit bytes with values (0-63).

f. 5 groups of 8 spectrally interleaved, spatially registered samples, 2 bytes from each 4 MSS bands are converted to 1 group of 40 spectrally interleaved spatially registered samples, 10 bytes per word for each of 4 MSS bands.

Characteristics of Digital Images

Certain properties of CCT digital images need to be discussed before proceeding with a description of image processing. The image consists of a series of scan lines of integral values of radiance. The radiance was sensed by a bank of six independent sensors, each of which views a different swath of the scene. The swaths are adjacent such that every sixth scan line was produced by the same sensor.

The sensitivity and calibration of each sensor in the satellite appears to be different and these produce differences in the character of adjacent scan lines within the image. That recurs on a cycle of six, i.e., every sixth scan line bears the same character and is different from adjacent scan lines.

This property of 6-cycle scanning leads to important effects in the digital images. If a sensor in the satellite malfunctions, the resulting error would occur every sixth scan line. If all six sensors are perturbed simultaneously, there would be an abrupt change in the nature of the digital image at one particular scan line.

If scan lines are sampled in a systematic manner, such as in scaling the output size, only certain specific sensors will be represented in the sample. Some samples of sampling are presented in Table 6.

Table 6

SENSORS REPRESENTED IN SYSTEMATIC SCAN LINE SAMPLING

Scale	Scan Lines Sampled	Sensors Represented
1/1	All lines sampled	All sensors
1/2	Every other line	Three sensors: either sensors Nos. 1,3, & 5, or 2,4, & 6
1/3	Every third line	Two sensors: either sensors Nos. 1 & 4, 2 & 5, or 3 & 6
1/4	Every fourth line	Same as 1/2 case
1/5	Every fifth line	All sensors
1/6	Every sixth line	Only one sensor
1/7	Every seventh line	All sensors

This table shows that the choice of scale can either enhance or repress errors resulting from the malfunction of individual sensors.

DIGITAL DENSITY SLICING:

The availability of local computer output devices led to the decision to generate line printer plots of the CCT data. These plots were to be used, in conjunction with other image formats, in the analyses of the "ocean truth" data. Programs were written to allow generation of plots for any (or all) bands at any scale. When all pixels for a given scene are presented, this results in computer output of 864 pages of data. When put together this forms a map 32' X 33' or slightly larger than most office floors.

While the three areas of interest in the project are smaller than an entire scene, at least one of these (Santa Barbara) occupies 60-70% of the scene. The Monterey Bay area (the smallest of the 3) is large enough to cover a wall from floor to ceiling. As the intent was to perform density slicing of the digital data, a different map would be generated for each of the density slices. It is obvious that a smaller scale is necessary for ease in handling. Accordingly, the printer plot program was written to allow selection of any intensity range of any MSS channel for any scale, 1/n. A scale of 1/n would create a printer plot based on each nth point from every nth scan line. Testing of the various scales suggested a 1/5 to 1/7 scale plot was a convenient size to work with. The radiometric striping problems discussed below led to the selection of a 1/6th scale for all analysis work. This is equivalent to 1 output page width (136 character printer) for each 1/4 scene strip (each CCT). This scale provided an adequate size image for analysis. Original plans called for the application of some sort of data smoothing algorithm to enable inclusion of the 5/6 of the data which would be lost by this scale method. Tests did not provide any clear indication of an applicable smoothing algorithm because of the radiometric striping. Further tests were made to determine the effects of choosing a particular scale for analysis. These tests showed that while the sensor responses differed, (i.e., the density levels for a given area and "forbidden number" set for a given sensor) each sensor saw the same general ocean features when modified by human judgement. Thus the choice of sensor was made interactively. In addition, one cannot determine which sensor is sampled from scene to scene. Density slices generated from computer printer output are presented in the imagery analysis section of this report. Figures 7 to 10 present a sample of the computer printer output. These are a 1/6th scale of a Santa Barbara channel scene 1235-18075, Reel 3, for 15 March 1973. Band 4 is shown

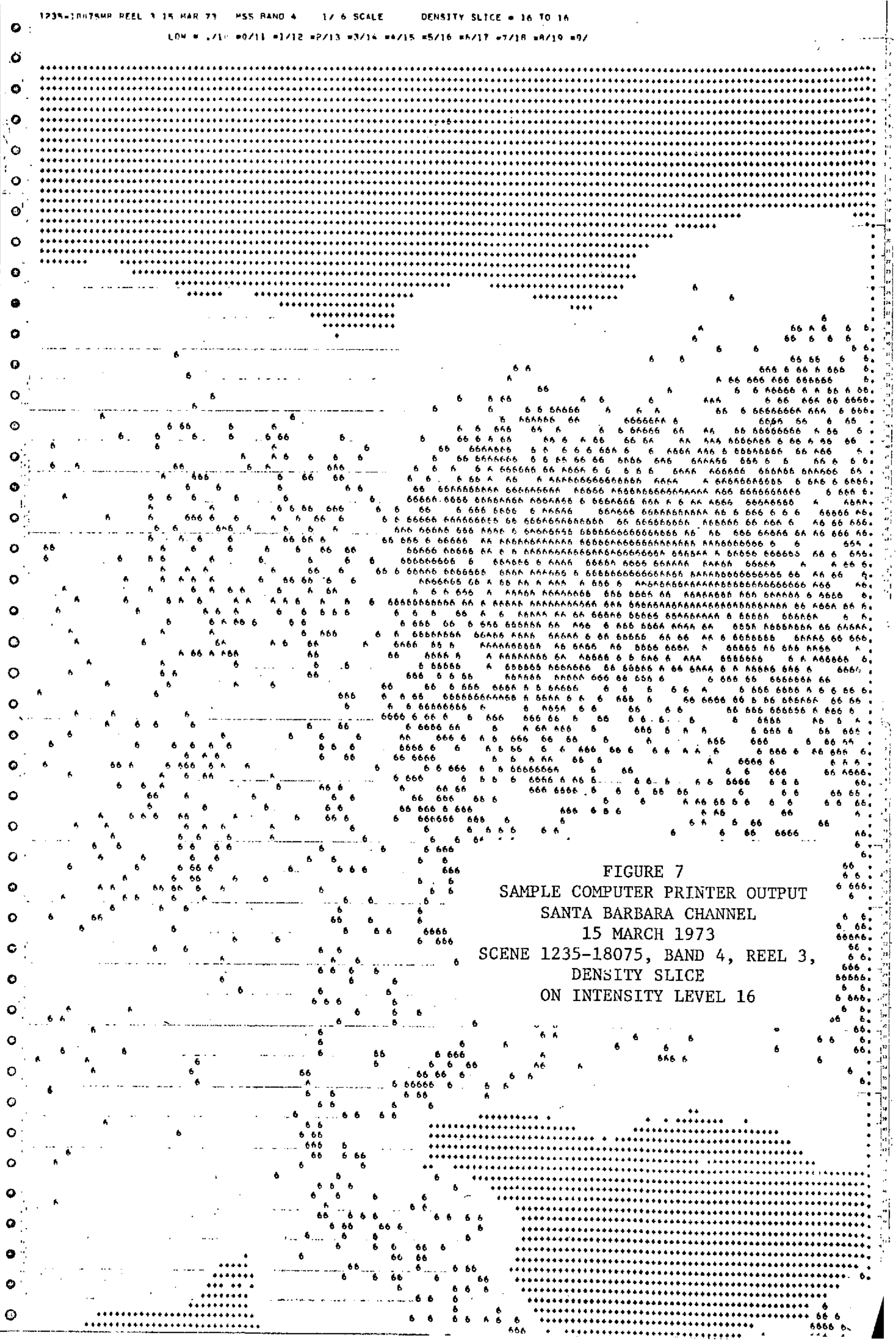

FIGURE 7
SAMPLE COMPUTER PRINTER OUTPUT
SANTA BARBARA CHANNEL
15 MARCH 1973
SCENE 1235-18075, BAND 4, REEL 3,
DENSITY SLICE
ON INTENSITY LEVEL 16

ORIGINAL PAGE IS
OF POOR QUALITY

1235-18075MA REEL 3 15 MAR 73 MSS BAND 4 1/ 6 SCALE DENSITY SLICE = 17 TO 17

LOW = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

FIGURE 8
SAMPLE COMPUTER PRINTER OUTPUT
SANTA BARBARA CHANNEL
15 MARCH 1973
SCENE 1235-18075, BAND 4, REEL 3,
DENSITY SLICE
ON INTENSITY LEVEL 17

ORIGINAL PAGE IS
OF POOR QUALITY

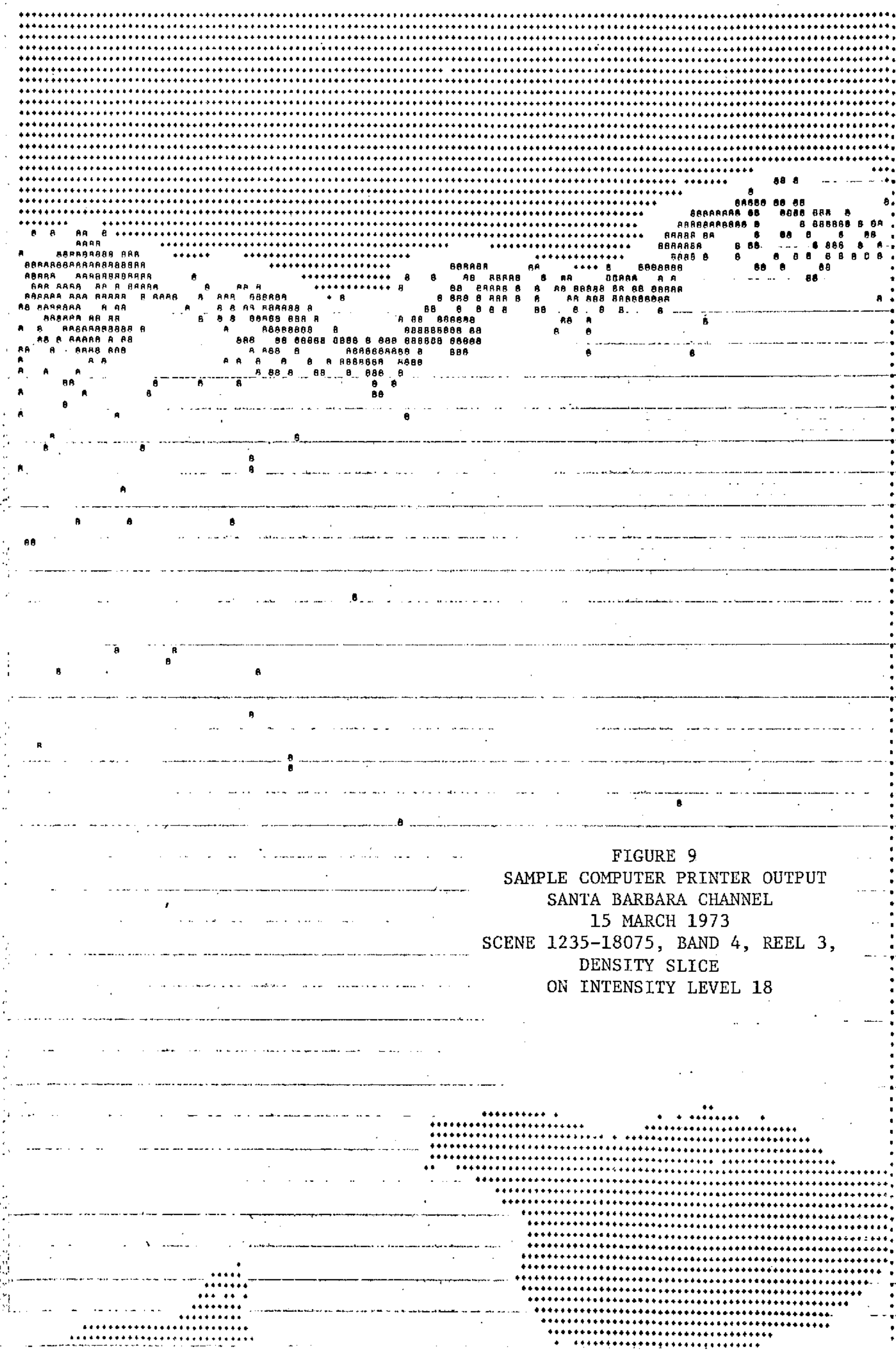

FIGURE 9
SAMPLE COMPUTER PRINTER OUTPUT
SANTA BARBARA CHANNEL
15 MARCH 1973
SCENE 1235-18075, BAND 4, REEL 3,
DENSITY SLICE
ON INTENSITY LEVEL 18

1235-18075MB REEL 3 15 MAR 73   MSS BAND 4   1/ 6 SCALE   DENSITY SLICE = 19 TO 19

LOW = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

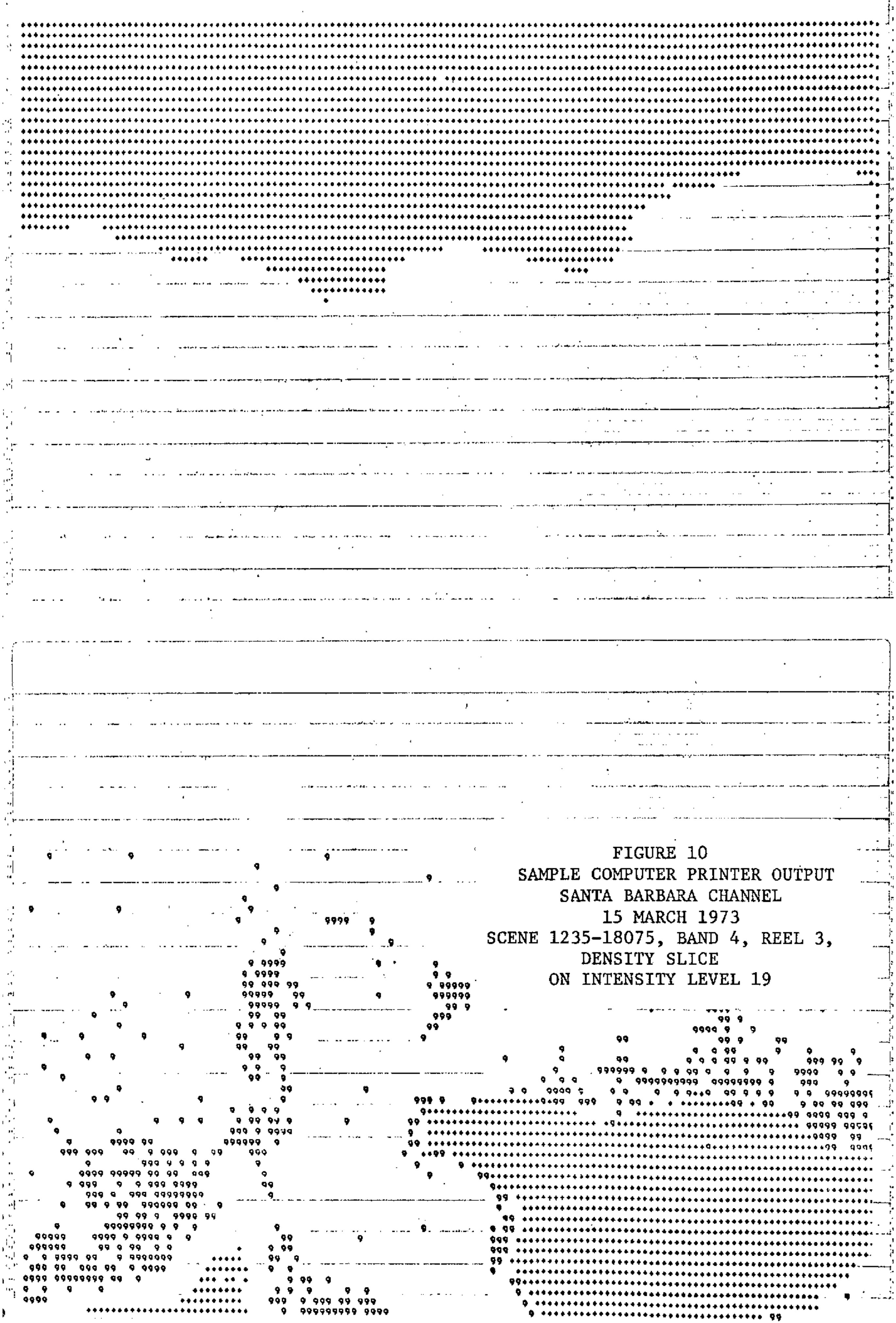

FIGURE 10
SAMPLE COMPUTER PRINTER OUTPUT
SANTA BARBARA CHANNEL
15 MARCH 1973
SCENE 1235-18075, BAND 4, REEL 3,
DENSITY SLICE
ON INTENSITY LEVEL 19

with density slices of levels 16-19 for Figures 7-10, respectively. The + symbol represents land or clouds (no clouds appear in the figures). The land locations were obtained from channel 7 information which then was used as a mask. The land in the lower portion of the figures represents Santa Cruz and Santa Rosa Islands. For the density slice, only the locations of the particular value is printed. Water areas with other intensity levels appear blank on the printout.

CRUISE TRACK RADIANCE PROFILING:

The goal of the study was to obtain ground-truth (ocean-truth) data in conjunction with the ERTS-1 overflights. Correlation of the ocean-truth data with the ERTS imagery required extraction of the intensity data along the cruise trackline. To accomplish this, the track line was first transferred to a printer plot of the digital data. Field station locations were determined in a scan line print position coordinate system. The choice of this coordinate system was one of simplicity as all ERTS data in the computer can be referenced by scan line and position along scan line. Station numbers and coordinate locations along with all ocean-truth data were then supplied to a cruise track plotting program which drove the Calcomp plotter subroutines.

Plots of the following parameters could be obtained:

1. Track line intensity of any or all sensors. These data could be averaged over any desired number of pixels. Areas of high reflectance (clouds) were not plotted. These appear as gaps in the track line plots.

2. Band ratioing plots of any set of sensors

3. Weighted combination of sensors

4. Water turbidity

5. Transmissometer data

6. Water nephelometer data

7. Air nephelometer data

8. Debris count data

9. Diatom count data

10. Dinoflagellate count data

11. Sun elevation data

12. Wind speed data

13. Temperature data

14. Ocean reflectance data

15. Fluorimeter data

16. Normalized reflectance data

17. Secchi depth data

18. Water color data

The plotting program was written to accept station data, continuous data between stations, or non-continuous data between stations.

Any or all plots could be generated on the same track line scale on demand (where data were available). Individual plots were made of each parameter to aid in the data analysis. This allowed the analyst to recombine any or all of the plots as desired.

Several considerations entered into the selection of the number of pixels over which the track line intensity data were averaged. The first and most obvious consideration is illustrated by Figure 11, which presents a plot of the unsmoothed data along the cruise track. Here,all of the problems: a) sensor noise, b) forbidden numbers, c) non-uniformity of sensor calibration, d) horizontal banding; are displayed in their worst light. It should also be pointed out that pixel by pixel band level ratioing and weighted band combinations also exhibit these problems.

It is obvious from the figure that an averaging scheme is necessary. The selection of an averaging length was primarily dictated by the spacecraft sensor package (i.e., 6 sensors per band) and the radiometric striping problems. Averaging was done over 6 pixels (or some multiple of 6 pixels). The uniform nature of the oceans suggested that while this smoothing would limit the resolution of oceanic features to about 600 meters, degradation of the data would be no worse than the data used in the density slices. Figures 12a and 12b present the same track line data as Figure 11, except averaging has been done over 6 and 12 pixels respectively. Smoothing over greater distances reduces feature resolution even further. For band level rationing and band combination plots, smoothed data were used.

CCT RADIOMETRIC STRIPING PROBLEMS:

This section presents a discussion of radiometric striping problems encountered during the analysis of CCT images. It is intended to provide users with some insight into these problems

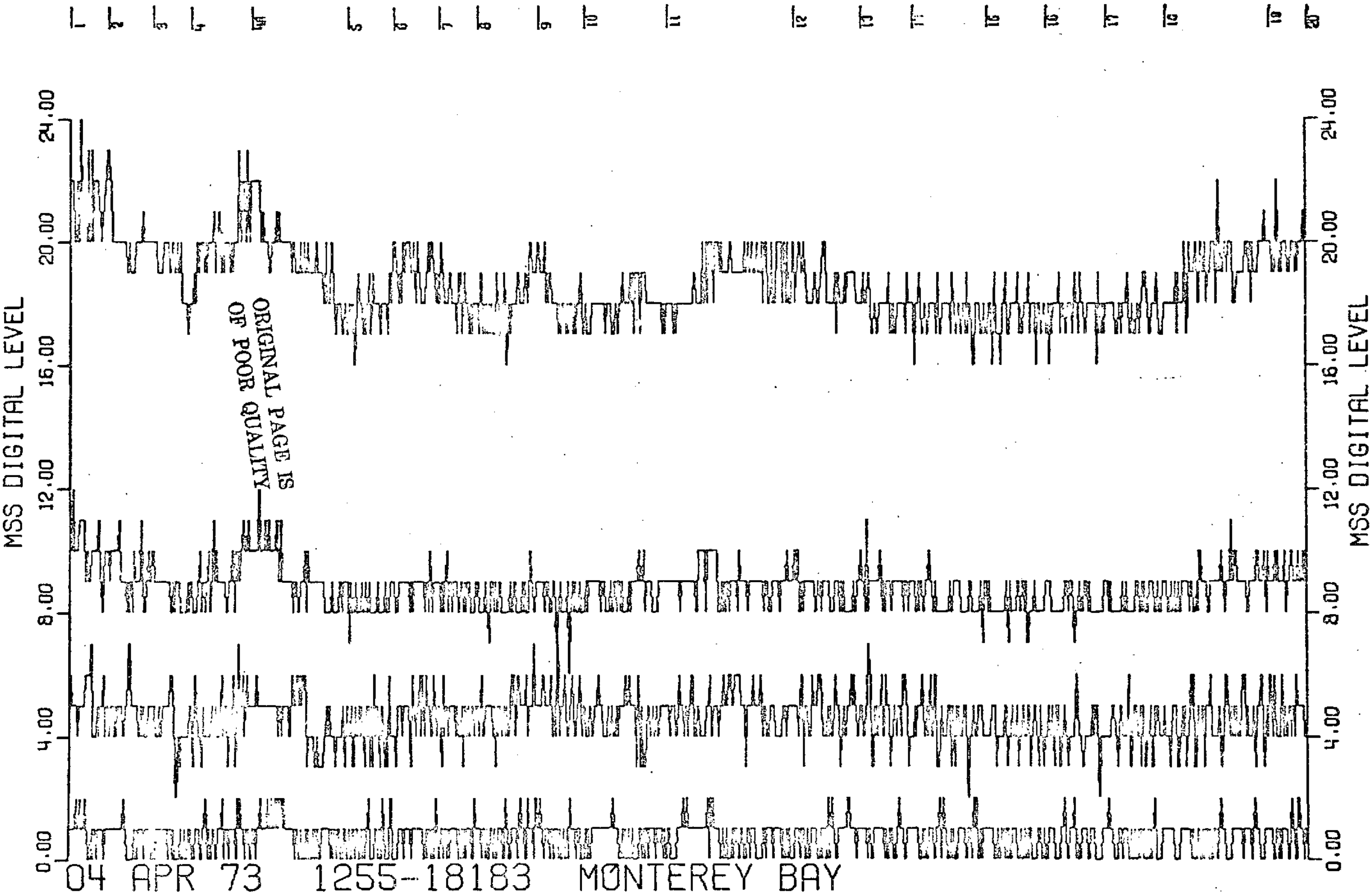

Figure 11

SAMPLE COMPUTER PRINTER OUTPUT OF UNSMOOTHED DATA ALONG A TRACK LINE

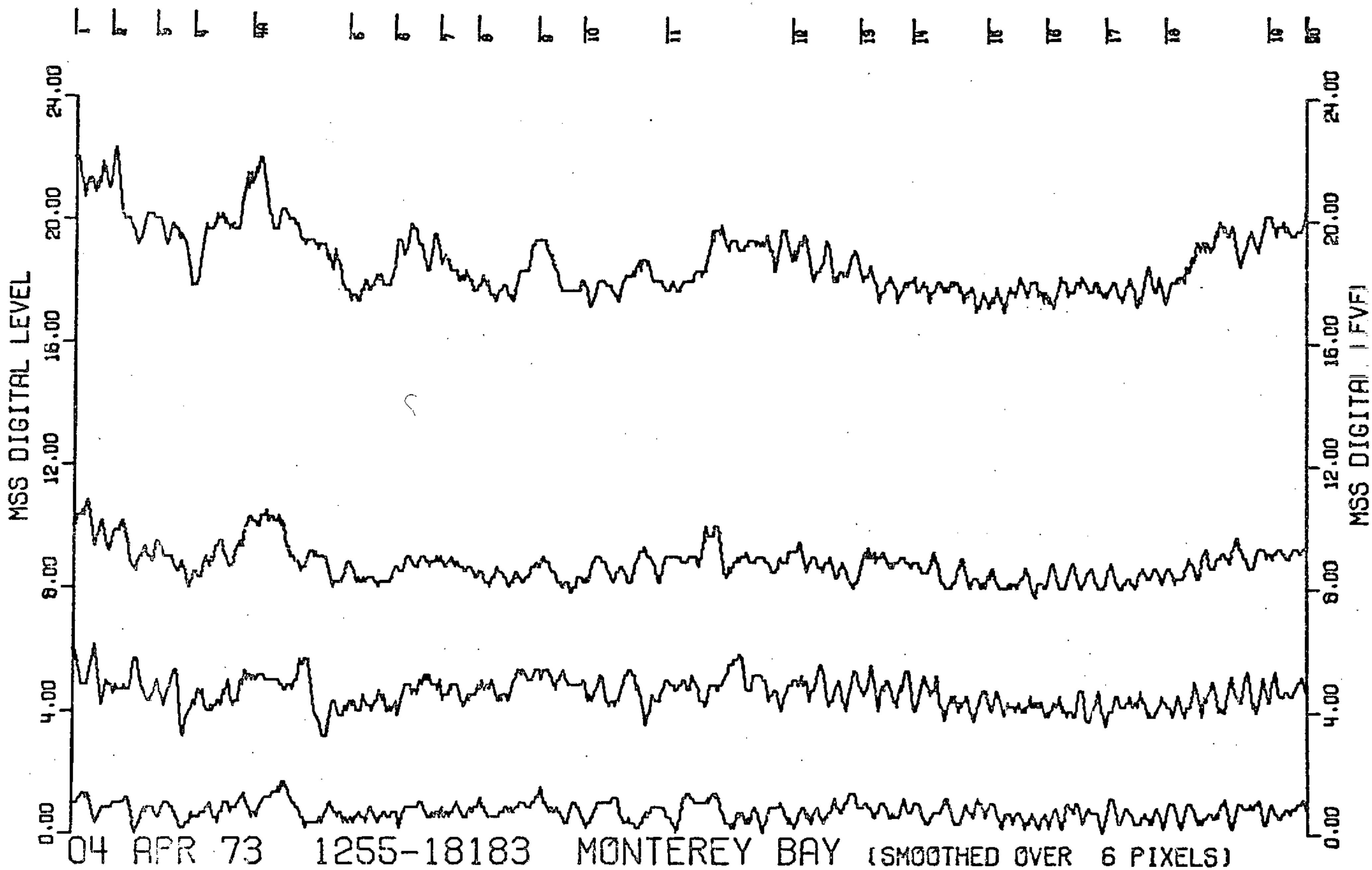

Figure 12a

SAMPLE COMPUTER PRINTER OUTPUT OF SMOOTHED DATA ALONG A TRACK LINE

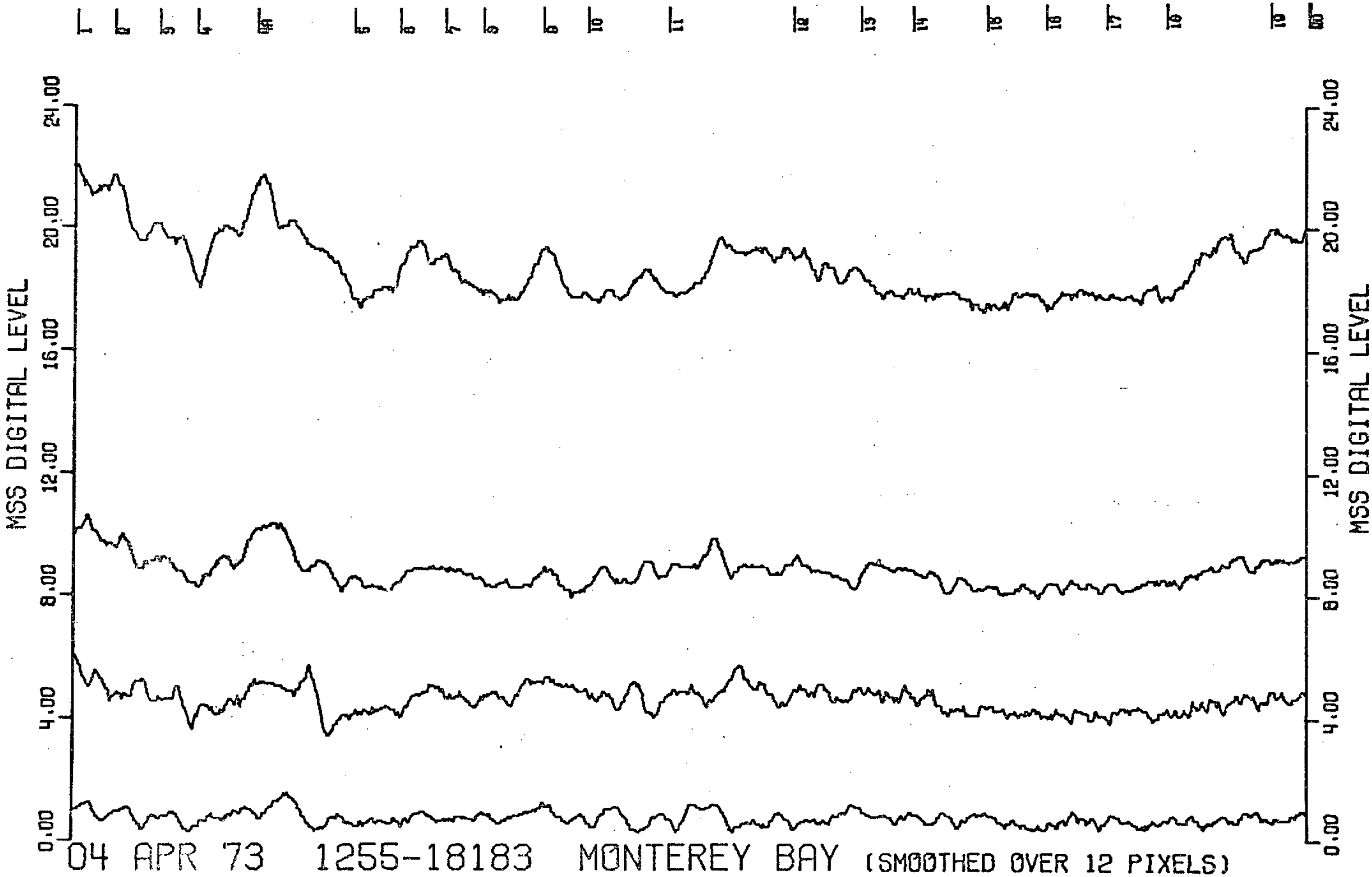

Figure 12b

SAMPLE COMPUTER PRINTER OUTPUT OF SMOOTHED DATA ALONG A TRACK LINE as they have not been discussed in detail in any ERTS reports or NASA documents. Indeed, the content of many reports and conversations with other users suggests that many users have encountered these problems but have had little or no success in understanding them. To our knowledge, the only written document which even suggests the origin of these problems is Report X-563-73-206, "Generation and Physical Characteristics of the ERTS MSS System Corrected Computer Compatible Tapes," by Valerie L. Thomas, Goddard Space Flight Center, dated July 1973, (which we received in late 1973). This report was extremely late in coming and is apparently not fully utilized by other CCT users.

The CCT radiometric striping problems we have identified and will discuss in order of importance to us in ocean-truth analysis are:

1. "Forbidden numbers"

2. Non-uniform calibrations (response of the 6 sensors in a MSS band

3. 6-cycle radiometric striping

4. Non-uniformity of calibration from scene to scene

5. Horizontal banding

6. Vertical banding

Each of these were discovered piecemeal during the attempt to utilize the CCT data in our analysis. They will be discussed and illustrated as we understand each of their origins and effects. It is hoped that this discussion will stimulate NASA to generate more (or correct) information on these problems in addition to the paragraph on page 27 and the footnote on page E-1 of Report X-563-73-206. A further reason for including this discussion is, much of our time and effort went toward an understanding and attempted solution of these problems. As the response of the ERTS sensors for a water path covers only a few intensity levels, the radiometric striping noise represents approximately 40% of the ocean radiance signature range. The effort expended on this radiometric striping investigation included valuable discussions with other CCT users (Aerospace Corp., Westinghouse, Lockheed, Hughes, etc.) the project engineer for the MSS package (Santa Barbara Research Center), NDPF, and GE. These discussions suggested that no one individual was completely aware of all of the idiosyncrasies of the MSS-CCT data.

Several averaging algorithms have appeared in various ERTS reports. These are generally described as having marginal success. It is hoped the material contained in this report will aid these users in understanding the nature of their problems, and in the refinement of their methodology. The discussion which follows applies only to CCT bulk full frame MSS data.

Following is a brief discussion of the MSS system in the satellite and the data processing system on the ground. A complete understanding of the entire system is imperative for proper understanding of the origin of the various radiometric striping problems.

The MSS contains 24 detectors, a total of 6 per band. (This is the origin of 6-cycle radiometric striping). When we originally talked to NASA of 6-cycle striping, we were told this had been corrected in April, 1973 and we should re-order CCT data. Accordingly, we re-ordered CCT's which were supposed to be without 6-cycle striping. The new tapes displayed the same characteristics as the old tapes; apparently the 6-cycle striping has not been removed despite the claims of NASA personnel. This impasse continued until the receipt of NASA document X-563-73-206 which stated that, "sixth line striping, a variation in every sixth scan line of six quantrum levels or more.... was corrected through modification of the software in April 1973." We have never experienced this particular type of striping. To overcome the semantic difficulty, we refer to the striping we observe as six-cycle radiometric striping to distinguish it from the sixth line striping NASA corrected in April, 1973.

In the spacecraft, the MSS system is operating in a compressed low grain mode for bands 4, 5, and 6. While the facility exists to change the operational mode of the MSS, it is our understanding it has operated in compressed low gain mode since launch. If this is true, all data processing should follow the same path. Calibration wedge data is obtained in the spacecraft in accordance with the discussion in Appendix G on the ERTS Data User's Handbook. The intent of this calibration wedge according to NASA Report X-563-73-206 is to check the relative radiometric levels and to equalize gain changes which may occur in the six detectors of a spectral band. Corrections are performed at the NDPF to equalize these levels so that striping will be avoided.

As the internal calibration lamp may change with time, a sun calibration is performed in accordance with the discussion in Appendix G of the ERTS Data User's Handbook. We have been informed that the sun calibration is not used at present (see pp. D1 of NASA Report X-563-73-206). This suggests that absolute radiance is not available from the system (this particular information has been verified by Goddard Space Flight Center). This lack of absolute radiance is particularly important when scene to scene comparisons are made for several passes of the spacecraft. At this point, it is difficult for the user to determine with certainty what percentage of variations of a particular area's radiance are due to variations of the calibration wedge and what percentage are due to variations of the image intensity itself. Refinement of the intensity data require long-term statistics of the calibration wedge which are not available to the user at present.

Six-bit data (both raw MSS and calibration wedge) are transmitted to the ground station. Here, both the 6-bit raw MSS compressed data (range 0-63) and the calibration wedge data are decompressed to 7 bits (range 0-127). Table 7 presents the MSS decompression table used for the MSS compressed 6-bit raw data. This table is reproduced here because prior to NASA Report X-563-73-206, the only reference we are aware of to this table is a NASA Memo number 1H05-016 Rev. "A" dated 26 May 1972, which to our knowledge did not receive wide user distribution. As is shown, one decompression scheme is used for MSS bands 4 and 6, while a second decompression scheme is used for band 5. Decompression is performed prior to the application of the calibration data. An examination of the decompression table shows that this decompression step leads to an "original forbidden number set." Actually, "original 65 forbidden numbers" are generated because quantum levels 2 and 3 are both mapped into linear level 2. The calibration wedge data are also decompressed to linear; a linear regression scheme is applied to the calibration wedge data utilizing the C_i and D_i values* that are presented in Appendix D, NASA document X-563-73-206. Offset and gain are then filtered and the resultant values applied to the original decompressed MSS data. This may rise to a new forbidden number set if forbidden numbers in the calibration coefficients are not removed by filtering. To guard against spurious calibration data, two

*The unusual expressions for defining C_i and D_i given in the User's Manual are derived in Johnson (1963), chapter 1.

Table 7

MSS DECOMPRESSION TABLE
FOR SPECIAL PROCESSING

MSS QUANTUM LEVEL OUTPUT IN COMPRESSED MODE (6 BITS)	EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 4 & 6 DATA		EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 5 DATA	
	Radiance Levels	Forbidden Levels	Radiance Levels	Forbidden Levels
0	0		0	
1	1		1	
2	2		2	
3	2		2	
4	3		3	
5	4		4	
6	5		5	
7	6		6	
8	7		7	
9	8		8	
10	9		9	
11	10		10	
12	11		11	
13	12		12	
14	13		13	
15	14		14	
		15		15
16	16		16	
17	17		17	
18	18		18	
19	19		19	
		20		20
20	21		21	
21	22		22	
		23		
22	24		23	
				24
23	25		25	
		26		26
24	27		27	
		28		
25	29		28	
				29
26	30		30	
		31		31
27	32		32	
		33		33
28	34		34	
		35		35
29	36		36	
		37		37
30	38		38	

Table 7

Continued
Page 2

MSS QUANTUM LEVEL OUTPUT IN COMPRESSED MODE (6 BITS)	EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 4 & 6 DATA		EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 5 DATA	
	Radiance Levels	Forbidden Levels	Radiance Levels	Forbidden Levels
		39		
31	40		39	
		41		40
32	42		41	
				42
33	43		43	
		44		44
34	45		45	
		46		46
35	47		47	
		48		48
36	49		49	
		50		50
37	51		51	
		52		52
38	53		53	
		54		
		55		
39	56		54	
		57		55
				56
				57
40	58		58	
		59		59
		60		
41	61		60	
		62		61
				62
42	63		63	
		64		64
		65		65
43	66		66	
		67		67
		68		68
44	69		69	
		70		70
		71		
45	72		71	
		73		72
		74		73
46	75		74	
		76		75
		77		76
47	78		77	

Table 7

Continued
Page 3

MSS QUANTUM LEVEL OUTPUT IN COMPRESSED MODE (6 BITS)	EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 4 & 6 DATA		EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 5 DATA	
	Radiance Levels	Forbidden Levels	Radiance Levels	Forbidden Levels
		79		78
		80		79
48	81		80	
		82		81
				82
49	83		83	
		84		84
		85		85
50	86		86	
		87		87
		88		
51	89		88	
		90		89
		91		90
52	92		91	
		93		92
		94		93
53	95		94	
		96		95
		97		96
54	98		97	
		99		98
		100		99
55	101		100	
		102		101
		103		102
				103
56	104		104	
		105		105
				106
57	106		107	
		107		108
		108		
58	109		109	
		110		110
		111		111
59	112		112	
		113		113
		114		114
60	115		115	
		116		116
		117		
61	118		117	
		119		118
		120		119
62	121		120	

Table 7

Continued
Page 4

MSS QUANTUM LEVEL OUTPUT IN COMPRESSED MODE (6 BITS)	EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 4 & 6 DATA		EQUIVALENT LINEAR LEVEL QUANTIZED TO 7 BITS (0 TO 127) FOR BAND 5 DATA	
	Radiance Levels	Forbidden Levels	Radiance Levels	Forbidden Levels
		122		121
		123		
63	124		122	
		125		123
		126		124
		127		125
				126
				127

techniques are involved. The first is to use calibration wedge data when the wedge is ± 4 quantum levels away from nominal. While NASA suggests calibration wedges do not change on a weekly interval, we find that several changes can occur within a single scene. These give rise to horizontal banding problems.

In summary, the following are the main steps of the MSS data acquisition and associated CCT processing.

1. 24 detectors scan the earth (6 per band).

2. Alternate scans sample the calibration wedge.

3. Data are transmitted to ground stations as 6-bit bytes (0-63).

4. Data are decompressed to 7 bit bytes (0-127); this introduces an original forbidden number set into the digital number system that represents scene radiance values.

5. Calibration wedge data are decompressed, linearized by linear regression techniques, and averaged over 16 wedges. Decompression probably introduces a set of forbidden numbers in the calibration wedge data.

6. Calibration wedge data ± 4 quantum levels from nominal are replaced by nominal calibration wedge values.

7. MSS data, decompressed (or raw in the case of band 7), are corrected for sensor offset and gain. This apparently gives rise to a new set of observed forbidden numbers, i.e., those existant on CCT's received from NDPF.

In the discussion that follows, it should be kept in mind that the primary area of interest was the oceans. This represents large scenes that have a very small intensity range on all bands (even after decompression). It should be remembered that ERTS was designed originally to examine land portions and not ocean areas.

Forbidden Numbers

The origin of the forbidden numbers has been discussed above. The decompression of six bit data to seven bit data of necessity gives rise to this problem. The original forbidden number set is presented in Table 7. The forbidden number set does not start until linear level 15, and on MSS bands 5 and 6 of ocean scenes. The intensity values all lie below level 15. For band 4, which coincidentally is the band with the most water information, the intensity levels include the forbidden number set.

The actual distribution of levels and forbidden numbers on the CCT of MSS band 4, scene 1235-18075, reel 3 represented by 1101 scan lines over the Santa Barbara Channel is given in Table 8. Most of the area in the portion of the scene for Table 8 contains water. In the table, sensor 2 shows no values of 20 while for levels 19 and 21 the sensor sees 5,385 and 4,780 values respectively. Sensor 4 on the other hand sees level 20 but not level 19, 22, or 23. The original forbidden number set of sensor 4 can be transformed into the observed forbidden number set if the calibration shifts the forbidden numbers 15, 20, 23, and 26 to either 15, 19, 22, and 23 or 19, 22, 23, or 27. In either case this represents a level shift of 3 or 4 quantum levels. Figure 13 presents detailed histograms of the information contained in Table 8. Here the forbidden number set can be seen more easily. Apparently the calibration used for each sensor shifts the forbidden number set in different directions. In the case of water, because of the slowly varying nature of the

Table 8

DISTRIBUTION OF INTENSITY LEVELS AND FORBIDDEN NUMBERS

1235-18075, REEL 3, MSS BAND 4, 15 MARCH 1973

SANTA BARBARA CHANNEL

SENSOR	QUANTUM LEVEL 11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	78	0	31,840	71,604	5,026	6,807	6.767	5,384	0	5,813	0
2	0	0	0	3,062	62,607	42,352	314	7,636	5,385	0	4,780	5,034	2,111	2,891
3	0	0	0	21	0	21,749	74,902	9,461	5,779	6,594	4,982	3,273	1,503	0
4	0	0	0	15	0	25,692	75,627	12,670	0	6,168	4,329	0	0	6,096
5	0	341	5,723	10,901	18,117	46,277	16,016	16,096	5,376	3,798	318	1,980	5,711	3,632
6	0	0	0	0	1,803	60,578	22,695	23,411	8,277	5,827	0	4,941	5,552	0

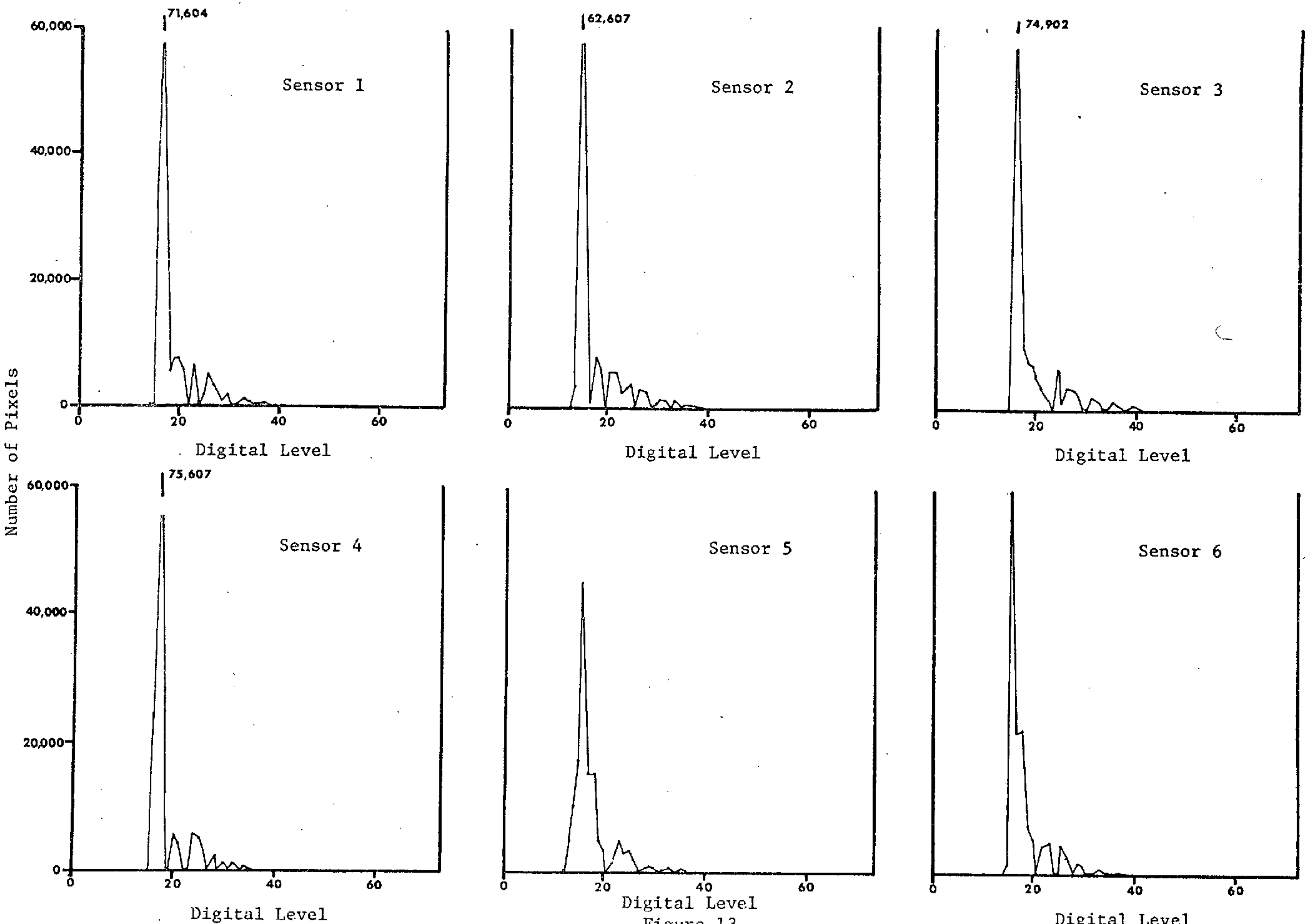

Figure 13

INTENSITY LEVEL DISTRIBUTION - SCENE 1235-18075, REEL 3, BAND 4

SANTA BARBARA CHANNEL - 15 MARCH 1973

surface intensity, the shift of forbidden numbers by calibration is quite apparent.

Two important facts are deduced from Table 8 and Figure 13. First, if calibration has the same effect upon each sensor in a particular band, then forbidden numbers would occur at the same level in each histogram. They do not, so we can conclude that each sensor is affected differently by calibration. Second, if the calibration corrected each sensor's response properly, the general shape (envelope) of the histograms representing each sensor in a particular band would be the same but offset laterally ± 1 quantum level. They are not, suggesting that the calibration procedure is improper, very likely because scene data containing forbidden numbers are being calibrated with coefficients calculated from values containing a different set of forbidden numbers.

The forbidden number set is more obvious in the quantum level distribution for each of sensors for each of the bands. Figures 14 thru 17 present histograms for all channels for bands MSS 4, 5, 6, and 7 respectively for a San Francisco/Monterey scene 1255-18183 (reel 3). As can be seen, band 7 has no forbidden number set (it is not decompressed). It is extremely significant that the envelopes of the histograms of each sensor in band 7 is virtually identical (± 1 quantum level).

Non-Uniform Calibrations of the 6-Sensor Set in an MSS Band

If the correct calibration were applied to each of the sensors, one would expect the sensors to show nearly identical intensity distributions for water scenes. That this is not the case can be seen in Figure 14 which presented a histogram of the water data from the Santa Barbara Channel. The difference of distributions is most probably the result of incorrect calibrations applied to the sensors. This problem renders it inherently

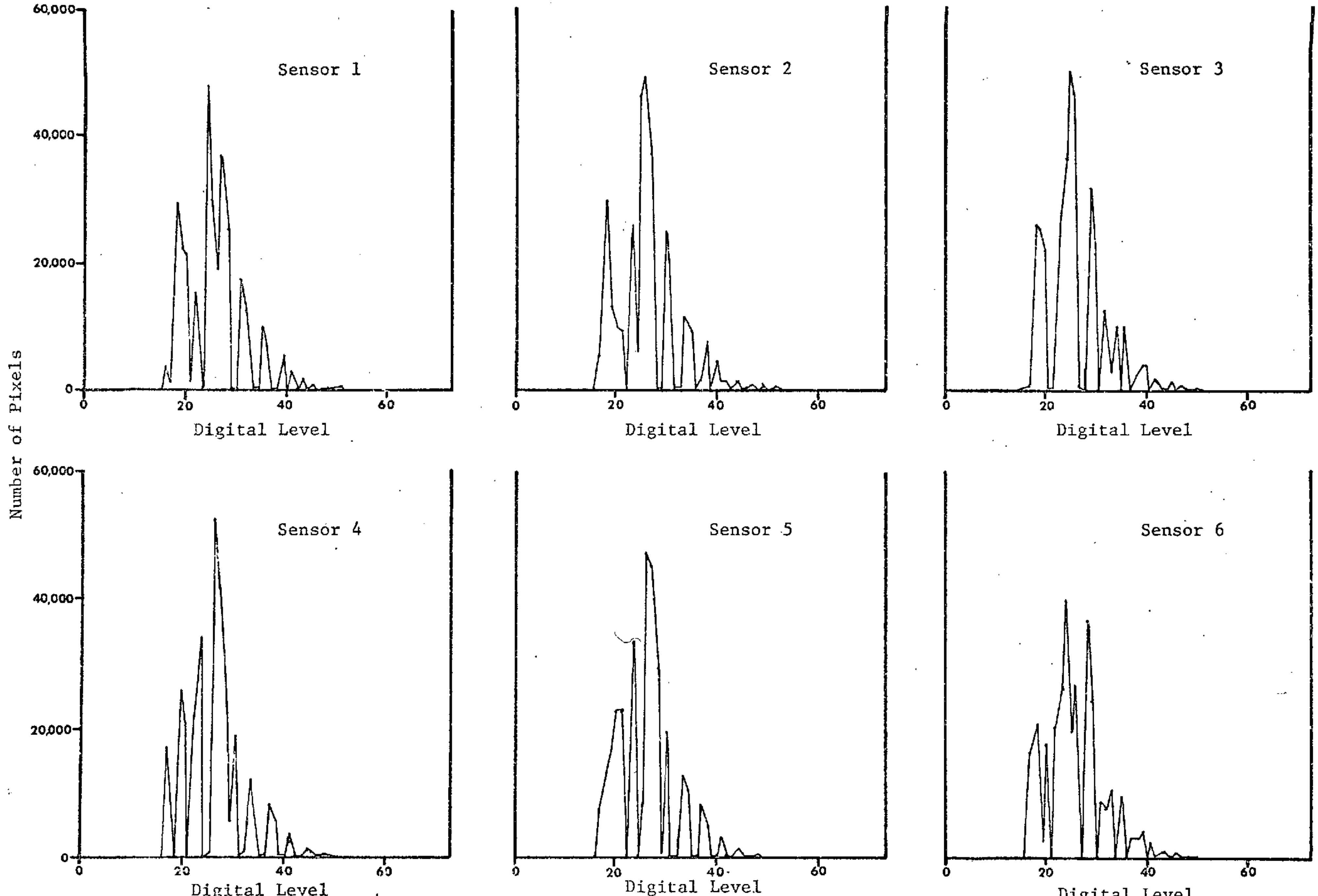

Figure 14

INTENSITY LEVEL DISTRIBUTION - SCENE 1255-18183, REEL 3, BAND 4
SAN FRANCISCO/MONTEREY - 4 APRIL 1973

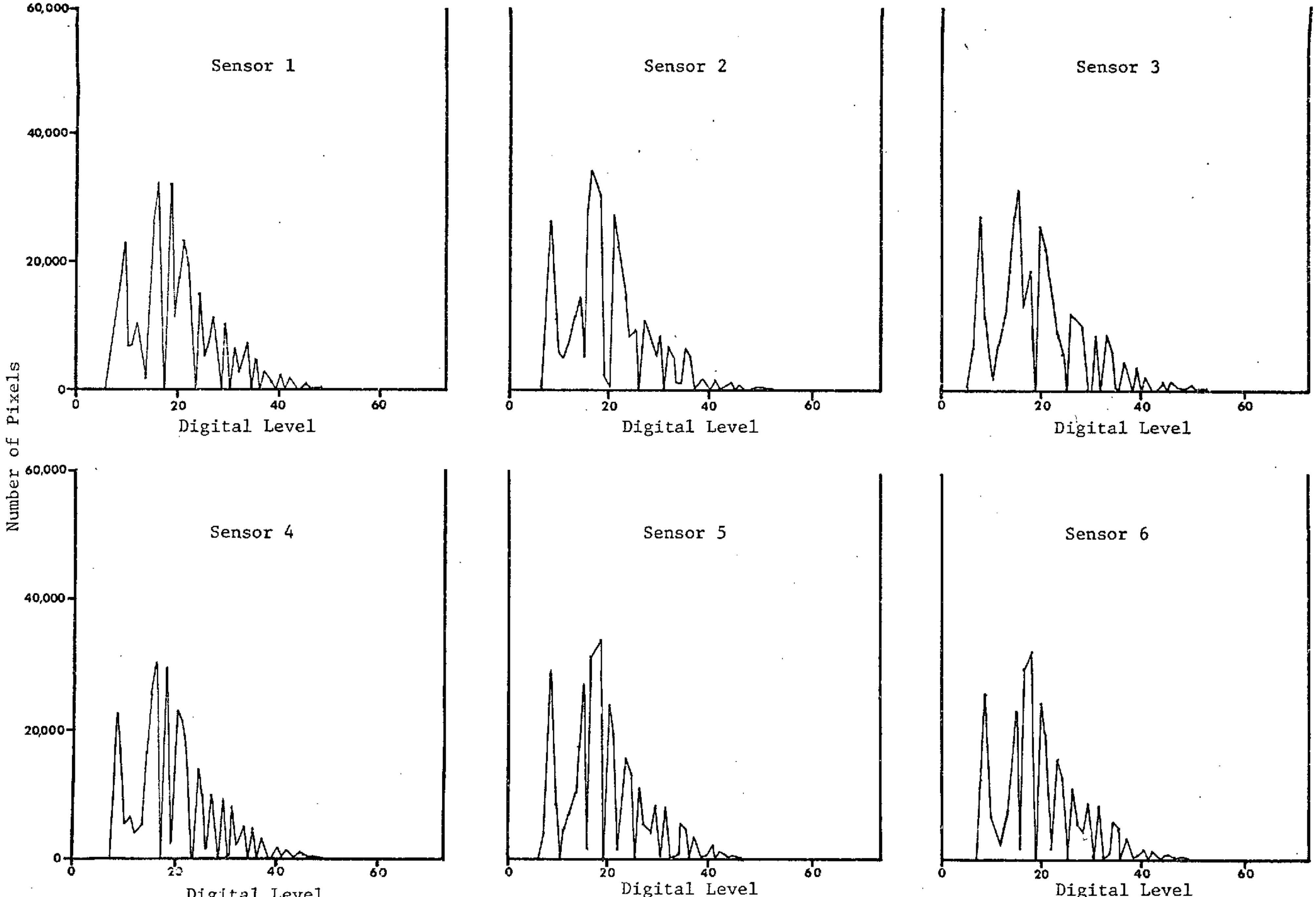

Figure 15

INTENSITY LEVEL DISTRIBUTION - SCENE 1255-18183, REEL 3, BAND 5
SAN FRANCISCO/MONTEREY - 4 APRIL 1973

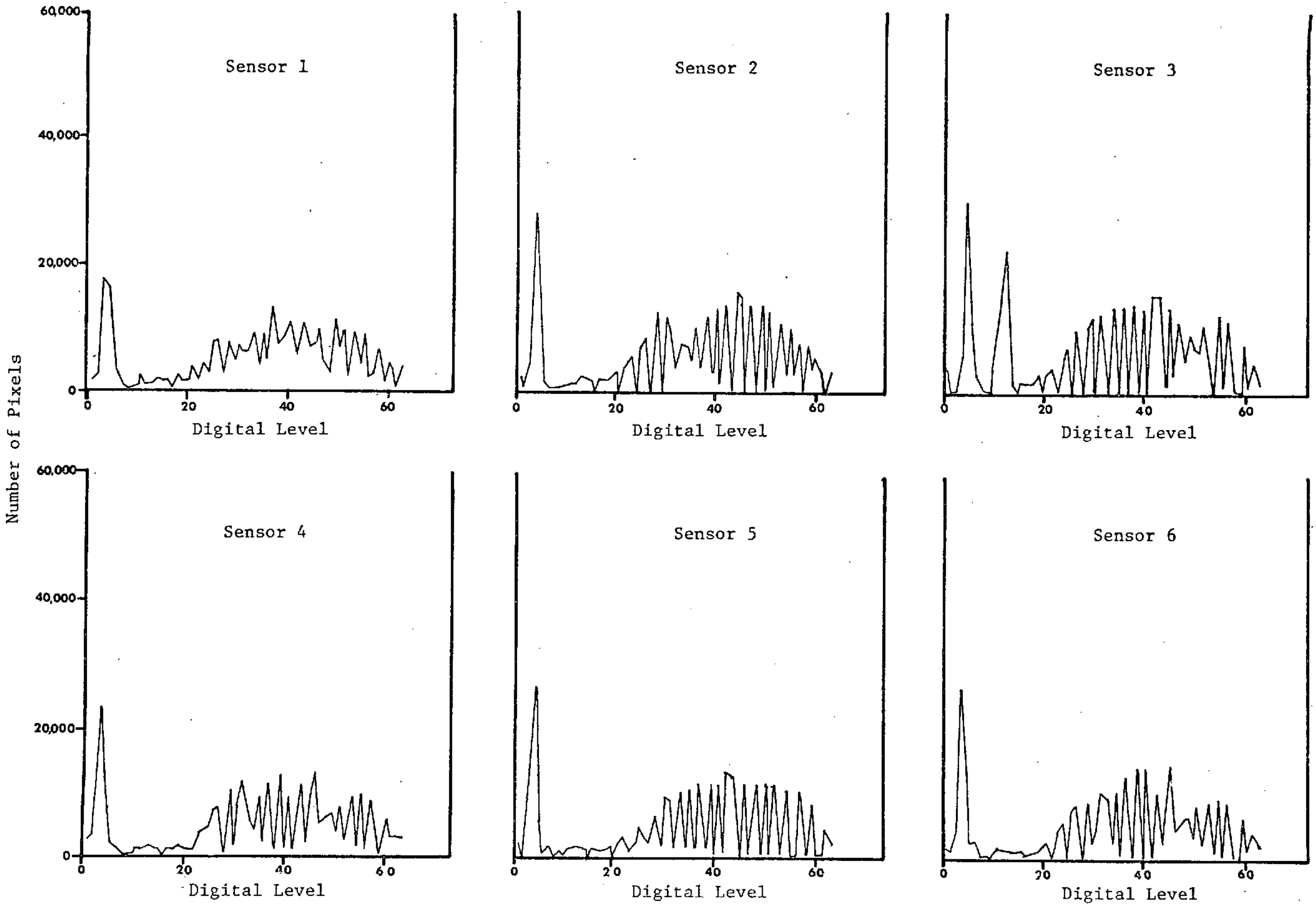

Figure 16
INTENSITY LEVEL DISTRIBUTION - SCENE 1255-18183, REEL 3, BAND 6
SAN FRANCISCO/MONTEREY - 4 APRIL 1973

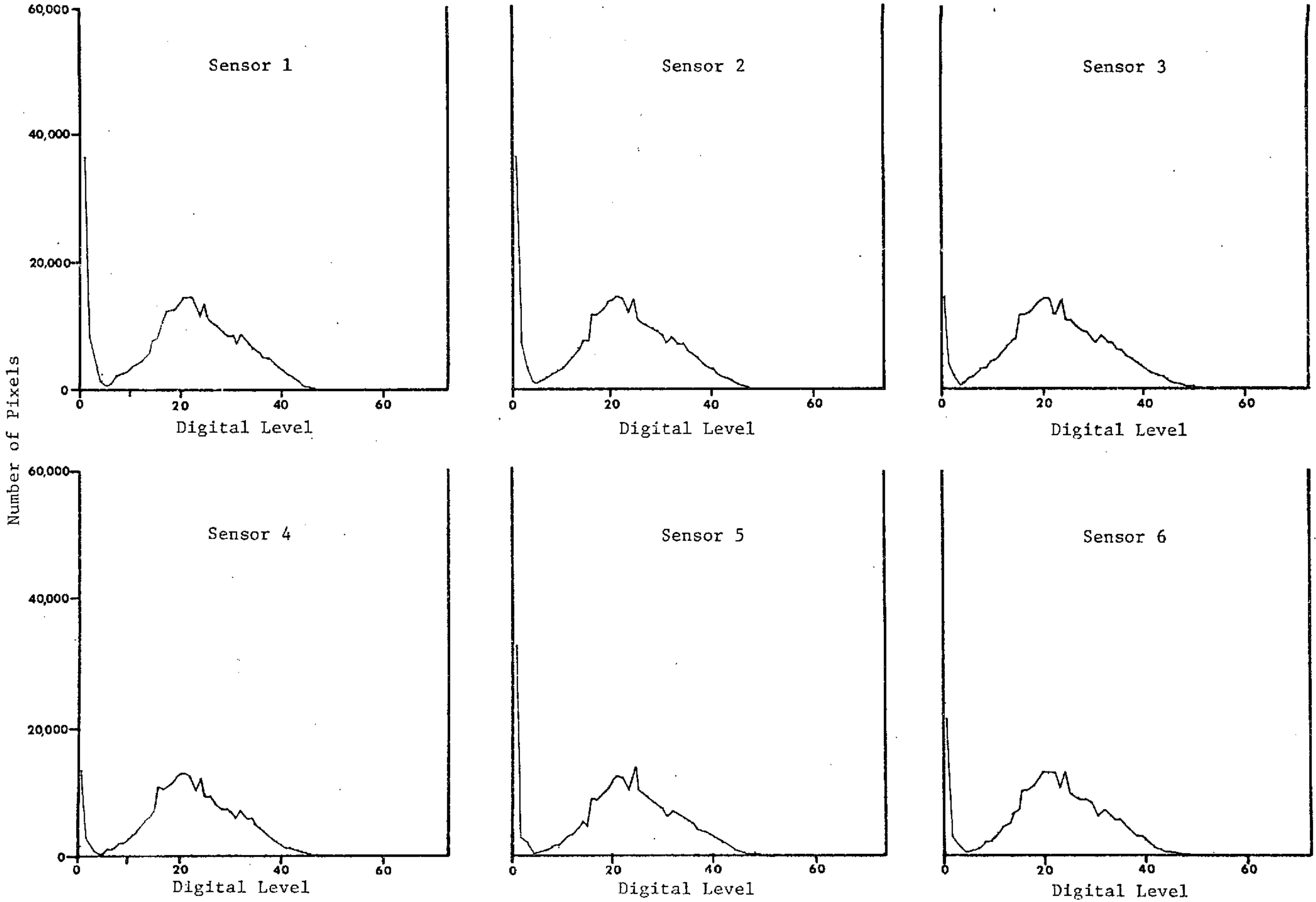

Figure 17
INTENSITY LEVEL DISTRIBUTION - SCENE 1255-18183, REEL 3, BAND 7
SAN FRANCISCO/MONTEREY - 4 APRIL 1973

improper to compare one scan line to the next to study features in ocean scenes.

6-Cycle Radiometric Striping

The combination of the decompression and calibration give rise to another major problem in the analysis of ERTS data for ocean scenes. The definition of 6-cycle radiometric striping is illustrated in Figures 18-29. These figures are computer printer density slices of MSS band 4 from a portion of scene 1235-18075 MB, reel 3, 15 March 1973, for Santa Barbara Channel. In the figures, the + symbol represents land (which has been determined on MSS band 7). The density slices were made at two scales, 1/6 and 1/7. The 1/6th scale presents every 6th pixel on every 6th scan line and thus samples only one (1) sensor (Figures 18,20, 22, 24, 26, and 28). No water features are apparent in density slices of levels 13, 14, and 15 (Figures 18 and 20). In Figure 22 (density slice 16) a large water mass is noted at the left side of the sub-area. Figure 24 (density slice 17) not only reveals more of the water structure in the data but the conspicuous absence of data indicates more water structure in the nearshore areas as well as in the center of the picture. Figure 26 (density slice 18) begins to fill in the detailed nearshore information in the upper portion of the figure while Figure 28 (density slice 19) starts to fill in the near island information at the bottom of the figure. Identification of the water mass intensity structure is reasonably straightforward in this sequence of figures. Additional density slices (from 20-30) fill in the remaining nearshore detail.

The second set of density slices was obtained at a 1/7th scale. This means that every 7th pixel from every 7th scan line was used to produce the figure. Sampling every 7th scan line causes print lines 1, 2, 3, 4, 5, and 6 to be derived from MSS sensors 1, 2, 3, 4, 5, and 6 respectively. Thus every 6th line on the

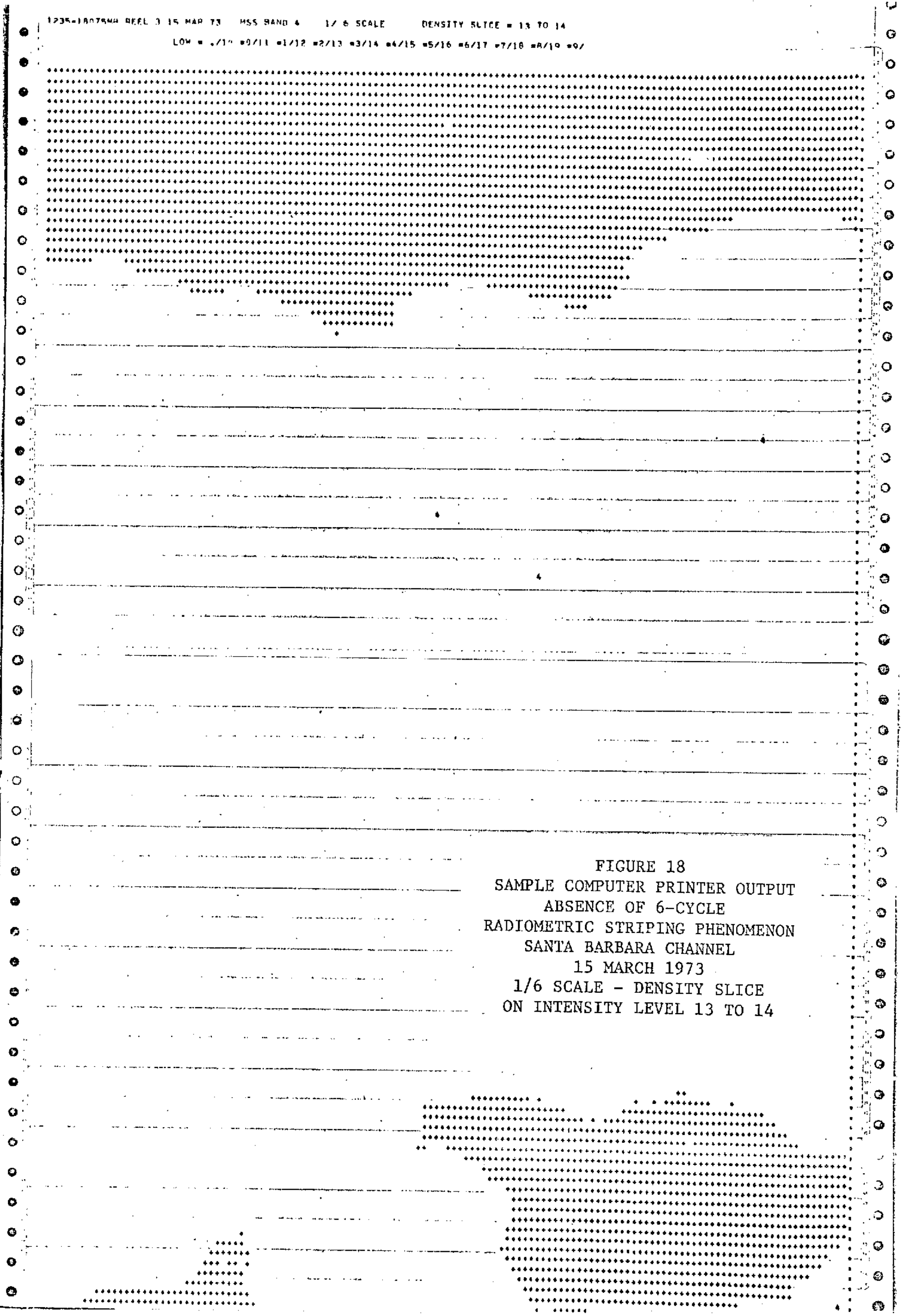

FIGURE 18
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 13 TO 14

1235-18075MR REEL 3 15 MAR 73 MSS BAND 4 1/ 7 SCALE DENSITY SLICE = 13 TO 14

LOW = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

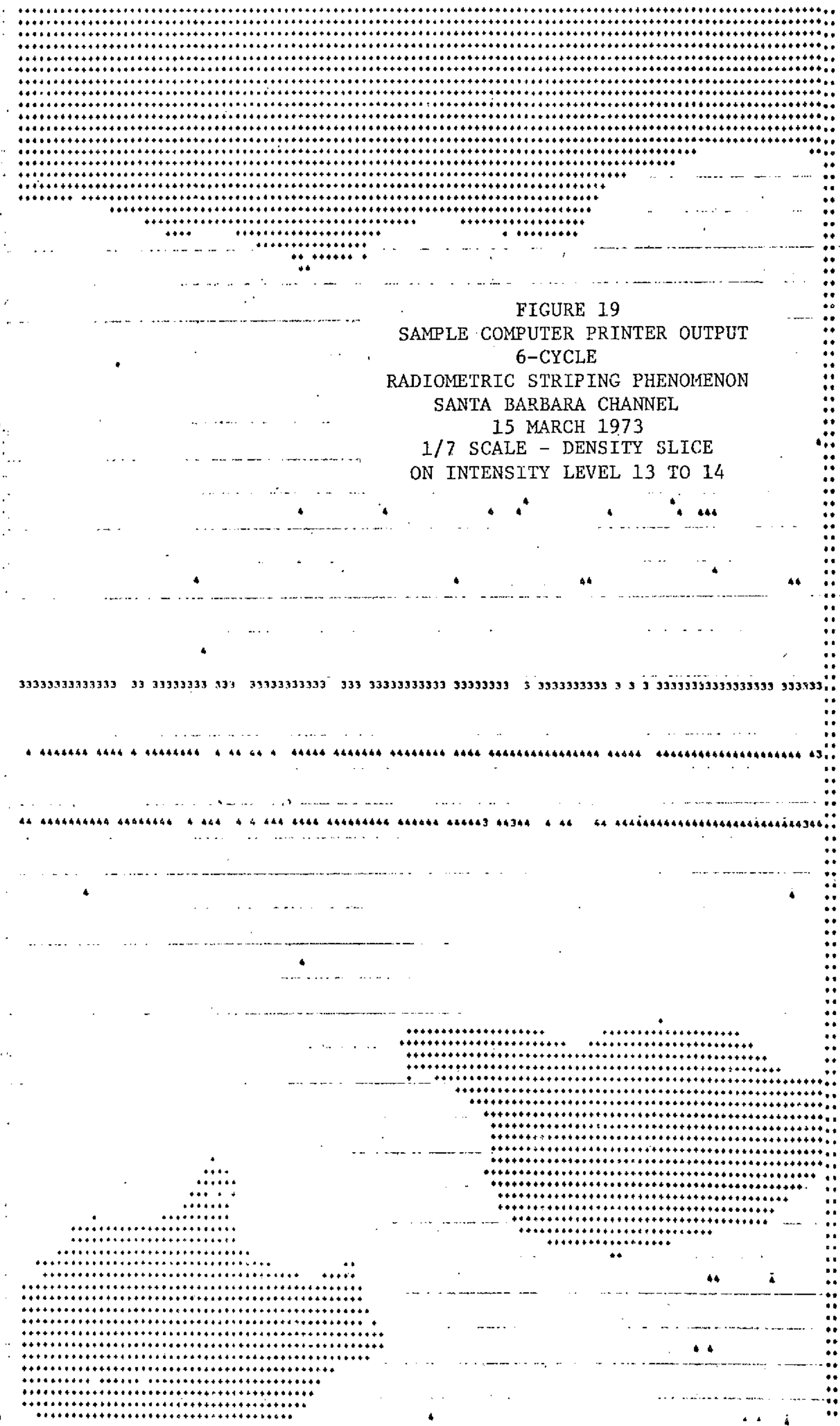

FIGURE 19
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 13 TO 14

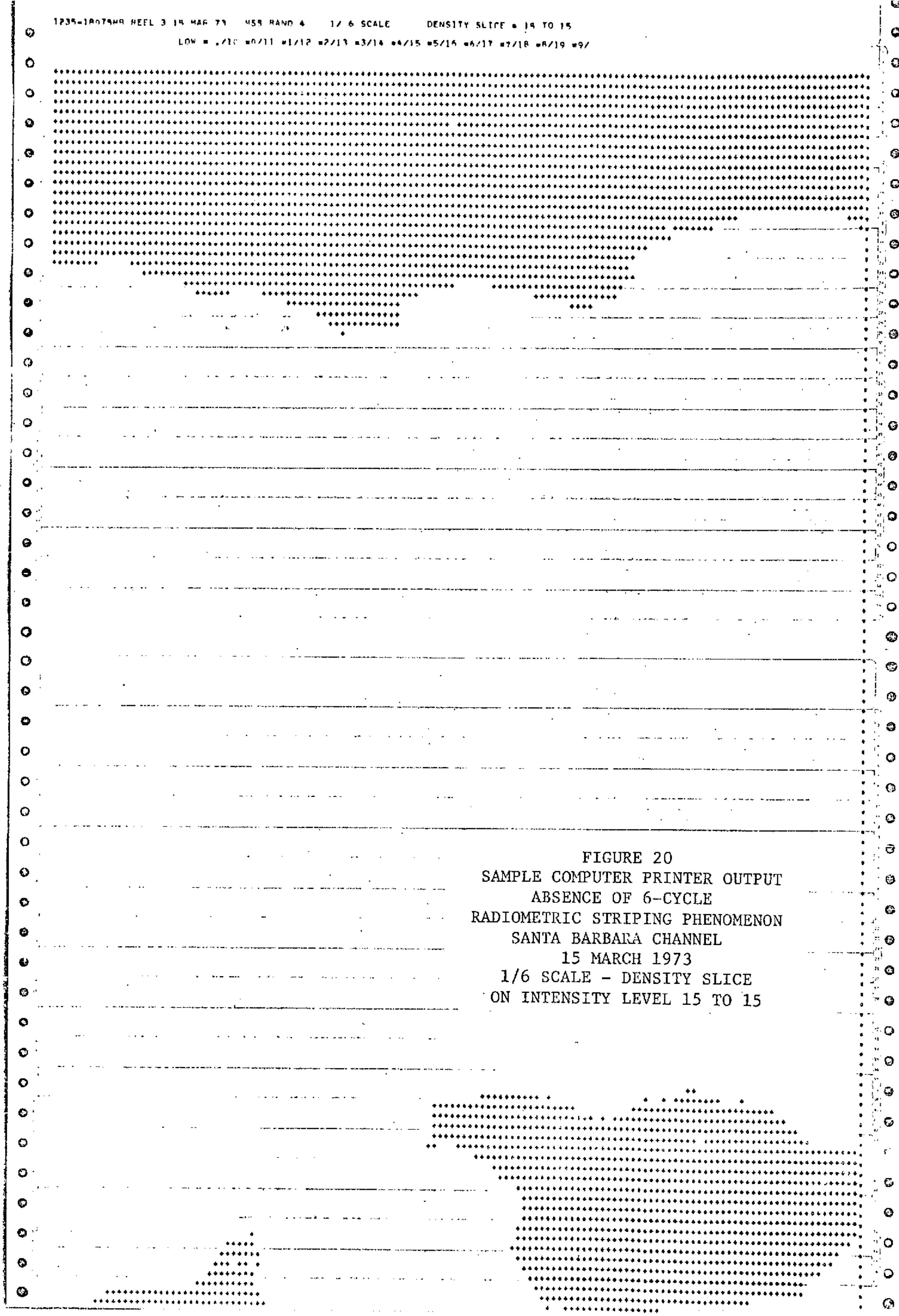

FIGURE 20
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 15 TO 15

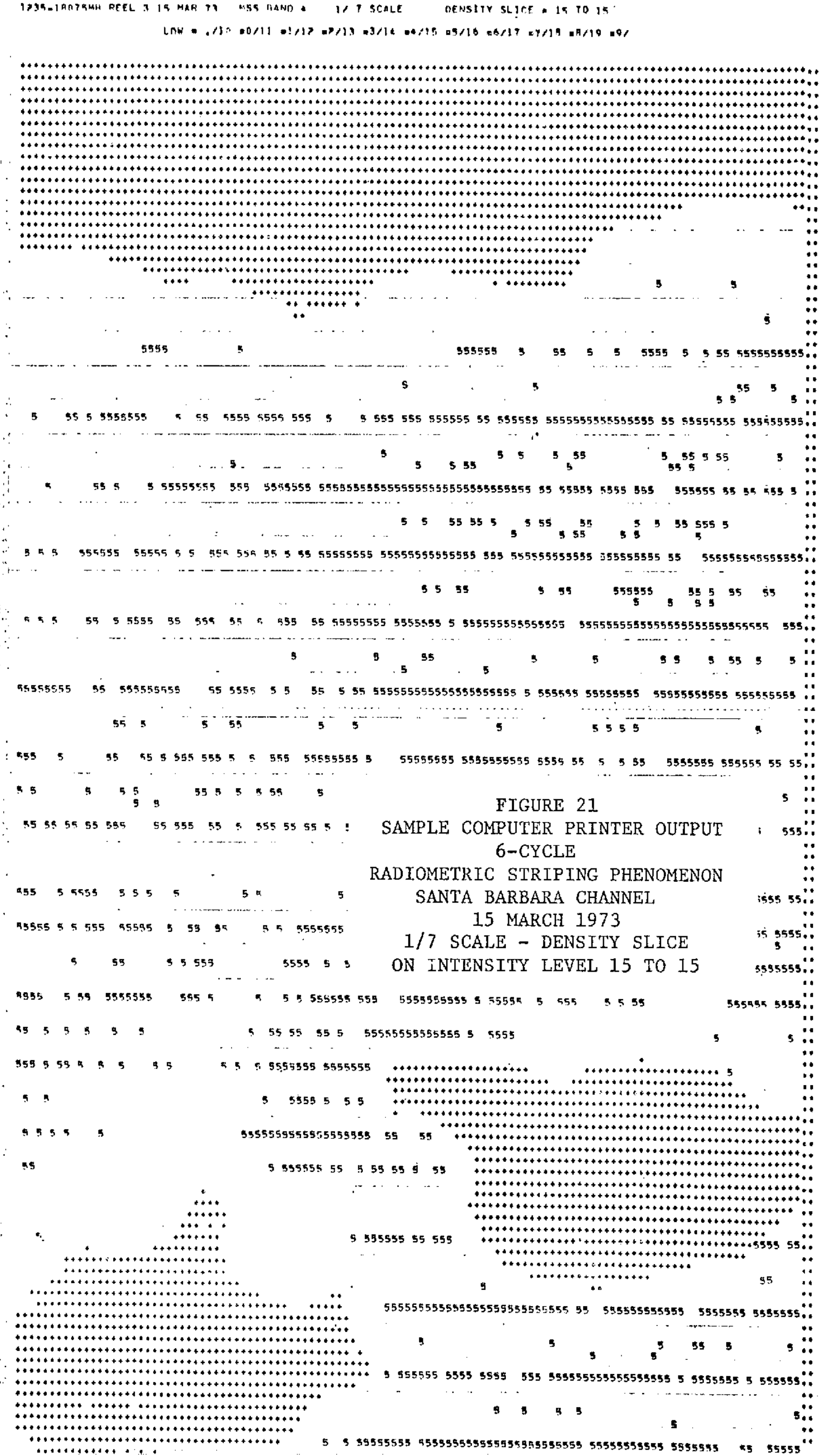

FIGURE 21
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 15 TO 15

ORIGINAL PAGE IS
OF POOR QUALITY

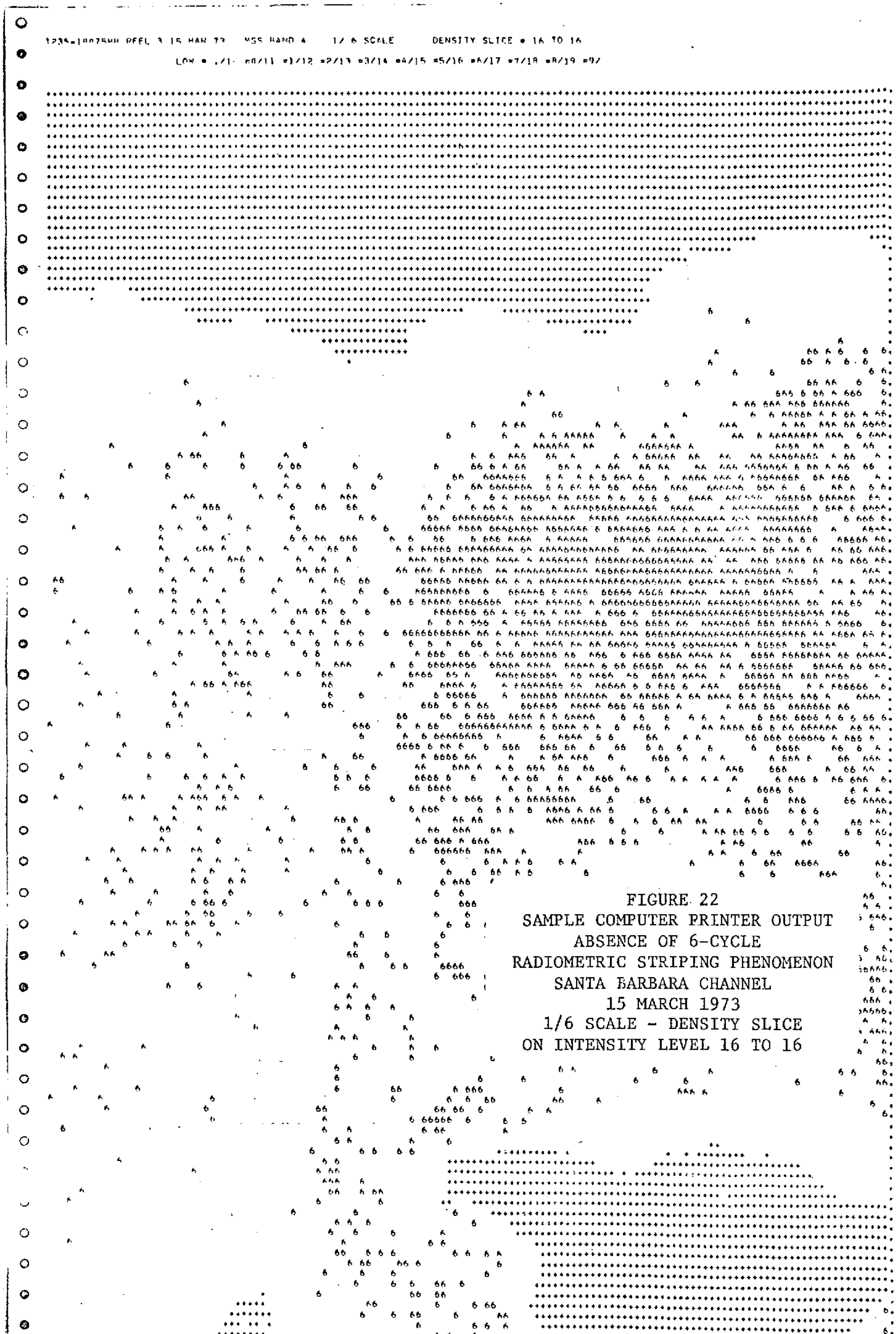

FIGURE 22
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 16 TO 16

1235-18075MA REEL 3 15 MAR 73   MSS BAND 4   1/ 7 SCALE   DENSITY SLICE = 16 TO 16

LOX = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

FIGURE 23
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 16 TO 16

1235-18075MA REEL 3 15 MAR 73   MSS BAND 4   1/ 6 SCALE   DENSITY SLICE = 17 TO 17

LO: = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

FIGURE 24
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 17 TO 17

1235-18075MR REEL 3 15 MAR 73 MSS BAND 4 1/ 7 SCALE DENSITY SLICE = 17 TO 17

LOW = ./1" =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

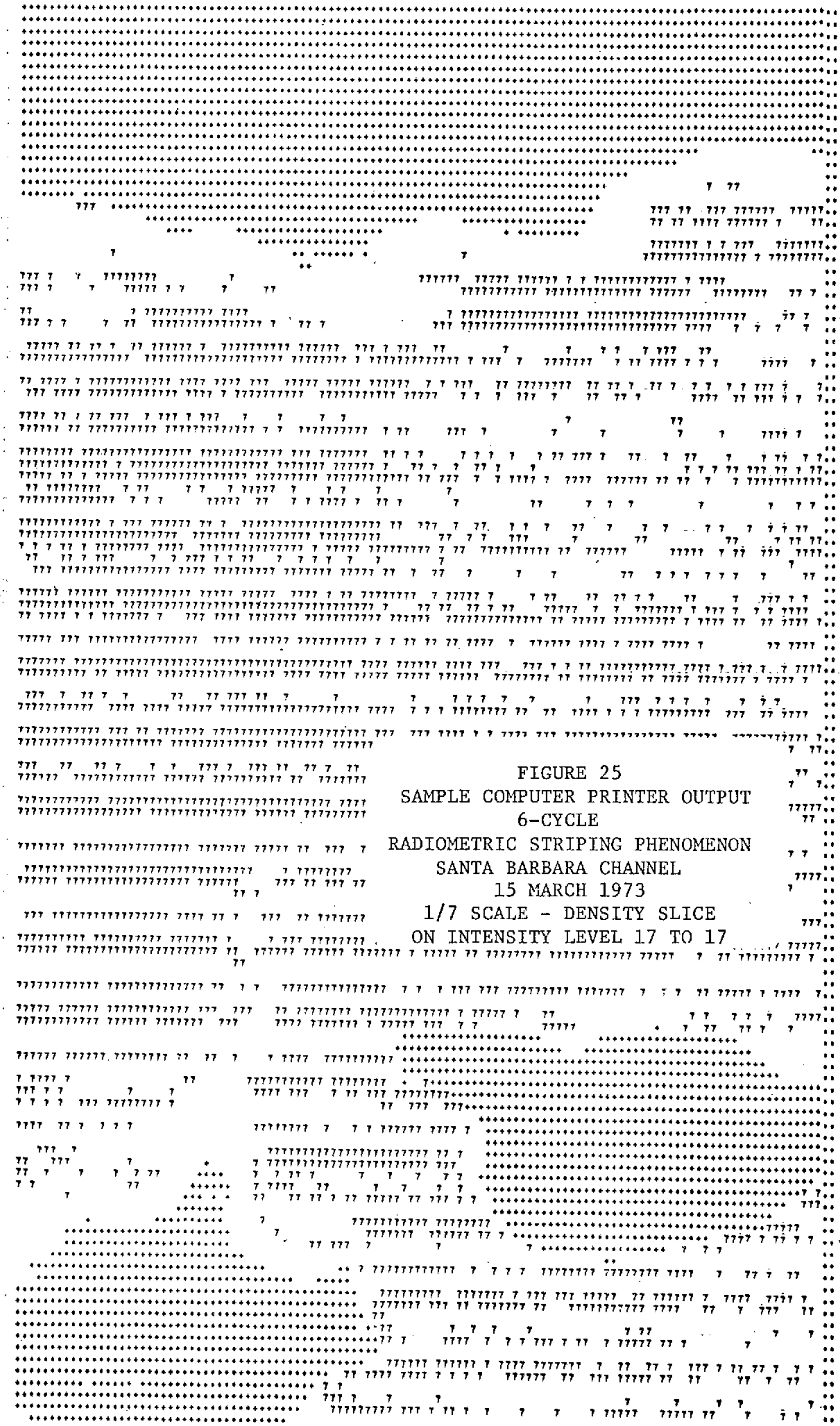

FIGURE 25
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 17 TO 17

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1235-18075HA REFL 3 15 MAR 73   MSS BAND 4   1/ 6 SCALE   DENSITY SLICE = 18 TO 18

LOW = .7) =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

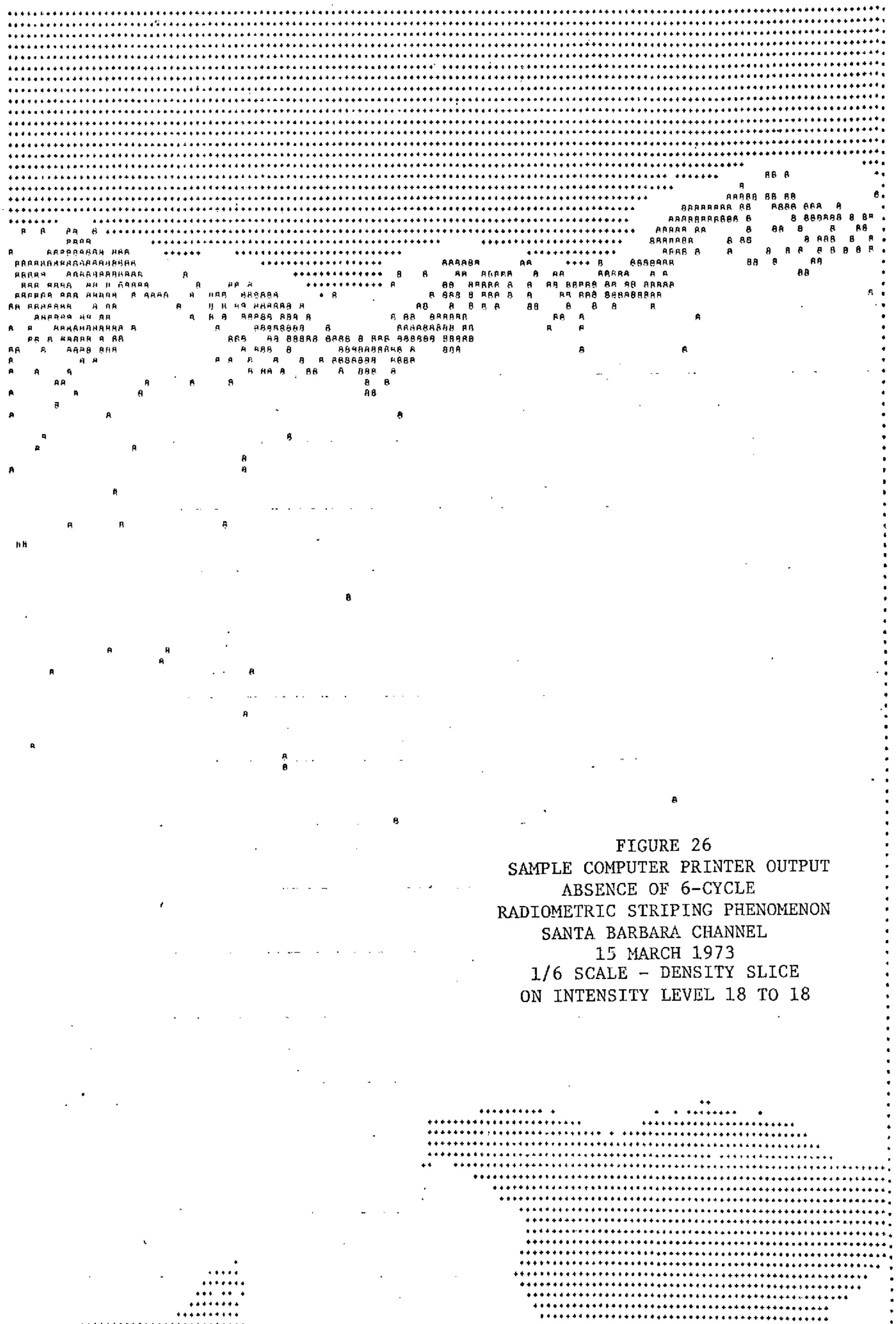

FIGURE 26
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 18 TO 18

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1235-18075MH REEL 3 15 MAR 73 MSS BAND 4 1/ 7 SCALE DENSITY SLICE = 18 TO 18

LOW = ,/10 *0/11 *1/12 *2/13 *3/14 *4/15 *5/16 *6/17 *7/18 *8/19 *9/

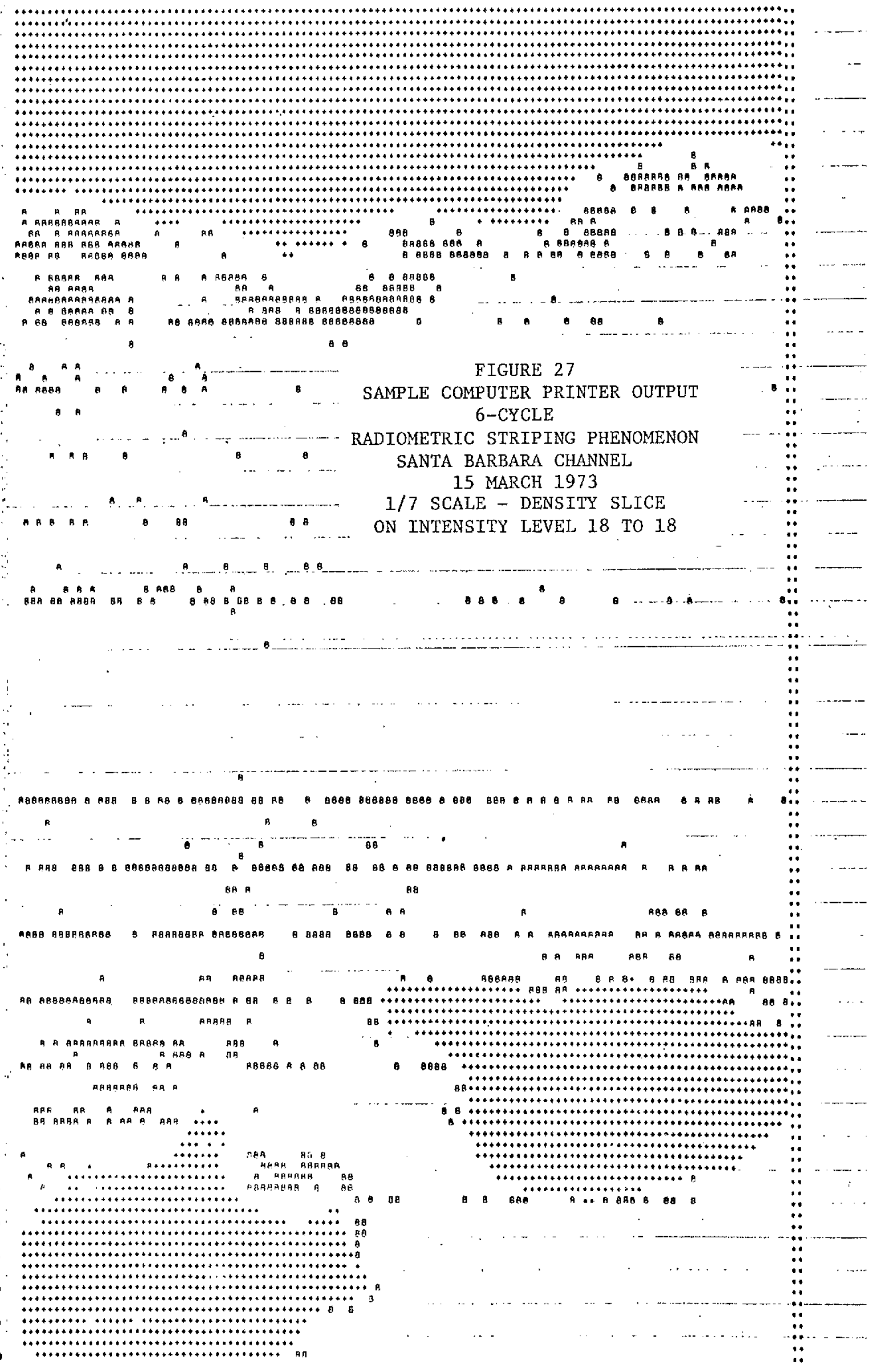


FIGURE 27
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 18 TO 18

1235-18074MSS REEL 3 15 MAR 73 MSS BAND 4 1/ 6 SCALE DENSITY SLICE = 19 TO 19
LOW = ./10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

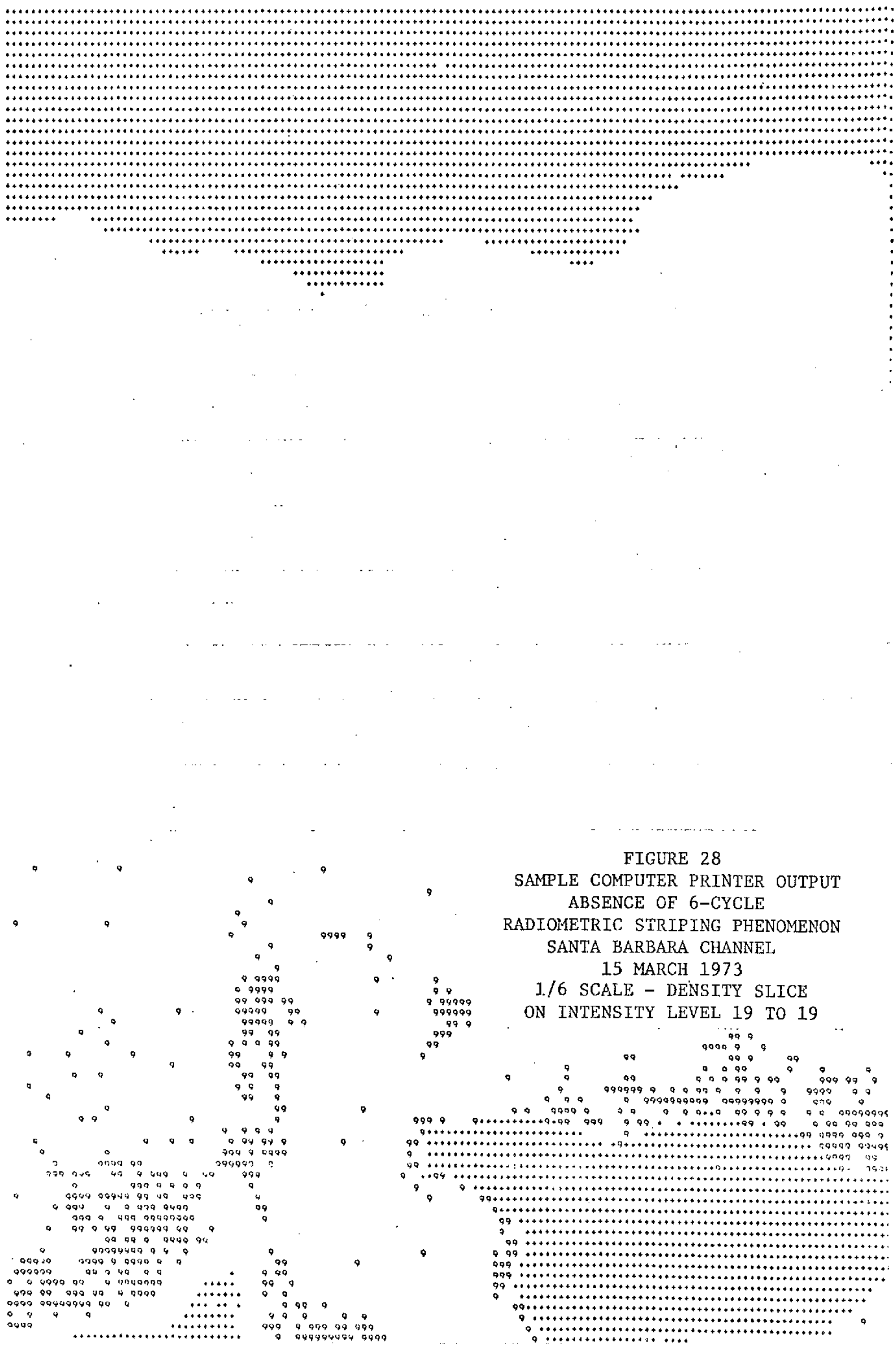


FIGURE 28
SAMPLE COMPUTER PRINTER OUTPUT
ABSENCE OF 6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 19 TO 19

1235-18075MH REEL 3 15 MAR 73 MSS BAND 4 1/7 SCALE DENSITY SLICE = 19 TO 19

LOW = ./10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

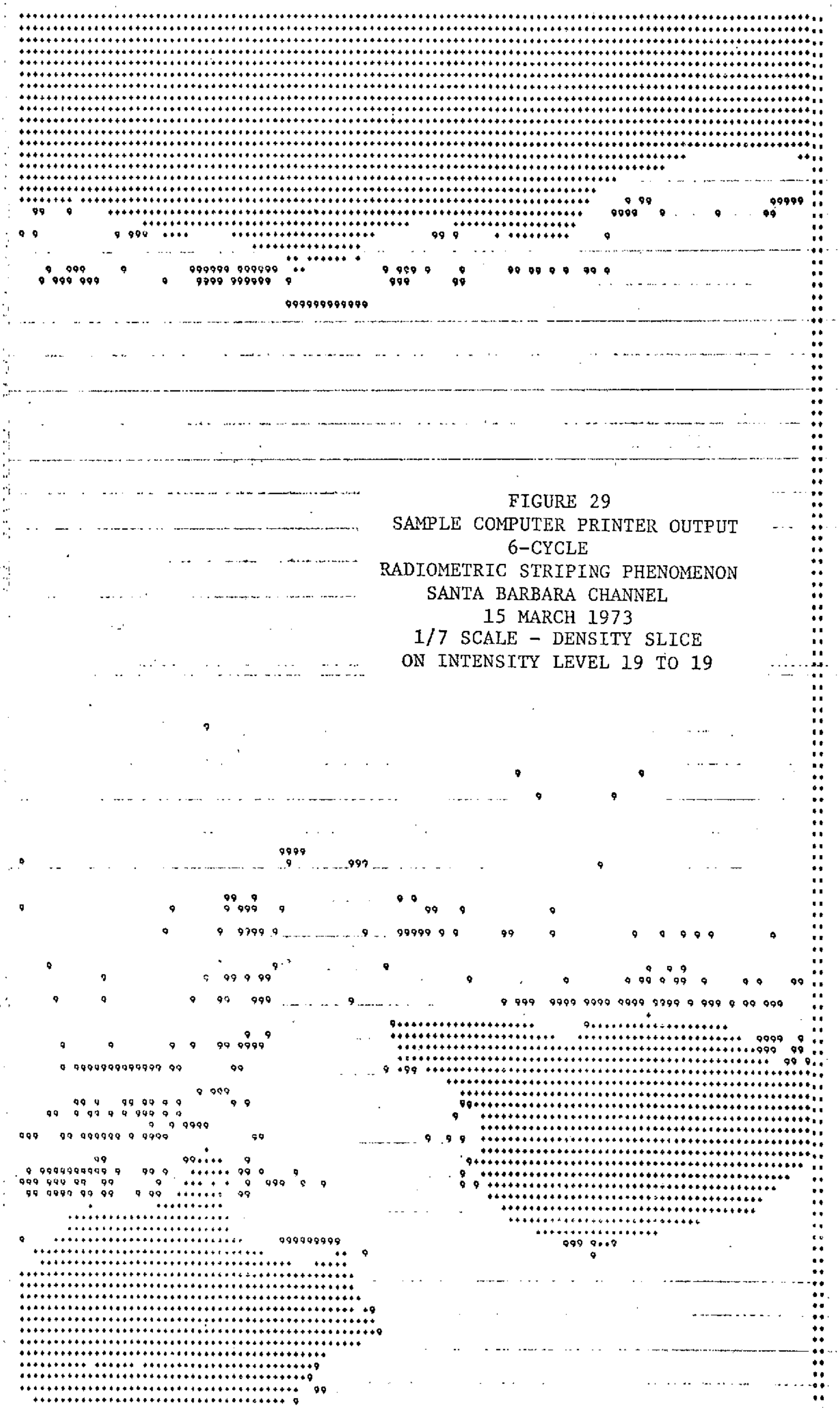


FIGURE 29
SAMPLE COMPUTER PRINTER OUTPUT
6-CYCLE
RADIOMETRIC STRIPING PHENOMENON
SANTA BARBARA CHANNEL
15 MARCH 1973
1/7 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 19 TO 19

printout is from the same sensor. The discussion which follows applies to a 1/1 scale as well, but size limitations prohibit presentation of the approximately 7' X 7' equivalent density slices. With regard to the water mass features seen in the 1/6th scale, one would expect the same features to appear using all sensors; however, the size of the features would be reduced somewhat. The same density slices presented at the 1/6th scale are presented in Figures 19, 21, 23, 25, 27, and 29.

Examination of Figure 19 (density slice 13-14) reveals three pronounced radiometric stripes in the center of the figure. A count of the print lines (made by counting the dot pairs at the right side of the figure) shows that these stripes appear every 6th line and thus come from a single sensor. Figure 21 (density slice 15) reveals only a 6th line radiometric striping pattern with no indication of water mass continuity. Examination of the figure reveals the 6th line striping is not limited to a single sensor. Figures 23 and 25 (density slices 16 and 17) are again dominated by the 6-cycle striping pattern with only a suggestion of the water mass continuity seen in Figures 22 and 24 (1/6th scale). Figure 27 (density slice 18) shows the same 6-cycle striping pattern with some nearshore information as seen in Figure 26 (1/6th scale) however the water mass boundaries are confused. Figure 29 (density slice 19) is the most informative of the 1/7th scale set but its value is also limited by 6-cycle radiometric striping.

The features discussed above have been seen on all scenes processed. In the areas of expected uniform radiance, a striping contrast of 4 levels (40% of the entire oceanic radiance range) persisted. The recognition of the 6th sensor radiometric striping problem lead to the use of only 1/6th of the data for analysis purposes. Various remapping procedures were attempted but none gave satisfactory results. One conclusion that can be made about the effect of this problem on land data is east-west trend features should be viewed with suspicion.

Horizontal Banding

Another of the radiometric error features observed was that of gross horizontal banding. Once this feature was recognized it did not present severe problems in the analysis. Figures 30 and 31 clearly indicate this feature. These figures are 1/6th scale printer density slices from a single MSS band 4, sensor, scene 1217-18074, reel 4, from 25 February, 1973, Santa Barbara Channel. This is another water scene with land on the upper right hand corner (+) and clouds in the lower portion of the scene (+). Figure 30 (density slice 18) shows the absence of any values in the center of the figure. This is followed by a band of data which is then followed by the absence of data. Closer inspection reveals the horizontal boundary is abrupt and complete. Figure 31 (density slice 19) shows the reverse pattern. Areas which are blank in this figure were represented by values in Figure 30 while areas showing values on Figure 31 are blank on Figure 30. This gross horizontal banding is produced by the abrupt shift of the forbidden number set to new intensity level positions. In Figure 30 level 18 is forbidden in the blank band in the middle of the figure. In Figure 31 level 19 is forbidden in the blank bands. Apparently the forbidden number switched from level 19 to level 18 and back to level 19 as the scene was scanned from top to bottom. It is felt this feature arises from variation of the calibration during the filtering process. This suggests the sensor calibration can vary more rapidly than indicated by conversations with NASA. The feature has been observed in most of the CCT scenes processed.

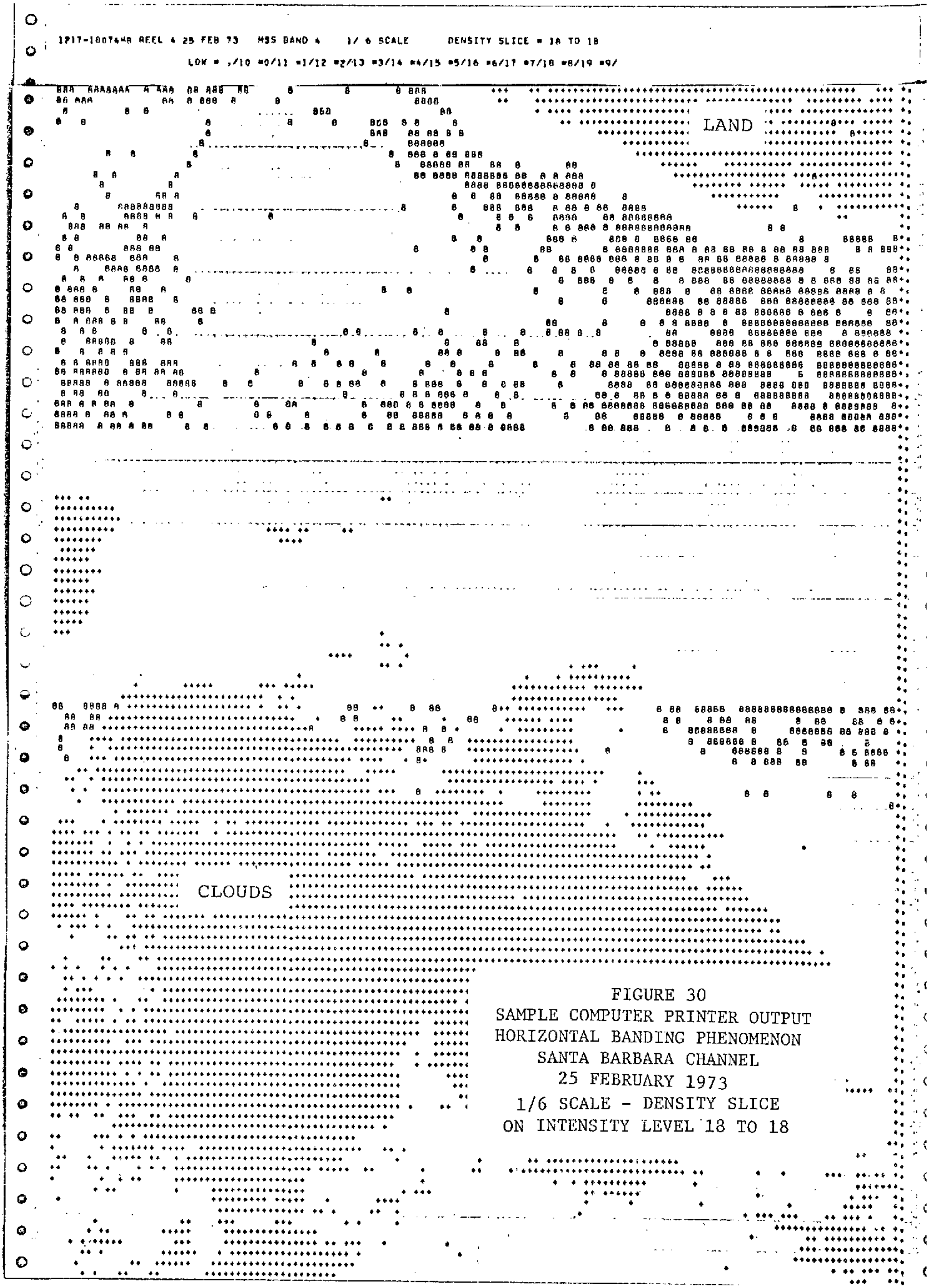


FIGURE 30
SAMPLE COMPUTER PRINTER OUTPUT
HORIZONTAL BANDING PHENOMENON
SANTA BARBARA CHANNEL
25 FEBRUARY 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 18 TO 18

1217-18074HB REEL 4 25 FEB 73 MSS BAND 4 1/ 6 SCALE DENSITY SLICE = 19 TO 19

LOW = ,/10 =0/11 =1/12 =2/13 =3/14 =4/15 =5/16 =6/17 =7/18 =8/19 =9/

FIGURE 31
SAMPLE COMPUTER PRINTER OUTPUT
HORIZONTAL BANDING PHENOMONEN
SANTA BARBARA CHANNEL
25 FEBRUARY 1973
1/6 SCALE - DENSITY SLICE
ON INTENSITY LEVEL 19 TO 19

Vertical Banding

Another minor feature of the system is vertical banding. This is best illustrated by Figure 32 which is Seis-chrome[tm] color enhancement of a 1/6th scale of the oceanic area in scene 1235-18075, reel 1, 15 March 1973, western Santa Barbara Channel and Pacific Ocean. Dark blue vertical banding is obvious in the scene. The origin of this feature probably lies in some periodic noise injected into the system. Exactly where this exists is not known. The feature presented very little problem in the interpretation of oceanic features, once its presence was known.

Non-Uniformity of Calibration (response) from Scene to Scene

A necessary conclusion of the preceding discussion is recognition that sensor response can change from scene to scene and absolute radiance is not available. This suggests that care must be exercised when comparing the same feature from scene to scene. No detailed study of the problem was undertaken as most of the time and effect went into the investigation of the previously mentioned problems and the correlation of relative intensity to ocean-truth data.

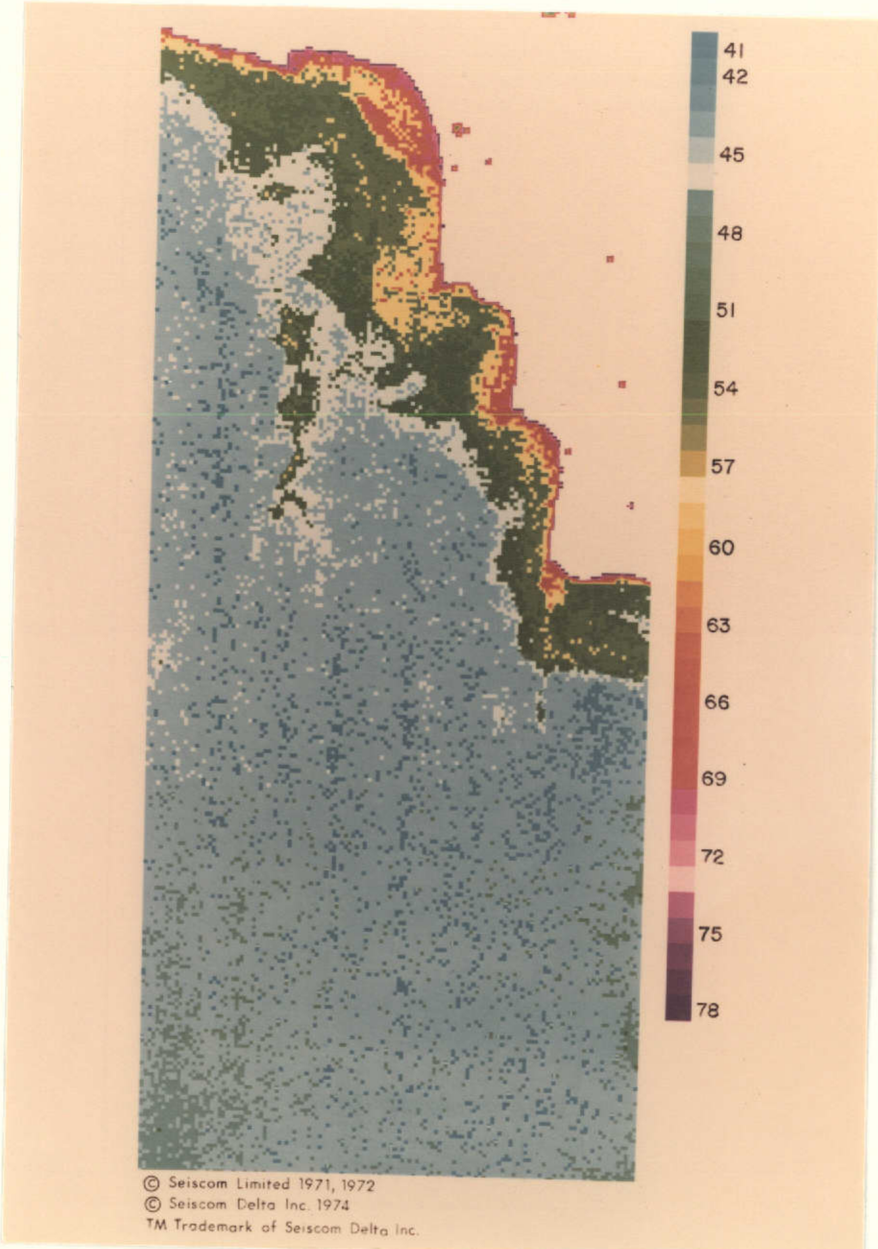


Figure 32

PHOTOGRAPH OF SEIS-CHROME COLOR ENHANCEMENT, VERTICAL BANDING PHENOMENON SCENE 1235-18075 REEL 1, BAND 4 WESTERN SANTA BARBARA CHANNEL - 15 MARCH 1973 1/6 SCALE

Part 4

OCEAN TRUTH DATA

The data obtained during the ocean truth cruises is summarized in Table 9. Weather, atmosphere, and sea state observations are listed in Table A-1 in the Appendix. Table 9 also includes values of water clarity and color; water clarity was assessed by Secchi disk measurements and turbidimetry. The values indicate that no unusual conditions were encountered during field activities. Values lie within normal yearly ranges.

In addition to on-site observations of weather, regional weather and marine conditions were monitored by OSI meteorologists. The regional synopses are included with the individual image analysis presented in the next section.

The results of the microscope analysis of material filtered from sea water samples are presented in Table A-2 in the Appendix. A summary of the analyses of filtered plankton is presented for each cruise in Table 10 and tabulations of particle concentrations are given in Table 11. Scanning electron microscope photographs of the dominant plankton genera are presented in Plates 1-16. Water temperature, air and water nephelometer and water transmittance data were recorded on strip charts during the cruises and were later reduced to computer compatible data. Plots of these data, intensity values from ERTS MSS bands, and other pertinent oceanic parameters along the charted cruise tracks are shown in Figures A-11 to A-74.

Suspensoids filtered out of water samples collected on the ocean truth cruises consisted mostly of debris and phytoplankton. Most

Table 9

SUMMARY OF DATA FROM OCEAN TRUTH CRUISES

Cruise	Date	*Weather & Sea Conditions	Nephelometry Air	Nephelometry Water	Water Transmittance	Ocean Reflectance	Filter Reflectance Colorimetry	Suspended Particle Concentration	Plankton Count
Santa Barbara Channel	25 Feb 1973	X	X					X	X
Santa Barbara Channel	15 Mar 1973	X						X	X
Monterey Bay	17 Mar 1973	X	X					X	X
Santa Monica Bay	1 Apr 1973	X						X	X
Santa Barbara Channel	2 Apr 1973	X						X	X
Monterey Bay	4 Apr 1973 **	X		X				X	X
Monterey Bay	15 Jun 1973	X						X	X
Monterey Bay	3 Jul 1973	X		X	X	X		X	X
Santa Monica Bay	23 Aug 1973	X		X	X		X	X	X
Santa Barbara Channel	24 Aug 1973	X					X	X	X

*-Includes sun azimuth, sun elevation, lateral visibility, vertical visibility, wave height, wave direction, wind speed, wind direction, water temperature, air temperature, Secchi disc depth, water color, humidity, turbidity.

**-Ultraviolet fluorometry for plankton pigments

Table 10

RELATIVE ABUNDANCE OF SIGNIFICANT GENERA

DATE AREA	25 Feb, 1973 Santa Barbara	15 Mar, 1973 Santa Barbara	17 Mar, 1973 Monterey	2 Apr, 1973 Santa Barbara
Dominant Genus	Bacteriastrum	Thalassiothrix Chaetoceros Skeletonema	Chaetoceros Skeletonema Thalassoisira	Chaetoceros Skeletonema Thalassiothrix
Genera also present, in decreasing abundance	Chaetoceros Schroderella		Biddulphia	
	few dinoflag- ellates	copepods	copepods	
	few copepods	Ceratium	Dinophysis Ceratium	

DATE AREA	4 Apr, 73 Monterey	15 Jun, 73 Monterey	3 Jul, 73 Monterey	23 Aug, 73 Santa Monica	24 Aug, 73 Santa Barbara
Dominant Genus	Skeletonema	Skeletonema Chaetoceros	Chaetoceros- Skeletonema Thalassiosira	Prorocentrum Dinophysis Ceratium	Peridinium Gonyaulax Dinophysis
Genera also present, in decreasing abundance	Biddulphia Thalassio- thrix	Biddulphia	Nitzschia	Gonyaulax	Ceratium
		copepods Ceratium Peridinium Dinophysis	Peridinium Dinophysis	copepods Silicoflag- ellates	Chaetoceros Silicoflagellates
	copepods	Gonyaulax Tintinnid			
	Ceratium Peridinium	Silicoflag- ellate	Ceratium	Chaetoceros	

Table 11

CONCENTRATION OF SUSPENDED PARTICLES

25 February 1973 Santa Barbara

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	21.7	11	1.7
2	6.5	12	1.3
3	1.5	13	10.1
4	1.6	14	5.4
5	1.7	15	0.8
6	1.0	16	0.7
7	1.0	17	2.9
8	0.8	18	1.5
9	14.6	19	9.6
10	0.9		

15 March 1973 Santa Barbara

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	24.1	11	81.4
2	20.1	12	18.3
3	20.1	13	4.9
4	7.5	14	3.9
5	111.0	15	3.9
6	35.6	16	18.2
7	35.7	17	9.9
8	18.7	18	4.6
9	6.8	19	3.0
10	93.4		

* Unit particles were taken as any debris particle greater than 10μ or any single planktonic organism except chain diatoms where a chain was counted as one particle, regardless of number of cells in the chain.

Table 11
Continued

Page 2

17 March 1973 Monterey Bay

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	11.6	10	15.6
2	11.1	11	11.2
3	11.0	12	11.0
4	8.9	13	2.8
5	15.6	14	2.6
6	10.8	15	1.9
7	10.7	16	1.9
8	12.5	17	1.6
9	10.6		

2 April 1974 Santa Barbara

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	31.7	13	5.5
2	2.5	14	3.5
3	5.2	15	5.5
4	6.1	16	5.6
5	6.0	17	7.3
6	5.7	18	6.5
7	3.2	19	7.7
8	3.4	20	2.4
9	3.4	21	3.4
10	4.2	22	7.8
11	4.2	23	7.8
12	2.9		

* Unit particles were taken as any debris particle greater than 10μ or any single planktonic organism except chain diatoms where a chain was counted as one particle, regardless of number of cells in the chain.

Table 11
Continued

Page 3

4 April 1973
Monterey Bay

Station	Total Number Particles/1x10⁶*	Station	Total Number Particles/1x10⁶*
1	3.1	10-5	3.0
1A**	2.8	10A	8.2
2	4.3	11	6.1
2A	19.2	11-5	27.0
3	13.5	12-5	9.3
3A	13.5	13H	6.2
3B	3.8	13-1	18.0
4	3.7	13-5	10.4
4A	2.3	13A	10.4
4B	3.0	14-5	19.8
4C	2.9	15-1	1.1
4D	1.8	15-5	3.9
4a	8.2	16-1	1.5
4aA	8.2	16-5	3.3
4aB	4.4	16A	2.5
5	6.8	17-1	2.5
6-1***	6.8	17-5	5.1
6-5	10.0	17A	2.1
6A	8.3	17B	3.7
7-1	5.3	18-1	3.7
7-5	6.0	18-5	5.0
7A	3.7	18A	1.5
8-1	9.9	18B	5.2
8-5	13.5	18C	4.5
8A	8.7	19	7.3
9-1	3.7	19A	7.3
9-5	20.6	19B	5.1
9A	12.0	20-1	5.1
10-1	10.5	20-5	18.1

* Unit particles were taken as any debris particle greater than 10μ or any single planktonic organism except chain diatoms where a chain was counted as one particle, regardless of number of cells in the chain.
** Samples taken between stations are denoted by a capital letter.
*** Depth of sample. Absence of numbers indicates water surface sample.

15 June 1973 Monterey Bay

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	1.3	10	4.1
2	2.1	11	4.1
3	21.6	12	4.6
4	21.6	13	4.6
5	6.1	14	No Data
6	No Data		
7	1.7		
8	No Data		
9	No Data		

3 July 1973 Monterey Bay

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	3.8	9	2.3
2	4.4	10	1.6
3	2.0	11	1.1
4	1.0	12	1.2
5	0.5	13	3.4
6	1.8	14	2.0
7	2.3	15	4.7
8	2.1		

* Unit particles were taken as any debris particle greater than 10μ or any single planktonic organism except chain diatoms where a chain was counted as one particle, regardless of number of cells in the chain.

Table 11
Continued

Page 5

23 August 1973 Santa Monica

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	10.7	8	4.9
2	4.3	9	1.1
2A**	0.9	10	1.2
3	0.4	11	5.4
3A	0.9	12	2.8
4	0.7	13	2.7
4A	4.3	14	2.8
5	0.5	15	1.4
6	1.6	16	2.7
7	4.9		

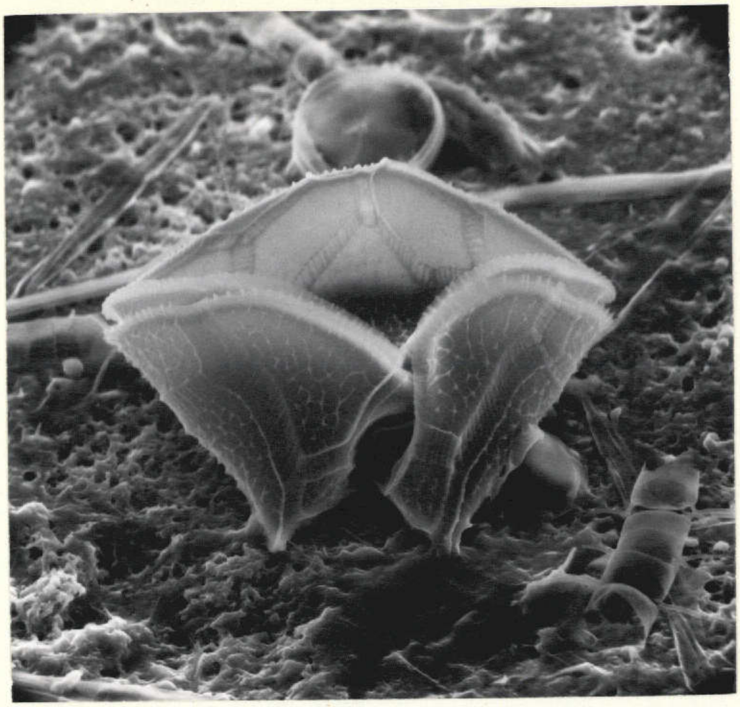
24 August 1973 Santa Barbara

Station	Total Number Particles/1x10^6*	Station	Total Number Particles/1x10^6*
1	10.1	10	3.8
2	1.1	11	18.8
3	0.7	12	5.6
4	1.3	13	5.6
5	0.9	14	4.0
6	1.0	15	2.1
7	1.0	16	2.0
8	0.4	17	3.8
9	5.3	18	2.7

* Unit particles were taken as any debris particle greater than 10μ or any single planktonic organism except chain diatoms where a chain was counted as one particle, regardless of number of cells in the chain.

** Samples taken between stations are denoted by a capital letter.

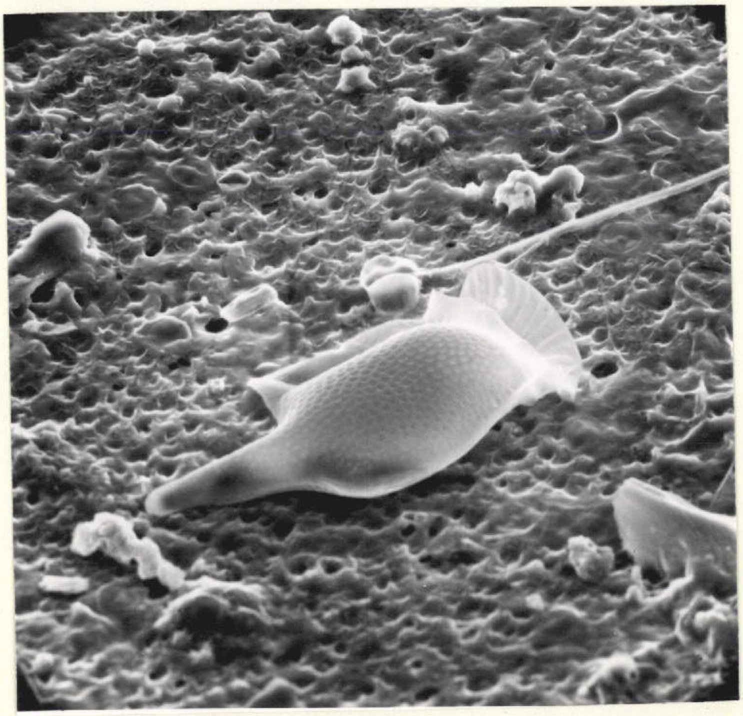
Plate 1



45 x 680 X

<u>Peridinium</u> <u>sp</u>.

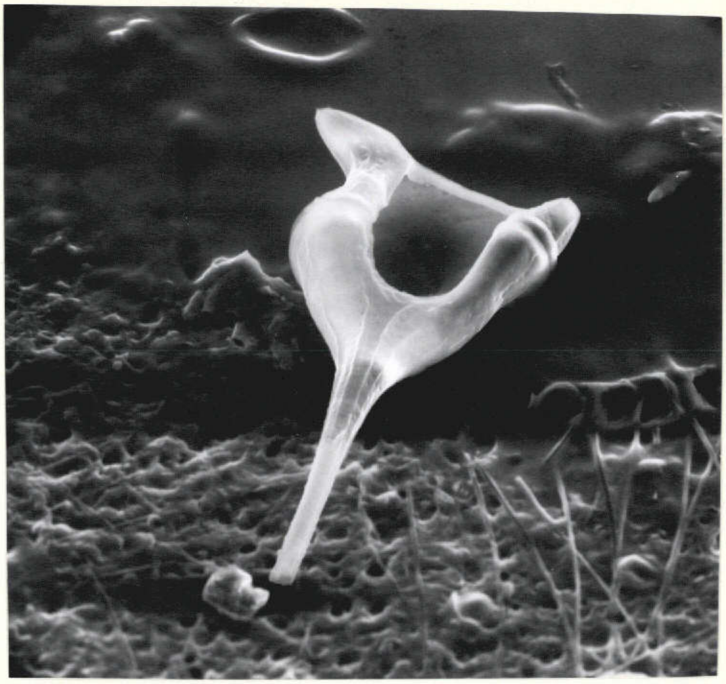
Plate 2



57μ 520 X

<u>Dinophysis</u> <u>sp</u>.

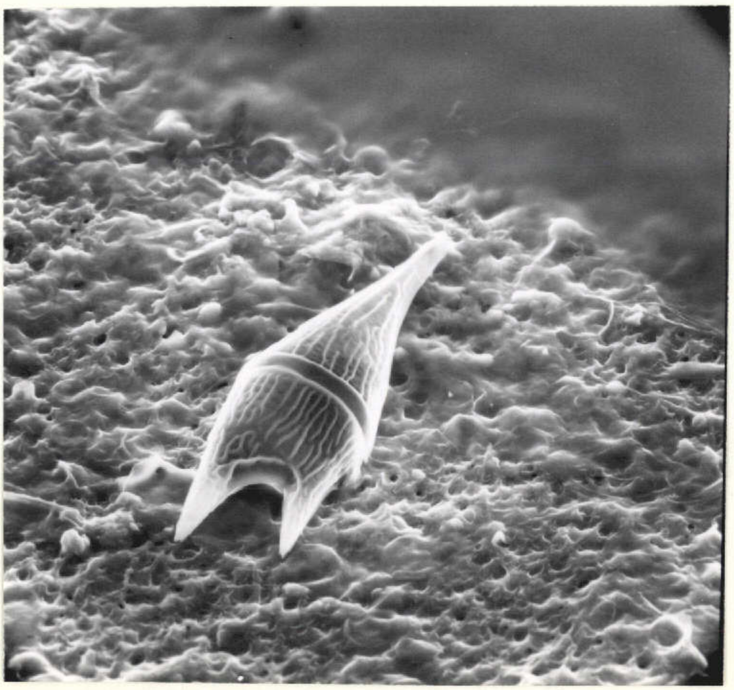
Plate 3



54μ 560 X

<u>Ceratium</u> <u>sp</u>.

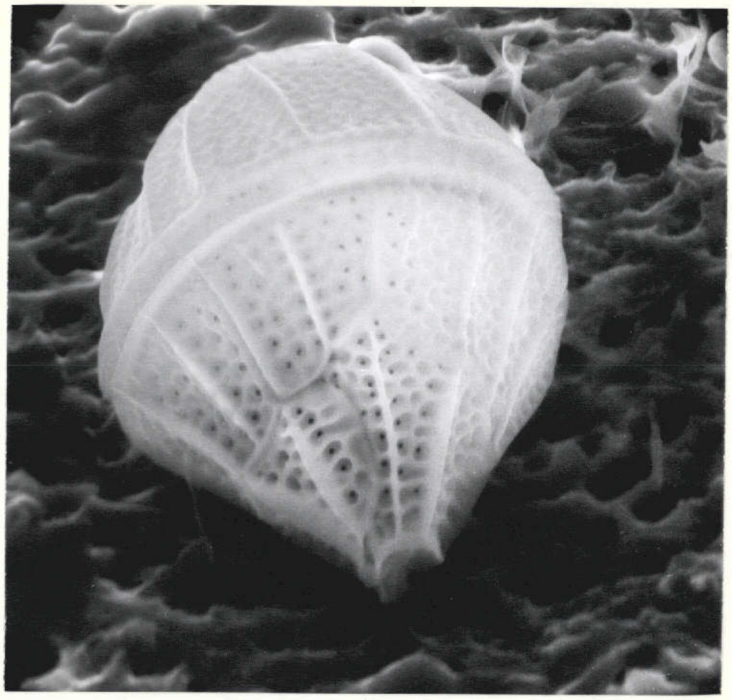
Plate 4



54μ 560 X

<u>Ceratium</u> <u>sp</u>.

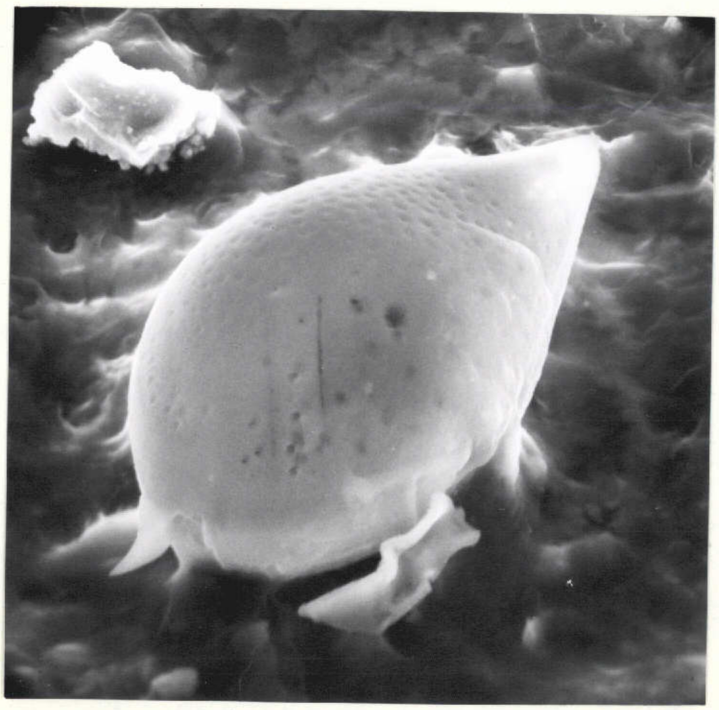
Plate 5



22μ 1360 X

<u>Gonyaulax</u> <u>sp</u>.

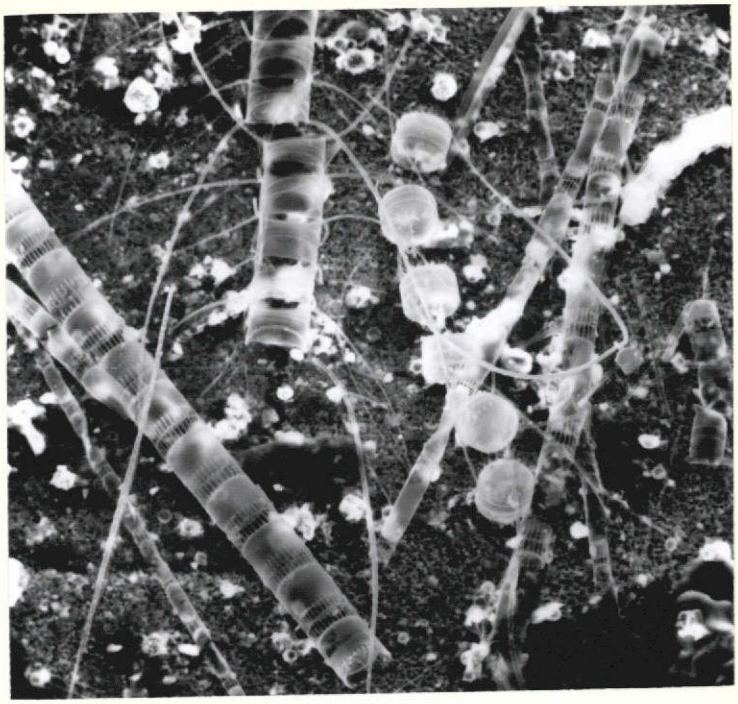
Plate 6



19μ 1600 X

<u>Prorocentrum</u> <u>sp</u>.

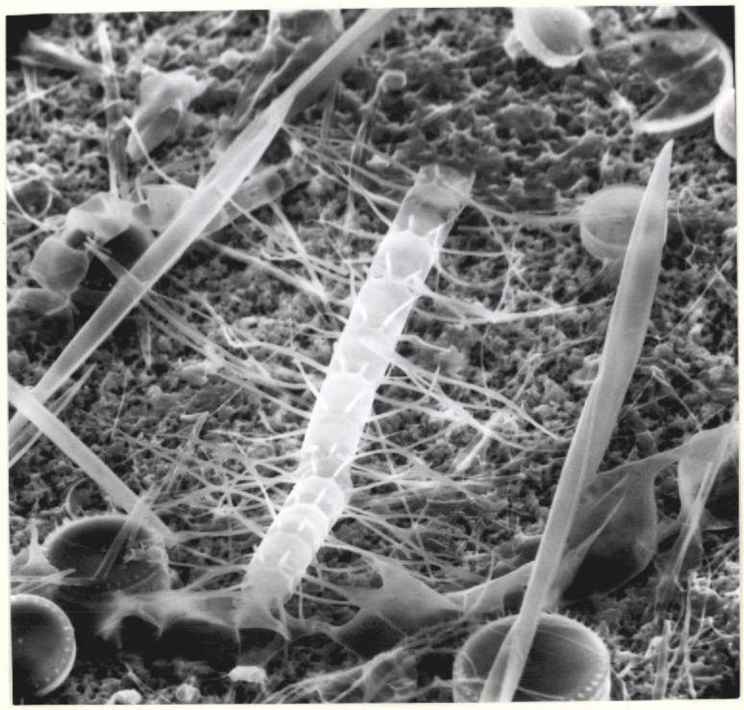
Plate 7



25μ 400 X

Skeletonema sp. *Thalassiosira sp.*
Chaetoceros sp. *Biddolphia sp.*

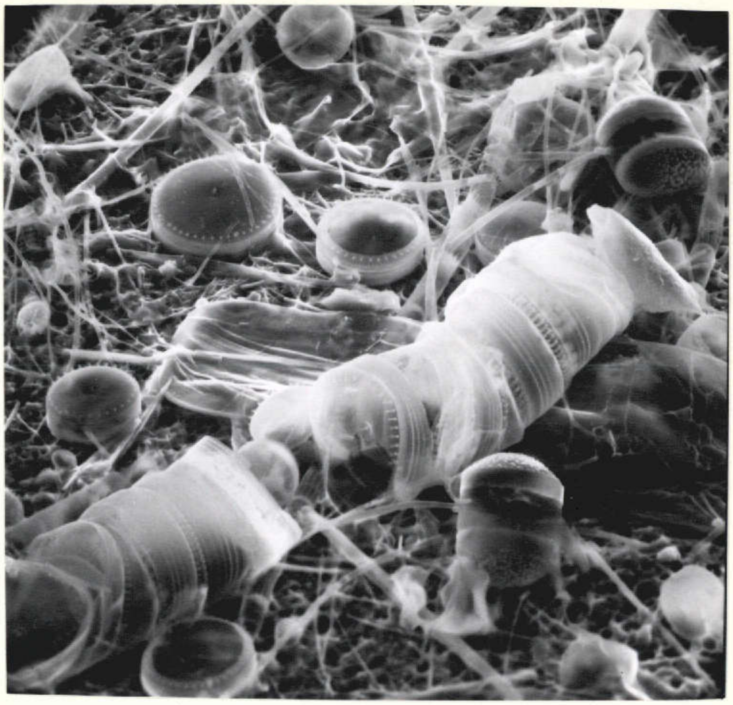
Plate 8



15μ 680 X

Bacteriastrum sp.
Nitzschia sp.

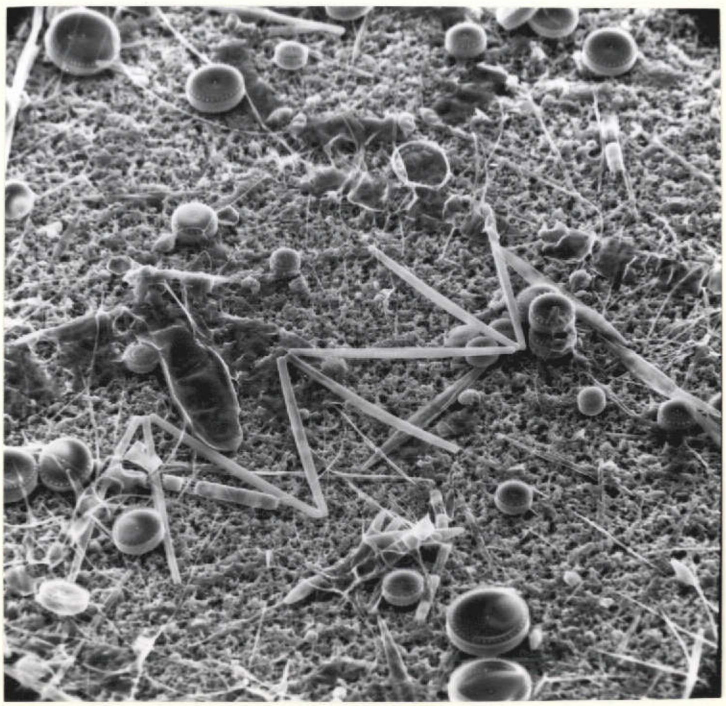
Plate 9



54μ 560 X

<u>Schroderella</u> <u>sp</u>.

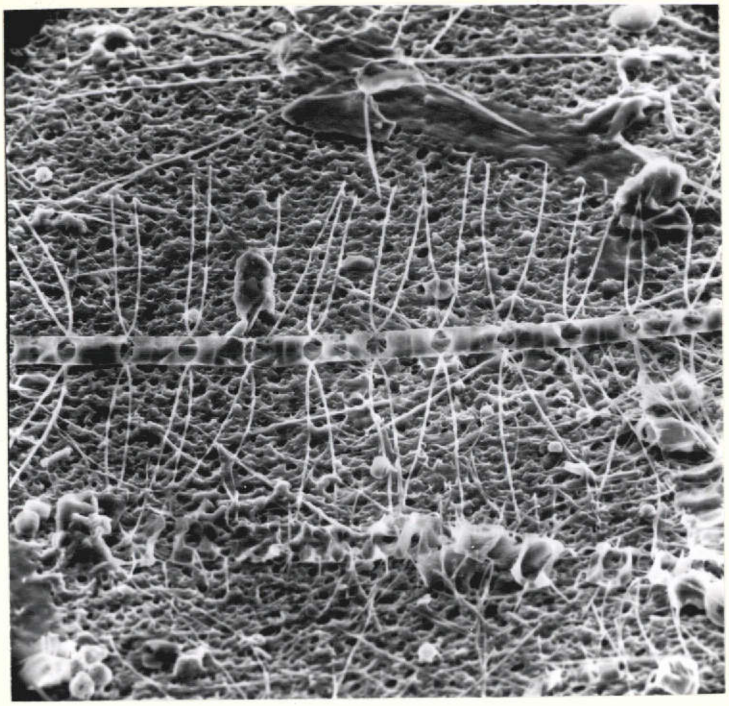
Plate 10



87μ 340 X

<u>Thalassionema</u> <u>sp</u>.

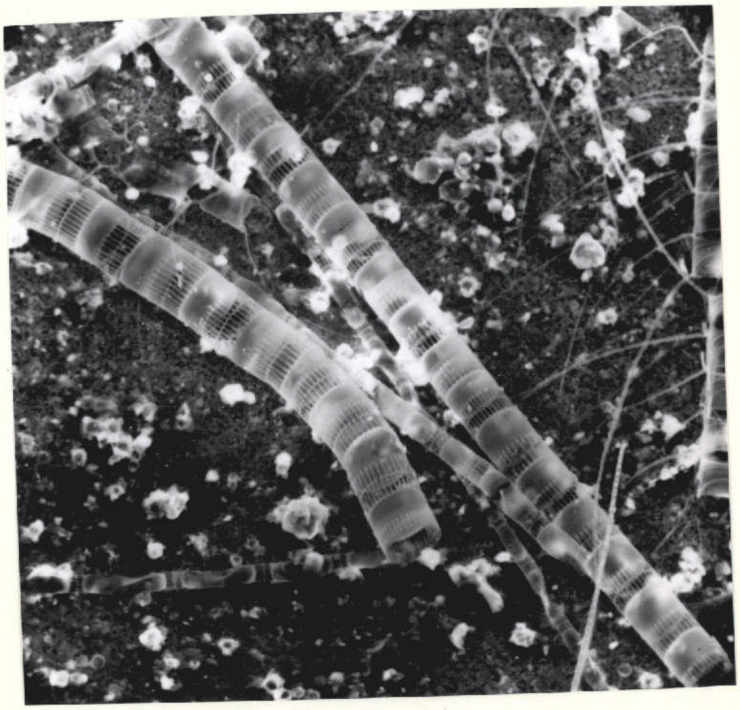
Plate 11



⊢—⊣ 30μ 320 X

<u>Chaetoceros</u> <u>sp.</u>

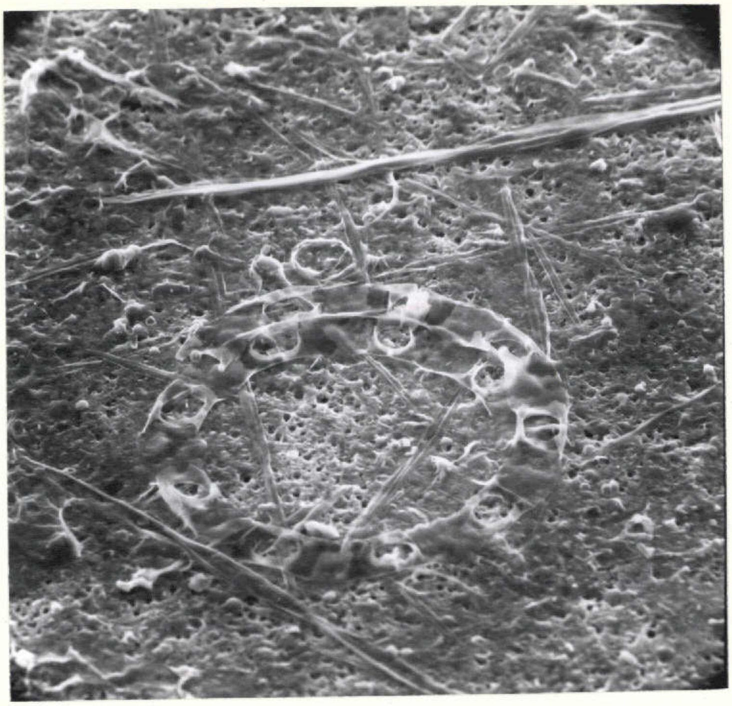
Plate 12



⊢—⊣ 25μ 400 X

<u>Skeletonema</u> <u>sp.</u>

Plate 13

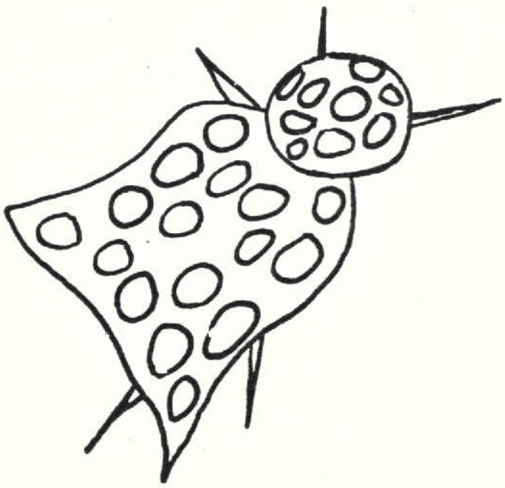


84 x

360 X

Eucampia sp.

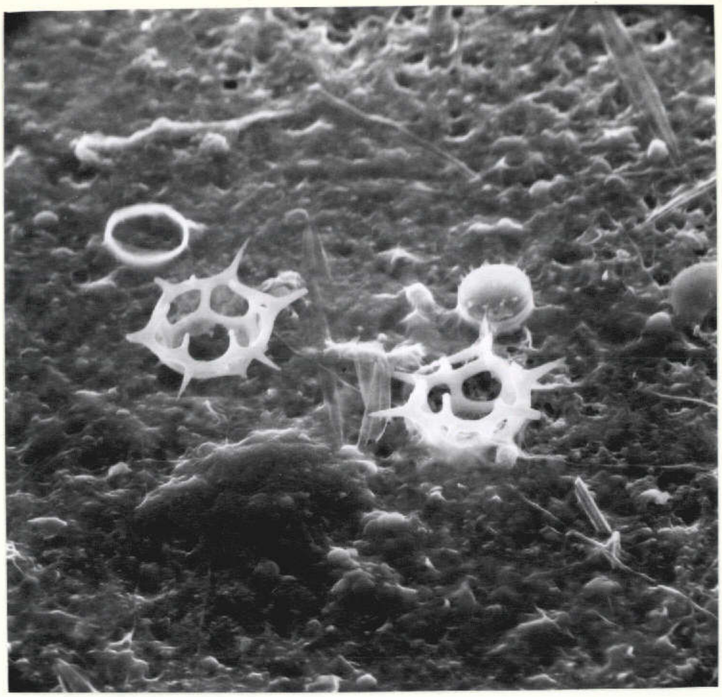
Plate 14



50μ X 70μ

Radiolarian

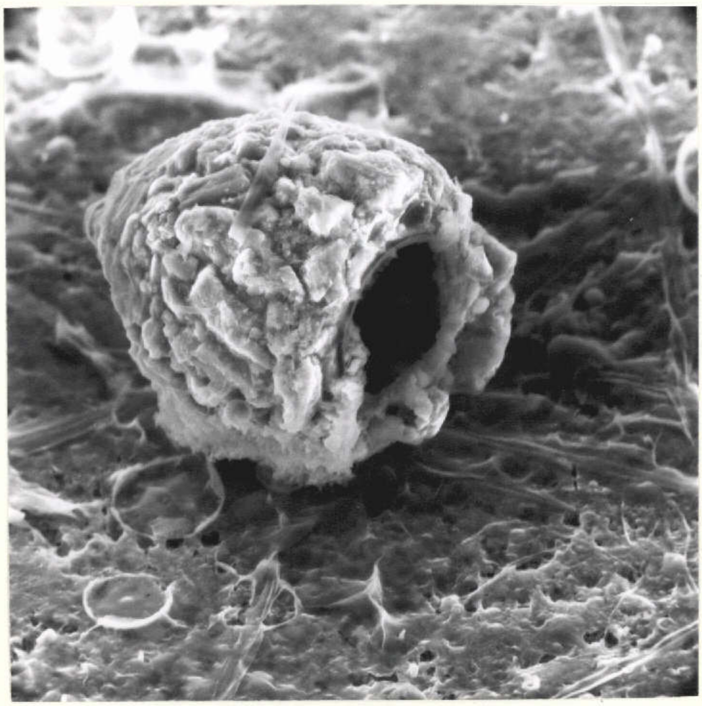
Plate 15



39µ   760 X

Silicoflagellate

Plate 16



42µ   720 X

Tintinnid

of the debris larger than 10 microns appeared to be finely divided pieces of red and brown algae (probably kelp). Debris smaller than 10 microns generally was found close to shore and may have been composed partially of clay and silt. The plankton was dominated by chain diatoms and dinoflagellates and blooms of different types of phytoplankton occurred during the sampling period. From February to July various genera of chain diatoms were dominant and few dinoflagellates observed. In August very few chain diatoms were seen but there were many dinoflagellates. Table 10 gives a summary of dominant and less abundant, though present in significant numbers, genera at various times. In addition to the chain diatoms and dinoflagellates, large solitary centric diatoms (about 50/μ) were found on almost every cruise, although never in large numbers. Table A-2 in the Appendix is a tabulation of types and numbers of suspensoids collected at each station during the cruises.

Other planktonic organisms, such as foraminifera, copepods, larval forms, and eggs, were not seen in large enough numbers to be significant. Large numbers of irridescent flakes, however, were observed on filters from the 25 February cruise in Santa Barbara Channel. The flakes, about 0.7 x 0.3 mm in size, appeared to be transparent, jelly or tissue rather than 0.1 droplets, and in a few cases showed a definitely pointed corner, like the tapered top of a larval form, although no internal structure or cilia fringes were observed.

OCEAN TRUTH DATA PREPARATION:

Some ocean truth parameters were measured only when the boat was stopped at a station. These measurements were recorded manually. Other parameters were recorded continuously, via strip chart recorders. The following instruments fall into the latter category:

1. Air Nephelometer
2. Water Nephelometer
3. Transmissometer
4. Temperature Sensor
5. Ocean Reflectance Sensor

Strip chart recorders were digitized and plotted by computer on the same scale as the ERTS MSS radiance data along the cruise track.

The details of digitizing the data were adapted for each parameter, but the method was generally as follows. The strip chart record between stations was arbitrarily divided into equal time intervals. Within each interval, a representative value was selected and tabulated.

In the case of the air nephelometer, the instantaneous value every 4 minutes was tabulated.

For the water nephelometer records, a 1-minute interval was used and the record was averaged visually over each interval. This was done to smooth the data. From the standpoint of comparison with ERTS MSS data, there was no significant loss of information in this smoothing because the interval corresponds to only one or two pixels.

The transmissometer records were also averaged over 1-minute intervals.

The strip chart record for the temperature sensor was very smooth, so instantaneous values at equally-spaced points between stations were tabulated. Various intervals were used, but none exceeded 2 minutes.

Ocean reflectance records showed a series of spikes on a background level. The spikes were caused by glare from individual waves. The size of each spike depended on the extent and duration of the glare. The record was smoothed by tabulating only the maximum and minimum value during each interval.

The upper and lower envelopes of reflectance data were presented on a computer plot. The upper envelope is a measure of the glare, which is a function of incidence angle and atmospheric attenuation, both of which are strong functions of sun elevation angle. For reference, sun elevation angle is also plotted for the same cruises. Surface roughness also plays a strong part, therefore wind is plotted for reference.

The lower envelope is a measure of the reflectance of the water without glare. The appearance of the strip chart records suggests that no part of the records is completely free of influence from glare - not even the lower envelope. This is because the instrument required about 5 seconds to recover from glare, and the spikes on the record are generally much less than 5 seconds apart.

The ERTS MSS data is also sometimes influenced by glare. The range of sun elevation angle over which glare influences ERTS MSS data depends on surface roughness.

On one cruise, personnel of the University of California Santa Cruz participated. They provided a fluorometer which sampled water pumped through the hull. Fluorescence values were later reported for each station and for each point between stations where OSI took extra water samples at the fluorometer discharge.

Due to a change in light source in the fluorometer, calibration was not provided. The values must be considered relative.

A sensor was developed for the purpose of measuring atmospheric parameters needed to obtain target reflectance from ERTS MSS radiance measurements. The instrument and its use have been described above. After the instrument was made ready, OSI was informed by NASA that ERTS MSS radiance data could only be considered relative, as absolute calibration had become impossible. Without ERTS radiance measurements, target reflectance cannot be obtained from atmospheric measurements, so these measurements were not made.

Part 5

IMAGE DESCRIPTION AND ANALYSIS

NDPF products were examined for the purpose of recognition of areal patterns indicating oceanographic features. Most of the photo interpretation was done using 70 mm positive and negative transparencies. These were examined by back lighting with diffuse illumination and viewing with the naked eye, a 45 X binocular microscope and a 10 X Hastings triplet hand lens.

Where CCT tapes are available, computer generated digital density slices were used to augment photo imagery. The results of the analysis are presented here in chronological order corresponding to dates of ocean-truth cruises.

25 February 1973

Scene 1217-18074   Santa Barbara Channel

This scene was obtained during a low slack tide (see Figure 33) of about 7 feet range. The wind was calm to light and northerly. The air was mild (about 60°F) and clear. Waves 4-6 feet high with periods between 8-10 sec. ran from the SSW. Water temperature was about 60°F. A few (<10%) cumulus clouds lay over the water of the Channel; more clouds occurred over topographic highs on Santa Cruz Island and the Santa Ynez mountains on the mainland.

The regional weather conditions were as follows. A low pressure system was situated 700 miles west of Oregon coast with high

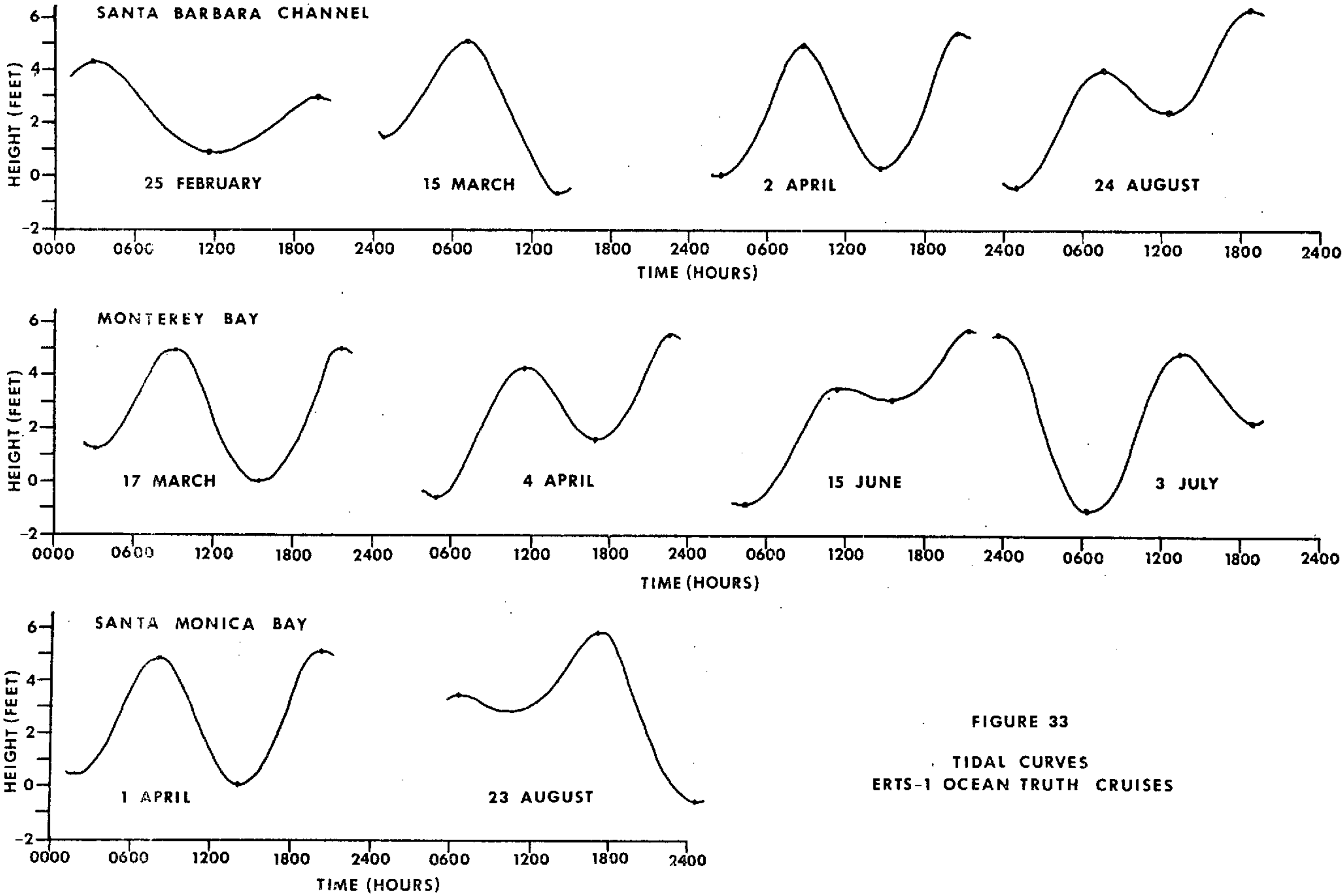
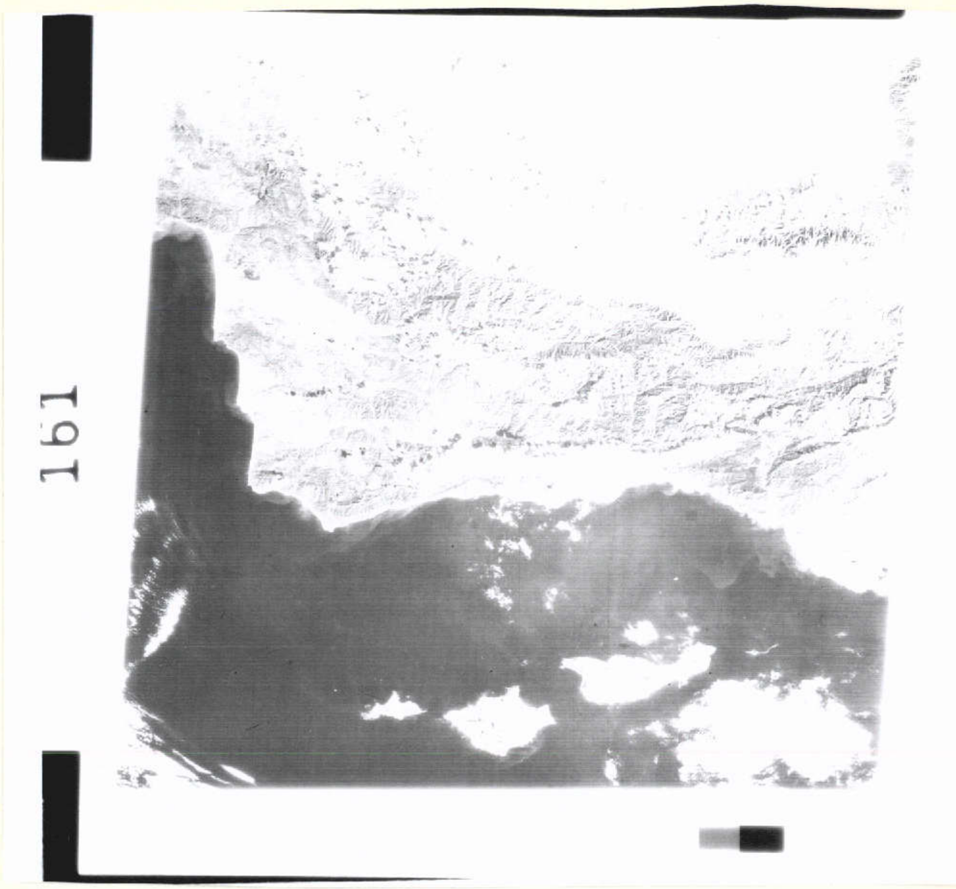


FIGURE 33

TIDAL CURVES
ERTS-1 OCEAN TRUTH CRUISES

pressure cells over the Great Basin and 500 miles southwest of Los Angeles. An inverted surface trough lay offshore southern California causing weak offshore pressure gradients and light Santa Ana conditions. The wind was variable at 5-10 knots over the entire Channel. Calm seas prevailed with low westerly swell (2-4 feet, period 8-10 seconds) in mid-Channel. Visibility was not restricted and scattered fair weather cumulus clouds lay over mountain ridges and Channel Islands. Rainfall in excess of one inch fell over the Santa Clara River watershed on 24 February.

ERTS photo imagery (Figure 34) reveals a pattern of offshore currents in the distribution of suspended materials that is more discernable in the digital density slice prepared from CCT, MSS 4 of this scene (see Figure 35). An overlay on Figure 35 shows the current pattern interpreted from suspensoid distributions. It is surprising to perceive that the transport of suspended sediments, usually regarded as a phenomenon of the littoral zone, extends so far offshore. There is clear evidence that the fine fractions of sediments introduced to the sea by storm swollen streams move seaward through the surf zone and beyond without settling appreciably. This lends support to the mechanism of entrapment of spilled oil by fine sediments postulated by Kolpack (1971 following his study of the Santa Barbara oil spill of 1969). Even stronger evidence is shown in the 15 March 1973 scene of Santa Barbara Channel taken after about a week of heavy rains. Other coastal features are visible on the MSS imagery of the 25 February scene. Beds of kelp (Macrocystis) can be mapped on the MSS 6 photo image and the Guadalupe dune field (upper left) is defined well on the MSS 4 image. Temporal changes in the areal extent of these features could be mapped from successive ERTS imagery although no attempt to do so was undertaken as part of this study.



BAND 4

BAND 5

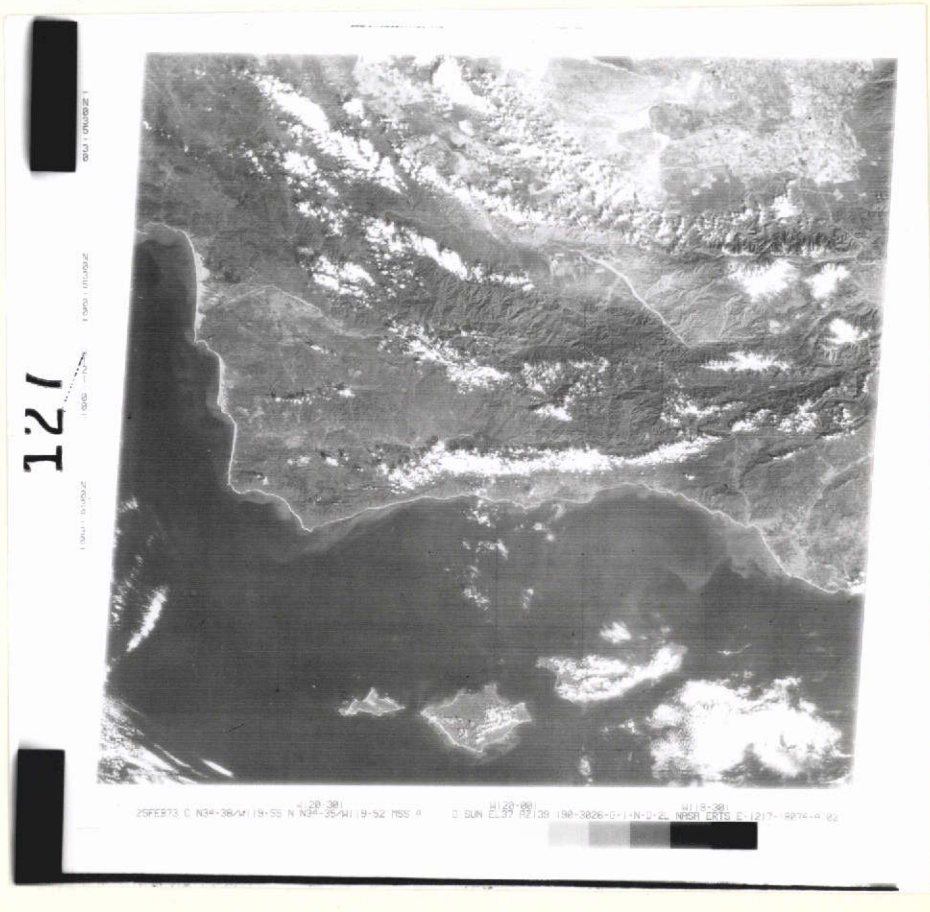
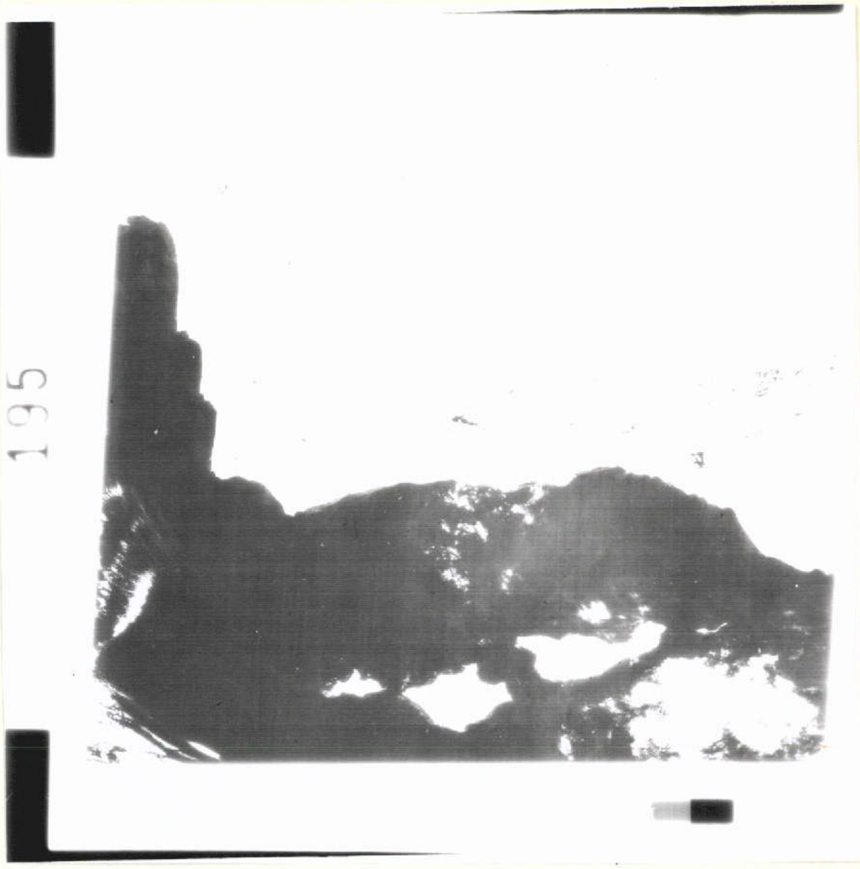


Figure 34a

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
25 FEBRUARY 1973, BANDS 4-5

BAND 6



BAND 7

Figure 34b

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
25 FEBRUARY 1973, BANDS 6-7

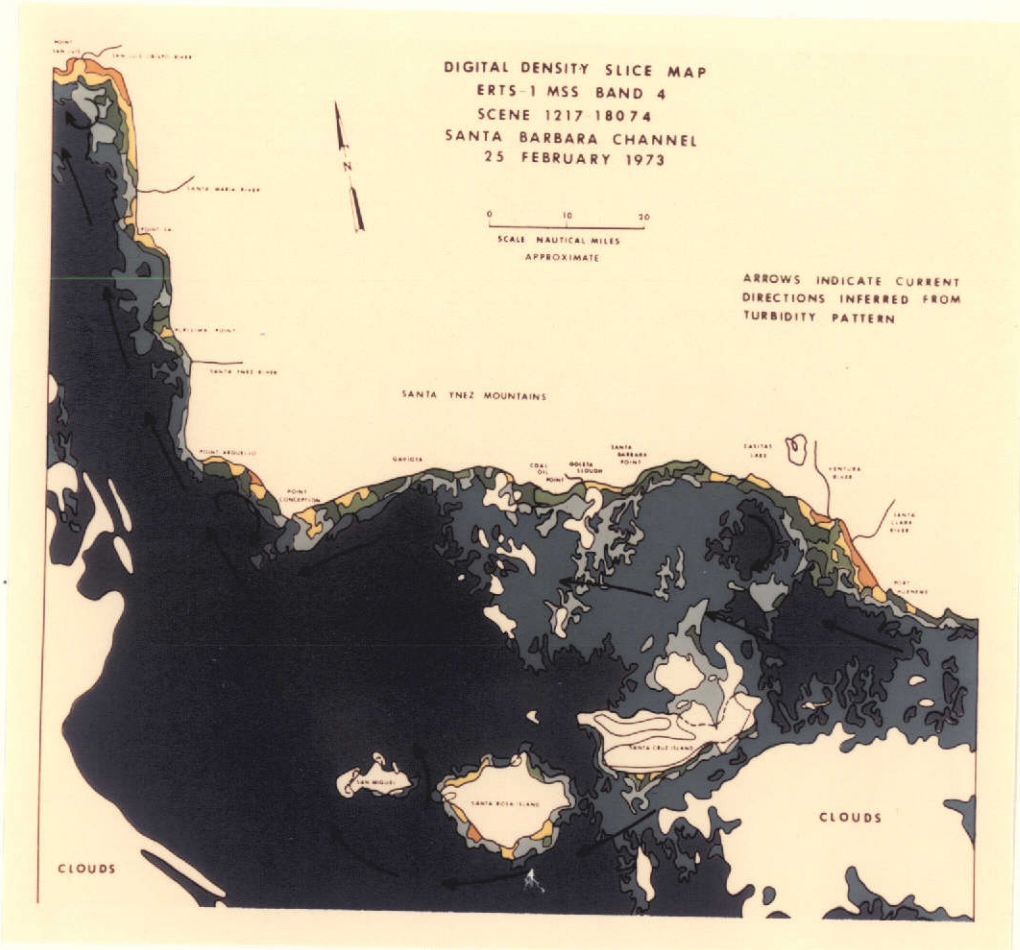


Figure 35

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

Comparison of MSS 4 and 5 images verifies that the observed turbidity pattern is produced by suspended sediment rather than plankton, inasmuch as the same pattern and extent of distribution of the turbidity is seen in both bands. Had plankton been the cause, band 5 would not have shown the same pattern of high radiance levels as does band 4. It was noted that the radiance in areas where diatoms occurred is higher in band 4; see, for example, the correlations between radiance and suspended matter for scene 1396-18004, Santa Monica Bay, August 23, 1973 (p. 6-18 to 6-20).

The circulation pattern deduced from the turbidity distribution is the result of surface water movement westward in the Santa Barbara Channel, and northward along the coast north of Pt. Conception. The California Current, flowing south, apparently lies some distance westward of the edge of this scene. The source of sediments appears to be wave attack at headlands in addition to river runoff. At Pt. Arguello, a dense cloud of suspended sediment is moved seaward by the combined effect of the surf and the ebbing tide. The seaward edge of this cloud is sheared northward by the currents offshore. Some of the clouds move along shore toward Pt. Conception under the influence of a local gyre there. The gyre appears to be controlled by the tides, inasmuch as two distinct lobes of the sediment cloud can be discerned between the two points of land.

The small sediment plumes issuing from the Santa Ynez and Santa Maria Rivers are deflected northward; there appears to be an accumulation of turbid water in the bight east of Point San Luis. The plume from the San Luis Obispo River is deflected to the east and quite possibly a small, local gyre exists in the bight.

The fan-shaped suspended sediment plume off the mouths of the Ventura and Santa Clara Rivers is not particularly deformed by along-shore currents. This may reflect a combination of heavy run off, local offshore winds associated with mild Santa Ana winds moving out of the canyons to the north, and local wind driven circulation. As the canyon winds blow over the water there is a tendency for them to diverge and set up gyres around a local temporary high pressure zone to the west and low pressure zone to the east. The surface circulation at the eastern end of the Santa Barbara Channel suggests the existence of the high pressure gyre in Figure 34. Small plumes between San Miguel and Santa Rosa Islands are caused by a north setting tidal current shearing off turbid water from the shores of the islands. Southeast of Santa Rosa Island the current has sheared turbid coastal water westward. This provides evidence that the currents outside the Santa Barbara Channel were flowing in the same general direction as those inside the Channel.

<u>15 March 1973</u>

Scene 1235-18075 Santa Barbara Channel

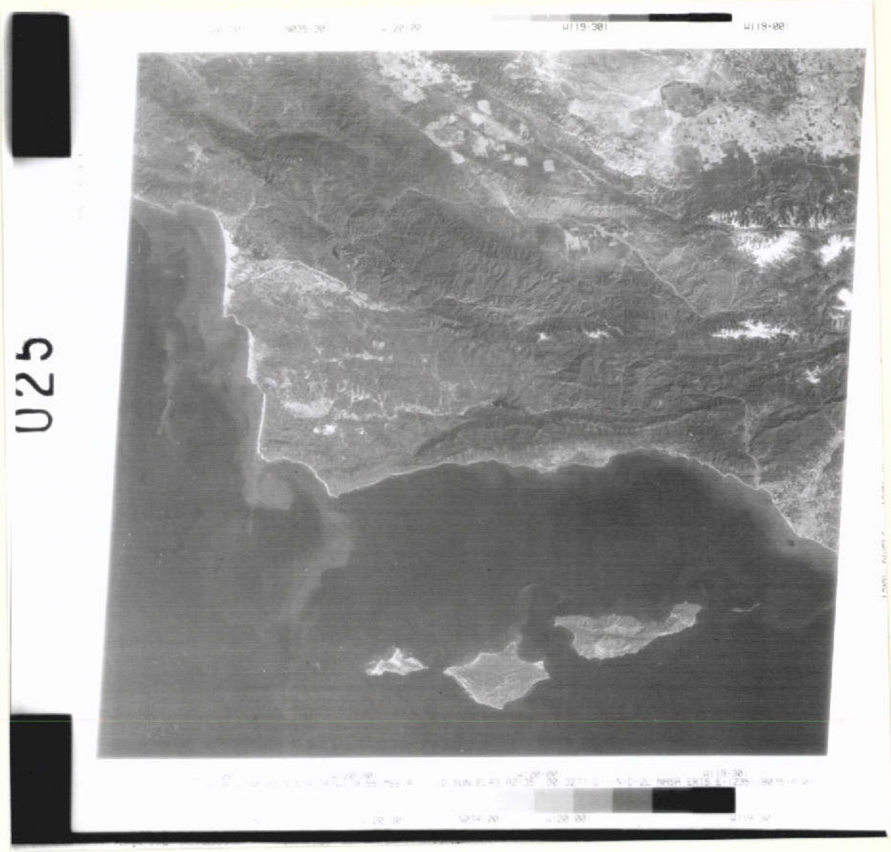
This scene was obtained just prior to low slack tide (Figure 33) that ebbed over a range of about 6 feet. The wind was light and southerly. The air temperature was mild (60°F) and quite clear. A light plane flown to 27,000 feet afforded a cloudless view of the entire Channel with unlimited visibility. Waves 2-4 feet high moved along the Channel from the west and their period ranged from 5-7 seconds. The water temperature was 62°F.

The regional weather conditions were as follows. A low pressure system was situated 200 miles northwest of Vancouver Island and a high pressure system existed over the Great Basin and 500 miles southwest of San Francisco. A narrow inverted surface trough over immediate offshore area of southern California (weak Santa Ana condition) caused offshore winds over the Channel area. The wind was variable at 5-10 knots. Good visibility and little cloudiness prevailed over the area. Very low, medium period, swell 1-2 feet with periods of 5-7 seconds ran in the Channel. No significant precipitation fell over watershed areas immediately prior to this date.

ERTS photo imagery captures the spectacular pattern of turbidity extending along the coast from the northwest corner of the scene to San Miguel Island (Figure 36). A digital density slice perpared from a CCT of MSS 4 enhances the turbidity pattern and permits an interpretation of the details of surface water circulation (Figure 37). At the left of the scene, there is a tongue of clear water probably associated with the south flowing California Current. As this major current moves past the stepped coastline, turbid coastal water is entrained and small counterclockwise gyres are generated. This is especially noticeable south of Point Arguello but can be recognized south of Purisima Point, Point Sal and Point San Luis.

Pronounced tidal current plumes are flowing northward between San Rosa and Santa Cruz Islands and between Santa Cruz and Anacapa Islands. Evidence of previous tidal events is visible as the long plume extending southward from Point Conception and as contorted bands of turbid water parallel to the coast between Point Arguello and Point San Luis. At least two tidal events are represented; a third might be represented by the elongated plume of turbid water oriented north-south and lying off Purisima Point on a meridian passing through Point Sal.

The cause of the turbidity is suspended sediments judging from their proximity to shore and the presence of the turbidity pattern in both MSS bands 4 and 5. The suspended sediments appear to be supplied by wave attack on the coast from Point Arguello northward.



BAND 4

BAND 5

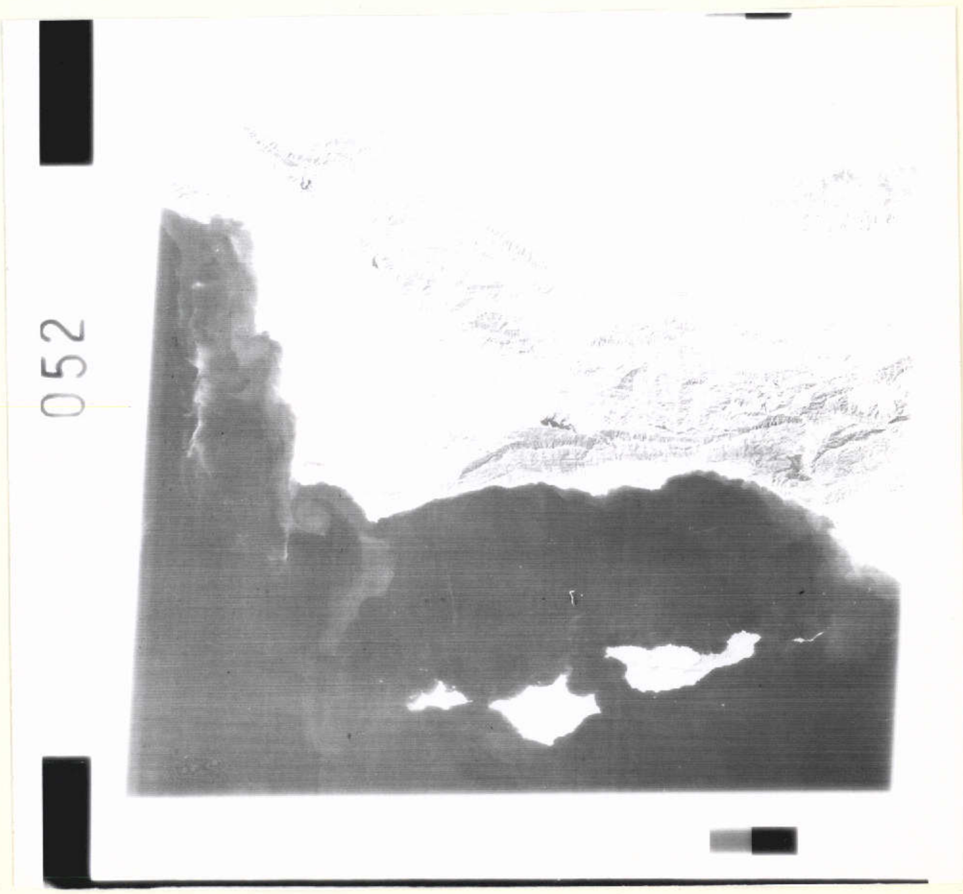
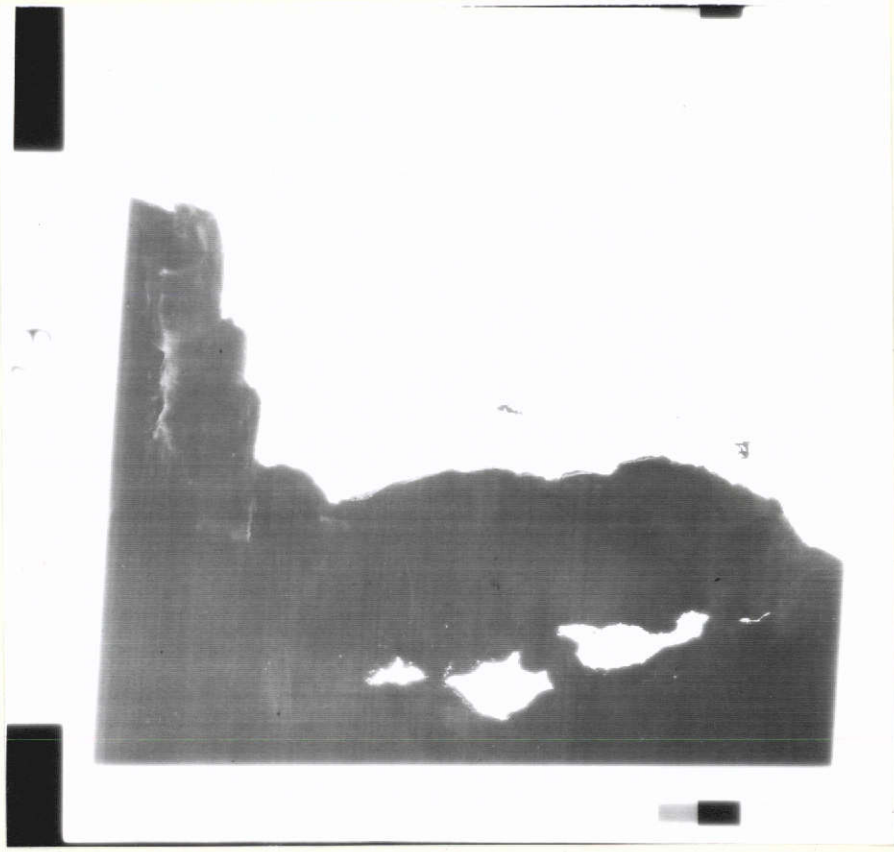


Figure 36a

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
15 MARCH 1973, BANDS 4-5



BAND 6

BAND 7

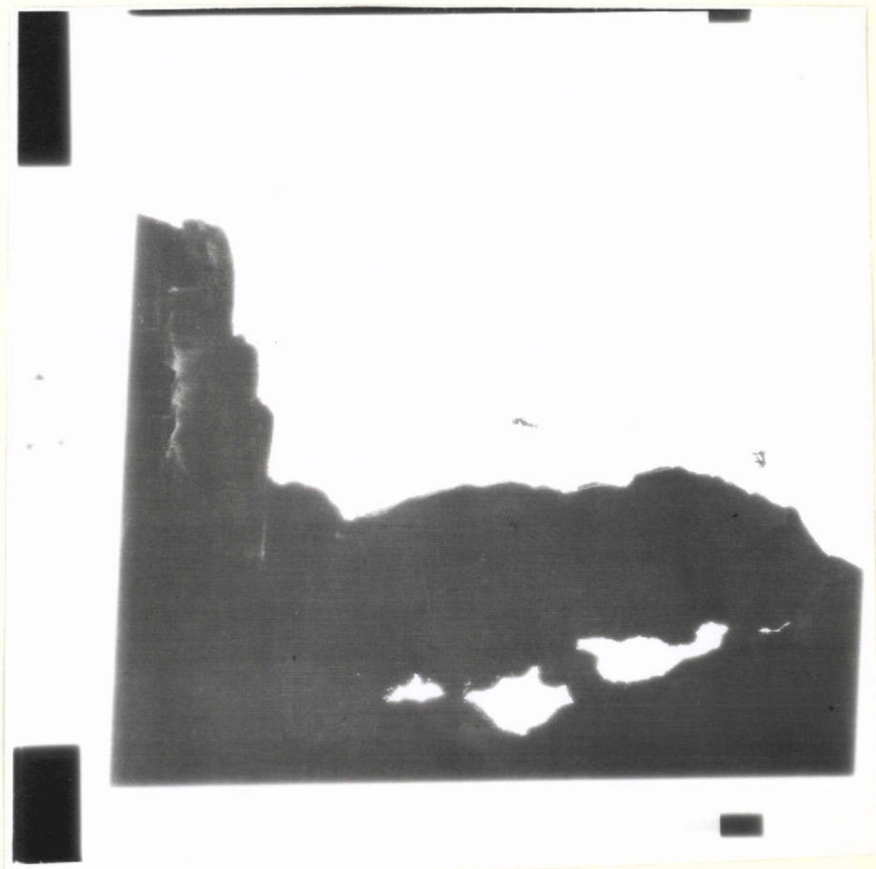


Figure 36b

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
15 MARCH 1973, BANDS 6-7

Figure 37

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

Waves offshore of this region were severe; heights ranged from 6 to 8 feet, periods from 8 to 10 seconds and the direction of wave attack was from the west to northwest. The extent to which surf and tidal action can move suspended sediment ashore is portrayed dramatically in this scene. Only the synoptic view afforded by the ERTS remote sensing imagery makes the perception of such a phenomenon possible.

Rivers and streams did not contribute sediments because there was no significant precipitation in the weeks preceeding the overflight of the satellite. The turbid water off the mouths of the Ventura and Santa Clara Rivers represents wave reworking of the sediments in the Santa Clara River delta built during floods in January 1969. Transport along the coast eastward is readily apparent in this scene.

Relatively clean water occurs in large patches in the Santa Barbara Channel proper. These patches appear to be related to large scale motion of the surface water of the Channel. They seem to be relics of clean water introduced into the Channel at some earlier time. Gyratory circulation between the Santa Barbara shoreline and the Channel Islands caused onshore turbid water to mix with the clean water until only the patches lying near the center of the gyres were left free of suspended sediments. The source of the clean water lies south and east of Santa Cruz Island. The exact relationship of this patch to the rest of the water in the Channel cannot be determined without reference to the scenes lying south of this one. Unfortunately, this very desirable scene was not provided by NASA as part of the present study.

17 March 1973

Scene 1237-18183 Monterey Bay

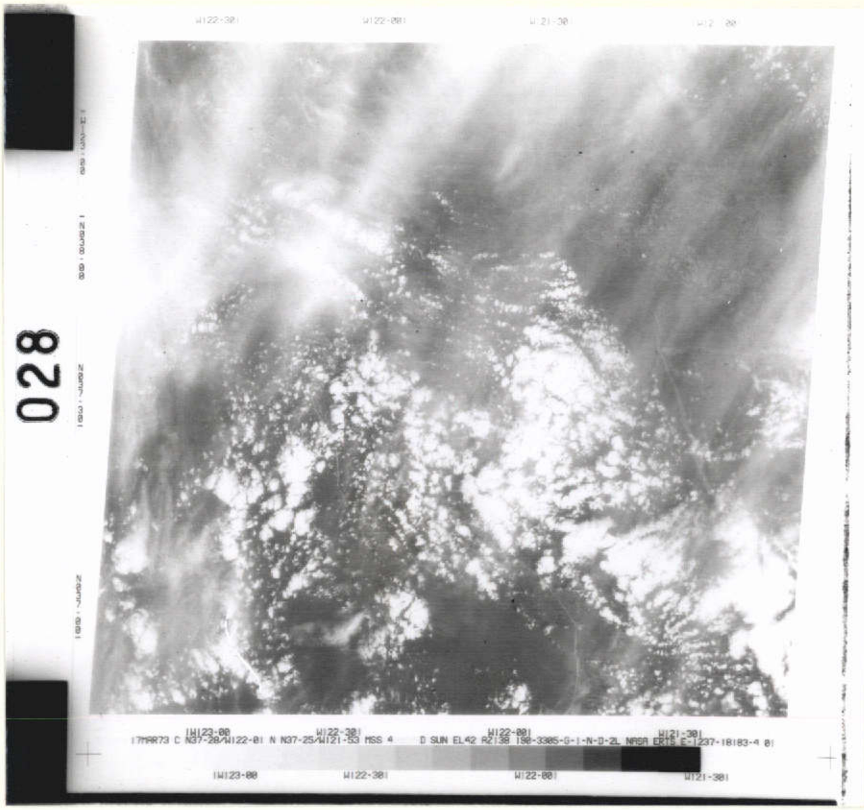
This scene was obtained during a high slack tide of 5 feet that followed a low of about 1 foot. The wind was light (0-2 mph) and westerly but it was preceeded by brisk winds (12-15 mph) from the northwest an hour previously. Waves 2-4 feet high with periods between 7 and 9 seconds ran from the west. The surface water temperature was 56°F. The air was cool, about 55°F, and the air was clear with scattered stratus and cumulus especially over the northern part of the bay.

The regional weather conditions were as follows:

A frontal system oriented northeast-southwest lay just west of Santa Barbara Channel; the next upstream system occurred 200 miles west of Washington - Oregon coast. A moderate northwesterly wind blew at 15-25 knots and numerous whitecaps developed offshore throughout period. Considerable cumulus cloudiness occurred over mountains and north portion of the Bay. Seas of 2-3 feet from the northwest were superimposed on 3-5 feet westerly swells (period 7-9 seconds). No significant precipitation fell over Monterey Bay watershed prior to this period.

ERTS photo imagery (Figure 38) shows cloud features superimposed on an almost uniformly dark sea surface. This suggests that a single mass of relatively non-turbid water occurred over the surface of the Bay. There is a vague suggestion in MSS bands 4 and 5 of a turbid water lobe entending about 3 miles offshore between the mouth of Elkhorn Slough and the Salinas River. If the feature was real it could represent a plume of turbid water that issued from Elkhorn Slough on the previous tide and was transported southward by nearshore circulation of surface water. The feature cannot be identified as such conclusively because

BAND 4



BAND 5

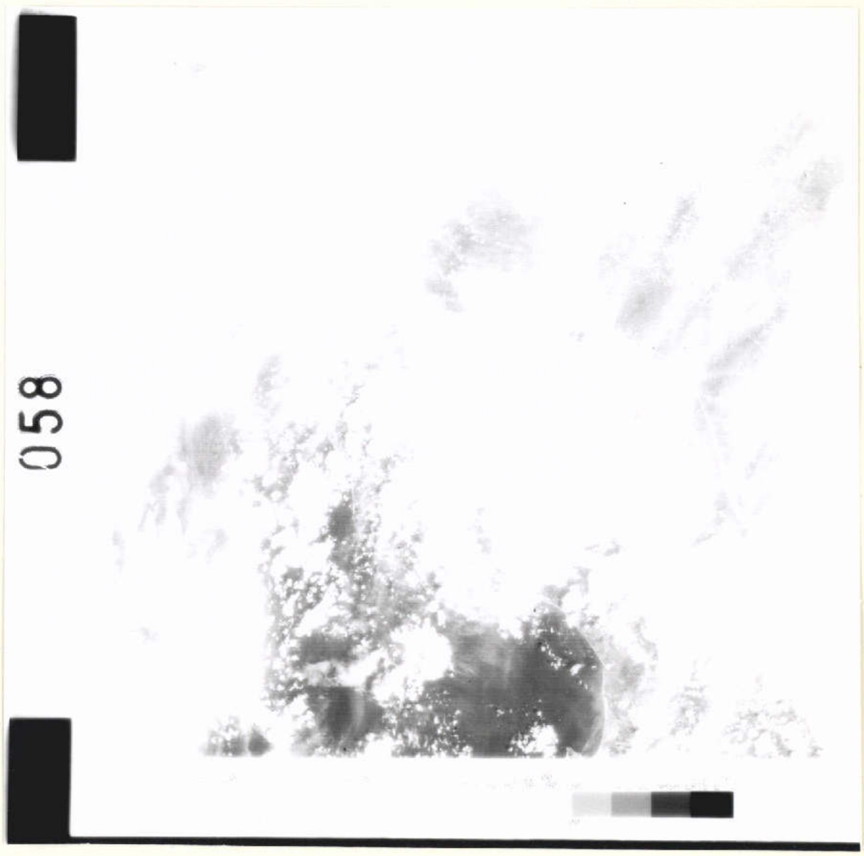
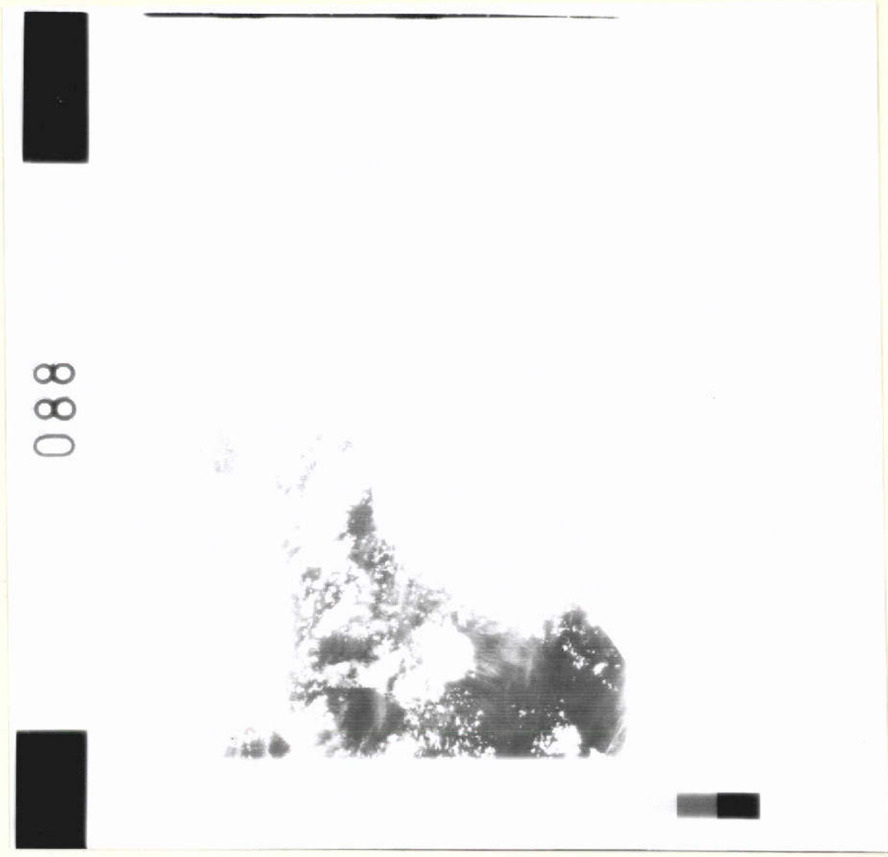


Figure 38a

ERTS-1 PRINT OF 70MM NEGATIVES
MONTEREY BAY
17 MARCH 1973, BANDS 4-5



BAND 6

BAND 7

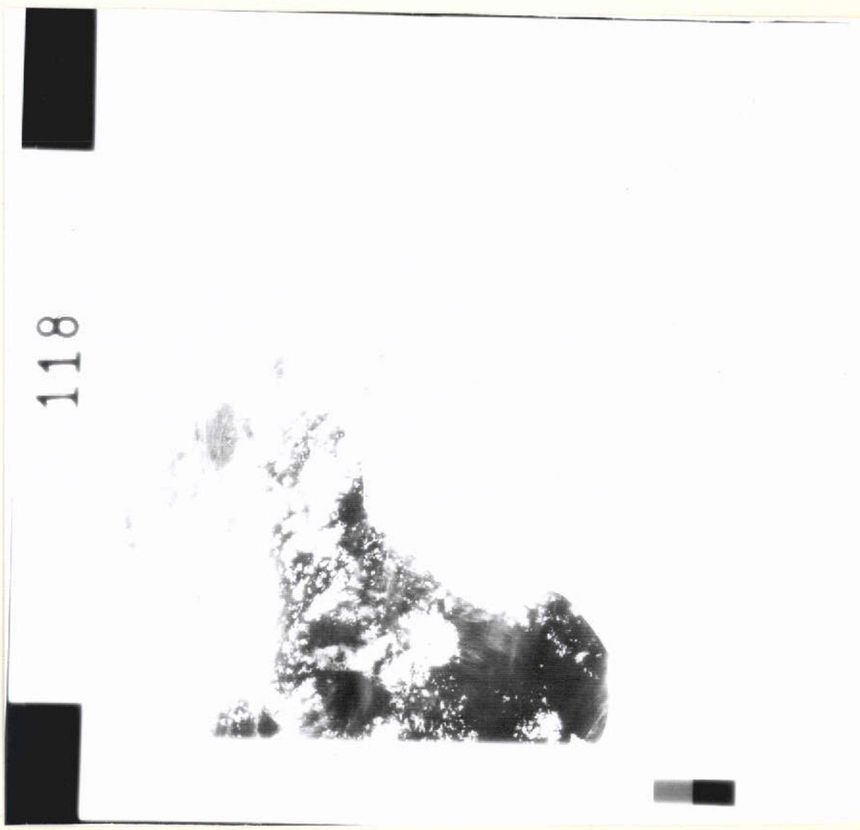


Figure 38b

ERTS-1 PRINT OF 70MM NEGATIVES
MONTEREY BAY
17 MARCH 1973, BANDS 6-7

MSS 6 shows the inshore half of the lobe clearly suggesting that the feature is atmospheric at least in part. CCT digital data from MSS band 4 (Figure 39) processed to generate a density slice map of this scene. The density slice map shows the presence of clouds but a concentric pattern of light, turbid water inshore and darker, clear water offshore is quite apparent. The concentric pattern is not visible on photo imagery; this is another example of the higher resolution of radiance present only in CCT digital imagery. Coastal dunes appear as a pronounced light streak along the shore of the Bay; the silica sand occurring there is quite reflective in MSS band 4.

<u>1 April 1973</u>

Scene 1252-18051 Santa Monica Bay

This scene was obtained during an ebb tide running from a high water at 5 feet to a low of 0 feet. The wind was westerly and brisk; it increased from 7 mph in the morning to about 18 mph at 10 a.m., the time of the satellite overflight. Choppy sea waves from the west rose to 6 feet with short (4-6 seconds) periods. The water temperature was 57°F. Small craft warnings were posted by the time of passage of the ERTS-1 satellite. The air was clear and its temperature varied near 60°F. No clouds were observed over the ocean although cumulus clouds lay over topographic highs to the north. The regional weather consisted of the following:

An offshore high pressure system was situated along the entire west coast and a low pressure system existed over Utah contributing to a strong onshore pressure gradient over Santa Monica Bay. West-northwesterly wind of 15-25 knots generated moderate whitecaps and sea waves of 2-4 feet with periods of 4-6 seconds over the Bay. Scattered fair weather cumulus lay over mountains

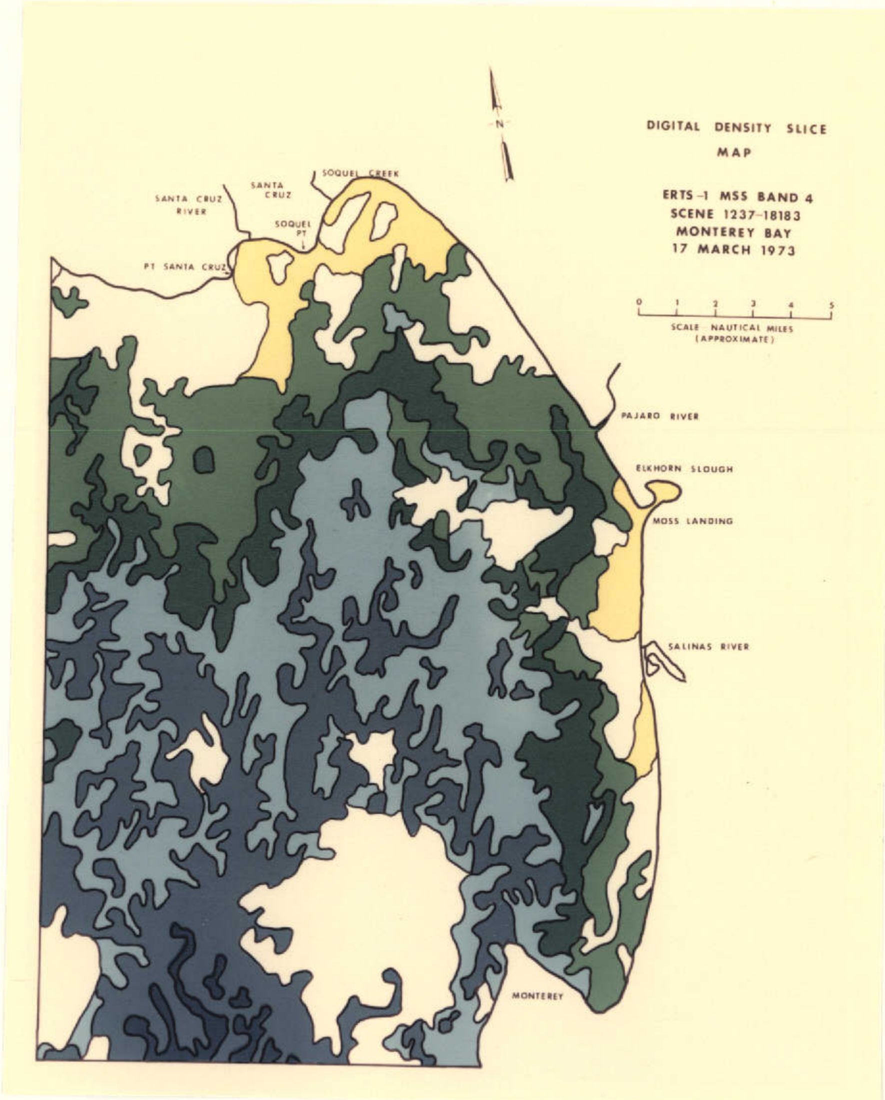


Figure 39

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

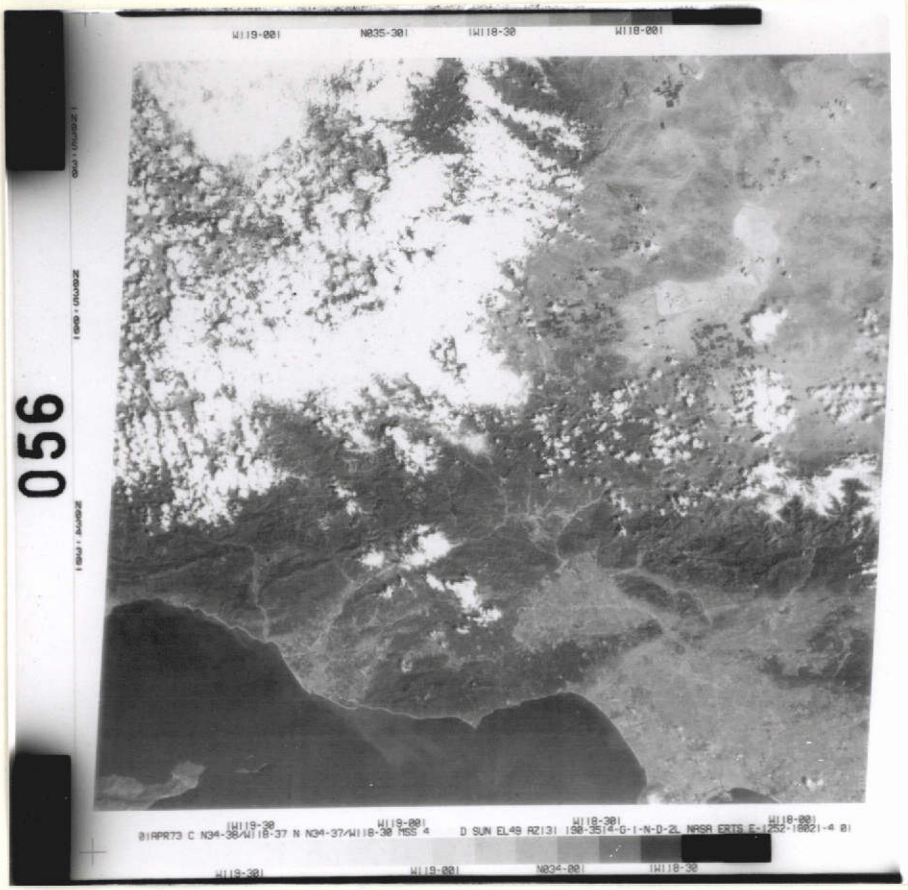
Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

with otherwise excellent visibility. No significant precipitation fell over the Los Angeles basin during the previous 10 days.

A plume of turbid water extending about 10 miles southeast from the mouth of the Santa Clara River is visible in images of MSS band 4 and 5 (Figure 40). South of Point Mugu the plume breaks into individual patches; two such patches of turbid water approximately 6 miles in diameter have moved across the central part of Santa Monica Bay. The patches may reflect two distinct tidal flood events superimposed upon a current sweeping through the bay from the west to the southeast. The source of the turbidity appears to be sediments thrown into suspension by wave attack on the Santa Clara delta and removed offshore by ebbing tides.

A density slice map (Figure 41) prepared from CCT digital data, MSS band 4, shows the plume of turbid water extending to the northwest side of the Palos Verdes peninsula where it merges with turbid water generated by the action of waves of normal incidence. The density slice map shows a lobe of turbid water extending offshore 2 miles from near El Segundo. This feature is barely discernable on the corresponding photo image. The lobe is symmetrical and seems to bear no relationship to currents or wave attack. It is most likely an expression of warm, turbid discharge water issuing from the diffuser field of the Hyperion Wastewater treatment plant at El Segundo. If so the turbidity pattern suggests that some discharge water is being driven shoreward under the influence of surface currents produced by the high winds prevailing that day. Surf action appears to spread the turbid water laterally along the shore in both directions from the discharge.

The pattern of radiance visible in the MSS band 7 image is visible in bands 4, 5, and 6 also. This suggests that the



BAND 4

BAND 5

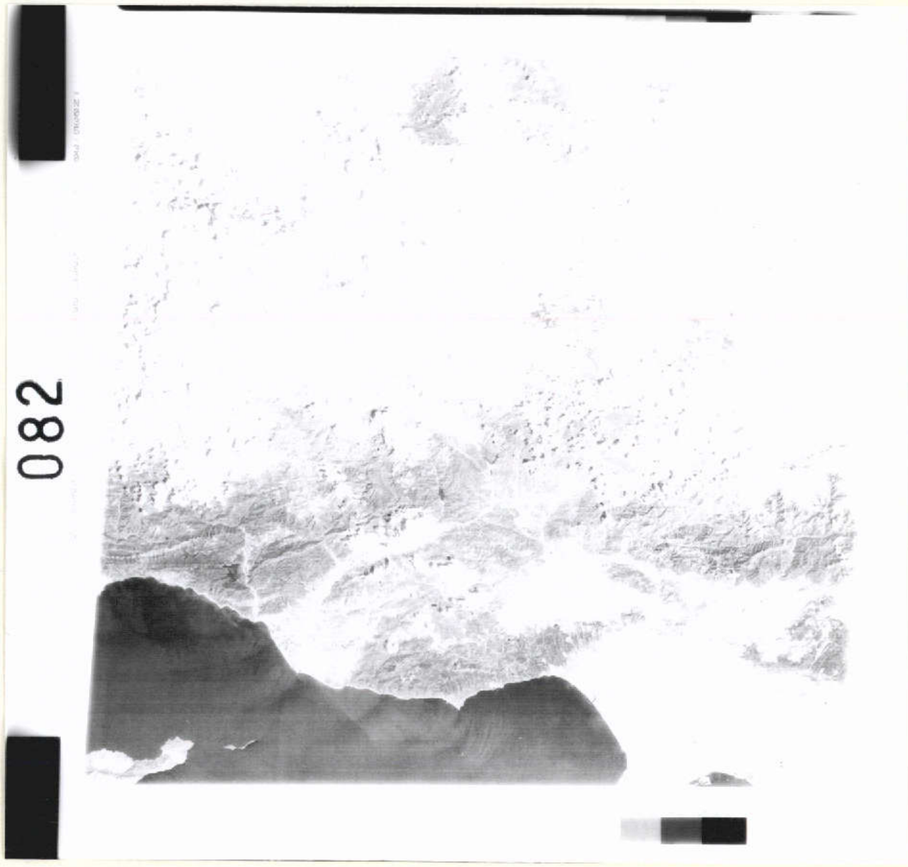


Figure 40a

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA MONICA BAY
1 APRIL 1973, BANDS 4-5

BAND 6

BAND 7

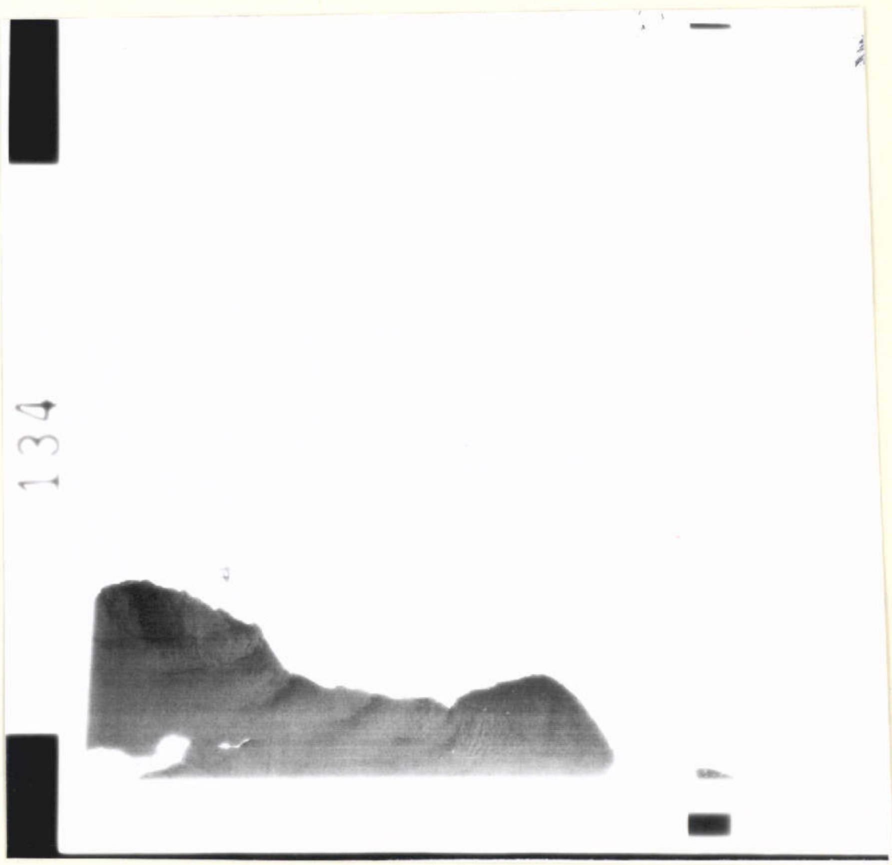


Figure 40b

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA MONICA BAY
1 APRIL 1973, BANDS 6-7

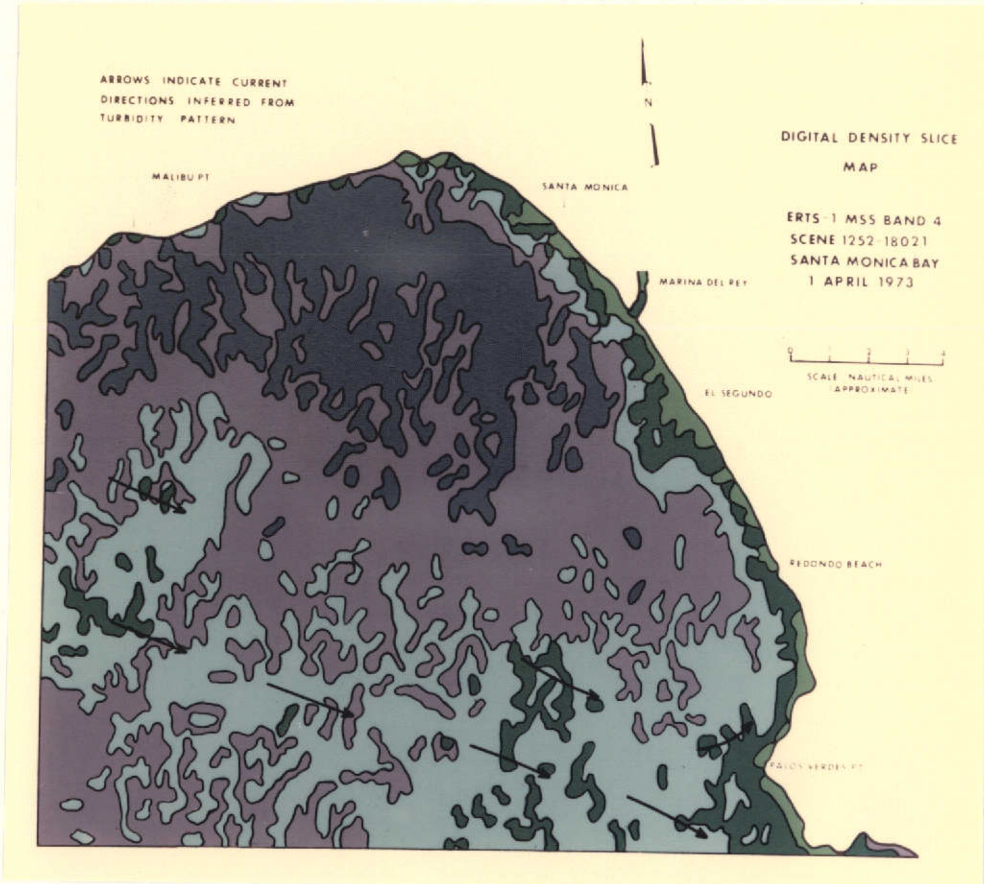


Figure 41

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

feature is situated at the water surface or atmosphere and produces changes in specular reflectance. The air was clear so one must assume that the pattern reflects differences in wave-induced roughness of the sea surface. The nature of the pattern affirms the assumption. The 70 mm film negative of MSS band 7 shows a series of curvi-linear features radiating seaward from the coastal sector between the Santa Clara River delta and Point Dune. The features appear to be regularly spaced with an interval of about 7 miles at the shore. They are believed to be bands of alternately smooth and rough water produced by a train of undulations in the wind field caused by local cyclonic circulation around the Santa Monica mountains. Southeast of Point Dune the wave length of the wind undulation pattern decreases at about 2 miles. The part of the Santa Monica Bay lying east of the Santa Monica mountains is dark in MSS band 7 film positive. This is expected if unroughened water lies in the mountains' wind shadow. Similar wind shadows appear SE of Santa Catalina and San Clemente Islands in the scene (1252-18023) just to the south.

Kelp beds can be mapped in MSS bands 5 and 6 imagery and sand dunes and beaches are readily discernable in MSS band 4 images. Some, but not all of the offshore oil well platforms southeast of Santa Barbara can be located on MSS band 4; however, the presence of oil slicks from these platforms or from natural oil seeps in this area cannot be detected.

<u>2 April 1973</u>

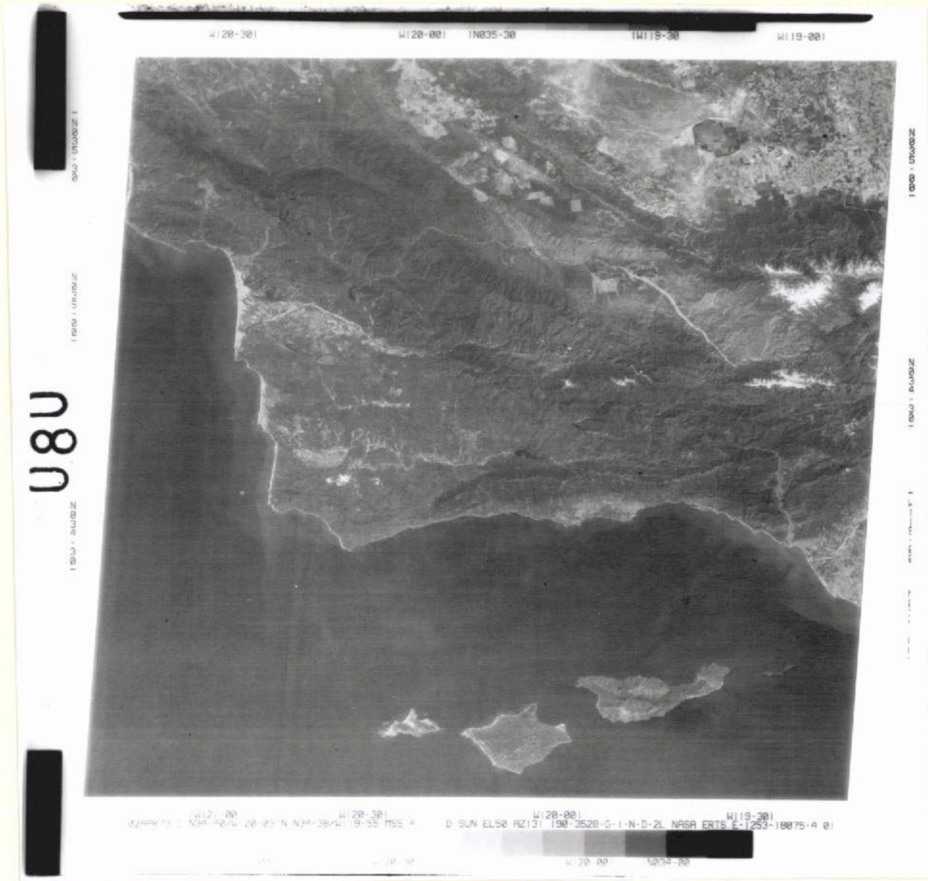
Scene 1253-18075 Santa Barbara Channel

This scene was obtained just after a high slack tide of 5 feet (Figure 33). The next low tide reached 0.5 feet. The wind was light and variable in the morning but reached 20 miles an hour westerly just after the ERTS-1 overpass. The seas rose from 2 feet to 5 feet with periods of about 8 seconds during this time. The surface water temperature was 53°F. The air was mild (60°F) and clear. No clouds were visible over the sea and most of the land.

The regional weather consisted of the following:

A ridge of high pressure with cells over western Washington and 500 miles west of San Francisco blocked a storm system in the southern reaches of the Gulf of Alaska. With downstream low pressure system in central Texas, the offshore pressure gradient weakened considerably. Isolated cumulus clouds lay over mountains and islands and visibility was unrestricted. West-northwesterly seas ran 1-2 feet high with periods of 8-10 seconds. No significant precipitation fell during the last two weeks.

ERTS-1 photo imagery (Figure 42) and the MSS band 4 density slice map (Figure 43) show features dominated by the pattern of surface winds throughout the channel except for a turbid water lobe extending offshore from the delta of the Santa Clara River. Upcoast from Point Arguello to Point Sal, a pattern of turbid water transport is evident. Plumes extend from each promontory of land where wave action and ebb tides move suspended sediments seaward. The orientation of the plumes indicates an offshore current moving southward. The texture seen in photo images and the density slice map of the rest of Santa Barbara Channel appears to be related to surface water roughening by wind. The surface water east of a line extending from Point Conception to the western tip of Santa Cruz Island appears darker in photo imagery of all MSS bands than does water to the west. The dark channel water is interrupted by bands of light (rougher) water oriented ENE-WSW that extend across the channel. Each band is about 5 miles wide; they are spaced on intervals of about 7 miles.



BAND 4

BAND 5

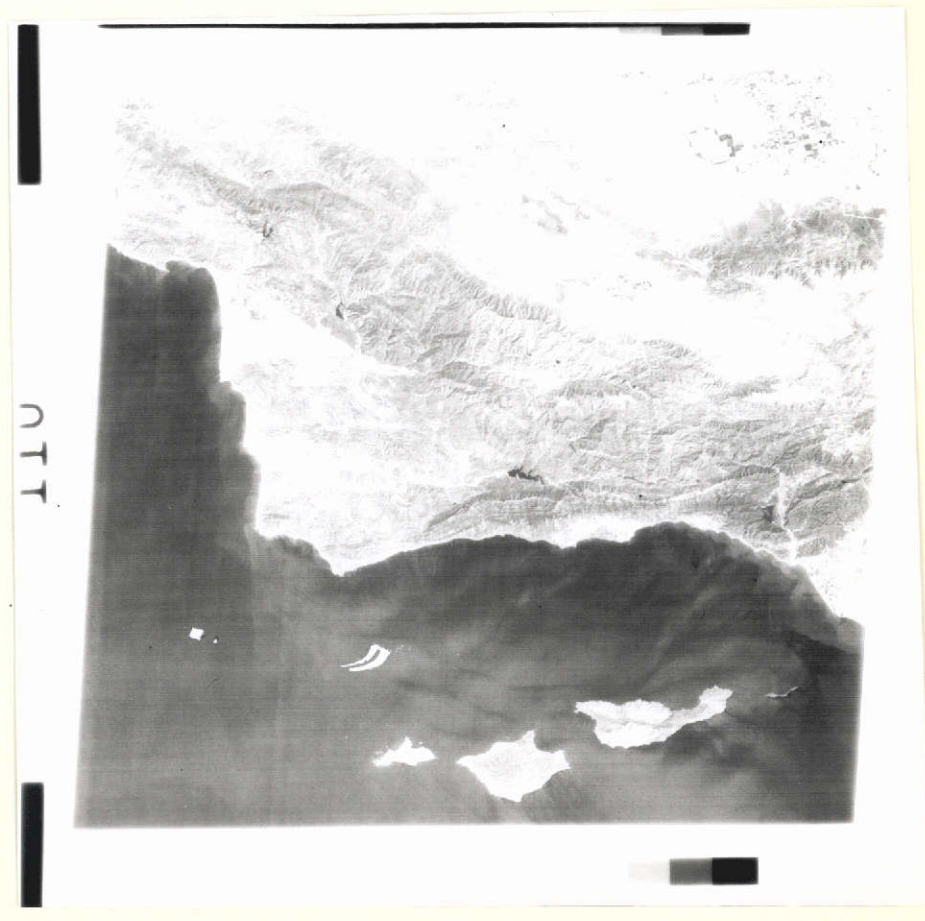
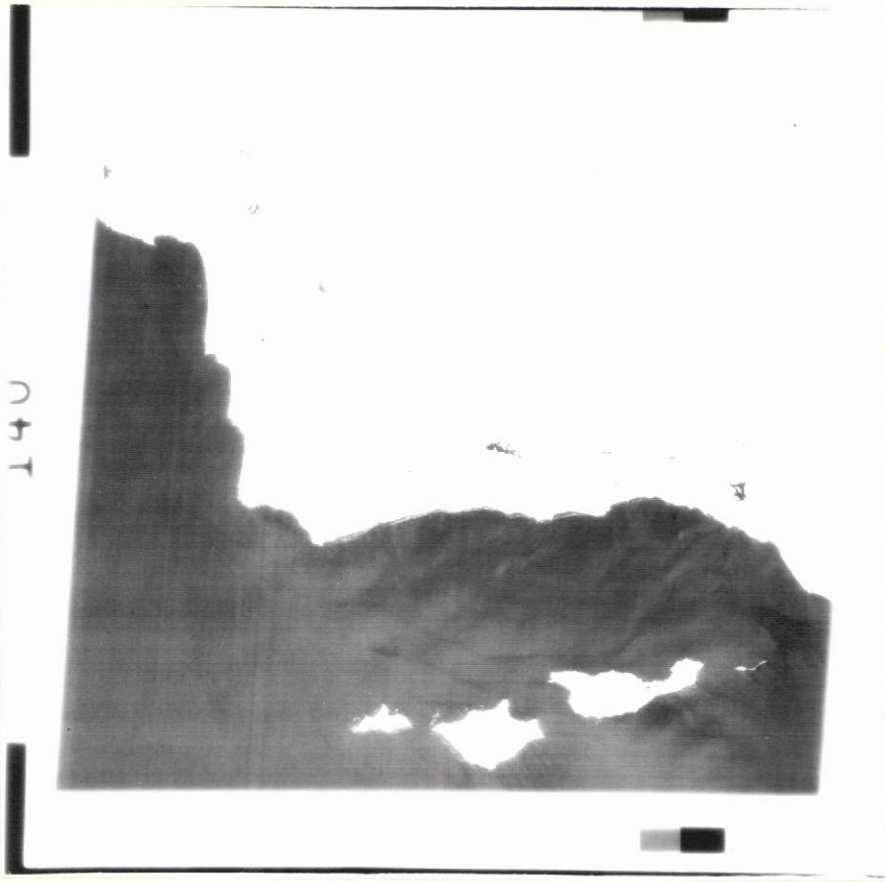


Figure 42a

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
2 APRIL 1973, BANDS 4-5



BAND 6

BAND 7

Figure 42b

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
2 APRIL 1973, BANDS 6-7

Figure 43

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

At the eastern tip of Santa Cruz Island a band of roughened water appears to curve toward Anacapa Island forming a loop extending from the central part of the north coast of Santa Cruz Island, toward Ventura, then back past the north shore of Anacapa Island to the eastern shore of Santa Cruz Island. It is easy to postulate that the wind moving southeastward through this area diverged over the plains surrounding Ventura and southward causing relatively smooth water in the central part of the eastern entrance of the Santa Barbara Channel while maintaining rough water north of Anacapa Island on the eastern tip of Santa Cruz Island. A similar effect to the north is probably obscured by the lobe of suspended sediments off the Santa Clara River delta. Also, higher wind velocities would persist over Ventura rather than over water in this area so the northern counterpart of the diverging wind field would not tend to produce wind roughened water along the northern shore of the Santa Barbara Channel in this area.

A wind shadow marked by dark (smooth) water extends ESE from Santa Cruz Island. The shadow tapers away from the island and seems to consist of alternating bands of dark and light water much like the water in the channel. This wind shadow is particularly well developed in Santa Barbara Channel, scene 1270-18023, obtained on 19 April 1973. Nine cycles of alternating dark and light water can be discriminated in the long (60 miles), thin wind shadow in the lee of Santa Cruz Island. The other channel islands have much reduced wind shadows; their elevations are rather less than that of Santa Cruz Island, see Table 12.

Table 12

MAXIMUM RELIEF OF THE CHANNEL ISLANDS

Islands, West to East	Maximum Elevation, Ft.
San Miguel	831
Santa Rosa	1574
Santa Cruz	2434
Anacapa	930

The striking feature of wind-related patterns is the evidence of regular undulations in the wind field. Such undulations are not unknown over land; "mountain waves" have been described in conjunction with perturbation of air flow over mountainous terrain and the development of regular, linear bands of clouds are thought to be related to those perturbations. The ERTS-1 photo imagery appears to be the first indication that wind undulation is expressed on the sea surface.

There is a possibility that the surface water may respond to wind undulations by forming alternating parallel lines of convergence and divergence in response to variations in surface wind stress. In such an event, turbid surface water would accumulate along lines of convergence and relatively clear subsurface water would be exposed at lines of divergence. The resultant turbidity pattern would be sensed in MSS bands 4 and 5 but not in bands 6 and 7 unless corresponding variations in sea surface roughness occurred also. Further, the formation of linear convection cells along converging and diverging lines is unlikely unless wind undulations remain stationary, i.e., standing waves exist in the wind field. It is not possible to determine if the undulations are stationary or progressive unless ERTS images taken in close temporal sequence are examined. Unfortunately, the nature of the ERTS-1 experiment precludes this method of verification. Nevertheless, the existence of surface roughening by wind field banding is supported strongly by the presence of the same pattern in imagery from all MSS bands. This fact makes it unlikely that the bands represent internal waves, particularly since the wave lengths are several kilometers long and the bands persist in water less than 30 m deep.

Imagery of this scene shows the extent of sand dunes along the north west coast and of kelp beds in the vicinity of Santa Barbara.

<u>4 April 1973</u>

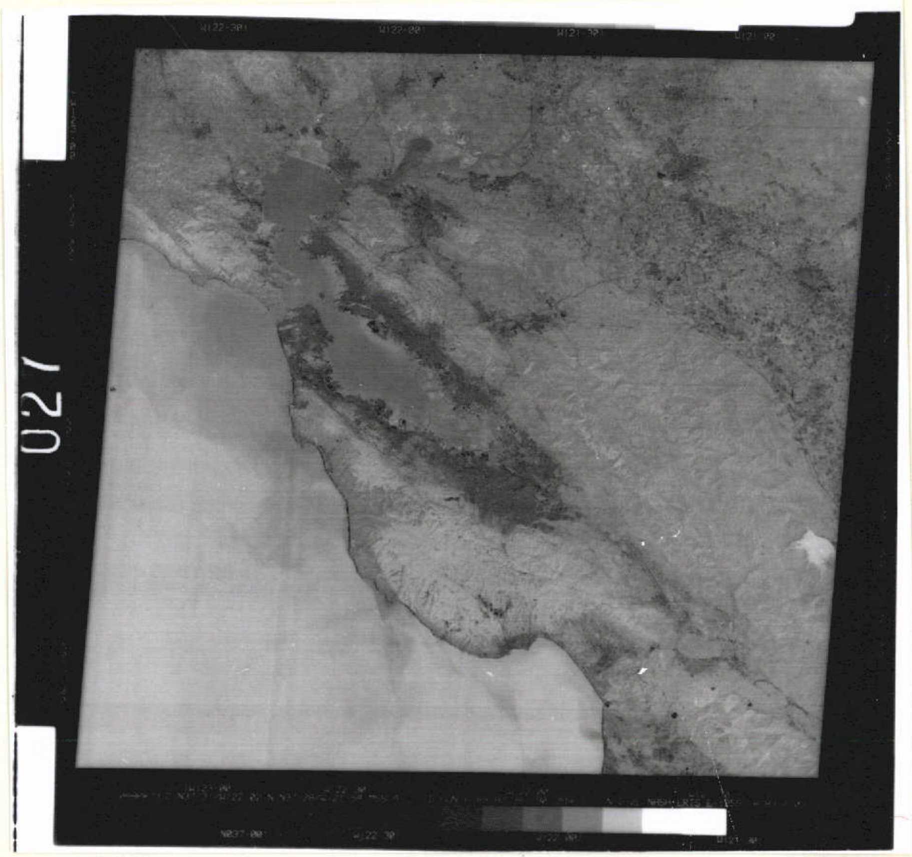
Scene 1255-18183 Monterey Bay

This scene was obtained during a tide flooding from -015 feet to 4.3 feet. The wind was calm and the air clear and mild (65°F). No clouds were visible and the visibility was unlimited. The sea ran from the west with low (2-3 feet) waves having about an 8 second period. The surface water temperature was 53°F. The regional weather was as follows:

High pressure cells existed over Idaho and 300 miles west of Oregon. An inverted trough off the entire California Coast produced a weak offshore pressure gradient over Monterey Bay. The wind was variable 3-5 knots with relatively flat sea surface conditions. A near cloudless sky produced unrestricted visibility over the entire region. No precipitation fell in the Monterey Bay area during the previous four days.

ERTS-1 photo imagery of this scene (Figure 44) is free of wind roughening effects with the area of Monterey Bay. About 50 miles northeast of the Bay, the water appears abruptly lighter in MSS band 7 photo imagery. Apparently stronger winds blew offshore.

A distinct turbidity pattern within the Bay appears on MSS bands 4 and 5 imagery and the band 4 density slice map (Figure 45).



BAND 4

BAND 5

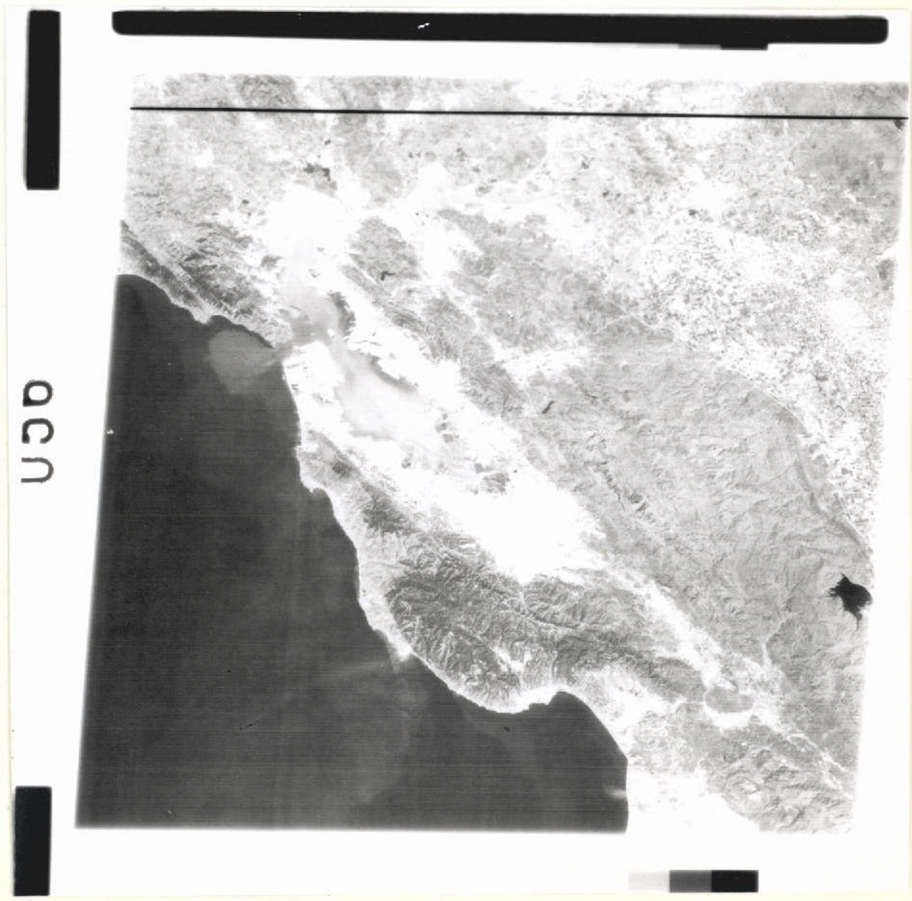
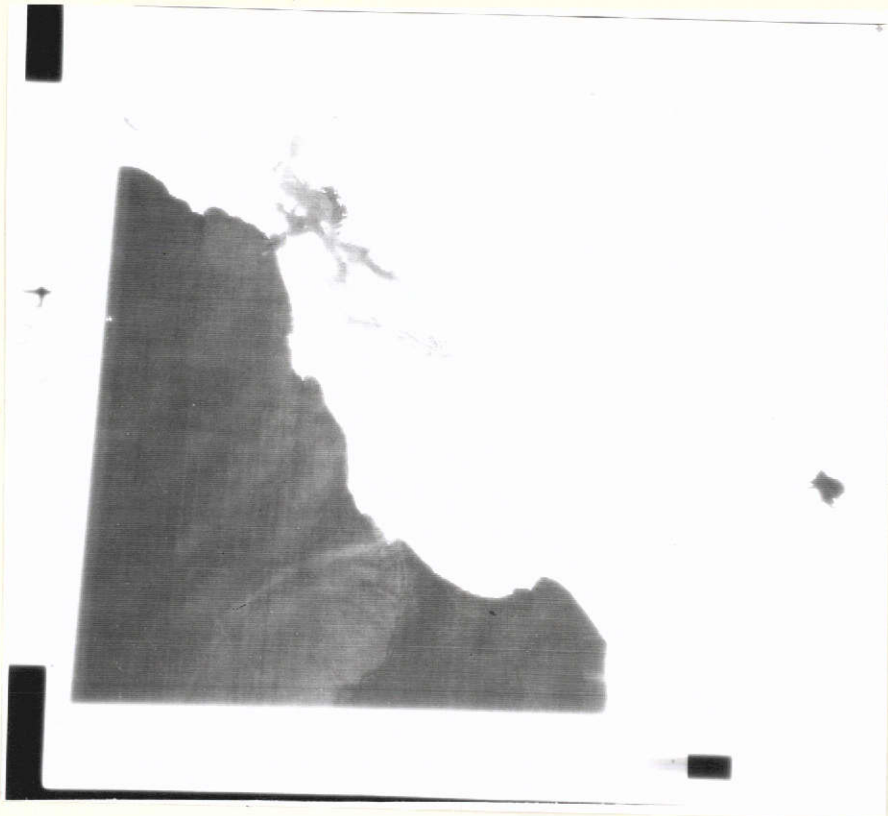


Figure 44a

ERTS-1 PRINT OF 70MM NEGATIVES (BAND 4 POSITIVE PRINTED)
MONTEREY BAY
4 APRIL 1973, BANDS 4-5

BAND 6



BAND 7

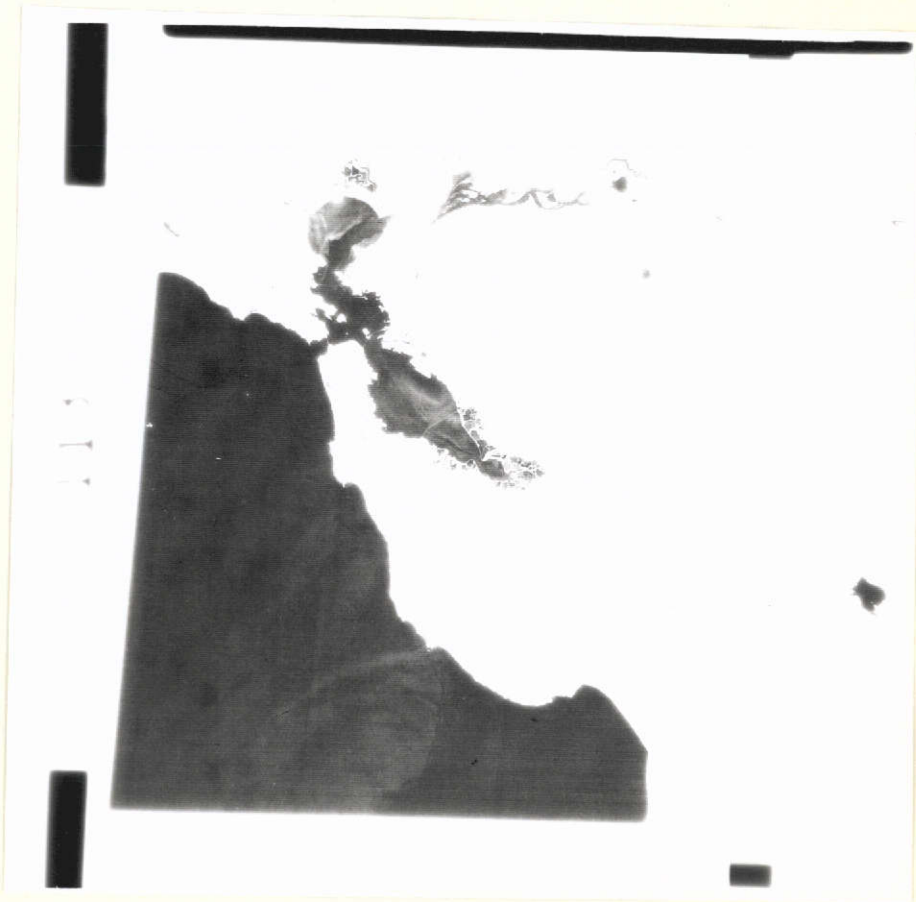


Figure 44b

ERTS-1 PRINT OF 70MM NEGATIVES
MONTEREY BAY
4 APRIL 1973, BANDS 6-7

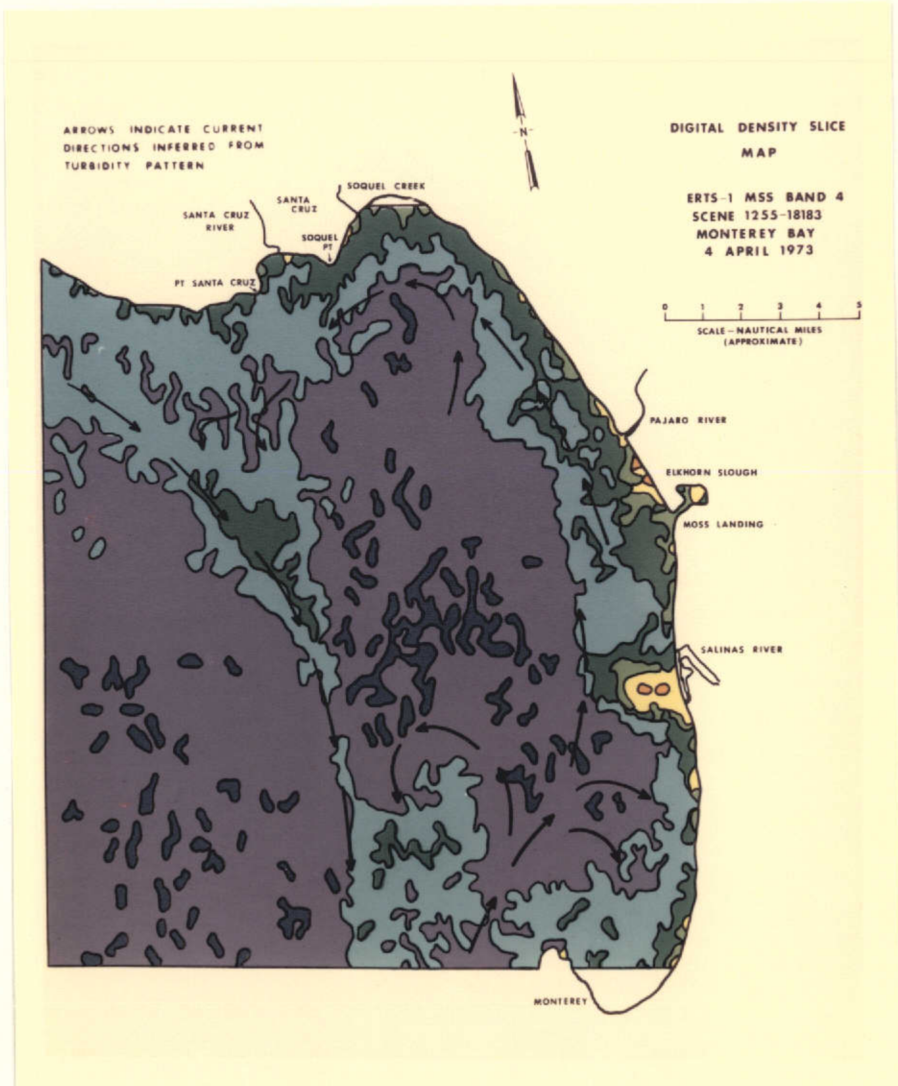


Figure 45

DIGITAL DENSITY SLICE MAP
PREPARED FROM ERTS CCT
PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

The pattern suggests the upwelling of relatively clear water over the Monterey Submarine Canyon in the central part of Monterey Bay. Plumes of sediment-laden water lie close to shore and extend across the mouth of the Bay from Point Santa Cruz southwestward. The source of the sediments is the coastal sector including the promontories: Pigeon Point, Franklin Point and Point Ano Nuevo. Sediments in the plume flowing out of the Golden Gate move southward and pass seaward of the Bay mouth plume.

Small plumes extend from Elkhorn Slough and the mouth of the Salinas River. They are deflected northward along the shore in response to a northward current in those areas. The pattern of turbidity in the north half of the Bay is interpreted to represent a counter-clockwise gyre maintained by the entrainment of water in the current carrying the suspended sediment plume southward from Point Santa Cruz. This gyre carries turbid water into Soquel Cove along the coast and relatively clear water from the northern mid-Bay is moved westward past Point Santa Cruz.

In the south half of the Bay a northward current flows past Point Pinos introducing relatively clear water between Point Pinos and the Salinas River plume. This current keeps Monterey Cove relatively free of turbid water and sweeps water from the east side of the Bay mouth plume toward the center of the Bay. There is some evidence for a flow from the center of the Bay southward in response to entrainment in the Bay mouth plume. Tidal influence upon surface circulation appears to have produced the radiance variations recorded in the northern half of the Bay mouth plume. It is separated from coastal water by a band of relatively clear water; each represents a pulsation in the movement of surface currents caused by the tide.

There is a possibility that the turbidity is partly due to plankton inasmuch as the turbidity pattern appears in MSS band 5 imagery to be considerably subdued. An exception to this is the suspended sediment plume off the Salinas River which is quite pronounced in MSS band 5 photo imagery.

<u>15 June 1973</u>

Scene 1327-18180 Monterey Bay

No imagery or CCT data was supplied to OSI by NDPF. The original tapes of this scene bore excessive noise to the extent that they could not be processed.

<u>3 July 1973</u>

Scene 1345-18174 Monterey Bay

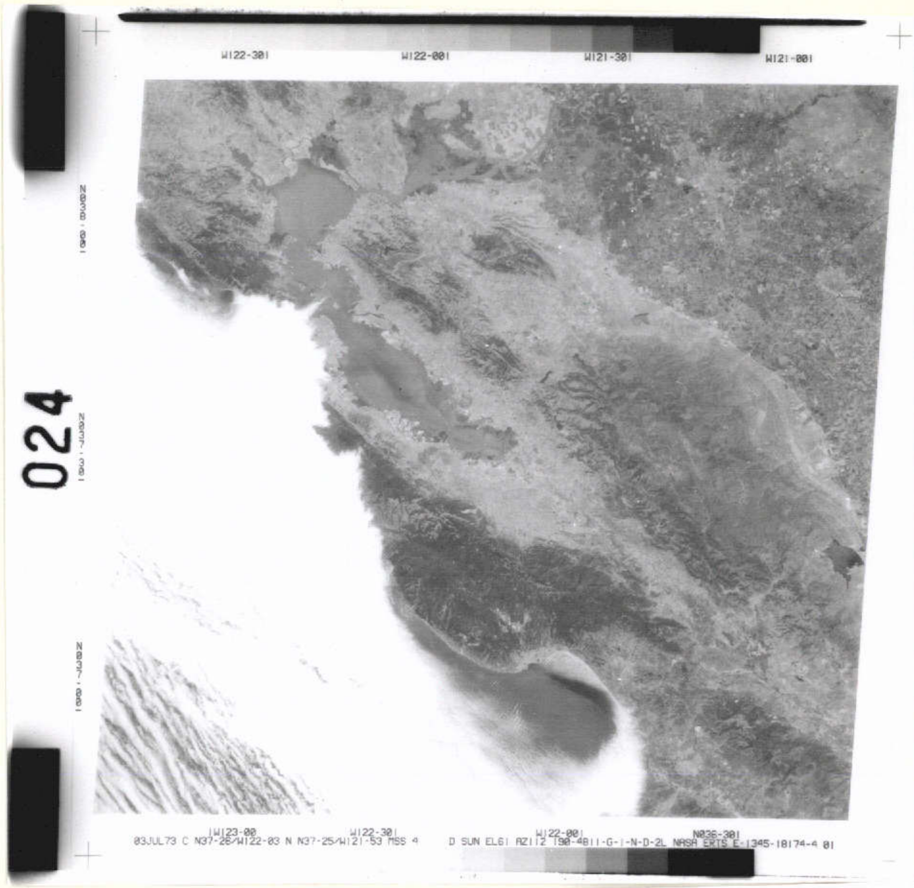
This scene was obtained at mid-flood tide running from a low of -1.0 feet to a high of 4.9 feet. The wind was light (4 mph) and variable at the time of the ERTS-1 overflight but strong (25 mph) westerly winds blew by noon. The air was cool (60°F) and dense fog covered most of the Bay but it cleared rapidly. At noon the visibility was unlimited but at the time of the ERTS-1 overflight only a portion of the Bay had become free of fog and clouds. Low waves 1-2 feet high with periods of 8-10 seconds moved from the southwest. The regional weather conditions were as follows.

A week low pressure system over high plateaus inland and high pressure offshore produced weak onshore pressure gradient along California Coast. Dissipating fog and scattered stratus produced cloudiness with a visibility of 1-3 miles. Wind and sea were nearly calm throughout the region. No recent precipitation fell within the area.

ERTS-1 imagery (Figure 46) shows Monterey Bay all but obscured by cloud cover. A part of the northern half of the Bay between Point Santa Cruz and Elkhorn Slough is visible in the photo imagery and the density slice map (Figure 47) prepared from CCT data. The entire coastline except for a small section near Santa Cruz was covered by fog and clouds. The coastline of the northern half of the Bay is discernable in MSS band 7 photo imagery. Band 7 shows dense clouds offshore and in southern Monterey Bay and fog in Soquel Cove. From Point Santa Cruz southeastward toward Elkhorn Slough a band 5 miles wide of wind-roughened water is visible. A series of (high?) linear clouds appear over this water in the northern half of the Bay mouth. The clouds are oriented northeast-southeast and are normal to the lineation in the (lower?) clouds offshore. A narrower (2 mile) band of calm (dark) water extending southeastward from Santa Cruz lies in abrupt contact with offshore rough water. The calm water appears to lie in the lee of the mountains to the north and probably extends to shore under the fog in Soquel Cove.

The density slice map (Figure 47) prepared from MSS band 4 CCT shows variation in radiance within the band of dark water southeast of Santa Cruz. The position of a more turbid mass of water close to Elkhorn Slough suggests that a tidal plume carrying suspended sediments issued from the slough. The absence of this feature on MSS band 5 photo imagery raises the possibility that the turbidity was caused by phytoplankton, however. The high degree of cloud cover precludes further interpretation of this scene.

BAND 4



BAND 5

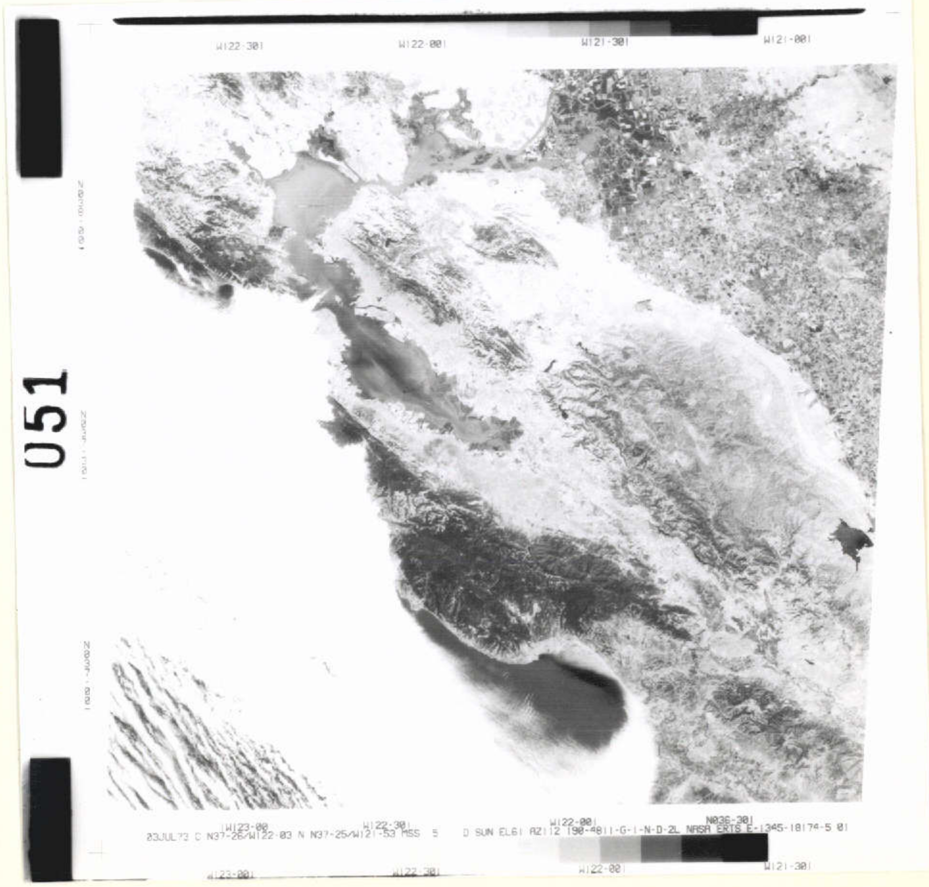
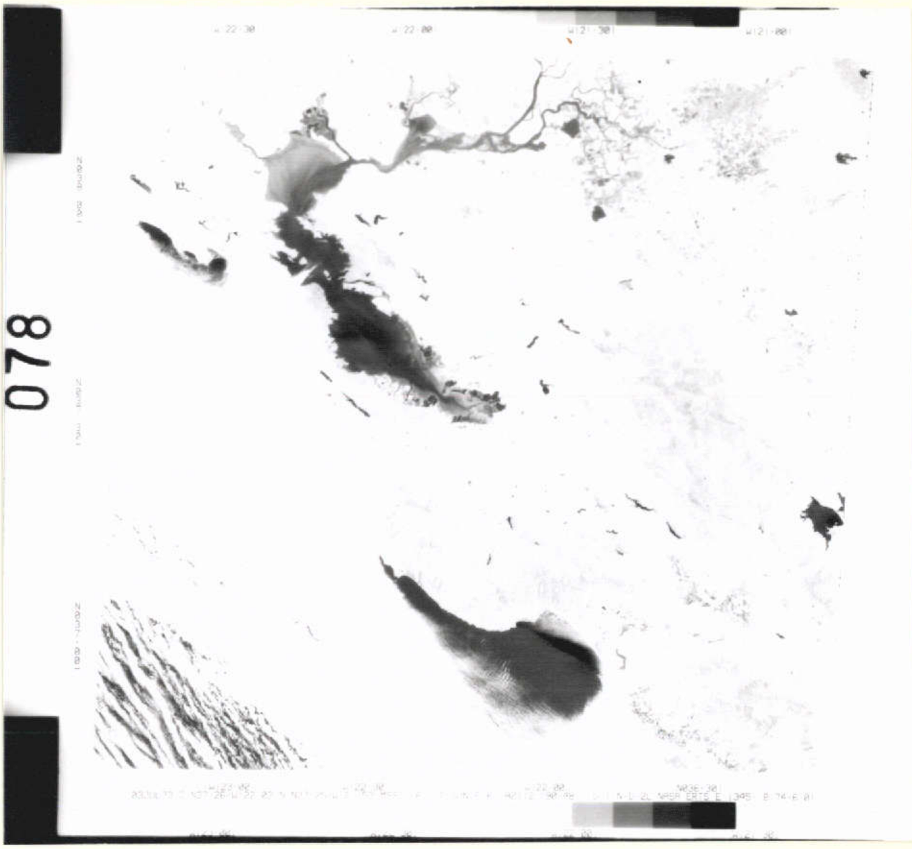


Figure 46a

ERTS-1 PRINT OF 70MM NEGATIVES
MONTEREY BAY
3 JULY 1973, BANDS 4-5



BAND 6

BAND 7

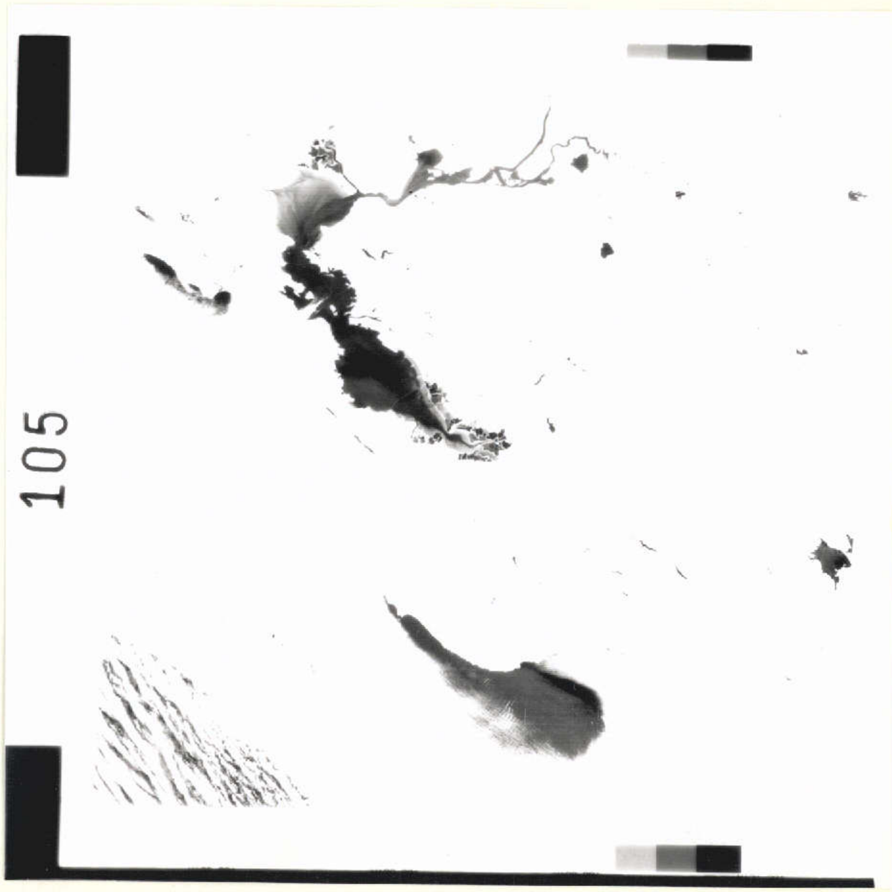


Figure 46b

ERTS-1 PRINT OF 70MM NEGATIVES
MONTEREY BAY
3 JULY 1973, BANDS 6-7

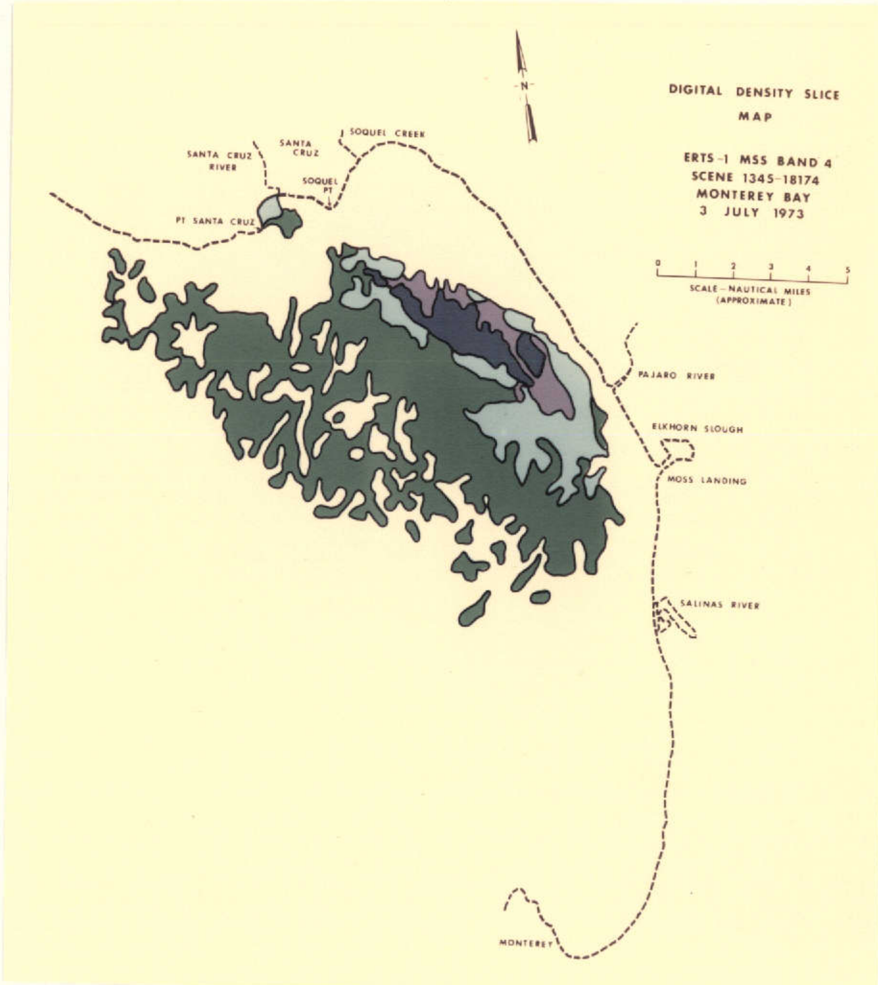


Figure 47

DIGITAL DENSITY SLICE MAP

PREPARED FROM ERTS CCT

PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

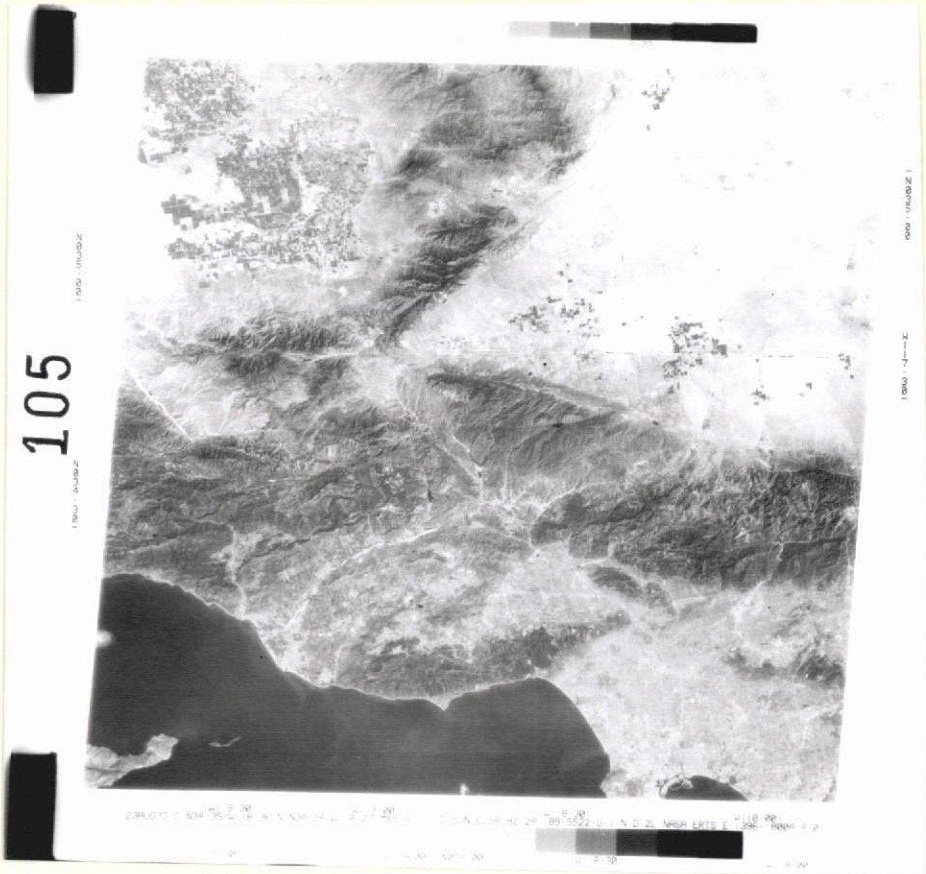
23 August 1973

Scene 1396-18004 Santa Monica Bay

This scene was obtained at low slack water that persisted for the previous 4 hours; actually the tide level dropped one foot in that interval. Light winds blew from southwest at 8 mph max. The air was warm (68°F) and clear with only occasional small clouds over the sea. Waves 3-4 feet high with an 8 second period moved from the southwest. Water temperature ranged from 18 to 20°C. The regional weather was as follows:

An upper level trough was situated off the west coast of the U. S. and a Santa Catalina low was centered between Santa Monica Bay and San Nicolas Island setting up a weak offshore pressure gradient over the Bay. Wind and seas were nearly calm. Westerly swells of 2-4 feet and with periods 8-10 seconds ran over the deep water of the Bay. West of the Santa Catalina low, the pressure gradient increased rapidly with NW winds 20 knots gusting to 25 knots at San Nicolas Island (see scene 1396-18010 just to the south of Santa Monica Bay). Local seas were estimated 6-8 feet from the NW in the swell 4-6 feet from the WNW, period 6-8 seconds. No precipitation fell in the week preceeding the ERTS-1 overflight.

ERTS-1 photo imagery (Figure 48) is free of wind roughening effects and only two small cloud areas are visible over the water. MSS band 7 photo imagery shows a vague lightening of the water surface east of the eastern tip of Santa Cruz Island. It is possible that this is produced by a wave chop associated with a convergence of surface water moving on either side of the island. All other MSS bands show this feature; bands 4, 5, and 6 show, in addition, a large area of darker water lying south of Santa Cruz and Anacapa Islands. The darker water is separated from lighter, more turbid water of the



BAND 4

BAND 5

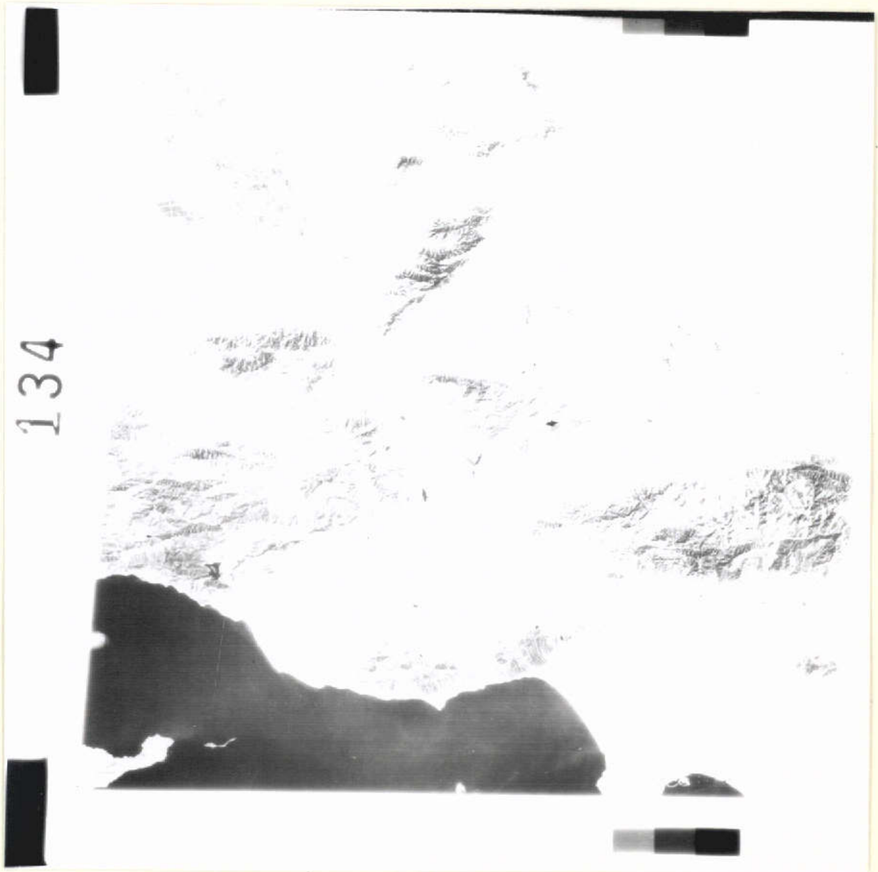
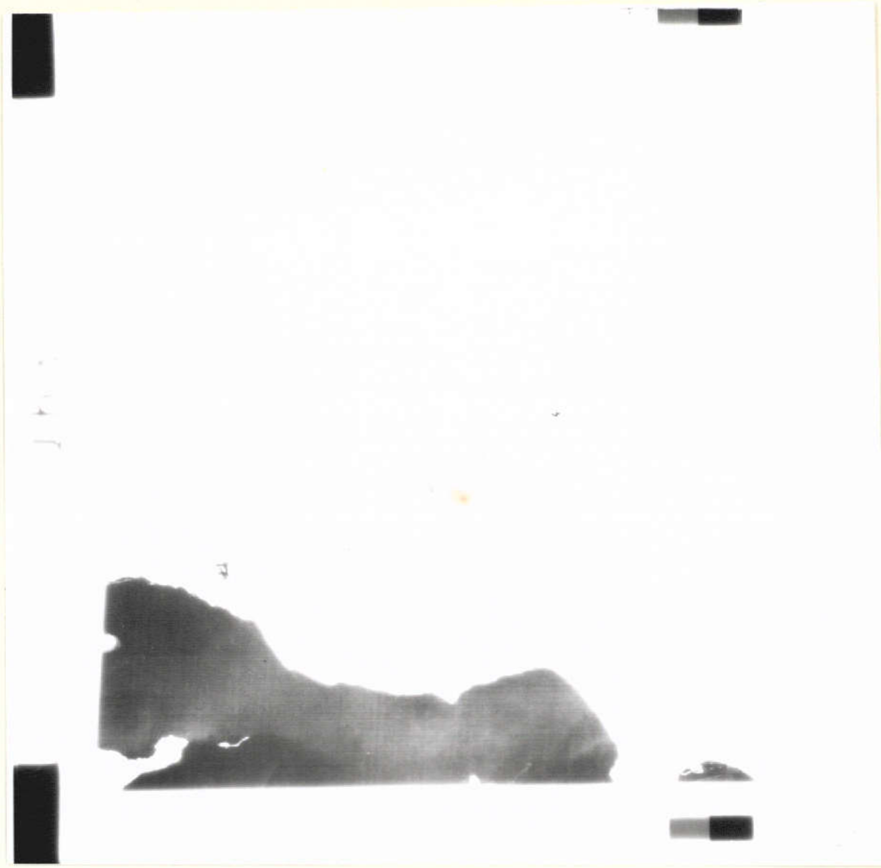


Figure 48a

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA MONICA BAY
23 AUGUST 1973, BANDS 4-5



BAND 6

BAND 7

Figure 48b

ERTS-1 PRINT OF 70MM NEGATIVES
SANTA MONICA BAY
23 AUGUST 1973, BANDS 6-7

Santa Barbara Channel by a sharp line of demarcation extending between those islands and east, then south, from the eastern tip of Anacapa Island. It appears that surface water from the channel has moved eastward, around the Santa Monica mountains promontory, into Santa Monica Bay. The turbid coastal water plume sweeping from the Santa Clara River delta area southeastward toward Santa Monica Bay and a similar plume moving eastward around Point Dume verify this major water motion.

MSS band 4 photo imagery and the digital density slice map (Figure 49) prepared from it reveal that turbid water moving into Santa Monica Bay from the west fills the northern half of the Bay. Turbid plumes are visible along the shore of the Bay, east of Malibu Point, at the mouth of Marina Del Rey and off Redondo Beach. These plumes are likely derived by wave attack on local beaches and removed offshore by tidal action. The plume at Marina del Rey is cleared by a narrow channel of less turbid water that might represent an outflow of quieter, warmer, but less turbid water from the Marina which has input only from the tides and minor runoff from Ballona Creek. The plume off Redondo Beach is rather wide (1 mile) and extends directly offshore 6 miles. It appears to be caused by warm turbid water being discharged from coolant outfalls of the large steam generating electrical plant located in Redondo Beach.

The dark water southwest of Palos Verdes Point may be formed by upwelling or it may be residual water that has not been intruded by turbid water from the west. It is not possible to decide which.

MSS band 7 photo imagery shows kelp beds along the shore between Point Dume and Santa Barbara and artificial oil drilling islands

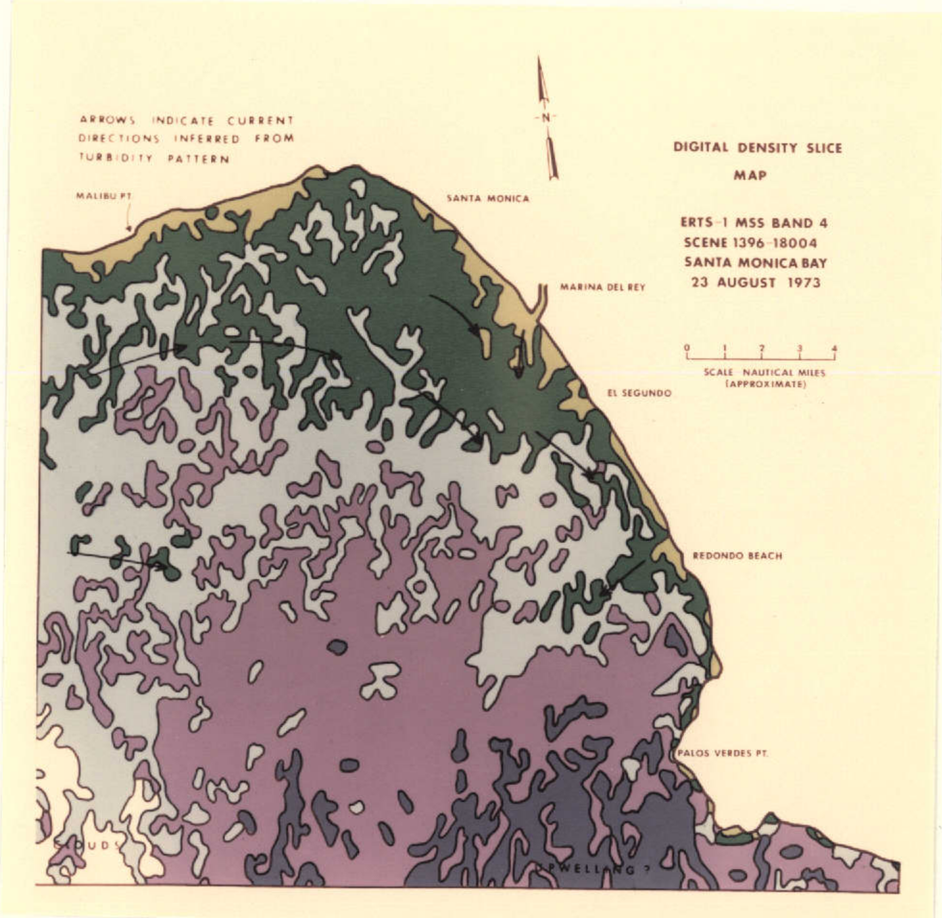


Figure 49

DIGITAL DENSITY SLICE MAP
PREPARED FROM ERTS CCT
PRINTED OUTPUT

Note: Lowest radiance level is rendered dark blue and higher levels are rendered chromatically toward red.

in Long Beach Harbor, just east of Palos Verdes. No effects of oil pollution can be discerned in any of the ERTS-1 imagery.

24 August 1973

Scene 1397-18062 Santa Barbara Channel

This scene was obtained during a tide ebbing from 4.0 feet to 2.5 feet. Easterly winds blew at about 6 miles per hour. The sea ran 4-6 feet high with a period of about 8 seconds. Waves moved from the west down the Santa Barbara Channel. The air was warm (68°F) and clear. Visibility was inimpaired and only one cloud lying 1/3 of the way from Santa Barbara to Santa Cruz Island was visible over the cruise area. Water temperature was warm (18.5°C); this value is near the maximum occurring at this time each year. The regional weather conditions were as follows:

The western U. S. upper level trough had moved inland over Nevada with its southern portion just east of the Santa Barbara Channel. A weak offshore pressure gradient over inner (northern half) channel graded into a moderate onshore gradient in the outer (southern half) channel area. Winds in the inner channel were variable at 5-10 knots; they shifted to northwesterly at 15-25 knots with higher gusts in outer channel areas. Sea wave heights were 1-2 feet over inner channel and 2-4 feet from northwest in mid-channel. Westerly swell waves ran 4-6 feet inshore and 6-8 feet in mid-channel. No precipitation fell in the area in the week preceeding the ERTS-1 overflight.

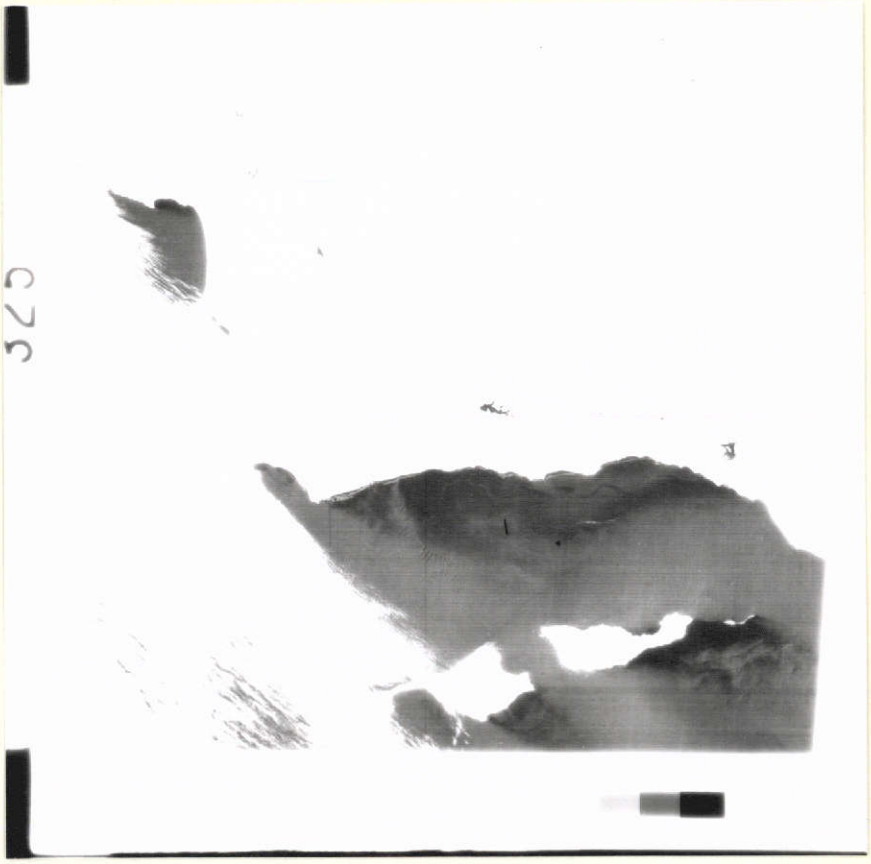
ERTS-1 photo imagery (Figure 50) shows the effects of high winds over the outer and western portions of the Santa Barbara Channel. Roughened surface water registering as light radiance values appears in all MSS bands. A sharp line of demarcation between smooth water to the north and rough water to the south extends

BAND 4

BAND 5

Figure 50a

ERTS-1 PRINTS OF 70MM NEGATIVES (BAND 4 POSITIVE PRINTED)
SANTA BARBARA CHANNEL
24 AUGUST 1973, BANDS 4-5



BAND 6

BAND 7

Figure 50b
ERTS-1 PRINTS OF 70MM NEGATIVES
SANTA BARBARA CHANNEL
24 AUGUST 1973, BANDS 6-7

from Point Conception to the center of the channel, then eastward to land at the mouth of the Ventura River. A dramatic confirmation of the importance of wind roughening of surface water is seen by the plume of light radiance values extending southward from the mouth of Gaviota Canyon which lies 15 miles east of Point Conception. High winds are frequently channeled through Gaviota Pass (max elevation 200 feet) particularly when northwest winds impinge upon the Santa Ynez mountains (mean elevation 2500 ft with peaks of 4000 ft). It is not hard to visualize the jet of high winds streaming from the pass and out over the channel setting up a chop on the water surface underneath. The Gaviota Pass jet joins the stream of air moving southeastward past Point Conception. Downstream from this junction is a regular series of linear streaks of dark water oriented normal to the flow direction and spaced about 3 miles apart. These appear to be related to undulations in the wind field and are identical to features noted in the 2 April 1973 scene (1253-18075) of this area.

A wind shadow southeast of Santa Rosa Island conforms to the pattern of flow in the western half of the Santa Barbara Channel. There is evidence in MSS bands 6 and 7 negative photo imagery that a counterclockwise eddy existed in the lee of Santa Rosa Island under the prevailing wind conditions.

The curvature of the wind field to an easterly orientation is confirmed by wind shadows extending east of Santa Cruz Island. There is some irregularity in the wind shadow pattern but no gyre or regular perturbations are discernable. Taken as a whole the pattern of wind roughening depicts strikingly the entire field of surface air motion in the channel and affords an excellent tool for mapping wind distributions, an important part of synoptic meteorology.

Offshore from Coal Oil Point and Santa Barbara Point there is somewhat linear array of 3 elongate, irregular patches, each 1 mile wide and 3 miles long of dark water barely visible in MSS band 7 imagery. The array extends eastward from a point just offshore of Coal Oil Point. It is possible that the dark water is produced by the smoothing effect of oil slicks from the natural underwater seeps in this area. The patches appear slightly darker than the smooth water in the lee of the Santa Ynez mountains. MSS band 5 photo imagery (band 4 is not available) shows a vague area close to shore along the coast from Coal Oil Point to the Santa Clara River delta that is probably by wave and tidal action. An easterly current appears to be carrying a diffuse plume southeastward from the Santa Clara River delta. The kelp beds along the coast in this scene are quite visible in MSS bands 6 and 7.

No digital density slice map was prepared for this scene as the CCT bears excessive noise and was not supplied by NDPF.

SUMMARY OF INTERPRETED FEATURES:

A system of photo interpretation was developed while examining ERTS-1 photo imagery; it is summarized in Table 13. It is apparent that the interpretation of oceanic features requires the examination and comparison of the image of the imagery of all MSS bands. In bands 4 and 5, film positive are to be used but in bands 6 and 7, the use of film negatives is recommended because the low radiance values from the ocean produce extremely dense film positives that fail to show much of the tonal detail present in the data. The use of Table 13 should be undertaken with the understanding that all indicated criteria must be met to make a successful interpretation and full cognizance must be taken of areal patterns in observed features, as these are often most diagnostic. One can recognize two broad classes of features in oceanic scenes. The first are

Table 13

INTERPRETATION OF ERTS-1 PHOTO IMAGERY

FEATURE	APPEARANCE IN MSS BANDS 4(+)	5(+)	6(-)	7(-)	CONFIRMATORY PATTERN
Shoreline	Shoreline somewhat diffuse			Maximum contrast at shore	Conformity w/ hydrographic charts
Clouds	Extremely white		Extremely dark against light sea		Presence of extreme densities in cloud shaped features in all bands. Conform to known patterns
Fog and Low Stratus	Light gray tones over large areas		Light gray tones over large area		Present in all bands
Sand on beaches and dunes, light colored rocks	Density much like clouds but on land as verified by band 7 image				Present in all bands conform to known patterns and oriented along shore. Dunes may show streaking shoreward. Beaches usually more narrow
Surface Wind Effects	Present but obscured by other features in many cases		Similar to band 7 but more subdued pattern	Light areas of quiet water distinguishable from dark areas of wind-roughened water. All in middle-gray tones	Present in all bands. Pattern conforms to wind motion around known promontories, peaks, islands, and windy canyons. Wind shadow in the lee of islands and calm water in lee shores are evident. May be parallel bands of alternating light and dark water occurring in rough-water areas or in wind shadows of islands.

Table 13
Continued
Page 2

FEATURE	APPEARANCE IN MSS BANDS 4(+)	5(+)	6(-)	7(-)	CONFIRMATORY PATTERN
Surface Wind Effects Continued					Bands are about 5 by 10 miles spaced 7 miles apart and do not refract like waves.
Oil Slicks	Vague light areas within light gray wind roughened areas. Extremely difficult to perceive.		Vague dark areas in wind roughened deep gray areas. More pronounced in band 7.		Present in all bands. Diffuse boundaries proximity to known oil seeps, spills, or offshore wells.
Internal Waves*	Visible in all bands but often obscured in band 4.				Occur in packets of short spaced bands (<1 mi). Packets separated by tidal events 12 hrs. apart. Probably not visible in wind-roughened areas. Show refraction on shelf and shoals.
Suspended Sediments	Light gray plumes and lobes often close to shore. Virtually the same intensity and extent in both bands 4 and 5.		Only extremely dense areas are faintly visible as light gray areas.	Not visible.	Proximity to shore and obvious sources at river mouths and coasts exposed to wave attack. May extend far offshore and show tidal modulation of boundaries. Boundaries usually sharp, close to shore but diffuse offshore. Show gyres in surface circulation.

Table 13
Continued
Page 3

FEATURE	APPEARANCE IN MSS BANDS 4(+)	5(+)	6(-)	7(-)	CONFIRMATORY PATTERN
Plankton Blooms	Light gray areas.	Faint darker gray area.	Not visible.		Pattern is irregular patches that bear no fixed relationship to coastal features.
Kelp Beds	Barely perceptable light gray bands near shore.	Vague gray bands near shore.	Deep gray against lighter ocean water.	Med. gray against very light ocean water.	Found in linear bands 8 1/4 mi. wide parallel to shore but separated from shore by 500 feet of water. Delineate submarine outcrops.
Outfalls	Light areas in both bands 4 and 5. Probably due to suspended material.		Not Visible.		Form as plumes resting on surface owing to their being relatively warm. Found at large municipal sewage outfalls and points of coolant discharge.
Tidal Flushing Plumes	Light areas in both bands 4 and 5 or dark areas contrasted against light areas of suspended sediments.		Not Visible.		Plumes and lobes extending from known estuaries and harbor entrances. Tidal plumes from estuaries will be light from suspended sediments and/or plankton. Harbors without inflowing stream drainage may show dark plumes of clear,warm water intruded into turbid offshore water.

* Not observed in this study but reported by Apel and Charnell, (1973)

specular reflectance features, i.e., features that reflect "white" solar radiation. These are clouds, fog, sand on beaches, and the extent of water roughening by waves generated by local winds. This class of features is visible in all bands of MSS imagery. The second class is related to turbidity and the presence of spectral reflectors such as kelp, in the surface water. These generally are not visible in MSS band 7 imagery.

The table deals only with relative radiance levels within a scene because photo processing varies gray scales from scene to scene and because the nature of the calibration of ERTS-1 video data precludes relating radiance to photo density conveniently.

Part 6

CORRELATION OF RADIANCE PROFILES AND OCEAN TRUTH DATA

A preliminary comparison of field data and ERTS radiance data indicated that correlations existed only where specular effects such as water surface roughening were absent. Specular effects are recognized in radiance profiles because each band produces almost the same signature where these effects, e.g., clouds and cloud shadows are present. An example of this effect appears in the radiance profiles in Figure A-11. Clouds create sharp spikes in the radiance profiles. These spikes are represented by gaps in the profiles because data are discarded where pixels contain radiance greater than level 6 in MSS band 7.

Specular effects were suppressed prior to the correlation of ground truth data and radiance data by removing a large part of the spectral components from the radiance signature in each band. The procedure consists of extracting regression lines of radiance values in bands 4, 5, and 6 on band 7 values and plotting the residuals. The SHARE program "POLYFT" was used for this purpose.

The results of correlating ground truth data with suppressed and unsuppressed radiance data are discussed on a scene-by-scene basis in the following paragraphs. An example of the nature of best correlations obtained is presented in Figure A-75.

25 February 1973

Scene 1217-18074 Santa Barbara Channel

Radiance profiles along the cruise track (Figure A-1) are presented in Figure A-12a. The gaps in the profiles represent extremely high radiances associated with clouds. The band 7 profile is flat, featureless, and contains quite low levels except between stations 3 to 7 where slightly higher ($\sim$1.0) values occurred. The suppressed radiance profiles (Figure A-12b) show that most of the variation in bands 4 and 5 is spectral. The profiles between stations 3 and 10 show decreasing radiance in crossing the Santa Barbara Channel from north to south. The radiances decrease a bit more along the south and east coast of Santa Cruz Island to a minimum radiance level of about 17 at station 16. There is a slight increase in radiance from station 16 to station 19 as the channel is crossed from south to north. The radiance profiles suggest the presence of turbid coastal water along the Santa Barbara coastline, clear water in mid-channel, and clearer water south of Santa Cruz Island.

Turbidity: The profile of turbidity values along the cruise track is presented in Figure A-13. The turbidity profile correlates strongly with the radiance profiles where clouds are absent. At stations 13 and 14, south of Santa Cruz Island, high ($\sim$1.0 FTU) values of turbidity were measured. These stations were obscured by clouds so a correlation between turbidity and radiance cannot be made there. Coastal water at station 1 had the highest turbidity, 2-5 FTU. Mid-channel water turbidity was about 0.2 FTU.

Secchi Disk: The profile of Secchi disk depths (Figure A-14) shows an excellent correlation with turbidity and with radiance. Coastal water and mid-channel water registered about 15 meters. The water at station 11 between Santa Rosa and Santa Cruz Islands was remarkably clear; the Secchi depth there was 20 meters. Similar water also existed at station 16 off the east end of Santa Cruz Island.

Suspended Particles: Profiles of the concentrations of non-living debris, chain diatoms, and dinoflagellates suspended in the water at stations along the cruise track are presented in Figure A-15. The correlation between the profile of debris and profiles of turbidity, Secchi depths, and radiance is excellent. The increased turbidity south of Santa Cruz Island apparently is caused by the presence of abundant suspended debris. Coastal water contains abundant diatoms as well as debris, as indicated by the high values at station 1. Dinoflagellates seem to be abundant only in relatively clear water as was encountered in mid-channel. The correlation between dinoflagellates and the other parameters discussed is fairly good, but inverse. The correlation of chain diatom concentrations was fair in comparison with the other parameters discussed. Low concentrations of diatoms were observed at all stations except 1, 2, and 4, near the Santa Barbara coast.

Water Color: The profile of water color values observed at stations along the cruise track is shown in Figure A-16. The numerical values are converted to color designations in Table 14.

Table 14

WATER COLOR DESIGNATIONS

Forel-Ule Numerical Value	Color
I - II	Blue
III - IV	Greenish-blue
V - VII	Bluish-green
VIII - X	Green
XI - XV	Greenish-yellow
XVI - XIX	Yellow
XX - XXII	Brown

The correlation between water color and other parameters, including radiance, is excellent. Coastal water was greenish-yellow and mid-channel water was greenish blue. The water south of Santa Cruz Island was bluish-green.

Air-Nephelometer: The profile of concentrations of aerosols, (Figure A-17) measured along the cruise track, is flat and featureless and shows no correlation with radiance or with any other of the parameters measured.

15 March 1973

Scene 1235-18075 Santa Barbara Channel

Radiance profiles along the cruise track (Figure A-2) are presented in Figure A-18a. Suppressed radiance profiles of bands 4, 5, and 6 data are presented in Figure A-18b. The band 7 radiance profile is flat and featureless from stations 1 to 12, becoming somewhat irregular at station 13. These features are interpreted to represent a lack of specular effects between Stations 1 and 12 and mild specular effects showing regular variations between stations 12 and 13. From stations 13 to 15, there are regular undulations in the profile that are visible, albeit subdued, in the band 4 profile. They are considerably more accentuated in band 6, and in band 5 the undulations are visible between stations 13 and 15, but they are inverted. The location of specular effects coincides with the higher velocity winds that blew south of the Channel Islands. Non-specular effects consist mainly of the sharp drop in band 4 radiance from station 1 to midway between stations 2 and 3 and a broad peak in band 4 radiance at station 16. These effects coincide with the location of turbid coastal water off Santa Barbara in the first case, and off the east coast of Santa Cruz Island in the second.

Band 4 radiance levels about about 16.6 represent turbid coastal water. The turbid streak of water between Santa Rosa and Santa Cruz Islands is discernable on the band 4 profile as a low, broad peak between stations 8 and 9.

The band 5 profile shows departures from band 4 throughout, indicating that the spectral composition of the radiance observed along the cruise track varies. The peak in band 5 radiance levels between stations 1 and 2 coincides with high levels of radiance in band 4. This is interpreted as representing high concentrations of suspended sediment in nearshore water. Elsewhere, the presence of plankton or colored debris can be suspected.

The band 6 radiance profile is roughly congruent with band 7. The increasing trend in band 6 levels between stations 10 and 12 is an exception with no obvious explanation.

Turbidity: The correlation of turbidity values (Figure A-19) and band 4 radiance level profile is quite good. Turbidity values from 0.65 to 1.20 FTU represent turbid coastal water. Offshore water samples yielded turbidity values from 0.20 to 0.65 FTU. The turbidity in the Santa Barbara Channel is more irregular along the west leg of the cruise track than along the east leg.

Secchi Depth: The profile of Secchi depth measured along the cruise track is presented in Figure A-20. It correlates quite well with the turbidity profile and the radiance profiles. Turbid water Secchi depths are less than 5 meters; Secchi depths reach 12 meters in clear water in mid-channel.

Suspended Particles: Profiles of the concentrations of non-living debris, chain diatoms, and dinoflagellates are presented in Figure A-21. The non-living debris profile correlates best with the radiance and turbidity profiles. Unusually high concentrations of chain diatoms were observed in mid-channel; they seem to bear a vague correlation with a broad increase in band 5 radiance between stations 5 and 10.

Water Color: The profile of water colors observed along the cruise track is presented in Figure A-22. The correlation of color and radiance is vague. There is a slightly greener cast to the turbid water at the Santa Barbara coastline. No marked contrasts in color were observed.

Temperature: The profile of surface water temperatures (Figure A-23) shows only a diurnal cycle that does not correlate with radiance or with the other parameters discussed.

17 March 1973

Scene 1237-18183 Monterey Bay

Radiance profiles along the cruise track (Figure A-3) are presented in Figure A-24a. The band 7 profile shows considerable irregularity, gaps (deliberately omitted cloud spikes in band 7 radiance) and generally high radiance levels (2-5). All profiles show congruency, signifying specular reflectance, and departures from congruency are evident in bands 4 and 5 indicating the presence of spectral effects. Spectral effects are isolated in the suppressed profiles shown in Figure A-24b. Band 6 is seen to contain a very small spectral component. Cloud peaks are not suppressed completely because of the regression of band 4 levels on band 7 levels is not linear at high radiance. Band 4 radiance contains the largest spectral component.

Radiance levels in the mid-Bay area (stations 1 to 6) are low. Stations inshore near Moss Landing (6 to 12) have higher radiance levels corresponding to turbid coastal water. Radiance levels from stations 13 to 16 increase from about 25 to 29 as the northern coast of the Bay is approached and more turbid water is encountered.

Turbidity: The correlation between the profile of turbidity (Figure A-25) and the profiles of radiance is excellent. Turbidity ranges from about 1.0 FTU in mid-Bay clear water to over 4 FTU in the suspended sediment plume off the Salinas River.

Secchi Depth: The profile of Secchi depths (Figure A-26) recorded along the cruise track correlates with the profiles of turbidity and radiance. The depth ranges from about 7 meters in mid-Bay to less than 1 meter in turbid coastal water.

Suspended Particles: Profiles of the concentrations of non-living debris, dinoflagellates, and chain diatoms are presented in Figure A-27. The abrupt change in concentration of non-living debris from over 10×10^6 per liter at station 12 to 1×10^6 per liter at station 13 correlates with the sudden drop in radiance and turbidity in passing out of the Salinas River plume. High concentrations of debris at stations 1 to 3 do not correlate with the lower levels of radiance there, however. One can only postulate that spurious, small patches of turbid water were sampled. A somewhat larger patch of such turbid water that was not sampled is probably responsible for the spike in band 4 and 5 radiance between stations 3 and 4. Concentrations of chain diatoms and of dinoflagellates were generally low and do not correlate with radiance.

Water Color: The profile of water color (Figure A-28) measured along the cruise track correlates quite well with radiance and turbidity, particularly with respect to delineating the Salinas River plume. Mid-Bay water appeared bluish-green and the plume appeared yellowish-green. The water of stations 13 to 17 was greenish-blue. This deeper hue correlates with the lower debris concentrations measured at those stations.

Air Nephelometer: The concentration of aerosols was monitored on this cruise to determine if this parameter correlated with radiance levels along the cruise track. The profile (Figure A-29) shows that low unvarying concentrations prevailed and no correlation exists.

Temperatures: The profile of surface water temperature (Figure A-30) shows only a slight diurnal warming trend (less than 1°C). No correlation with radiance exists.

1 April 1973

Scene 1252-18021 Santa Monica Bay

Radiance profiles along the cruise track (Figure A-4) are presented in Figure A-31a. The band 7 profile shows irregularities that are not congruent with the other MSS band profiles although profiles of bands 4, 5, and 6 are roughly congruent. This suggests that some specular effects are present but they hardly mask the spectral effects of water turbidity at all.

The suppressed profiles (Figure A-31b) show the spectral radiance in bands 4, 5, and 6 that remains after removal of the specular component indicated by the band 7 profile. The band 4 spectral residual profile shows high values at station 2 and lower values at stations 3 and 4. At station 1 an intermediate value is recorded. This value corresponds with relatively clear water off the mouth of Marina del Rey which might be a tidal plume. Station 2 was located in an area of turbid coastal water as were stations 3 and 4 but apparently the water toward the Palos Verdes peninsula was clearer.

Turbidity: The turbidity profile (Figure A-32) verifies this supposition. It correlates strongly with both suppressed and unsuppressed bands 4 and 5 profiles.

Secchi Depth: This profile (Figure A-33) does not correlate as well as the turbidity profile but a trend toward clearer water south of Marina del Rey is indicated.

Suspended Particles: The profile of non-living debris concentrations (Figure A-34) also correlates well with the radiance and turbidity and Secchi depth profiles. Diatom concentrations show a similar correlation but in an inverse sense.

Water Color: The color of the water (Figure A-35) is uniformly blue along the cruise track and does not correlate with radiance or any other measured parameters.

Temperature: The profile of surface water temperatures (Figure A-36) shows an abrupt lowering of temperatures at station 4 suggesting that the clear water at that point is about 1°C cooler than the coastal water nearer Marina del Rey. However, insufficient stations could be occupied to establish if the variation in the profile is spurious or real.

2 April 1973

Scene 1253-18057 Santa Barbara Channel

Radiance profiles along the cruise track (Figure A-5) are presented in Figure A-37a. The band 7 radiance profile shows general trends and abrupt changes in trend but radiances are restricted to levels between 0 and 3. There are no spikes (represented as omitted data for clarity in other scenes) because the scene is free of clouds. Profiles of MSS bands 4, 5, and 6 are somewhat congruent and show changes in trend similar to those in the band 2 profile; the abrupt increase in radiance between stations 15 and 16 occurs in all bands. The congruence gives evidence of the presence of specular effects so a set of suppressed profiles were prepared (Figure A-37b). The departure of the profiles of bands 4, 5, and 6 from band 7 shows the transition from turbid coastal water at stations 1 and 2. Clearer water in mid-Channel (stations 3 to 8) is defined by lower radiance levels after the specular effects of wind from stations 5 to 8 are removed. Between Santa Rosa and Santa Cruz Islands (stations 10 to 12) the increased radiance is in all bands and probably corresponds to rough water in the pass. Lower radiances occurred along the southern shore of Santa Cruz Island. The band 7 profile does not exhibit the degree of change of radiance that the other bands do. This suggests that the spectral effect of clearer ocean water might predominate in this area. A wind shadow effect could be responsible for the specular component indicated in band 7.

The profiles of all bands show an abrupt rise in radiance between stations 15 and 16 at the east end of Santa Cruz Island. The sharp increase in specular reflection probably marks the emergence from the wind shadow in the lee of Santa Cruz Island. From station 16 on, the profiles show a congruent decrease in radiance levels. From stations 21 to 23 the radiance levels decrease more rapidly. The suppressed profiles show some spectural variation in this area but it appears that a general decrease in specular reflectance from south to north across the Santa Barbara Channel accounts for the shape of the radiance profiles. A sharp spike in band 4 radiance occurs near station 19. This might have been caused by a ship's wake. The major shipping lane through the Santa Barbara Channel passes near this point. The spikes in the band 6 profile are difficult to explain. They occur in no discernible pattern except that they are not present south of Santa Cruz Island.

Turbidity: The correlation between turbidity and radiance is poor owing to specular effects in the radiance profile. However, the turbidity profile (Figure A-38) shows a slight decrease from levels of about 1.0 FTU in coastal water to about 0.5 FTU in open channel water along the western leg of the cruise track. No difference in turbidity was seen in the profile along the south side of Santa Cruz Island. The open channel water along the east leg of the cruise track had slightly higher turbidity levels (0.8 to 0.9 FTU) that show little correlation with the radiance profiles. The suppressed radiance profile (Figure A-37b) indicates a general correlation between turbidity and the spectral portion of MSS radiance. The suppressed profile along the east leg of the cruise track is quite irregular in contrast to the west leg portion. Maximum irregularity occurs south of Santa Cruz Island. The irregularity suggests the presence of non-uniform, strong spectral effects on the west leg and south of Santa Cruz Island.

Secchi Depth: The profile of Secchi depths (Figure A-39) shows a slight variation between values of 5 to 10 meters. Low values (turbid water) characterize the coastal water just off Santa Barbara and the water at the northern half of the east leg of the cruise track. Higher values were obtained in water from mid-Channel and near Santa Cruz Island. There is only a vague correlation between the profile of Secchi depth and the profiles of turbidity and radiance.

Suspended Particles: Profiles of the concentrations of non-living debris and of chain diatoms along the cruise track are presented in Figure A-40. The concentrations of non-living debris were quite uniformly low except at station 1. This suggests that relatively clean water existed throughout the area exclusive of the Santa Barbara coast. Little correlation is seen between the debris profile and the radiance profile.

Chain diatom concentrations varied between 2 to 8 X 10^6 per liter and do not seem to correlate with radiance levels.

Water Color: The water color (Figure A-41) appeared uniformly greenish-blue and does not correlate with radiance. The uniform appearance of the water, the low and uniform concentrations of suspended particles and uniformity of low turbidity values all confirm the conclusion that the radiance profiles display specular variations rather than spectral variations along the cruise track.

Temperature: The profile of temperature along the cruise track (Figure A-42) shows a general warming to about station 13 then a general cooling. This is probably a diurnal effect that does not correlate with scene radiance.

4 April 1973

Scene 1255-18183 Monterey Bay

Radiance profiles along the cruise track (Figure A-6) are presented in Figure A-43a. The band 7 profile is rather flat and featureless verifying the absence of specular reflections in the scene. The suppressed radiance profiles (Figure A-43b) verify this further inasmuch as the shape of the profiles is not as modified by the suppression algorithm. Band 4 levels above MSS digital level 18 represent coastal water and levels below correspond to clearer offshore water.

Bands 4 and 5 show congruent profiles; the locations of peaks and the general shape are remarkably similar. The band 6 profile is congruent with band 5 in its right half but shows some departures in its left half. Nevertheless the transition from near-shore water to clearer water in mid-Bay can be discerned in both bands 5 and 6 as well as band 4.

Turbidity: The correlation of turbidity values (Figure A-44) and the radiance level profiles is excellent. Measurements at stations in turbid coastal water yielded values at and above 1 FTU and offshore stations had values below 1 FTU. The only exception is station 16, an offshore station which measured about 2 FTU. It is likely that a small detached area of coastal water was sampled but the level of radiance integrated over the pixel area reflects a preponderance of offshore water.

Secchi Depth: The correlation of Secchi depth (Figure A-45) and radiance level profiles is good. Secchi depths of 6 meters or greater were measured at stations in offshore water. Depths less than 6 meters correspond to coastal water.

Suspended Particles: The profiles of concentrations of chain diatoms and non-living debris (Figure A-46) bear a general correlation with radiance levels but several exceptions occur. This might be caused by the inherently patchy distribution of particulate materials suspended in the ocean. The debris concentrations correlate better than do the chain diatoms. Station 1 near the mouth of Elkhorn Slough shows an anomalously low amount of debris and chain diatoms. Stations 8 and 10 have anomalously high concentrations of chain diatoms and station 7 has an anomalously low concentration of debris. Elsewhere, coastal water carries debris concentrations of about 2.2×10^6 particles per liter or greater and chain diatom concentrations of about 4.5×10^6 per liter or greater.

Fluorometry: The profile of concentration of algae chlorophyll as measured by in-situ fluorometry (Figure A-47) shows a general correspondence with the band 4 radiance profile. Nearshore stations show higher concentrations than offshore stations but there are contradictory data in both areas. Over three times as many fluorometer samples were obtained as were obtained for other turbidity parameters so it is likely that patchiness is enhanced in the fluorometer profile. Two peaks, each defined by several data points in the fluorometer profile occur in areas of offshore water. These peaks correlate negatively with radiance levels in those areas. It is apparent that the fluorometer is not as effective in securing ground truth as are other, more direct methods of assessing turbidity.

Extinction Coefficient: The flat, almost featureless profile of extinction coefficients (Figure A-48) appears to consist of values fluctuating randomly a small amount from a mean value. This parameter appears to be independent of radiance levels and turbidity.

Water Color: Figure A-49 shows the profile of Forel-Ule water color values measured along the cruise track. The numerical values used in the figure are converted to color designations in Table 14. Most of the water colors were greenish-blue or bluish-green. Greenish-yellow water was observed at station 13 and 14 in a transitional zone between offshore and coastal water. There appears to be little correlation between water colors and radiance levels, however, the anomalous color at stations 13 and 14 coincides with a peak in the fluorometer profile in Figure A-47.

Temperature: The temperature profile (Figure A-50) shows no obvious correlation with radiance levels. There is a suggestion of diurnal warming of surface water in the left half of the profile (0814 to 1322 hrs); the afternoon cooling is obscured by sudden lower temperatures between stations 10 and 11 and between stations 12 and 13 and by a warming trend as coastal water was approached at the end of the cruise (stations 19 and 20). The two pronounced dips in surface water temperature coincide with the anomalous peaks in fluorometer values and the presence of anomalous greenish-yellow water but not at all with singular features in the radiance profile. It must be concluded that the anomalous features relate to a real condition in the surface water which is not sensed by the MSS unit.

Sun Elevation: No correlation between sun elevation (Figure A-51) and radiance profile is apparent. The profile is included here only for the purpose of reference.

15 June 1973

Scene 1327-18180 Monterey Bay

No photo imagery or CCT data are available for this scene, therefore correlation between radiance and ocean truth data cannot be examined.

3 July 1973

Scene 1345-18174 Monterey Bay

Radiance profiles along the cruise track (Figure A-8) are presented in Figure A-52a. The profiles are congruent and there is considerable variation in the band 7 profiles suggesting the presence of specular effects in the scene. Clouds are recognizable by extremely high radiance levels (gaps in the profiles) in all bands at stations 1 and 3. Dips in the profiles at stations 4 and 9 are cloud shadows.

Between stations 5 and 9, the band 4 profile shows a decreasing trend while the band 7 profile is essentially flat. This suggests that non-specular effects occur in that segment. This possibility is tested by preparing suppressed profiles of bands 4, 5, and 6 radiance (Figure A-52b). The suppressed profiles show that spectral components are present along the cruise tracks despite the heavy cloud cover portrayed in the digital density slice map (Figure 47) of this scene. Station 2 is located inshore and displays a high radiance level. Between stations 3 and 4, low radiance levels (∿22.0) were recorded in open water before clouds were encountered. Stations 5 to 14 were free of clouds except for the cloud shadows at station 9. The radiance levels were quite high along this part of the cruise track. The band 7 radiance levels were uniformly high whereas band 4 levels decrease from about level 30, corresponding to turbid coastal water, to level 27 over clear water at mid-Bay. This suggests that a thin haze was present but changes in spectral radiance could be detected through the haze. The digital density map (Figure 47) displays the haze as a green color; cloud-free water is shown as shades of blue and violet. Stations 14 to 16 were also close inshore but the radiance there is dominated by clouds.

Turbidity: The turbidity profile (Figure A-53) does not correlate with radiance very well owing to the severe specular effects. However, the values of turbidity do indicate where the cruise track intercepted turbid coastal water (levels above 1 FTU).

Secchi Depth: The profile of Secchi depths (figure A-54) along the cruise track shows very little variation. No correlation with radiance and rather poor correlation with turbidity are evident.

Suspended Particles: Profiles of the concentrations of non-living debris, chain diatoms, and dinoflagellates are present in Figure A-55. None of the profiles correlate well with radiance, although the location of turbid coastal water is marked by concentrations of non-living debris over 3×10^6 per liter.

The variation of dinoflagellate concentrations seems to bear no discernible relationship to spectral radiance.

Water Color: The profile of water color (Figure A-56) shows considerable variation. Greenish-blue to bluish-green water was observed from stations 1 to 6 and greenish-yellow water from station 8 on. These colors do not correlate with any other of the parameters discussed so far, however there is some correlation with the low radiance levels between stations 2 and 3 and with the generally higher radiance levels between stations 5 and 13. A possible explanation for such a correlation is the existence of upwelled, clear water inshore and more turbid surface water offshore. This is somewhat corroborated by the temperature profile (Figure A-57), which shows cooler surface water on the inshore leg of the cruise track and water almost 2°C warmer on the offshore leg.

Optical Properties: The profiles of the percent transmission of light through sea water measured along the cruise track is presented in Figure A-58. The transmission values correlate directly with the general trend of radiance, i.e., low transmission where radiances are low, as along the inshore leg of the cruise track. The values correlate negatively with the water color and temperature profiles, however. There is a slight correspondence between light transmission and the concentration of non-living debris; if upwelling has occurred, then the upwelled water is cold, blue, and is characterized by lowered light transmission caused by suspended debris.

Ocean Reflectance: The profiles of ocean reflectance with and without glare are shown in Figure A-59. The glare profile (upper set of points) correlates with cloud-free radiance and with the wind speed profile (Figure A-60). Low values of glare (less than 20%) correlate with generally low radiance and low (below approx. 10 mph) wind speeds, while high values of glare correlate with higher radiance levels (greater than 25%) and higher wind speeds. The profile of sun elevation (Figure A-61) shows a strong correlation with glare also.

The ocean reflectance exclusive of glare does not correlate with radiance. The profile of reflectance (Figure A-59, lower curve) shows values trending in rough correspondence with glare (upper curve). This probably represents a small component of glare that was retained as an instrumental artifact.

23 August 1973

Scene 1396-18004 Santa Monica Bay

Radiance profiles along the cruise track (Figure A-9) are presented in Figure A-62a. The band 7 radiance profile is virtually flat and only slightly irregular. Profiles of bands 4, 5, and 6 are generally congruent but some departures between band 4 and 5 occur between stations 7 and 10. Profiles of suppressed radiance (Figure A-62b) shows that specular effects existed along the entire cruise track while spectral variations are present as shown in the unsuppressed profiles. This suggests that specular effects are minor and spectral effects predominate; the departure of band 4 from band 5 suggests that the spectral content of radiance from turbid water varies along the cruise track.

The profiles of bands 4, 5, and 6 radiance from station 1 to 3A decrease as coastal water gives way to clearer water off Palos Verdes Peninsula. A prominent peak in band 4 radiance at station 2 marks a turbid water plume extending offshore from Redondo Beach. The same plume was crossed farther offshore between stations 5 and 6 and another peak, somewhat attenuated, occurs in the band 4 radiance profile. Low radiance values between stations 3 and 7 correspond to clear ocean water and may mark a region of upwelling. From station 7 on, increasingly more turbid water was encountered as the shore was approached and the radiance levels increase correspondingly. The broad peak in band 4 radiance between stations 7 and 10 is not present in any of the other profiles. Apparently the water there was richer in yellow-green spectral reflectance.

Turbidity: The correlation of turbidity values (Figure A-63) and the radiance level profiles is not striking because the turbidity values range over narrow limits (0.4 to 0.8 FTU). Nevertheless there is a definite tendency for low turbidity to correspond to low radiance and vice versa.

Secchi Depth: The profile of Secchi depth values (Figure A-64) corresponds to the turbidity values profile rather closely. Depths range from about 2 meters nearshore to 10 meters in clear water. The correlation of Secchi depths and radiance is generally good except at stations 7 and 8 where the depths seem excessive (by about 3 feet). Apparently the clear water at those stations was not representative of the more turbid water elsewhere in the corresponding radiance pixel areas.

Suspended Particles: Profiles of the concentrations of dinoflagellates, chain diatoms and non-living debris (Figure A-65) correlate well with radiance profiles when considered jointly. In the southern half of the Bay the radiance correlates with debris concentrations. Water inshore contained suspended sediment and some dinoflagellates while water off Palos Verdes was virtually free of suspended sediments but contained large concentrations of dinoflagellates. The presence of such large concentrations of dinoflagellates there reinforces the conclusion that upwelling is active in that area.

In the northern half of the Bay, suspended sediment concentrations were relatively low in coastal water and dinoflagellates were about as abundant as in south Bay coastal water. The occurrence of chain diatoms in offshore north Bay water might correlate with the excess band 4 radiance noted between stations 7 and 10. Although diatoms were recovered at stations 10 through 14, their inherent patchy distribution could account for the offset between the peak in the band 4 radiance profile and the peaks in the chain diatom concentration profile.

The profile of normalized reflectance (Figure A-66) presents values of the difference in band 5 and band 4 reflectance of particles filtered from sea water at each station. Particles with values greater than 2.0 are relatively rich in red and particles with negative values are slightly richer in yellow-green.

The profile of normalized reflectance correlates generally with the radiance profiles. Clear water (low radiance) areas having suspended particles are relatively rich in red and coastal water areas have particles containing equal amounts of red and yellow-green coloration. Comparison of normalized reflectance with suspended particle concentrations (Figure A-65) shows that non-living debris (mainly sediment) is yellow-green and dinoflagellates impart a red coloration to the reflected radiance. Diatoms tend to import a greenish coloration in the absence of dinoflagellates.

Extinction Coefficient: The profile of extinction coefficients (Figure A-67) shows values ranging from about 0.3 to 2.0 m^{-1} independent of values of radiance. The lack of correlation is probably caused by patchiness of turbidity and by the fact that the extinction coefficient is derived by measurements in a water column including water deeper than that sensed by the ERTS MSS system.

Water Color: Figure A-68 shows the profile of Forel-Ule water color values along the cruise track. The numerical values used in the figure are converted to color designations in Table 14. The water color at stations 1, 2, 2A, 12, 13, 14, 15 and 16 was greenish-brown, a color that does not fall on the Forel-Ule scale but which should correspond to a number in excess of 20. This color is associated with turbid coastal water. Clear water exhibited the colors blue, greenish-blue, and bluish green. The water color profile correlates quite well with radiance profiles and also with the total suspended particles concentrations. There is an inverse correlation between dinoflagellate concentrations and water color; low concentrations are found in brownish water and high concentrations occur in blue water.

Ocean Reflectance: The profile of reflectance is shown in Figure A-69. The lower profile is reflectance without glare and the upper profile is the reflectance when glare is present. The glare profile correlates with radiance; glare is large (about 40%) at minimum radiance stations corresponding to the area of clear water.

The wind speed profile (Figure A-70) shows an inverse correlation with the glare profile suggesting that glare is a maximum when the wind disturbs the water surface the least. However, the correlation might be fortuitous. The profile of sun elevation (Figure A-71) indicates that glare is a maximum when the angle of sun elevation exceeds about 40° and that is a more reasonable correspondence.

The lower profile on Figure A-69 shows that the reflectance varies hardly at all; the broad maximum at station 6 probably represents the maximum in the glare component retained in these measurements as an instrumental artifact. Nevertheless the profile verifies that ocean reflectance in the absence of glare is quite low (only 2 to 3%).

Optical Properties: The profile of light transmission values along the cruise track is shown in Figure A-72. There appears to be no correlation between transmission and radiance; the transmission profile represents non-systematic variation about a value of transmission (about 4%) that is independent of station location. This suggests that the material that produces the turbidity in coastal water sensed by the MSS unit does not affect the transmission of light. However, the profile of underwater nephelometer values (Figure A-73) shows that coastal water (high radiance) and light scattering by suspended particles correlate strongly.

Temperature: The profile of surface water temperatures along the cruise track is presented in Figure A-74. The variation in measured temperatures bears no correlation with the radiance profiles.

24 August 1973

Scene 1397-18062 Santa Barbara Channel

No CCT data was provided for this scene so radiance could not be prepared by digital processing as in previous scenes. Correlation of ocean truth with photo imagery was not attempted.

DISCUSSION:

The correlation of ERTS radiance data with coastal ground truth data is described in relative terms rather than by applying a numerical analysis and deriving correlation coefficients because the MSS digital data is somewhat arbitrary. Absolute scene radiance could not be measured so scene-for-scene comparisons cannot be made reliably. Instead, the degree of correlation is assessed for each scene individually. Despite this limitation the results are of value inasmuch as they permit identifying the extent to which any one particular ground truth parameter determines the observed scene radiance and also because it is possible to evaluate the feasibility of interpreting ERTS digital imagery of marine scenes without using supporting ground truth measurements.

Certainly the most strongly correlated ground truth parameter is water turbidity in scenes free of the specular effects of wind roughening. Secchi depth measurements are generally poorly correlated, presumably because these measurements involve water deeper than that sensed by the MSS unit.

The turbidity of the water is correlated strongly with the concentration of non-living debris in the water. Living forms, the phytoplankton, do not correlate well unless they are present in abundance and then only to the extent that subtle spectral differences in bands 4 and 5 are suggested. Water color does not correlate well unless large contrasts in water turbidity are present.

Indirect methods of securing coastal ground truth data on ocean radiance are not effective. Fluorometry, measurement of extinction coefficients and the transmission of light through sea water correlate poorly, if at all, with scene radiance. Underwater nephelometry, which is actually in-situ turbidity measurement, yields data that correlates strongly with radiance.

Ocean reflectance measurements are of little value as ground truth data because they are dominated by glare which correlates strongly with the elevation of the sun. Calculating sun elevation from orbital data would provide reflectance ground truth data directly.

The spectral reflectance of particles filtered from sea water is a potentially useful ground truth technique because it provides information on the spectral composition of scene radiance and relates the spectral composition of scene radiance to the distribution of individual kinds of pigmented particles suspended in the sea water. The temperature of the surface water is of little value as coastal ground truth except to verify the presence of upwelled cold water or of warm thermal plumes associated with small estuaries, harbors, and outfalls.

Wind measurements were important because they showed that the wind speed is most strongly correlated with the presence of specular radiance in ERTS scenes. However, the congruency of the profiles of radiance in all MSS bands indicates the presence of specular effects in the absence of ground truth wind measurements. Aerosol concentrations in the air near the sea surface seem to be uniform and do not correlate with scene radiance.

Investigation of radiance and ground truth correlation indicate that considerable interpretation of digital imagery can be made without recourse to ground truth measurement. The method of interpretation can be described although feature identification criteria will vary from scene to scene. The steps involved are:

1. Identify clouds by extremely high radiance in all bands. The edges of clouds are usually marked by sharp steps in the radiance profiles.

2. Cloud shadows occur near cloud spikes in the radiance profiles. All bands show sharp dips in their radiance profile where cloud shadows occur. The dips are not as extreme as cloud spikes are; band 4 radiance drops about 5 levels, for example.

3. Specular reflection can be recognized by several effects. The band 7 radiance profile will be flat and will contain low (0-2) radiance levels where specular effects are absent. Congruent variations in all profiles (including band 7) signify specular reflection. Uniformly high radiance in all bands signifies uniform spectral reflectance in the data.

4. Specular components of radiance can be removed at least in part from scene data by transforming band 7 levels linearly and subtracting the transformed levels in bands 4, 5, and 6.

5. The profiles that remain from suppressing specular effects can be interpreted in terms of surface water turbidity. High radiance levels (20-30 in band 4) correspond to turbid water containing about 10-100 particles X 10^6 liters.

6. Variations in the specular component of radiance can be interpreted in terms of surface water roughness and, indirectly the distribution of winds of speed exceeding 10 mph that blow along the sea surface.

7. The composition of suspended particles causing turbidity can be deduced by comparing band 5 radiance levels with band 4 levels provided one has sufficient background data on the particle spectral reflectance of individual kinds of particles. This implies that ground truth be obtained from different locations at each season although not necessarily synchronous with a satellite overflight. In general, suspended sediment enriches band 4 radiance and dinoflagellates (in abundance) enrich band 5 radiance.

Interpretation of profiles with spectral variation must be made with the awareness that the inherent patchiness of plankton distributions will contribute substantial irregularity to radiance profiles.

<u>Part 7</u>

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS:

1. ERTS photo imagery can be interpreted for oceanic features by combining a systematic examination of all 4 MSS bands with a confirmatory pattern recognition.

2. Film negatives of MSS bands 6 and 7 show more oceanic detail than the corresponding film positives.

3. There are two classes of oceanic features evident on ERTS photo imagery; those present in all bands and related to clouds and wind effects, and those present only in certain bands and related to seawater turbidity.

4. Wind effects are quite pronounced when the local wind velocity exceeds 10 knots. These effects can be predominant in marine scenes.

5. Parallel, linear bands of low radiance associated with broad areas of higher radiance produced by wind roughening are probably caused by regular undulations in the wind field near the sea surface. It is unlikely that vertical circulation of surface water produces these features.

6. It is possible to identify areal distribution and trajectories of severe winds at the sea surface, shoreline, clouds, fog or low stratus, beach sands, dunes, suspended sediment plumes, tidal circulation events, outfall plumes, plankton, kelp beds, harbor configuration, and possibly oil slicks in the ERTS imagery examined during this investigation.

7. Although much marine intelligence is present in ERTS photo imagery, marine radiance values are limited to the 4 lowest density levels on the photos. Corresponding CCT's contain 10 digital levels so they are more suitable for data correlation purposes.

8. Digital density slice maps prepared from CCT data provide a better resolution of patterns discerned in ERTS marine scenes because of the higher resolution of radiance inherent in the CCT's. However, noise in the form of 6-cycle radiometer striping and gross banding detracts from the areal definition of the patterns because only a part of all available scan lines can be used without sacrificing confidence in the relative precision of radiance data.

9. Automated production of graphic displays from CCT data is extremely difficult. It is necessary that an oceanographer interact during production so that subjective corrections of radiometric striping and banding can be made on each marine scene.

10. Test areas for ocean truth measurements and correlations should be larger than approximately 10 miles x 10 miles to avoid spurious results from the inherent patchiness in the distribution of turbidity-producing particles.

11. Of the several methods investigated for the color enhancement of MSS data, photographic methods were least satisfactory because of the non-linear D log E characteristics of the photo materials. The best enhancement was obtained by using CCT digital scene data to drive a color printing press. This system produced exactly reproducible hard copy products directly with each digital level represented by a discrete

color. Spectral signatures can be color coded by combining digital levels from each MSS band into a single, diagnostic digital code word.

12. ERTS digital data contain system artifacts that produce visible effects in images of marine scenes where broad fields of uniform radiance prevail. Examples are vertical banding apparently produced by mechanical vibration in the satellite, gross horizontal banding caused by an abrupt change in the calibration coefficients during processing, and 6-cycle radiometric striping caused by the imperfect inter-detector calibration.

13. Conversion of scene data and calibration data from 6-bit binary format to 7-bit format introduces "forbidden numbers" into each type of data. The calibration procedure introduces a different, discontinuous number system into scene data each time it is applied. As a result, levels from adjacent scan lines cannot be averaged without introducing several distortions in radiance values. Smoothing along a scan line is subject to similar error but to a lesser extent because only one discontinuous number system is involved.

14. The range of radiance levels in marine scenes is so small that system artifact errors tend to obscure oceanic features. This problem was overcome by using only every sixth scan line, thereby avoiding striping caused by imperfect inter-detector calibration. The choice of lines is made interactively in order to choose those lines corresponding to the detector with maximum sensitivity.

15. Once the effects of radiometric 6-cycle striping have been removed from scene data, interpretation of the scene is possible provided that the remaining system errors are taken into account.

16. Interpretation must be made on a scene-by-scene basis because absolute scene radiance was not measured. For the same reason, interpretation and correlation must be made using relative radiance differences within each scene.

17. The MSS system records two major effects in marine scenes. If the wind speed exceeds about 10 mph, specular reflections from the roughened water surface predominate and are registered congruently in all MSS bands. In the absence of wind effects, water turbidity variations are recorded in bands 4 and 5.

18. The strongest correlation with radiance is obtained from measurements of turbidity by in situ or laboratory nephelometery (90° light scattering) and by the measurement of the concentration of non-living debris (mainly suspended sediment) filtered from sea water.

19. Indirect measures of turbidity or optical properties of sea water correlate poorly with scene radiance. Water color correlates with radiance only if turbidity contrasts are high.

20. Spectral radiance comparison (band ratioing) is a potentially useful technique for assessing the composition of suspended particles in sea water by using ERTS digital imagery, if laboratory data on the spectral reflectance of filtered suspensoids is available.

21. Ocean reflectance measurements are dominated by glare which correlates strongly with sun elevation.

22. Surface water temperatures do not correlate directly with scene radiance.

23. Much interpretation of marine scenes is possible in the absence of ground truth data. The turbidity pattern in coastal water can be determined directly from digital or photo imagery once specular effects are determined to be absent or minor.

24. Information on surface water circulation and sources of turbidity can be extracted from ERTS imagery by an oceanographer once the turbidity pattern is defined. No ground truth is required for this operation.

25. Meteorologists are able to derive a pattern of regional surface winds after specular effects are identified on ERTS imagery. Ground truth is not required for this operation.

RECOMMENDATIONS:

The recommendations presented here are derived from all aspects of the study. They are listed in the order that topics were considered in the study and not necessarily in order of importance or significance.

1. The sensitivity of sensors or gain of signal processing amplifiers should be increased over ocean areas. The range of radiance in marine scenes is about 10 levels. Even if system noise is kept to ±1 level, this still represents a ±10% error band.

2. The presence of clouds and highly radiant sandy beaches imposes the necessity that a wide dynamic range in sensor response be maintained.

3. Digital data from the sensor amplifier system should be telemetered and recorded with a minimum of data manipulations. Particularly, the conversion of 6-bit data to 7-bit format should be avoided. This operation appears to be irreversible and makes original data inaccessible when system noise or partial failure must be corrected.

4. The choice of bands in the MSS system could be optimized for ocean sensing. A band in the blue region (400-500 nm) should be substituted for the near infrared band 6 (700-800 nm).

5. The band width of individual MSS bands could be made more narrow (about 30 nm) and bands chosen to be more diagnostic of marine conditions. For example, the four bands 410-440, 470-500, 555-585, and 665-695 nm, could be used to discriminate between clean ocean water, phytoplankton, suspended sediment and sewage effluent.

6. The time of overflight in coastal areas should be designed to accommodate local weather conditions, if possible. The coast of Southern California is subject to morning low stratus clouds during the summer months. Winds increase in mid-afternoon so the optimum time for taking satellite observations is from 12:00 to 3:00 pm, local time. During fall and winter months, the increased afternoon wind is the only constraint.

7. Decompression seems to create more problems than it solves in marine scenes. Original, compressed, uncalibrated data on CCT's should be made available routinely to users of marine scenes.

8. A new version of the ERTS data users handbook should be prepared. This version should use actual data as obtained by the satellite and should describe, with abundant examples, exactly how the data is processed through the satellite, telemetry, and NDPF. Emphasis should be placed upon describing what the system actually does, not what it was designed to be capable of doing.

9. Data characterizing the spectral reflectance of species of plankton and other turbidity-producing particles should be obtained in further studies. The studies need be performed only once. A technique of performing spectral reflectance spectrophotometry on materials filtered from large volumes of sea water appears to be suitable.

10. Interpretation of ERTS imagery composites consisting of several ERTS frames should be made to demonstrate to users the utility of ERTS images in mapping large scale, offshore circulation. This sort of water motion is hemispheric in nature and cannot be understood well if only a single ERTS frame is examined. It is important to understand offshore circulation patterns so that inshore coastal circulation can be mapped from ERTS frames most effectively.

BIBLIOGRAPHY

Apel, J. R. & R. L. Charnell, "Oceanic Internal Waves Off North America & Africa as Observed From ERTS," Paper M2, Third ERTS Symposium Abstracts, Dec. 10-14, 1974, NASA, GSFC.

Duntley, S. Q., "Light in the Sea," Journal Optical Society of America, v. 53, pp. 214-233, 1963.

Holmes, R. W., "The Secchi Disk in Turbid Coastal Waters," Limnology & Oceanography, v. 15, n. 5, pp. 688-694, 1970.

Johnson, J., "Econometric Methods," McGraw Hill, N.Y., 300p, 1963.

Kolpack, R. L., "Biological & Oceanographical Survey of the Santa Barbara Channel Oil Spill, 1969-1970", v. II, "Physical, Chemical, & Geological Studies" Allan Hancock Foundation, University of Southern California Sea Grant Pub. 2, 477p, 1971.

O'Neill, J. P. Jr., "From Gray Scale to Rainbow. A Six Level Color Posterization Technique," Photographic Applications in Science, Technology, and Medicine, 20p, May 1973.

Rogers, R. H. & K. Peacock, "A Technique for Correcting ERTS Data for Solar & Atmospheric Effects," NASA SP-327, Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1, v. 1, Technical Presentations Section B, pp. 1115-1122, 1973.

APPENDIX A

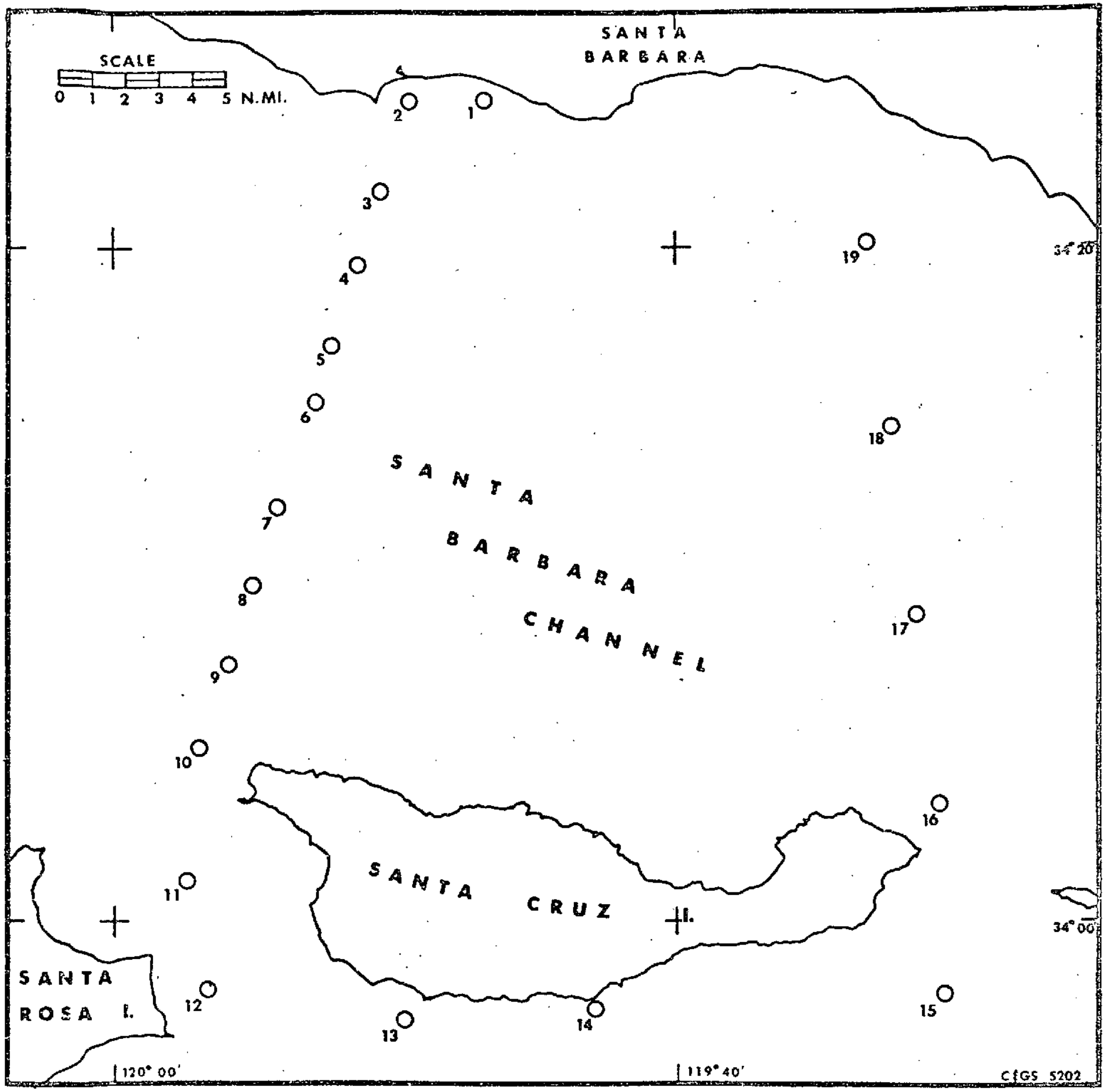


Figure A-1

CRUISE TRACK AND STATION NUMBERS
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

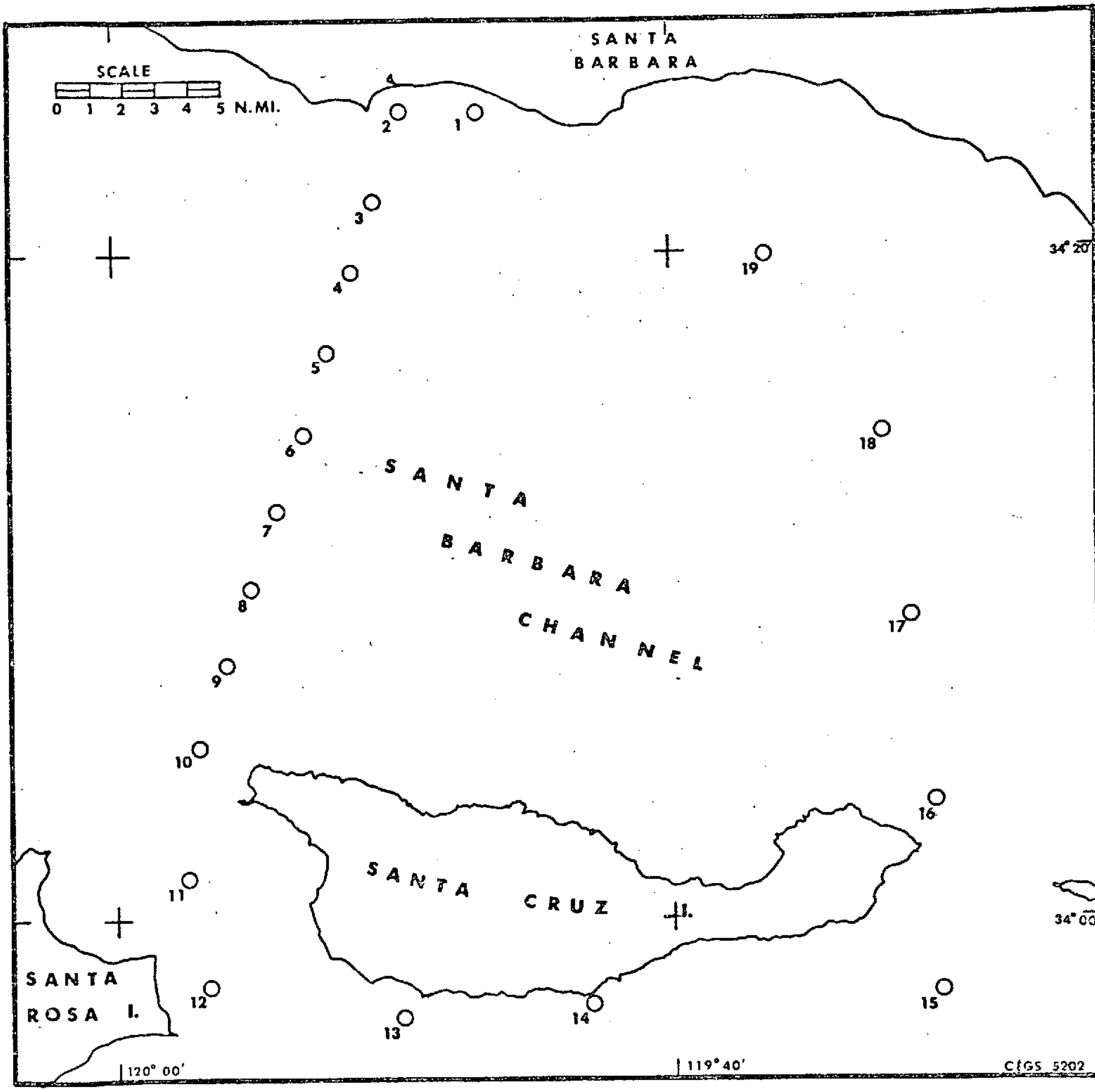


Figure A-2

CRUISE TRACK AND STATION NUMBERS
SANTA BARBARA CHANNEL - 15 MARCH 1973

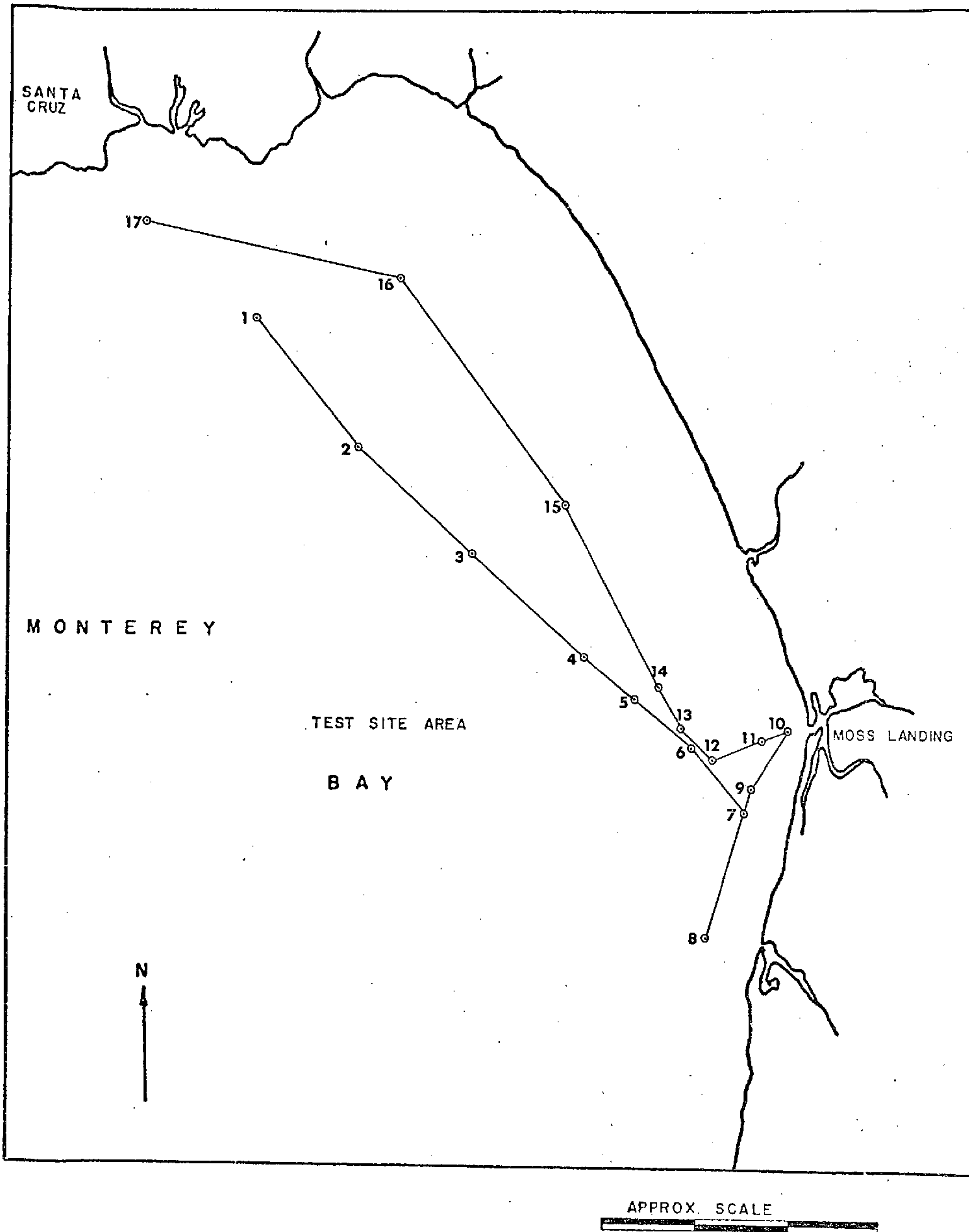


Figure A-3

CRUISE TRACK AND STATION NUMBERS
MONTEREY BAY - 17 MARCH 1973

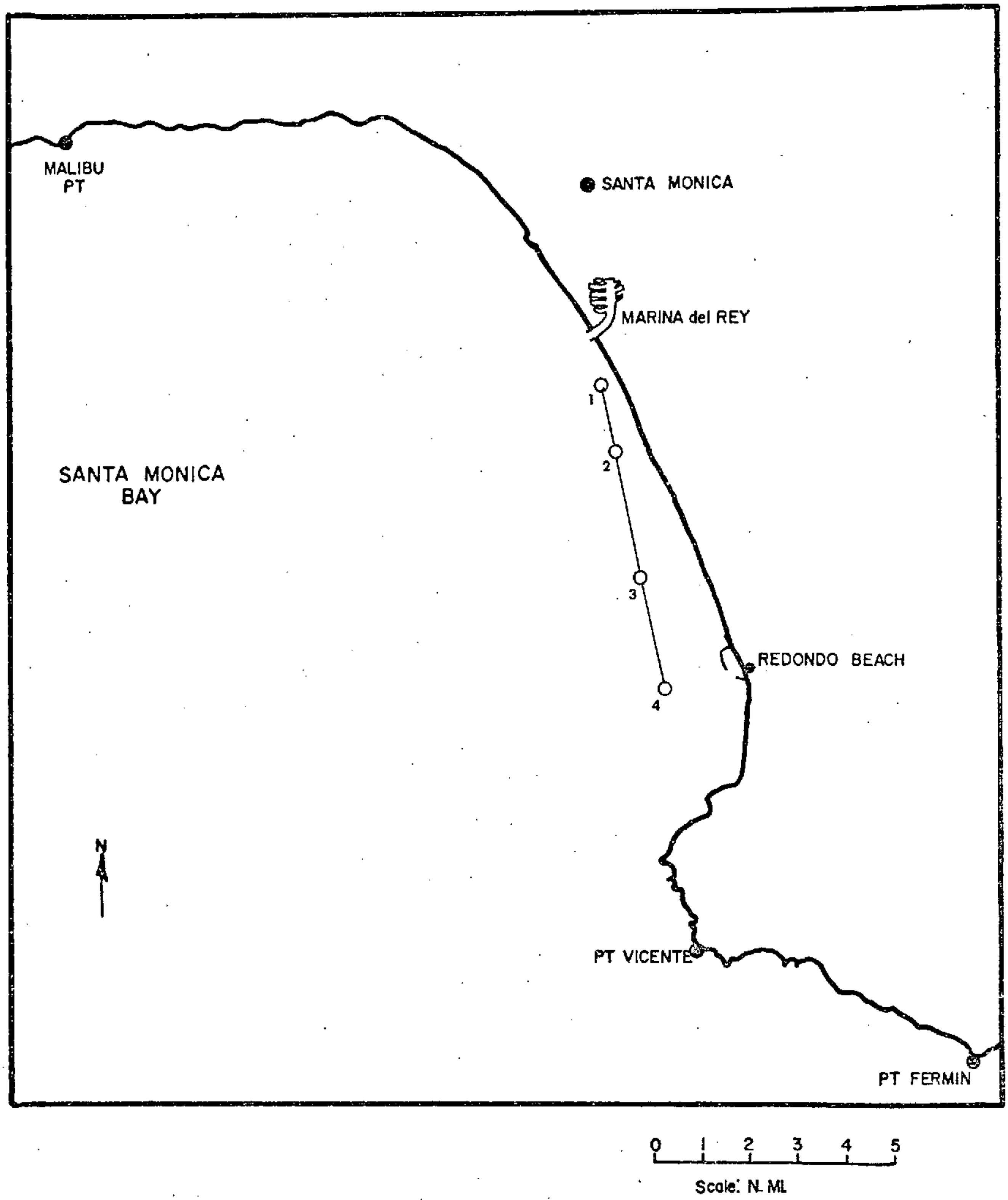


Figure A-4

CRUISE TRACK AND STATION NUMBERS
SANTA MONICA BAY - 1 APRIL 1973

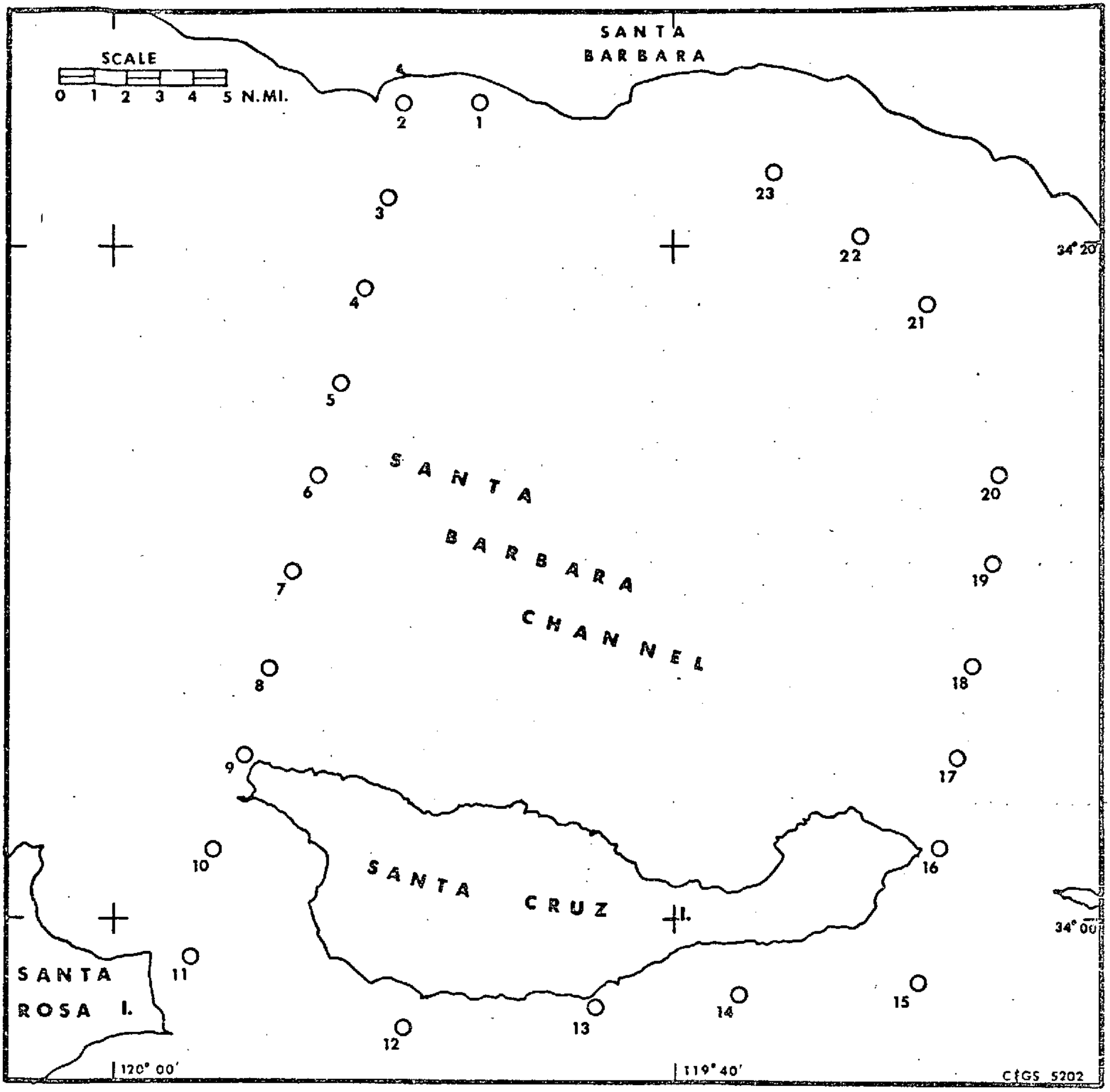


Figure A-5

CRUISE TRACK AND STATION NUMBERS
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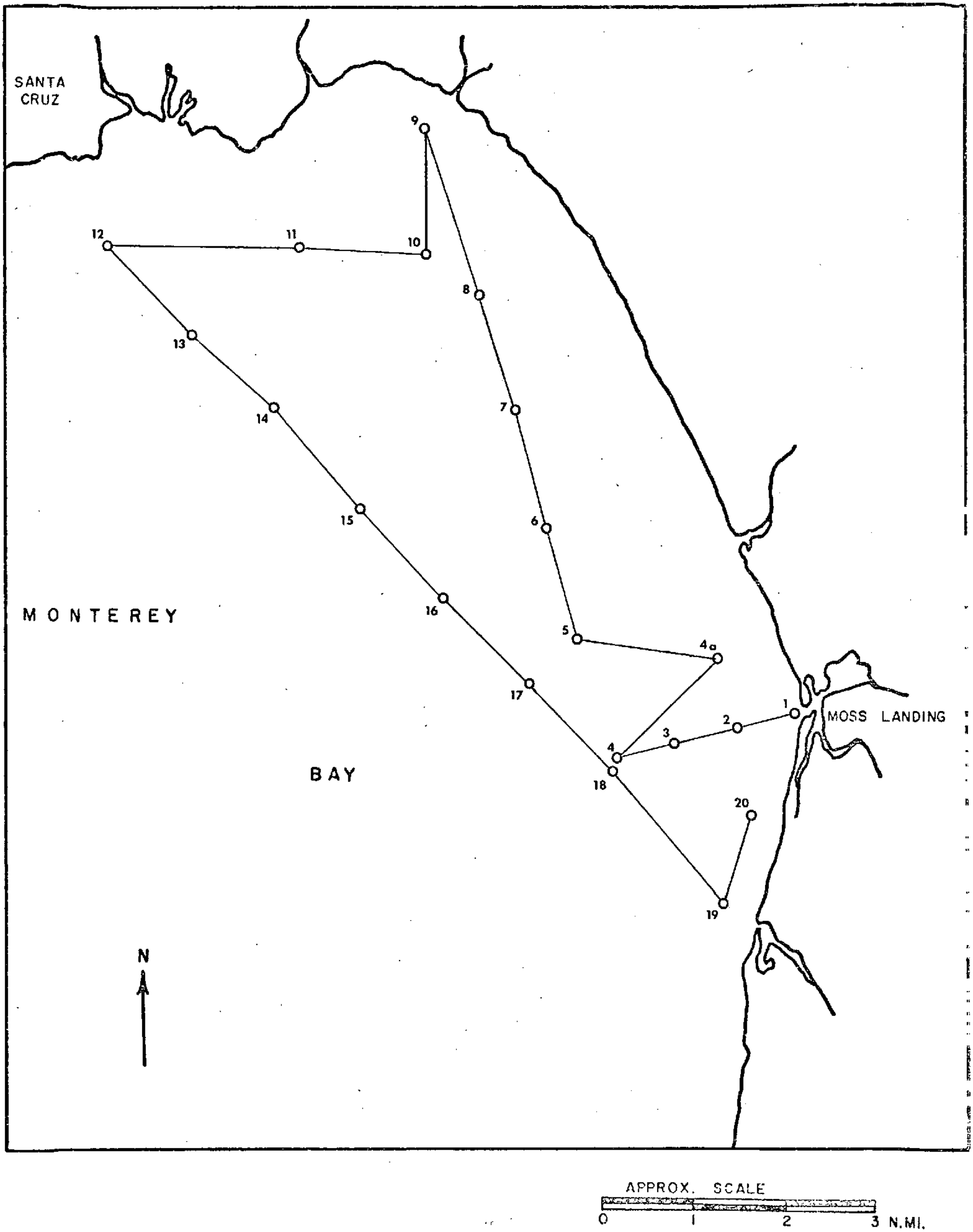

Figure A-6

CRUISE TRACK AND STATION NUMBERS
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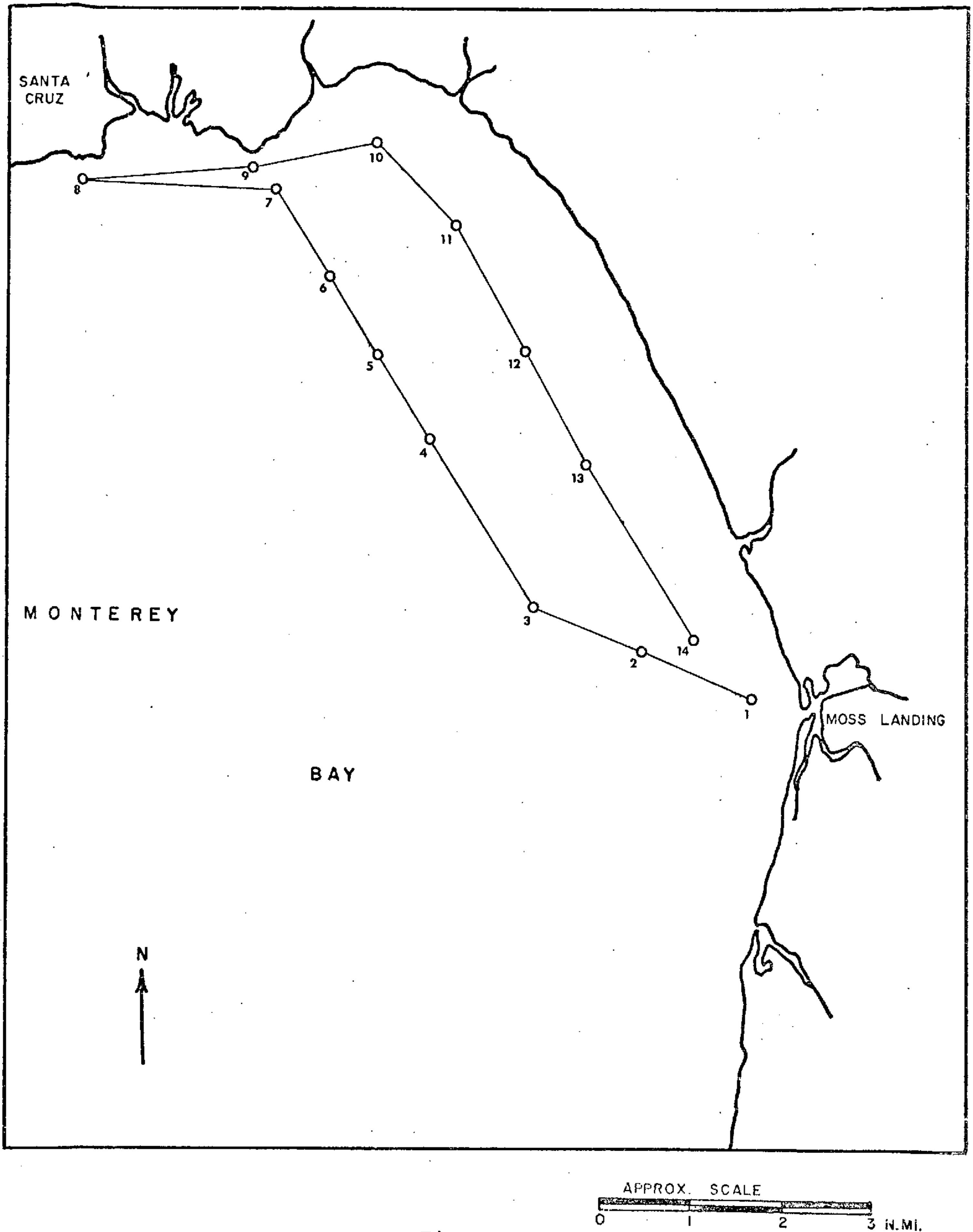

Figure A-7

CRUISE TRACK AND STATION NUMBERS
MONTEREY BAY - 15 JUNE 1973

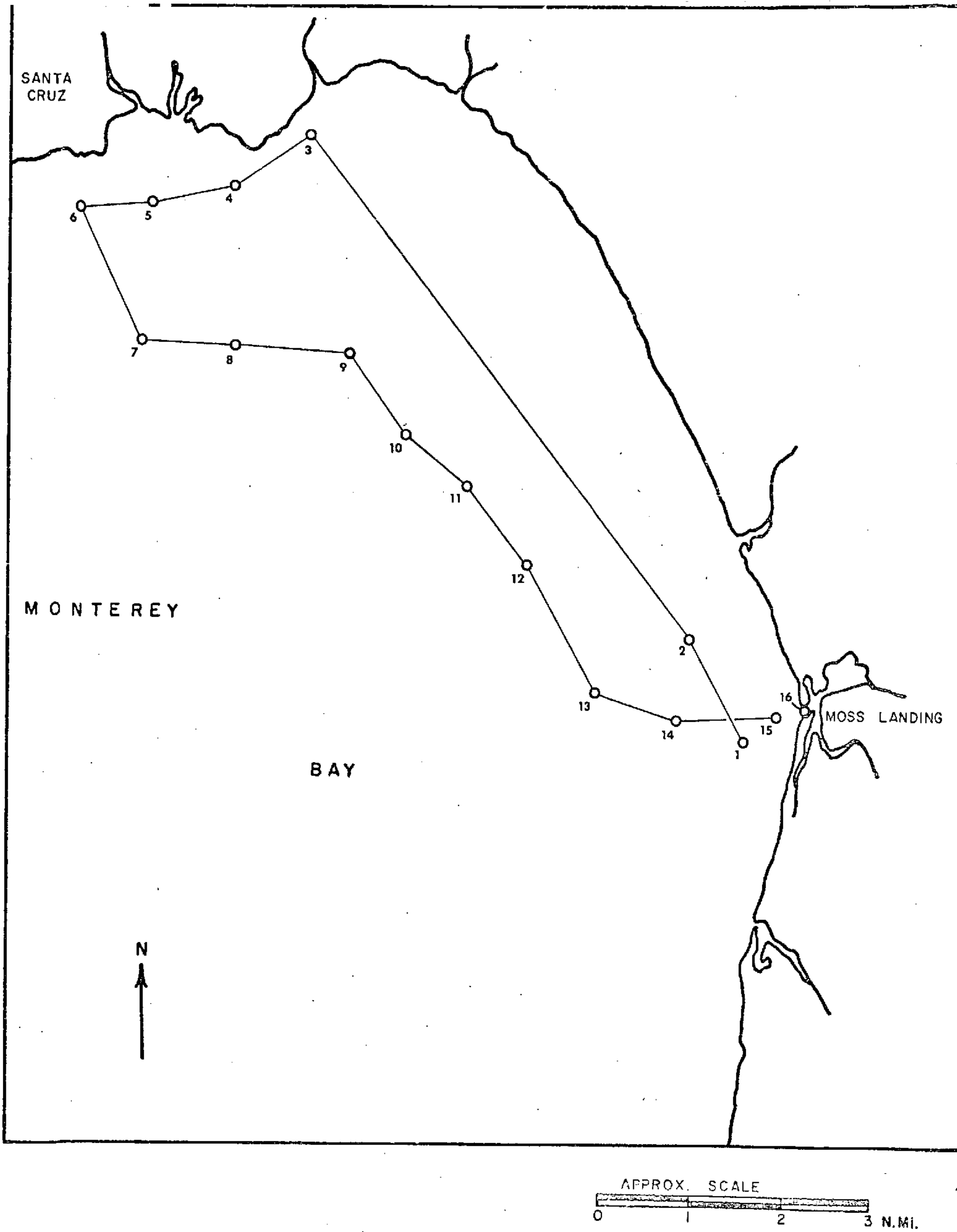

Figure A-8

CRUISE TRACK AND STATION NUMBERS
MONTEREY BAY - 3 JULY 1973

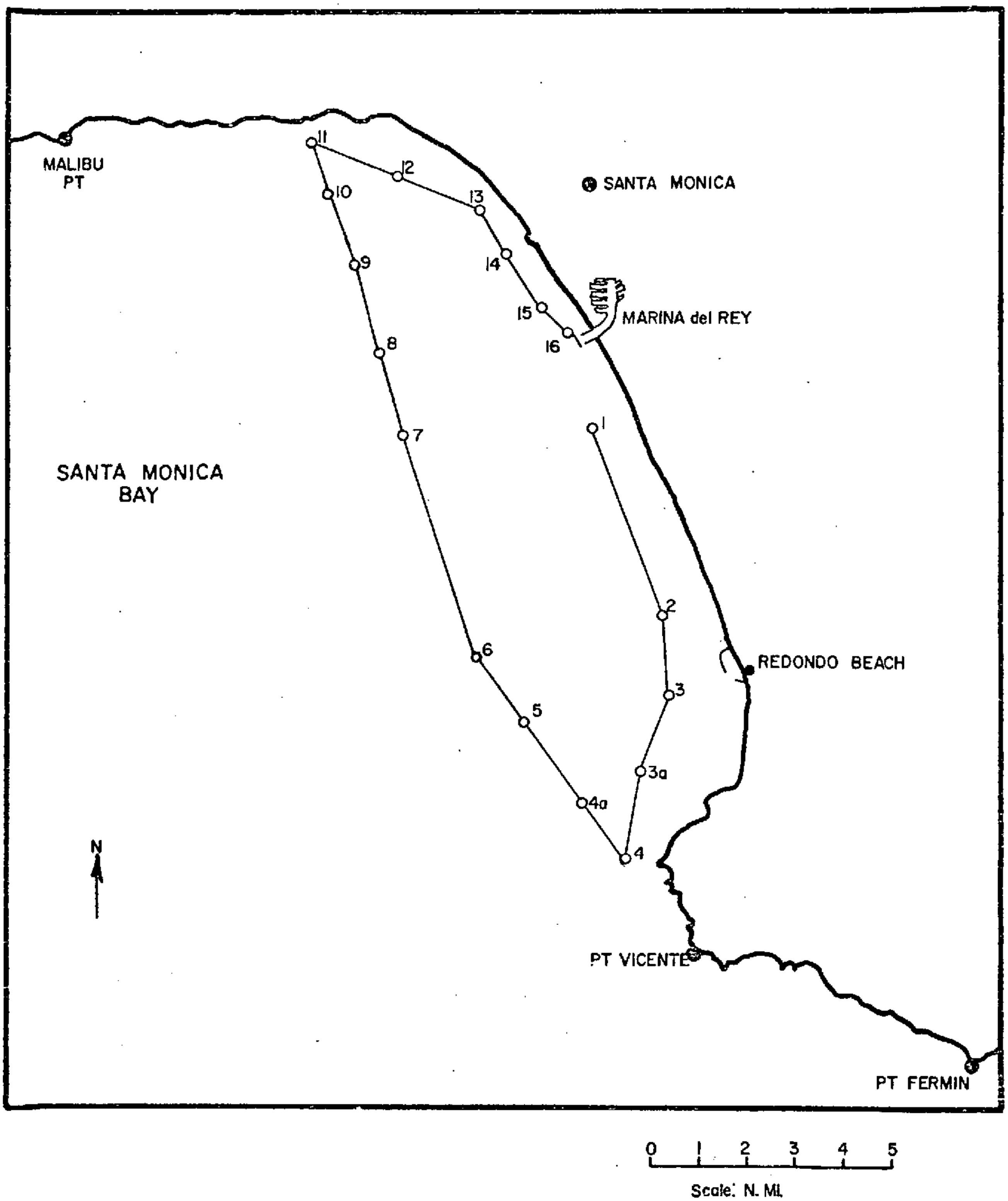

Figure A-9

CRUISE TRACK AND STATION NUMBERS
SANTA MONICA BAY - 23 AUGUST 1973

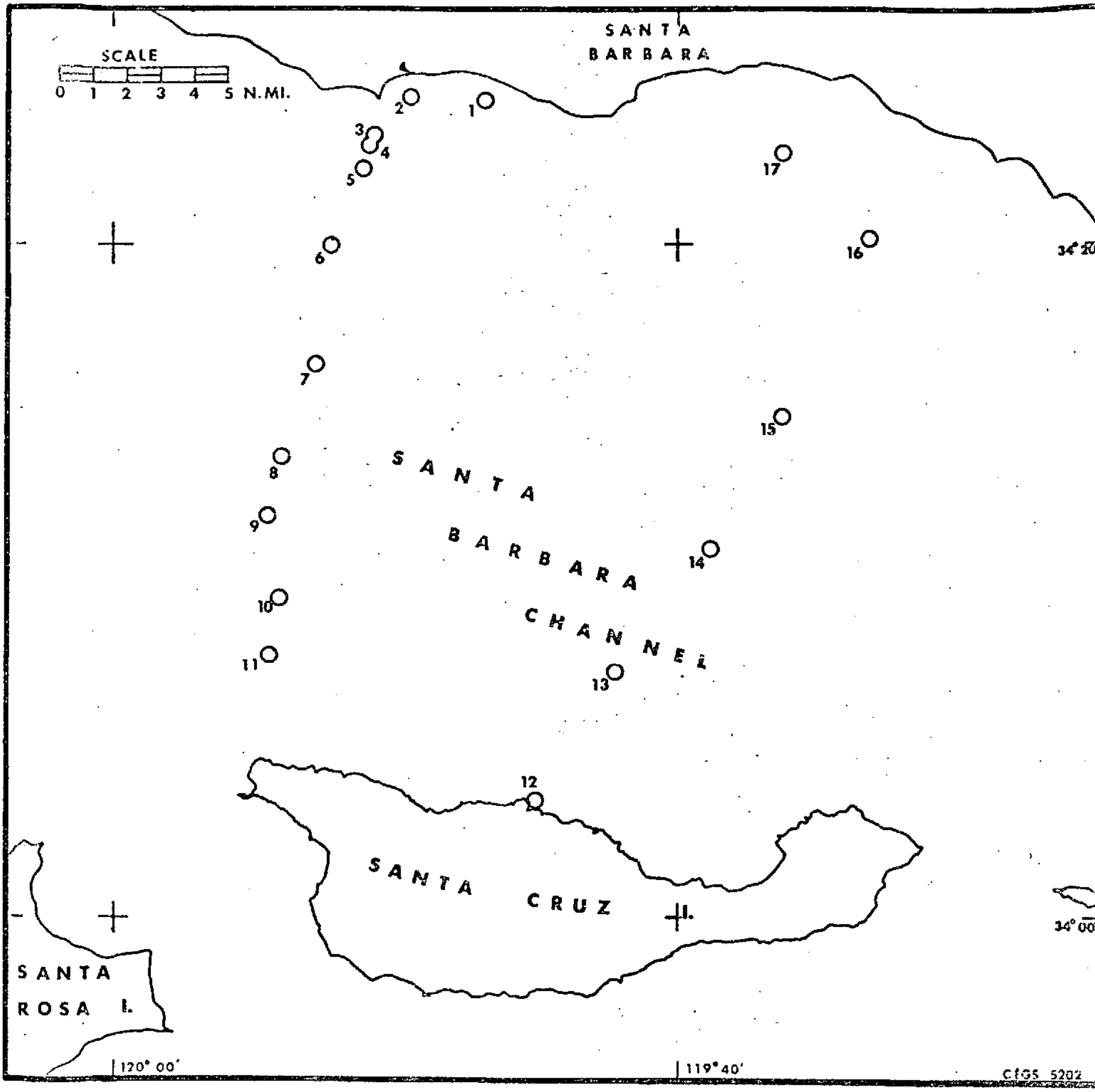

Figure A-10

CRUISE TRACK AND STATION NUMBERS
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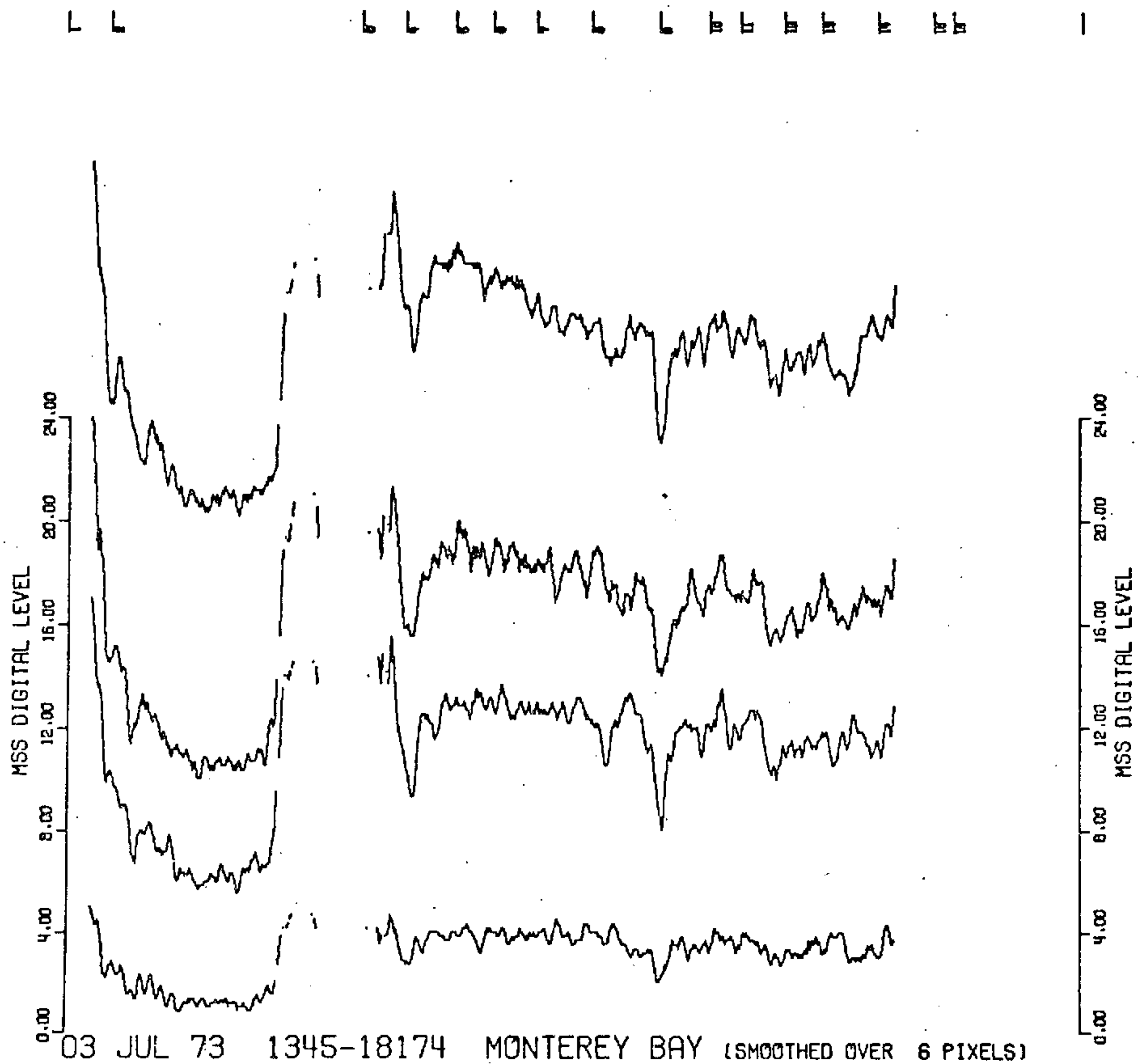

Figure A-11

EXAMPLE OF SPECULAR EFFECTS
IN RADIANCE PROFILES

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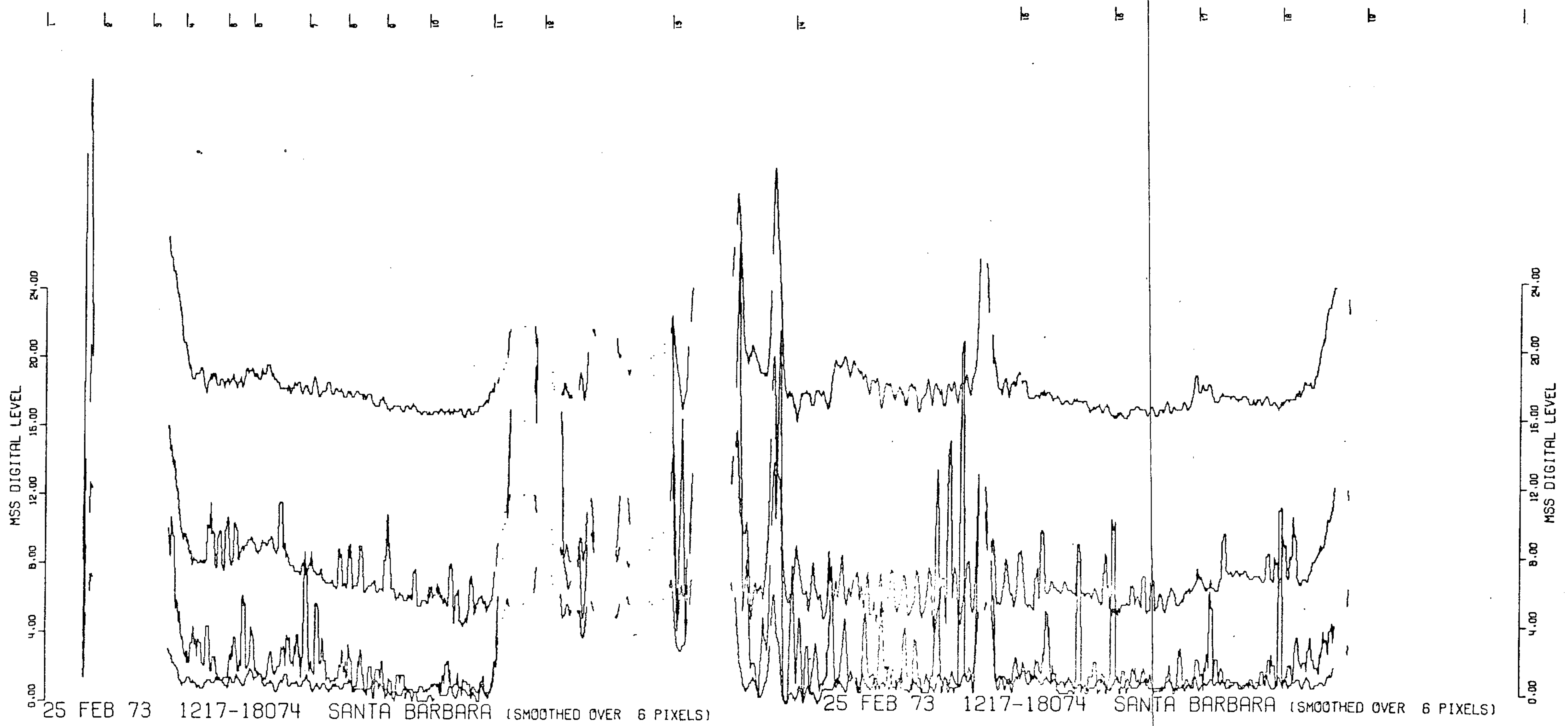

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Figure A-12a

RADIANCE PROFILES, BANDS 4-7
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

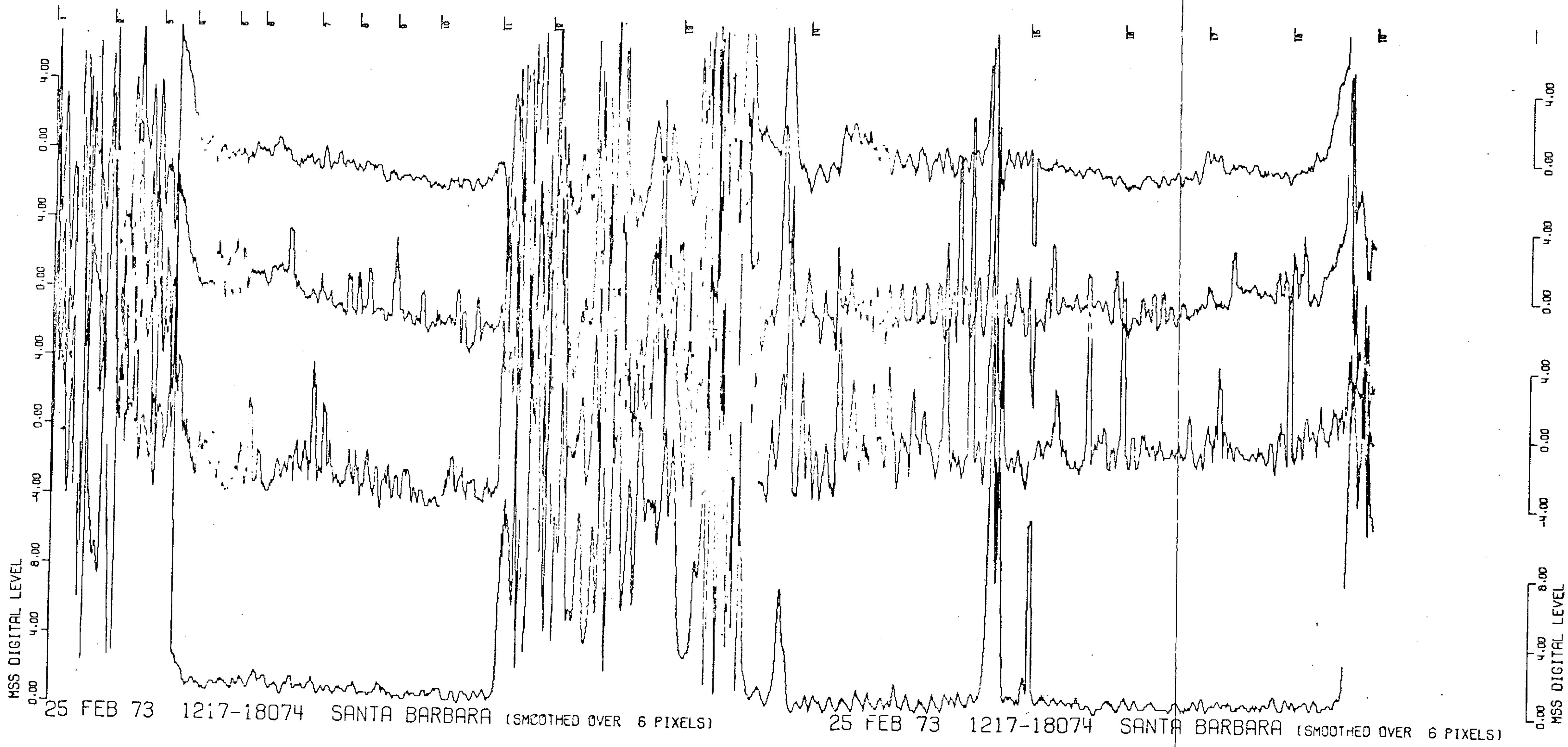

Figure A-12b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6,
COMPARED WITH BAND 7 RADIANCE
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

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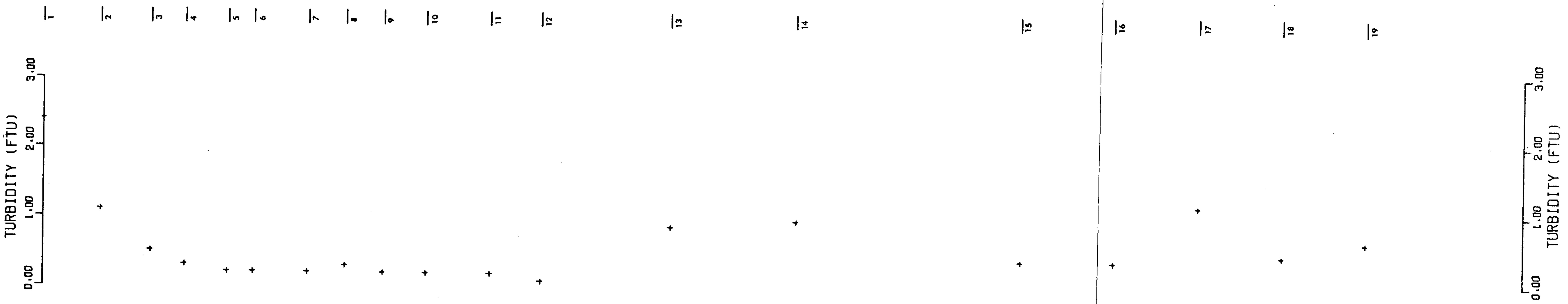

Figure A-13
SURFACE TURBIDITY PROFILE
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

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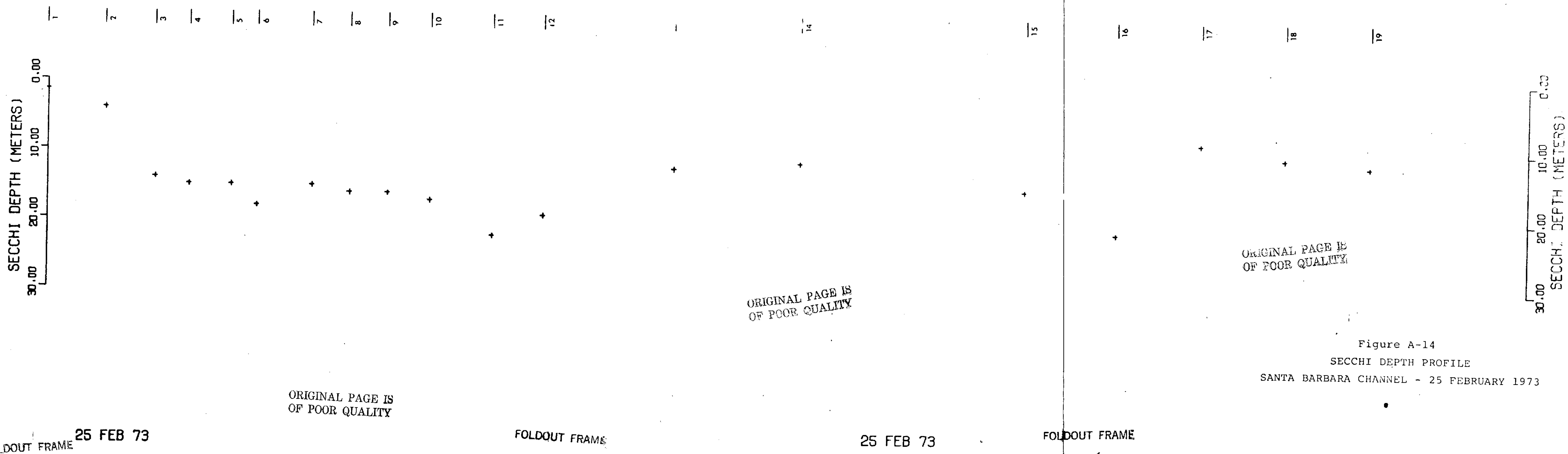

Figure A-14
SECCHI DEPTH PROFILE
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

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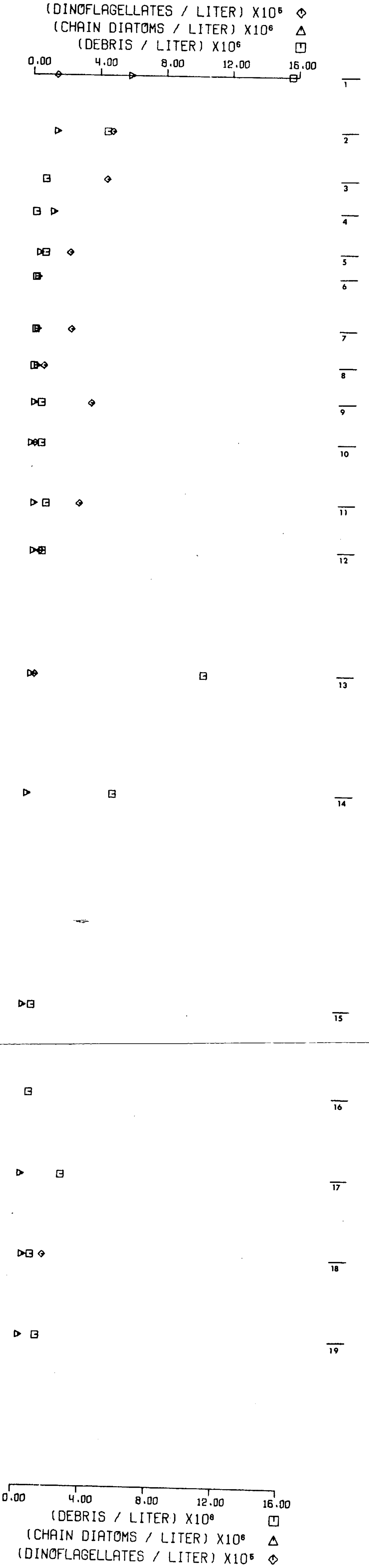
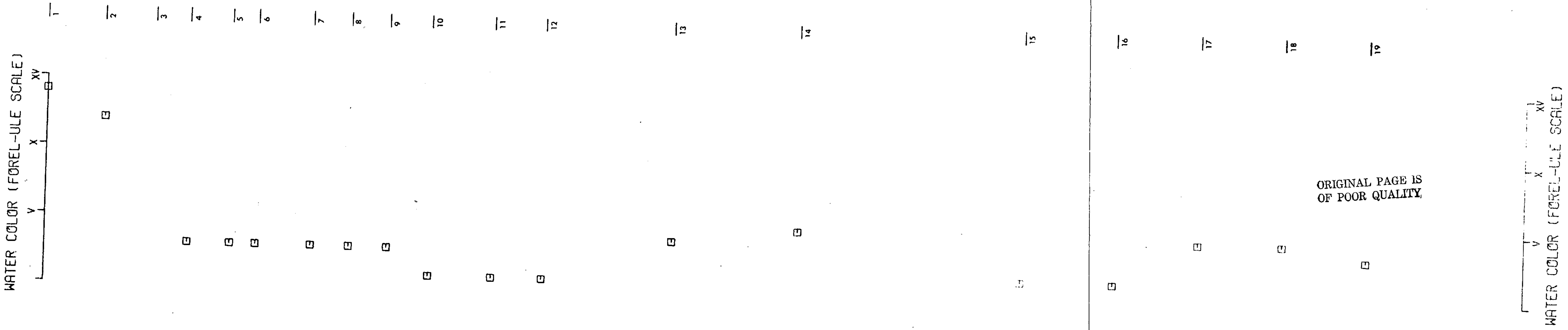


Figure A-15

CONCENTRATIONS OF NON-LIVING DEBRIS, CHAIN DIATOMS, AND DINOFLAGELLATES IN SUSPENSION SANTA BARBARA CHANNEL - 25 FEBRUARY 1973



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25 FEB 73

Figure A-16
[illegible] OF FOREL-ULE WATER COLOR VALUES
SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

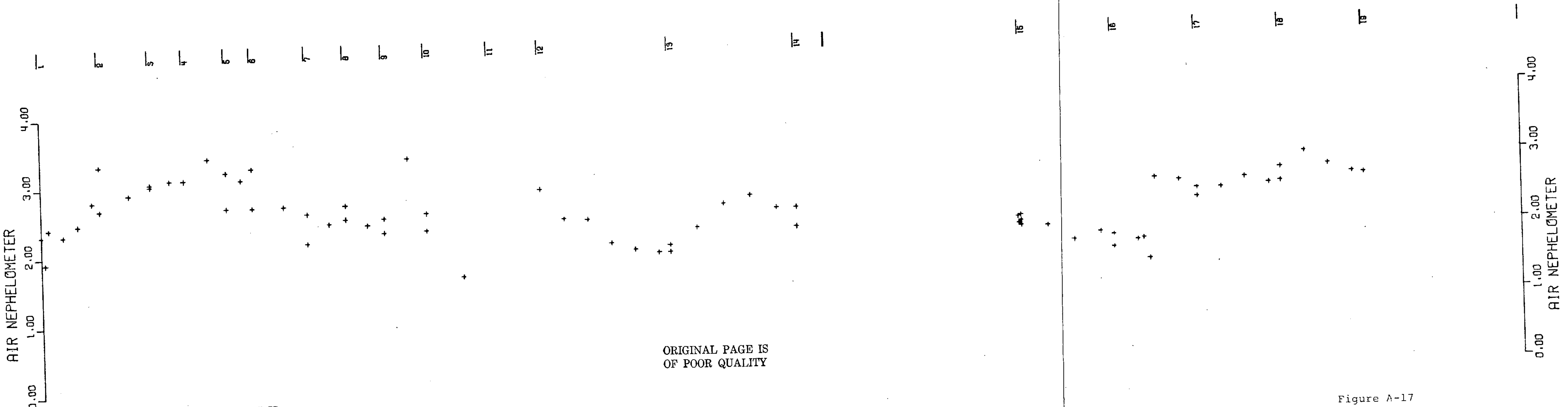

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Figure A-17

AIR NEPHELOMETER PROFILE

SANTA BARBARA CHANNEL - 25 FEBRUARY 1973

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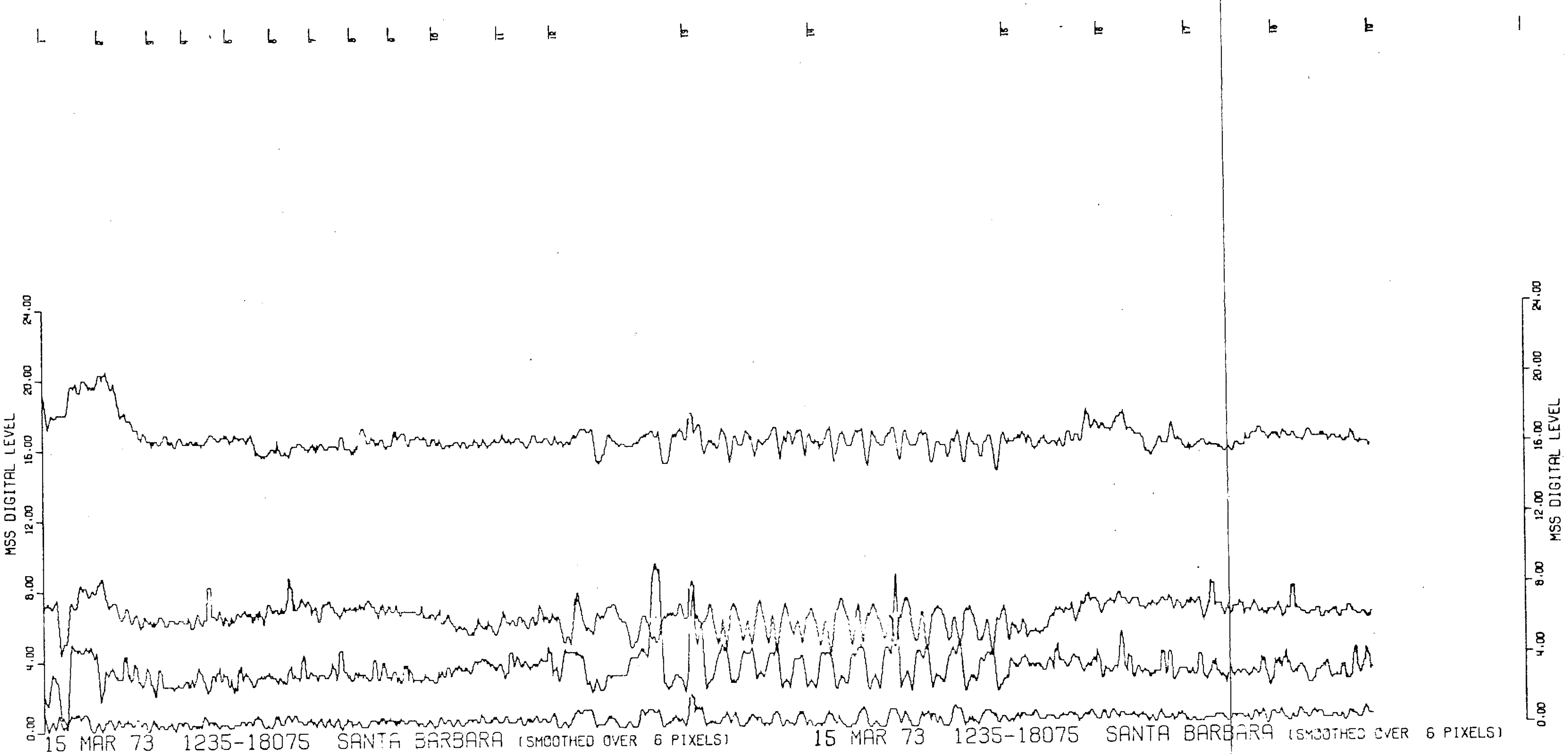

Figure A-18a

RADIANCE PROFILES, BANDS 4-7
SANTA BARBARA CHANNEL - 15 MARCH 1973

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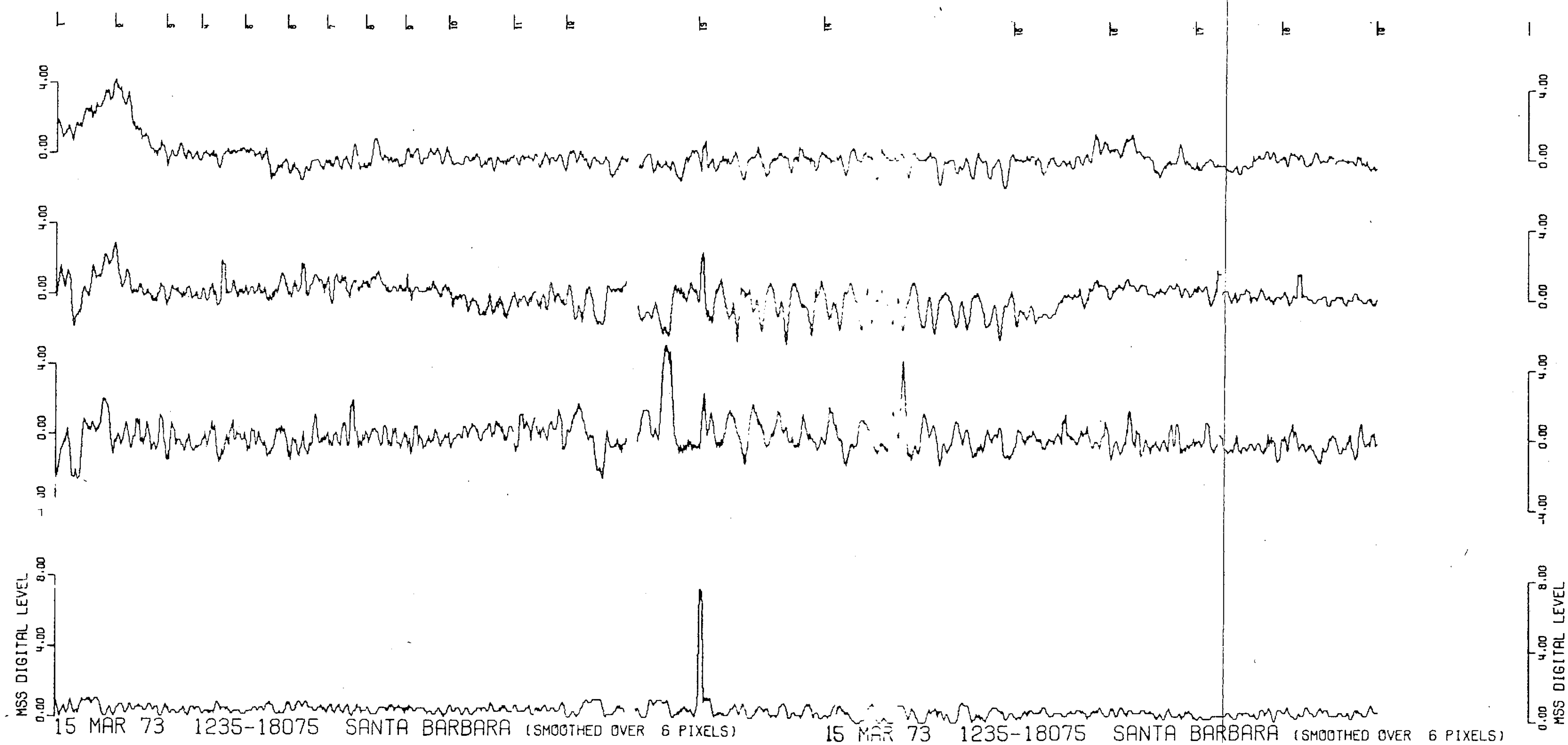

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Figure A-18b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6
COMPARED WITH BAND 7 RADIANCE
SANTA BARBARA CHANNEL - 15 MARCH 1973

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME

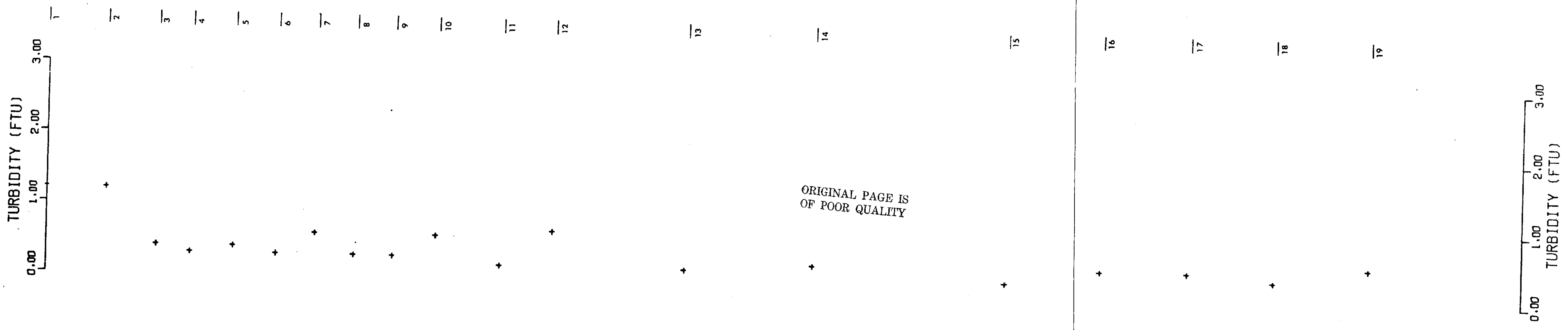

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Figure A-19
WATER SURFACE TURBIDITY PROFILE
SANTA BARBARA CHANNEL - 15 MARCH 1973

FOLDOUT FRAME 15 MAR 73

FOLDOUT FRAME

15 MAR 73

FOLDOUT FRAME

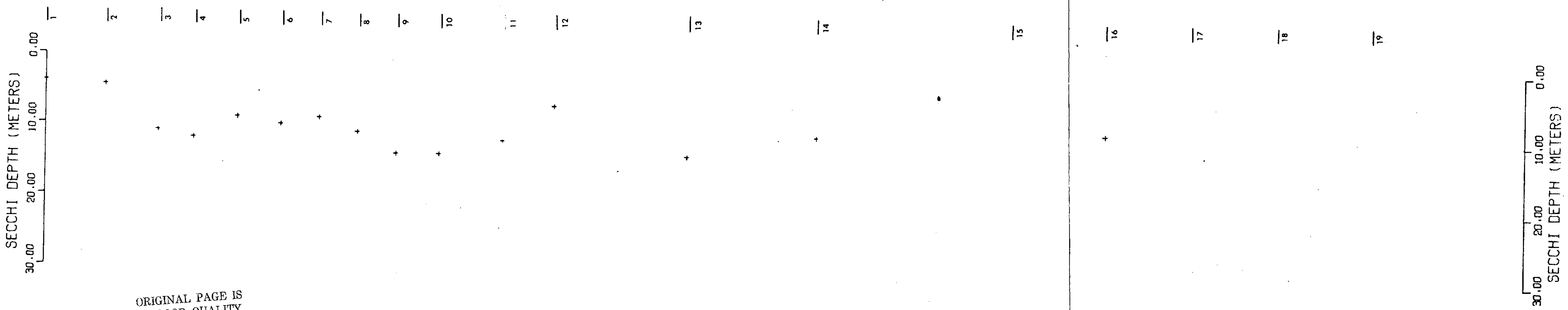


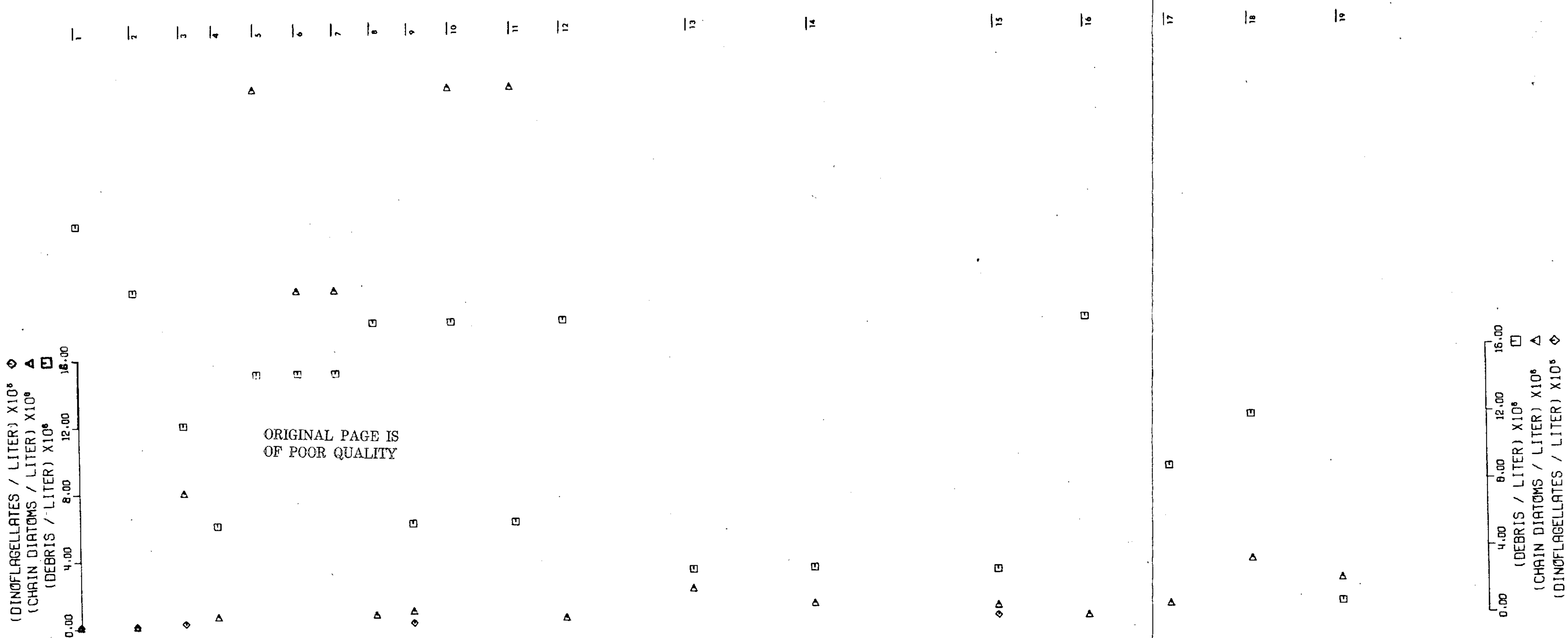
Figure A-20
SECCHI DEPTH PROFILE
SANTA BARBARA CHANNEL - 15 MARCH 1973

FOLDOUT FRAME 15 MAR 73
1

FOLDOUT FRAME
2

15 MAR 73

FOLDOUT FRAME
3



FOLDOUT FRAME 1

15 MAR 73

FOLDOUT FRAME 2

15 MAR 73

Figure A-21
CONCENTRATIONS OF NON-LIVING DEBRIS, CHAIN DIATOMS,
AND DINOFLAGELLATES IN SUSPENSION
SANTA BARBARA CHANNEL - 15 MARCH 1973

FOLDOUT FRAME 3

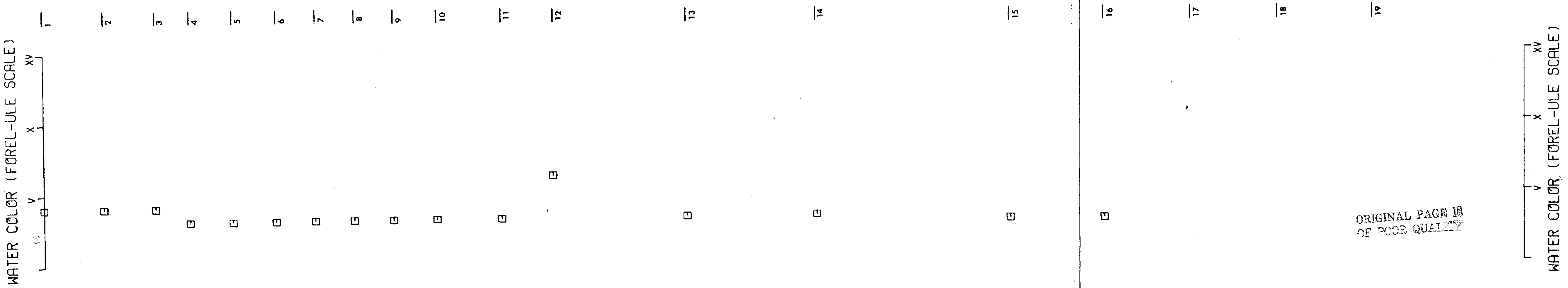


Figure A-22
PROFILE OF FOREL-ULE WATER COLOR VALUES
SANTA BARBARA CHANNEL - 15 MARCH 1973

15 MAR 73

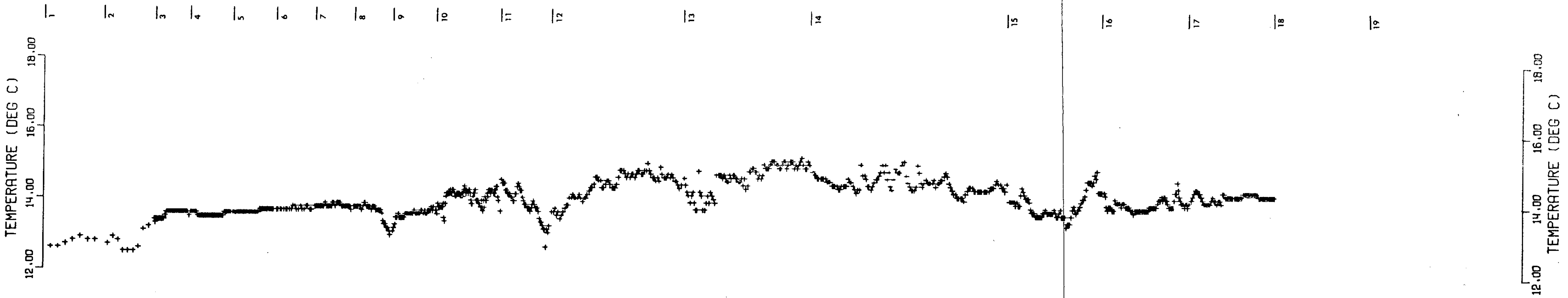


Figure A-23
SURFACE WATER TEMPERATURE PROFILE
SANTA BARBARA CHANNEL - 15 MARCH 1973

FOLDOUT FRAME 1 15 MAR 73 FOLDOUT FRAME 2 15 MAR 73 FOLDOUT FRAME 3

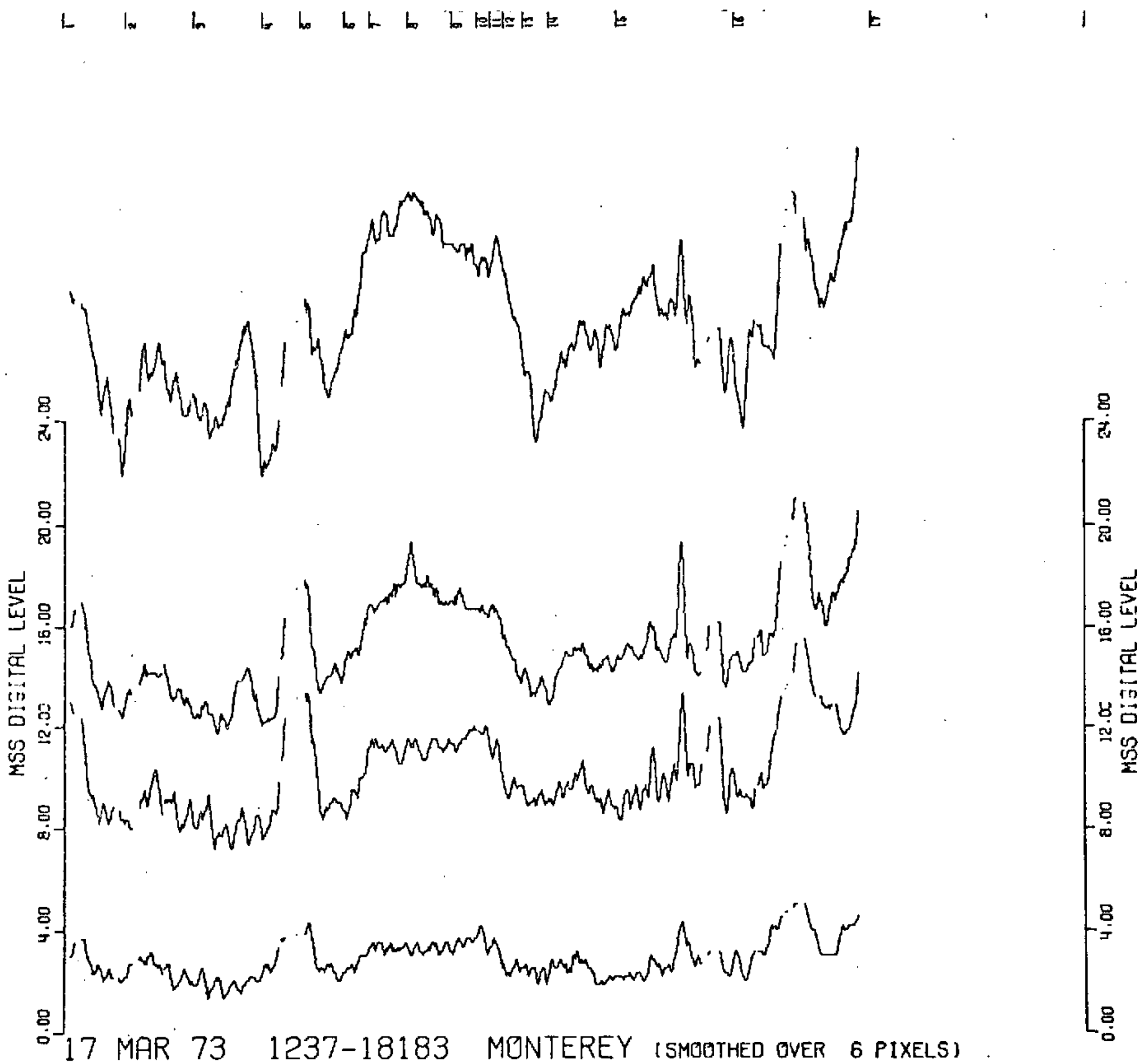


Figure A-24a

RADIANCE PROFILES, BANDS 4-7
MONTEREY BAY - 17 MARCH 1973

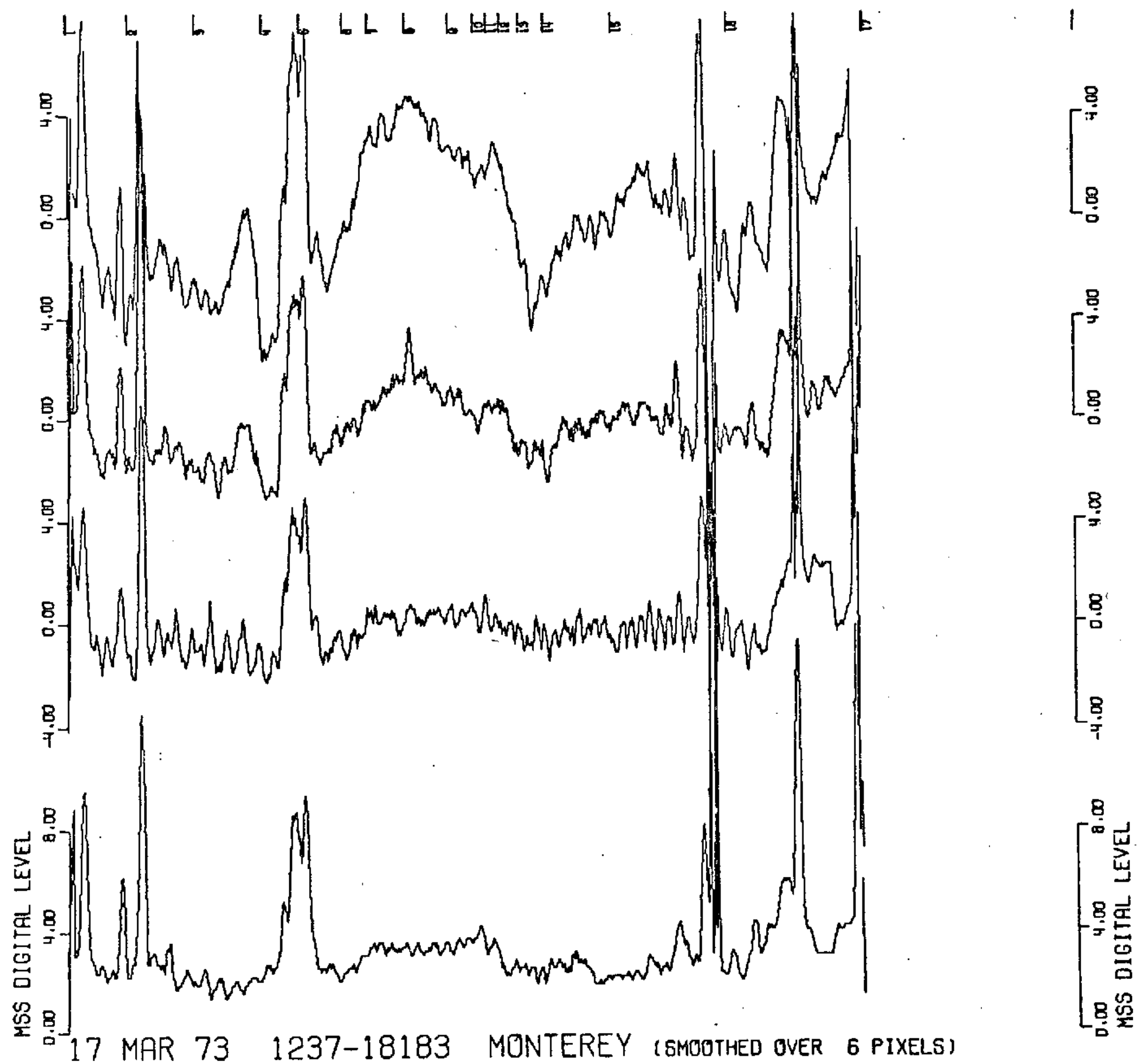
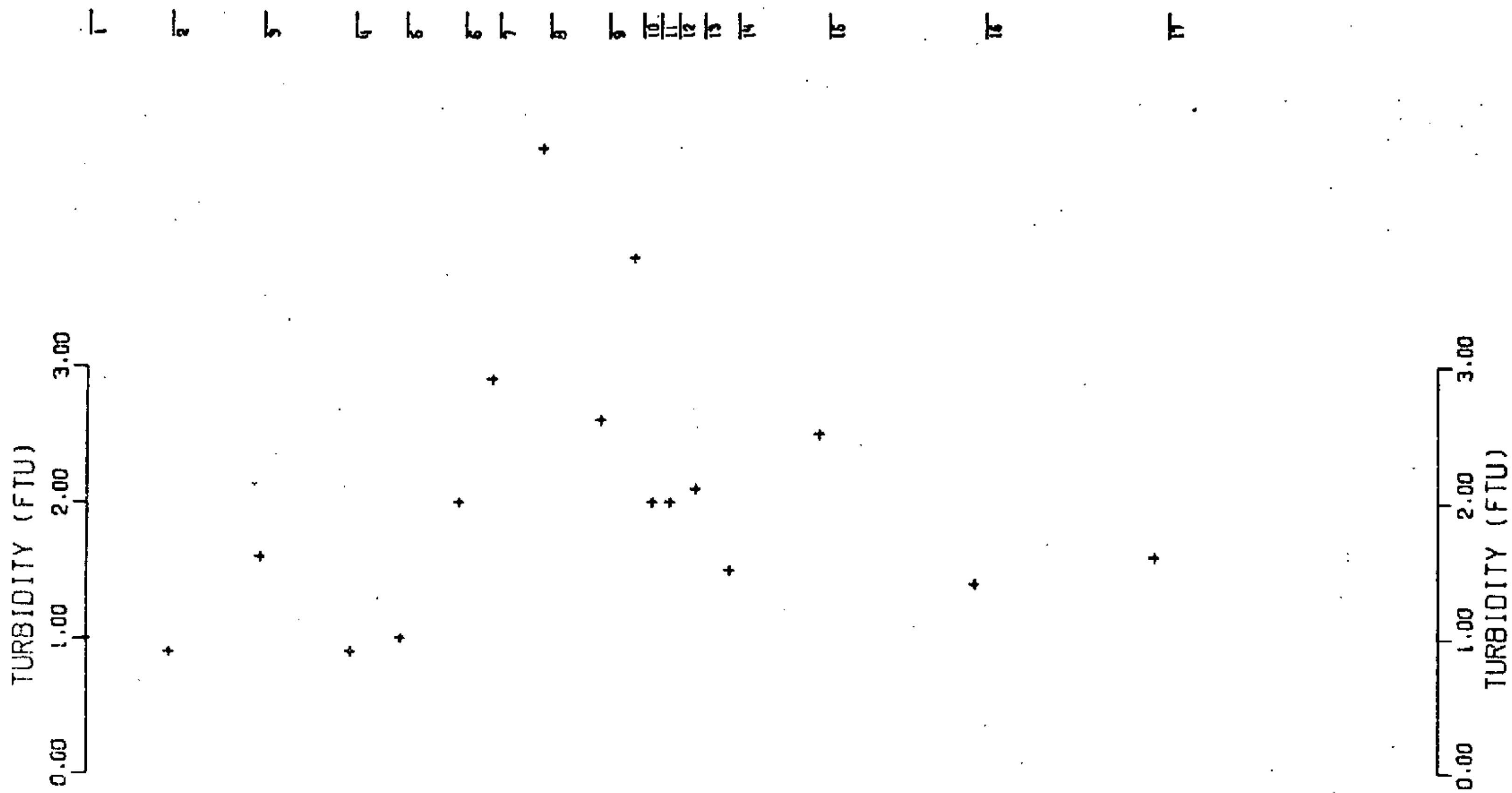


Figure A-24b

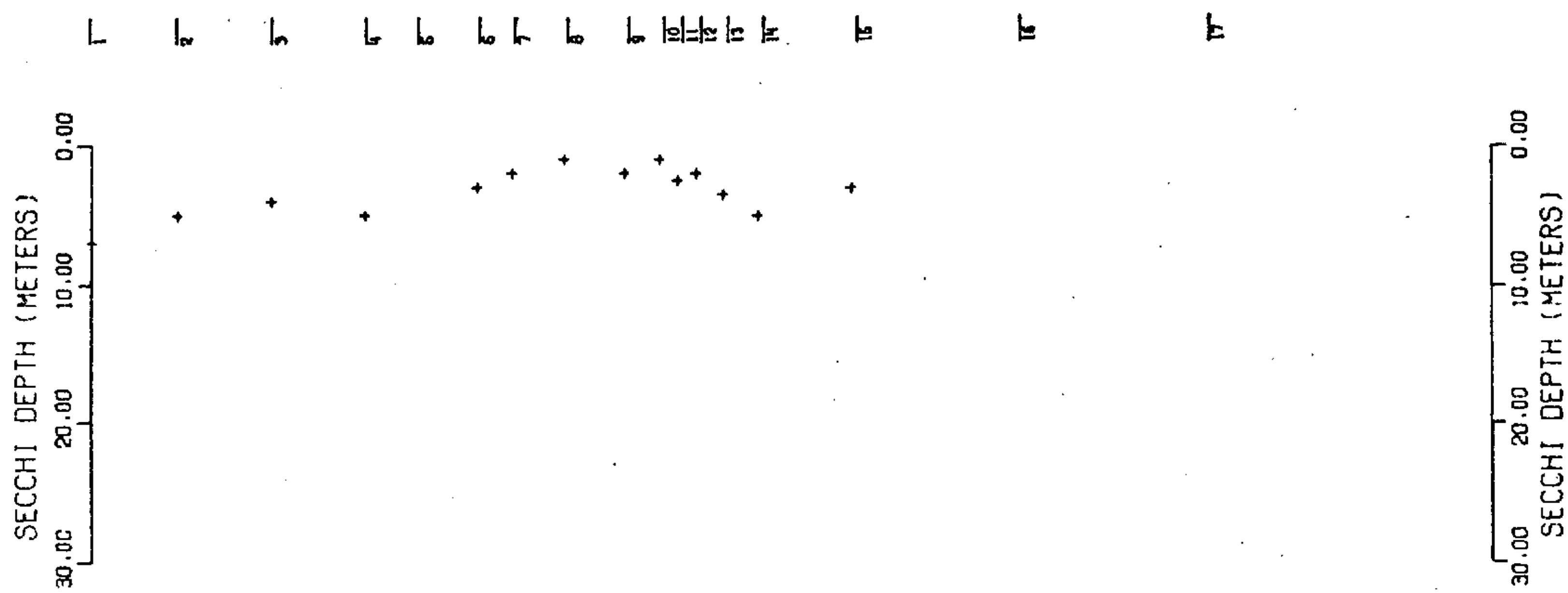
SUPPRESSED RADIANCE PROFILES, BANDS 4-6
COMPARED WITH BAND 7 RADIANCE
MONTEREY BAY - 17 MARCH 1973



<u>Figure A-25</u>

WATER SURFACE TURBIDITY PROFILE
MONTEREY BAY - 17 MARCH 1973

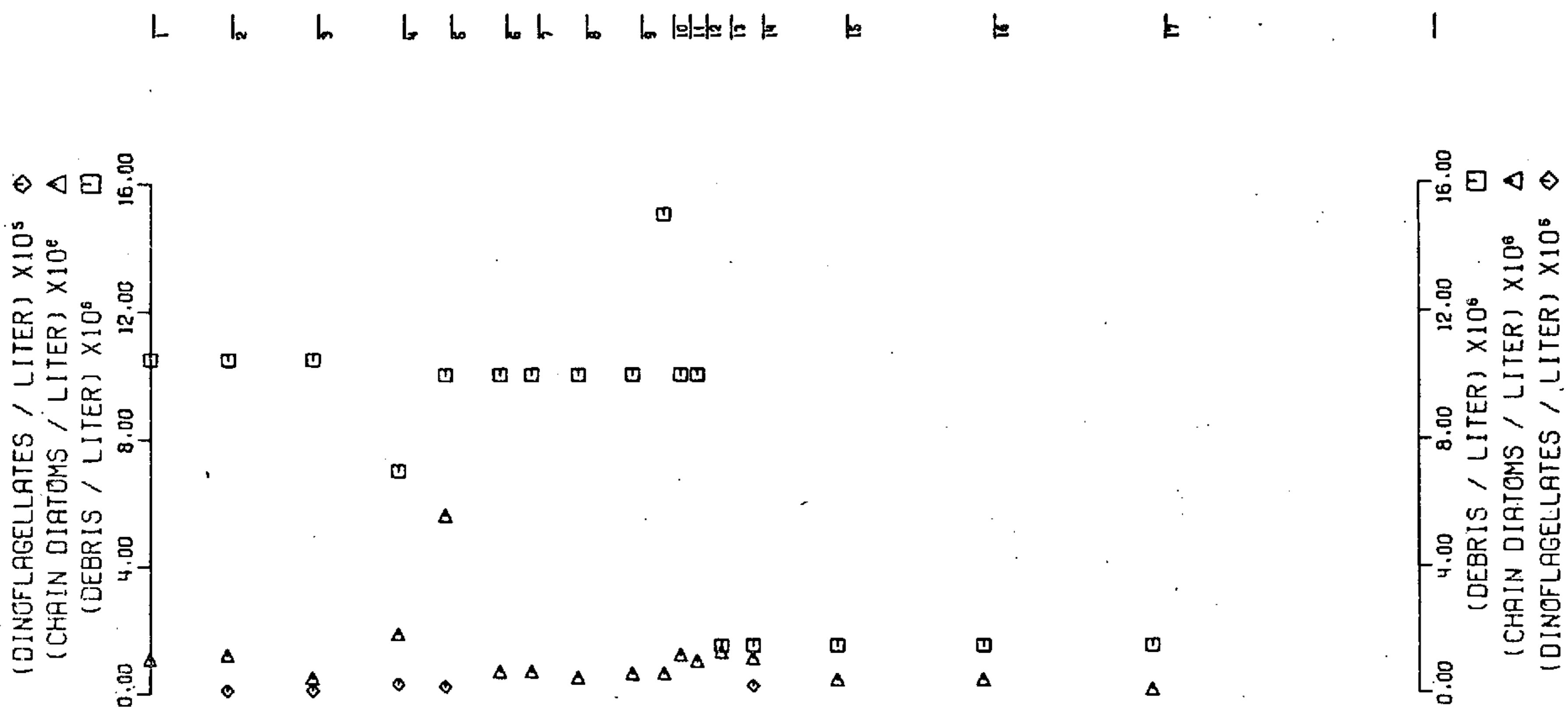
17 MAR 73



17 MAR 73

Figure A-26

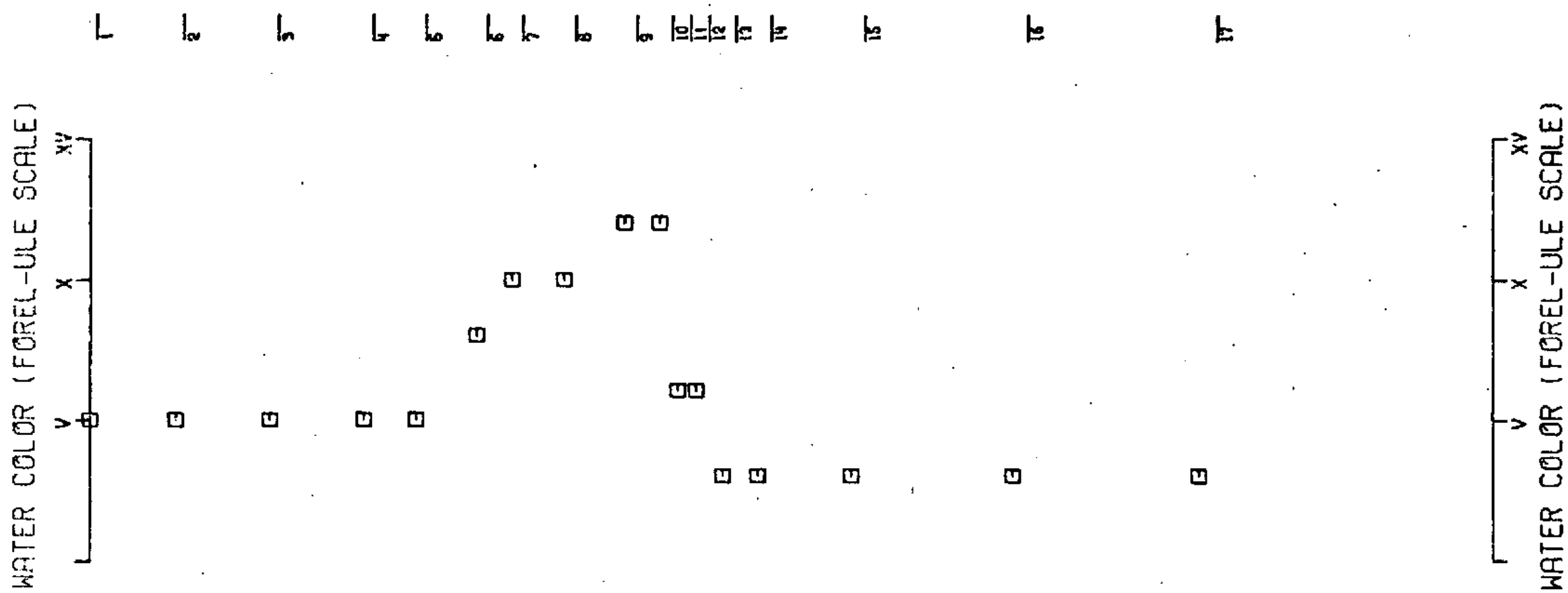
SECCHI DEPTH PROFILE
MONTEREY BAY - 17 MARCH 1973



17 MAR 73

Figure A-27

CONCENTRATION PROFILES OF NON-LIVING DEBRIS, CHAIN DIATOMS, AND DINOFLAGELLATES IN SUSPENSION MONTEREY BAY - 17 MARCH 1973



17 MAR 73

Figure A-28

PROFILE OF FOREL-ULE WATER COLOR VALUES
MONTEREY BAY - 17 MARCH 1973

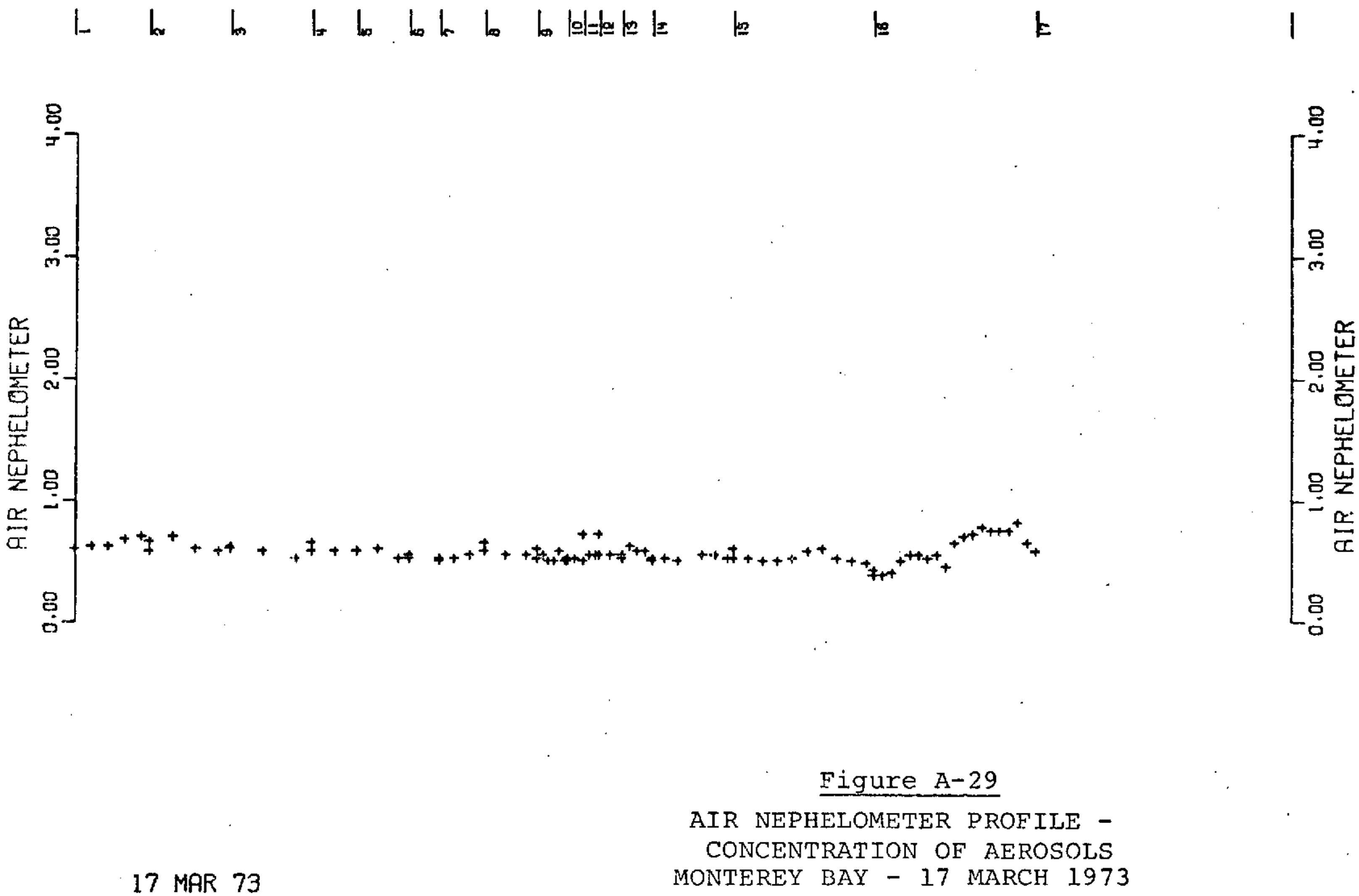
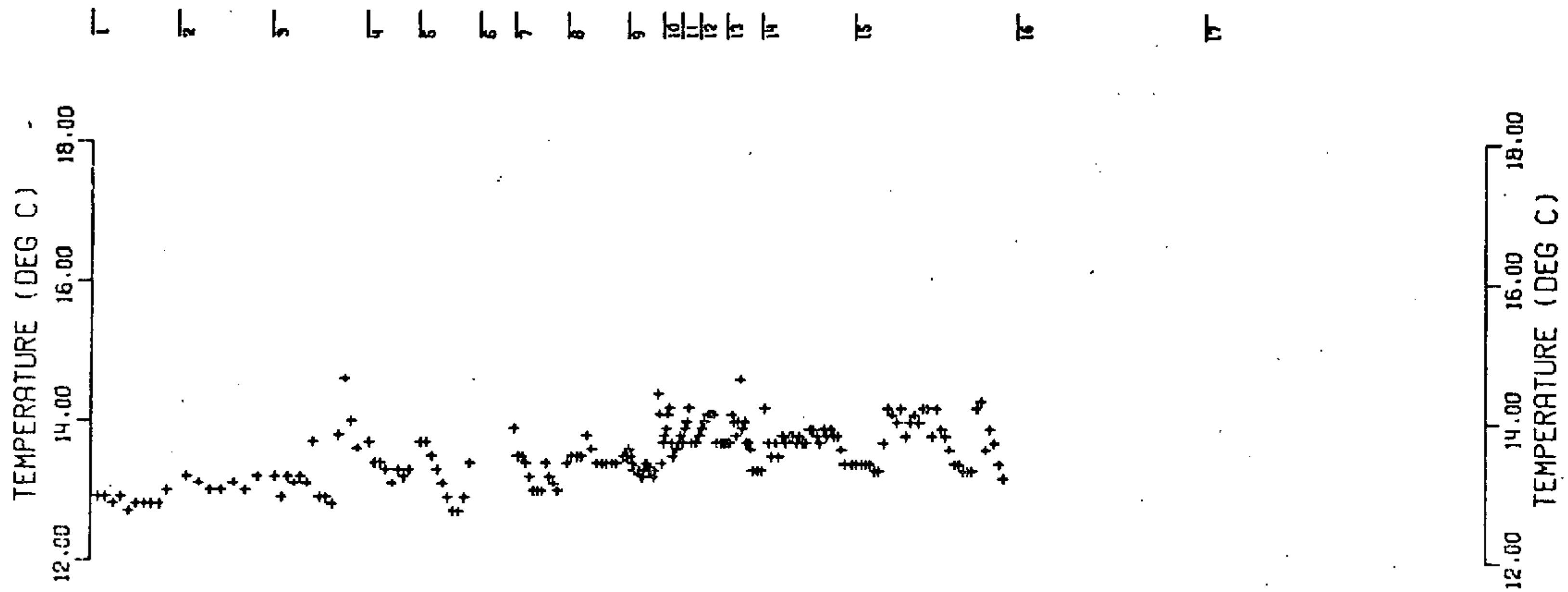


Figure A-29

AIR NEPHELOMETER PROFILE -
CONCENTRATION OF AEROSOLS
MONTEREY BAY - 17 MARCH 1973



17 MAR 73

Figure A-30

SURFACE WATER TEMPERATURE PROFILE
MONTEREY BAY - 17 MARCH 1973

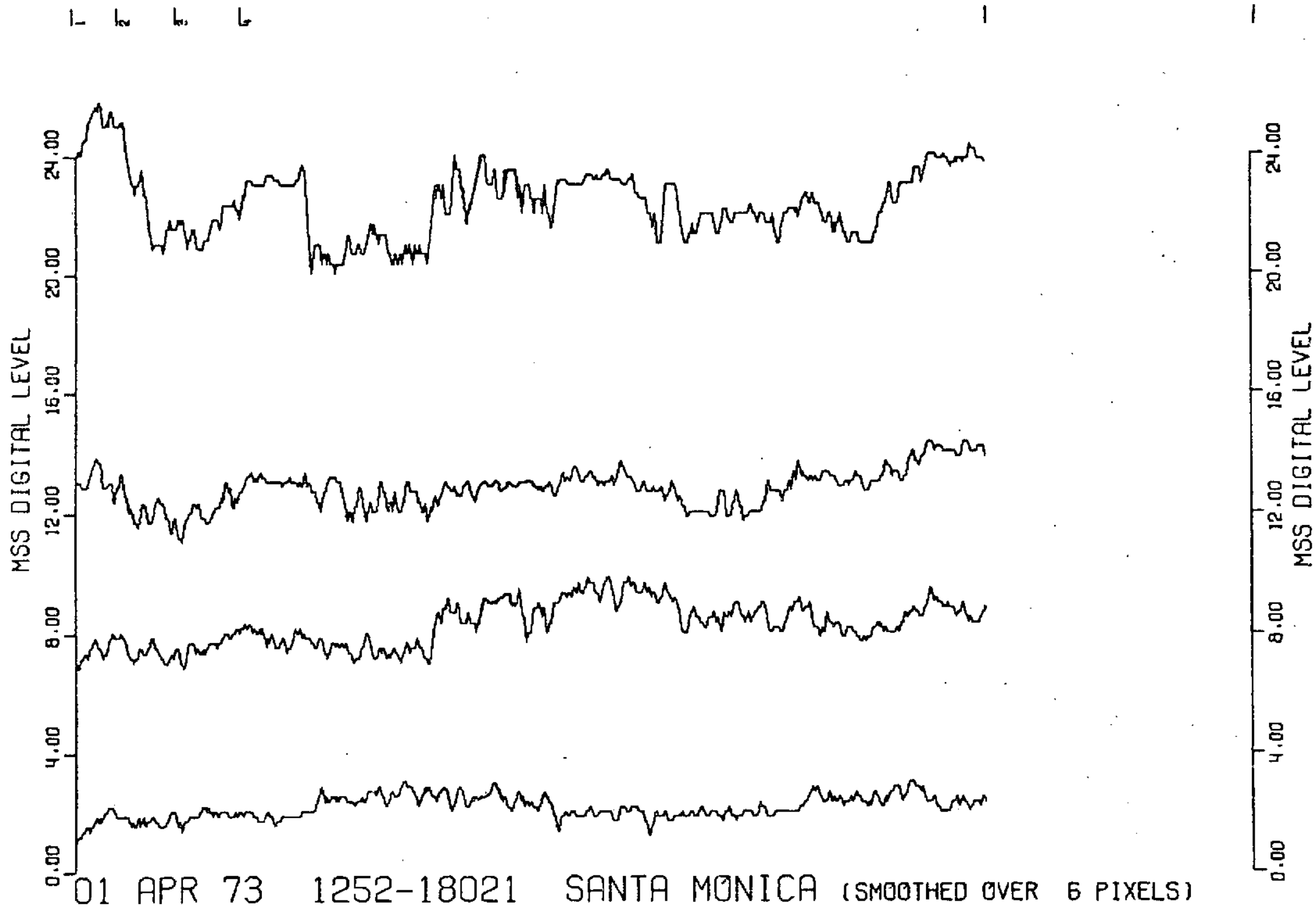


Figure A-31a

RADIANCE PROFILES, BANDS 4-7
SANTA MONICA BAY - 1 APRIL 1973

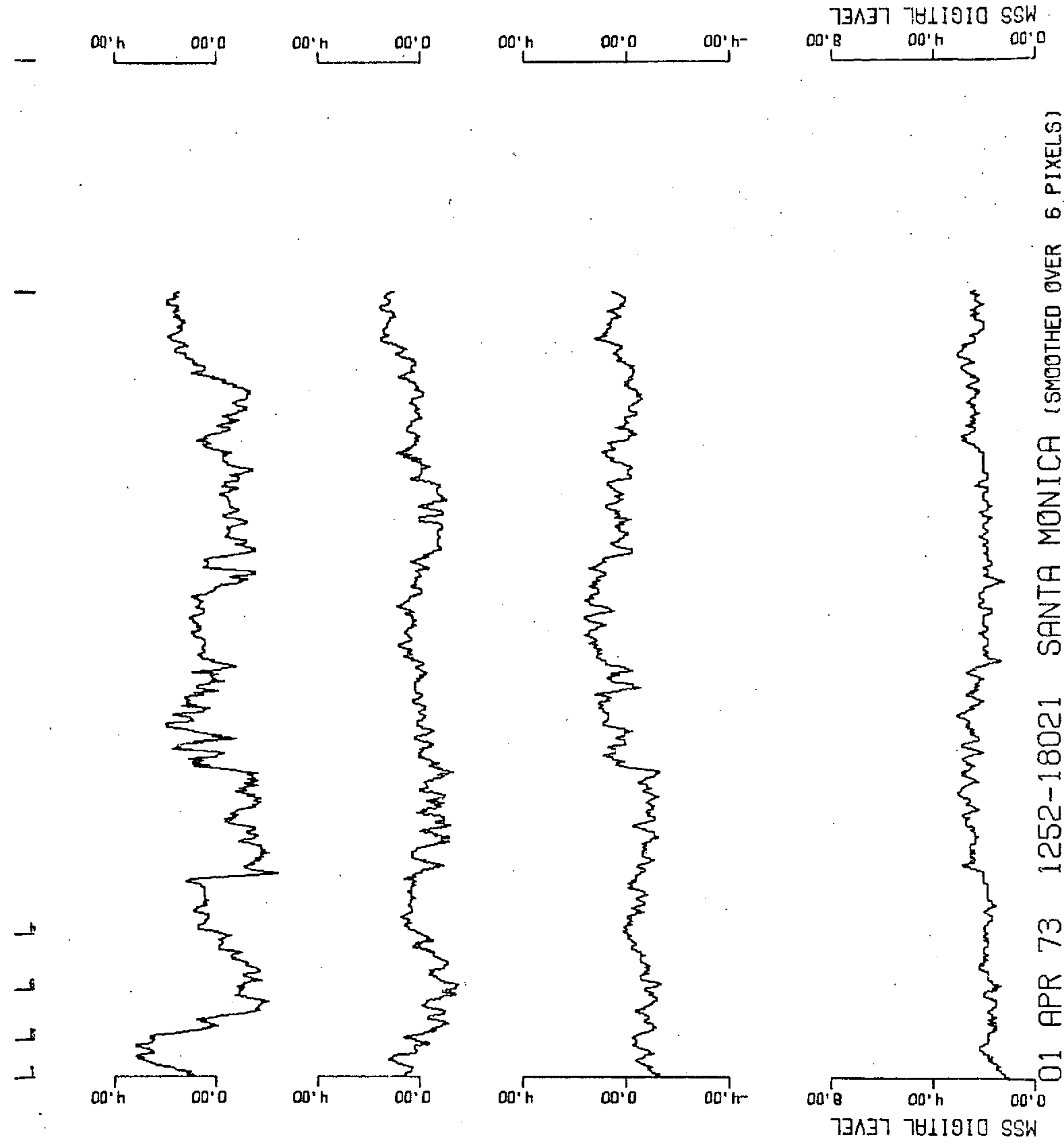


Figure A-31b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6,
COMPARED WITH BAND 7 RADIANCE
SANTA MONICA BAY - 1 APRIL 1973

01 APR 73

Figure A-32

WATER SURFACE TURBIDITY PROFILE
SANTA MONICA BAY - 1 APRIL 1973

01 APR 73

Figure A-33

SECCHI DEPTH PROFILE
SANTA MONICA BAY - 1 APRIL 1973

01 APR 73

Figure A-34

CONCENTRATION PROFILES OF NON-LIVING DEBRIS, CHAIN DIATOMS, AND DINOFLAGELLATES IN SUSPENSION
SANTA MONICA BAY - 1 APRIL 1973

Figure A-35

PROFILE OF FOREL-ULE WATER COLOR VALUES
SANTA MONICA BAY - 1 APRIL 1973

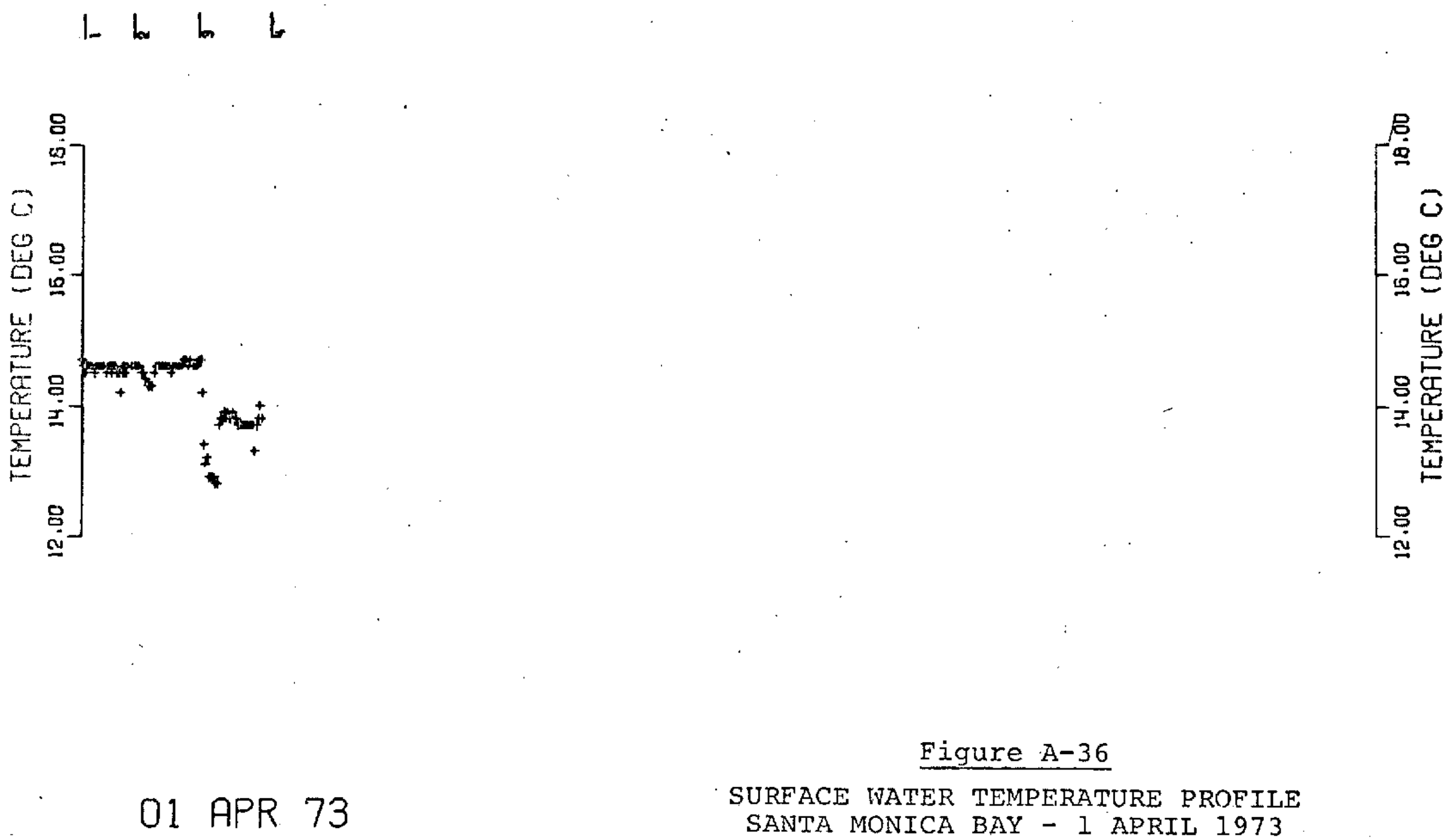


Figure A-36

SURFACE WATER TEMPERATURE PROFILE
SANTA MONICA BAY - 1 APRIL 1973

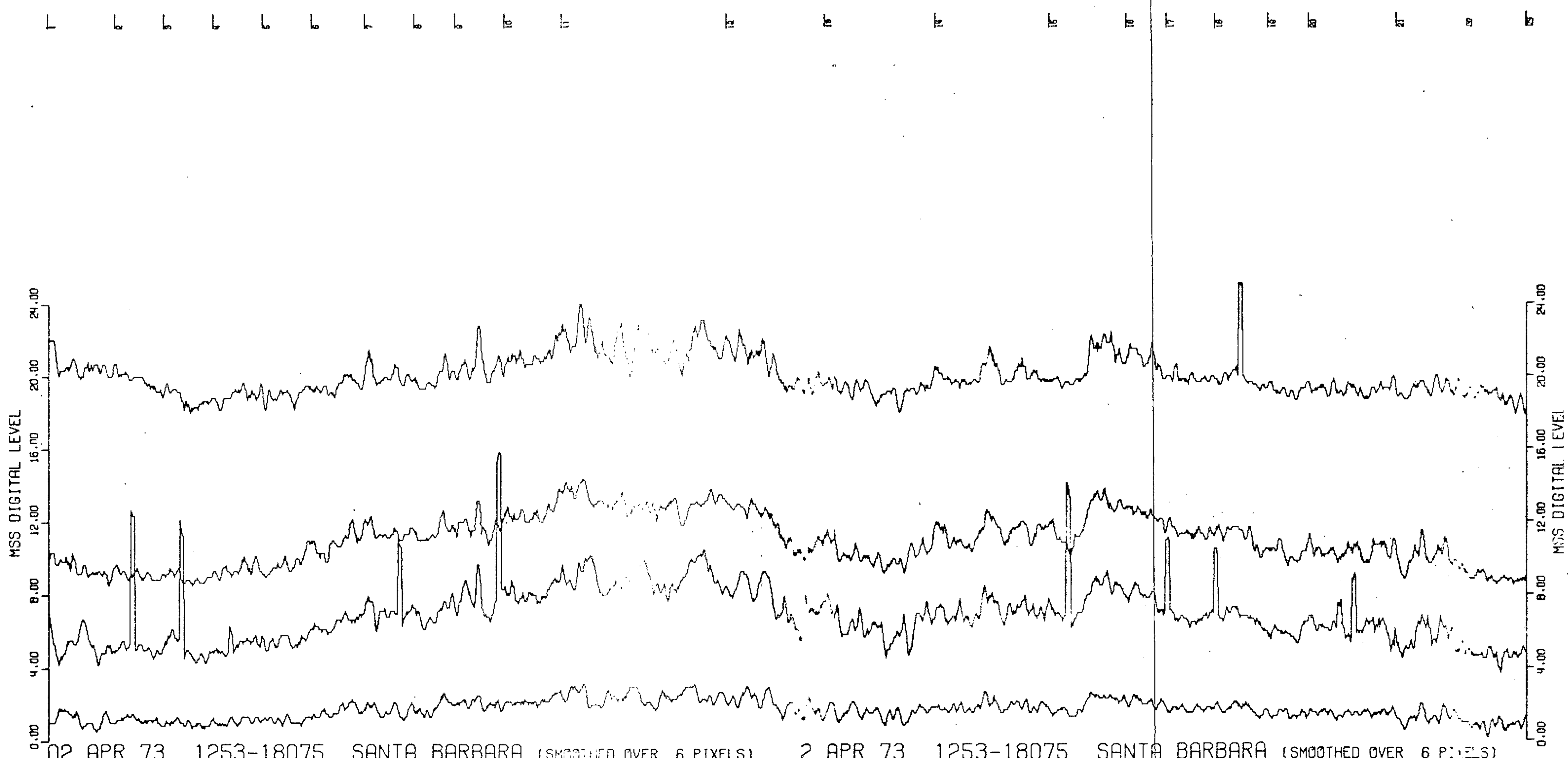


Figure A-37a

RADIANCE PROFILES, BANDS 4-7
SANTA BARBARA CHANNEL - 2 APRIL 1973

FOLDOUT FRAME 1

FOLDOUT FRAME 2

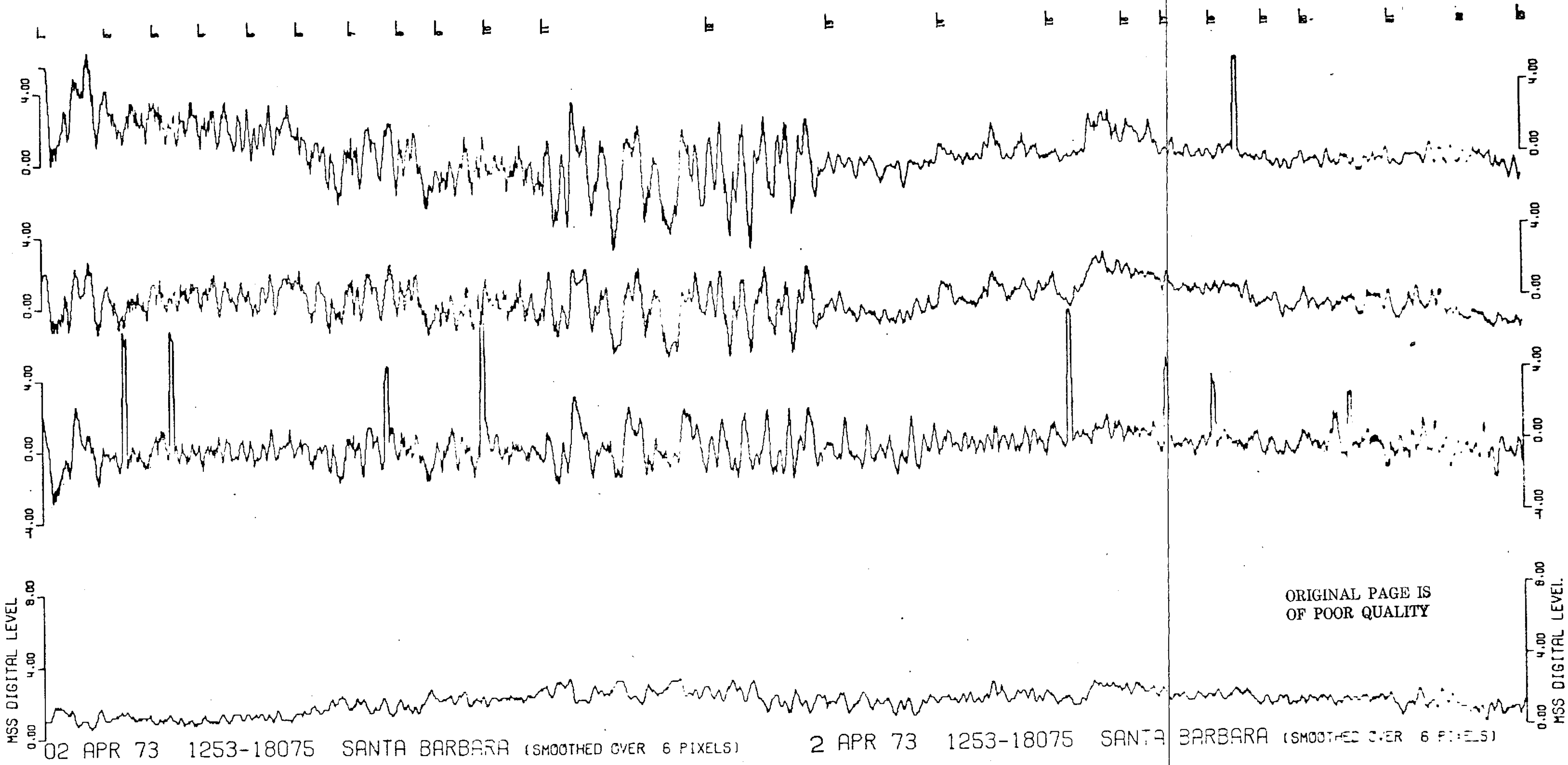


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Figure A-37b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6
COMPARED WITH BAND 7 RADIANCE
SANTA BARBARA CHANNEL - 2 APRIL 1973

FOLDOUT FRAME 1

FOLDOUT FRAME 2

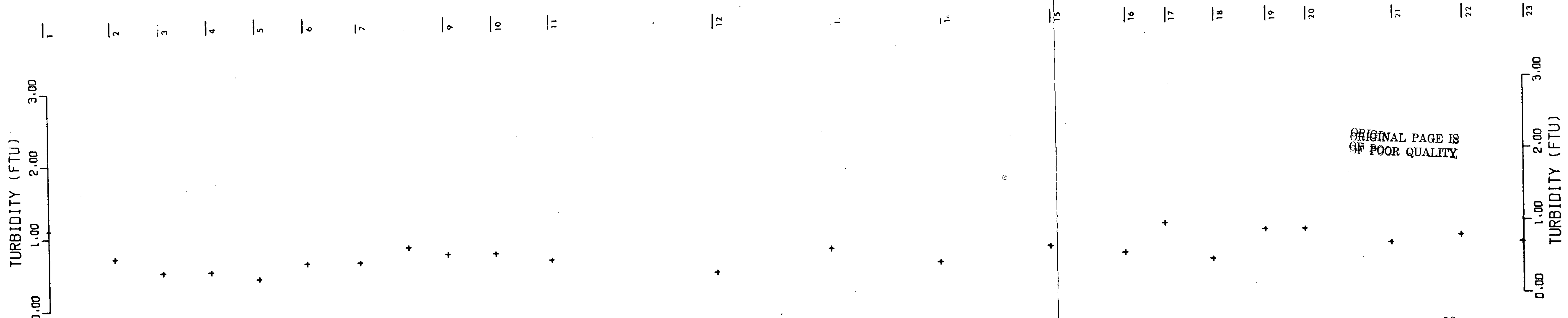

Figure A-38
WATER SURFACE TURBIDITY PROFILE
SANTA BARBARA CHANNEL - 2 APRIL 1973

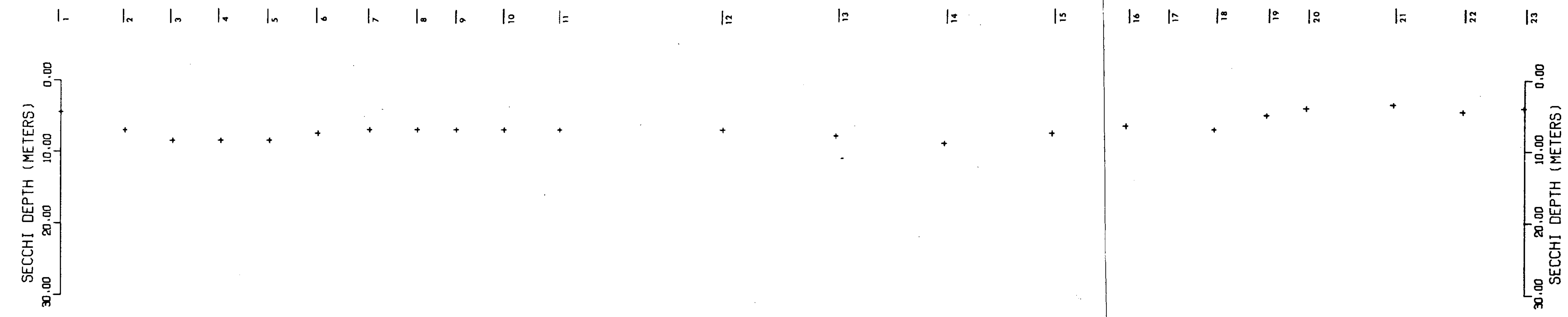

Figure A-39

SECCHI DEPTH PROFILE

SANTA BARBARA CHANNEL - 2 APRIL 1973

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

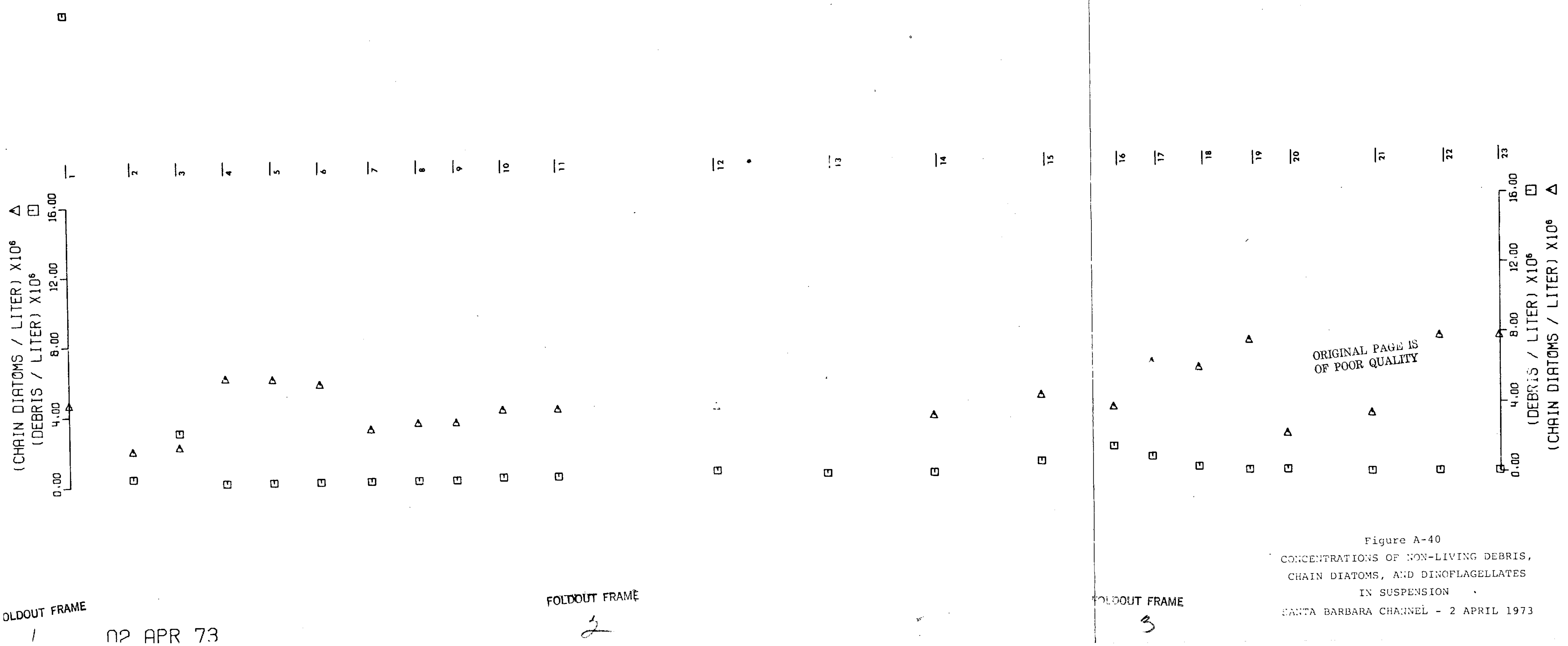

Figure A-40
CONCENTRATIONS OF NON-LIVING DEBRIS,
CHAIN DIATOMS, AND DINOFLAGELLATES
IN SUSPENSION
SANTA BARBARA CHANNEL - 2 APRIL 1973

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3

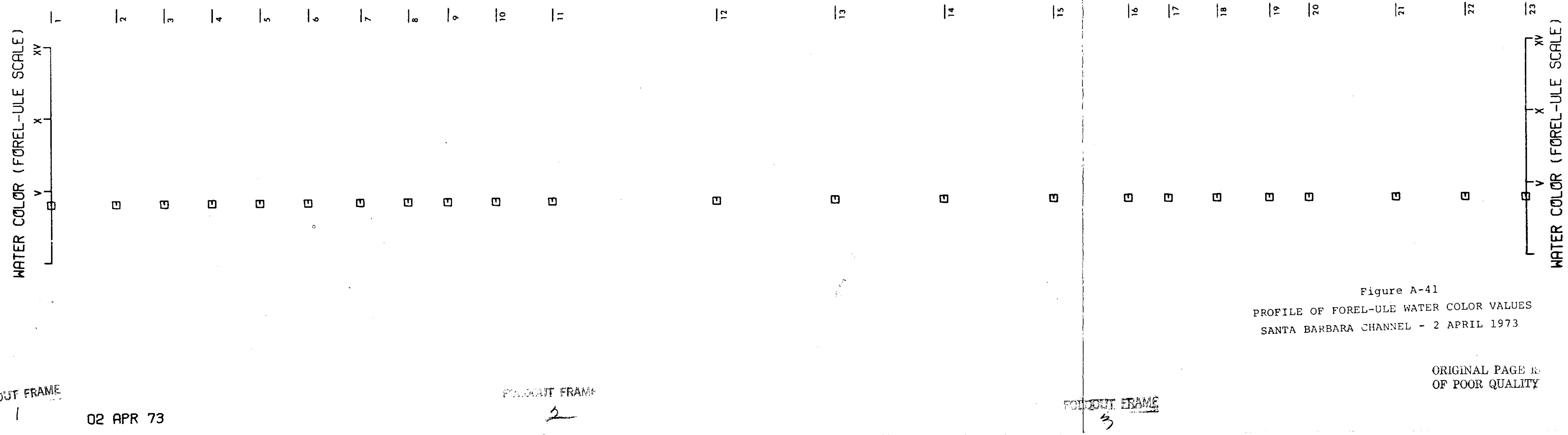

Figure A-41
PROFILE OF FOREL-ULE WATER COLOR VALUES
SANTA BARBARA CHANNEL - 2 APRIL 1973

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FOLDOUT FRAME 1

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FOLDOUT FRAME 3

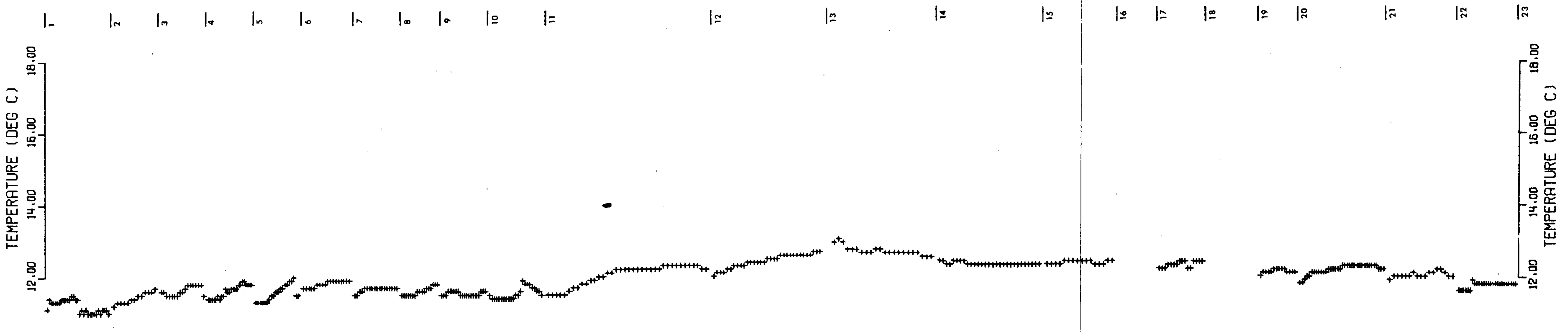


Figure A-42
SURFACE WATER TEMPERATURE PROFILE
SANTA BARBARA CHANNEL - 2 APRIL 1973

FOLDOUT FRAME 1

02 APR 73

FOLDOUT FRAME 2

FOLDOUT FRAME 3

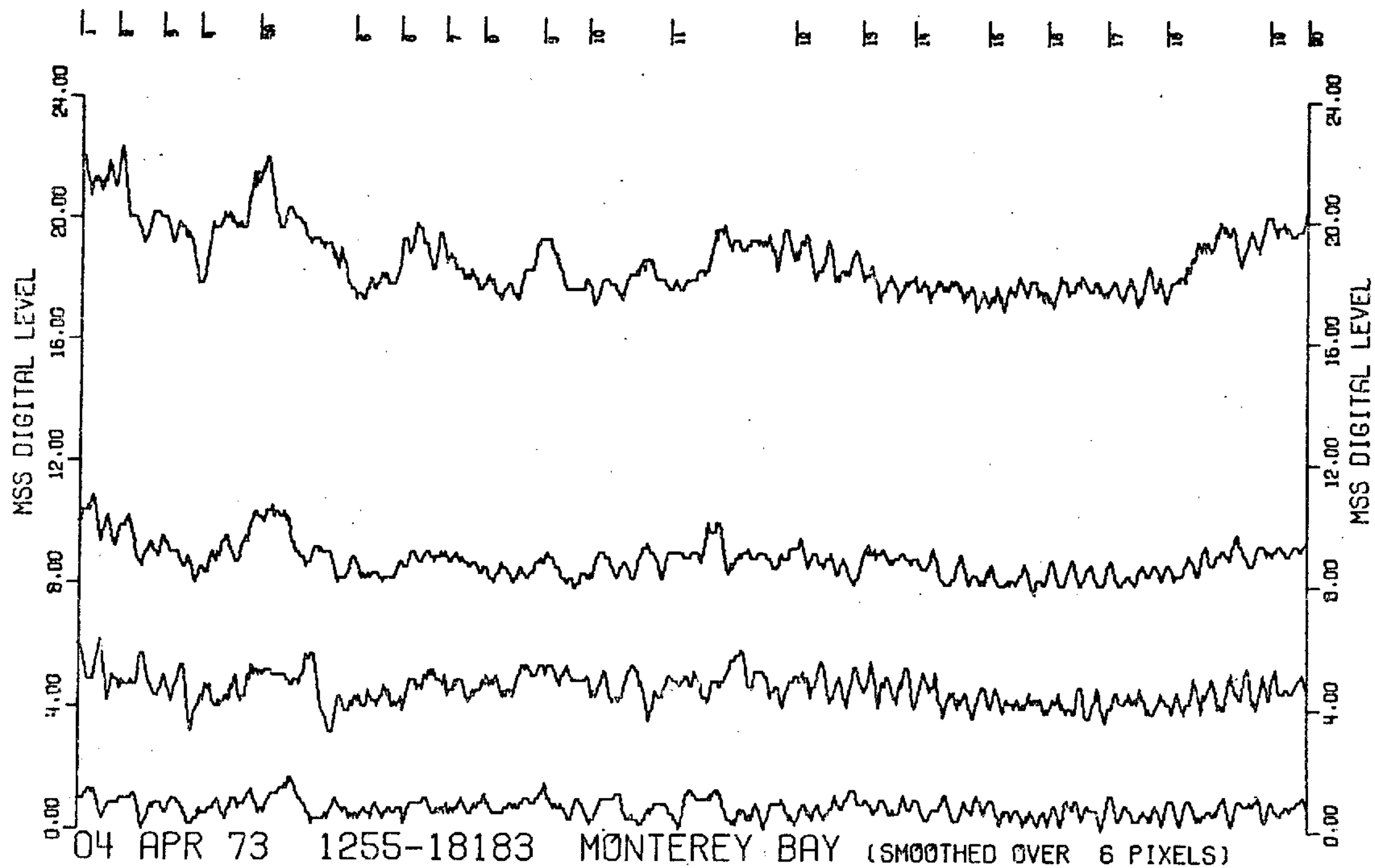


Figure A-43a

RADIANCE PROFILES, BANDS 4-7
MONTEREY BAY - 4 APRIL 1973

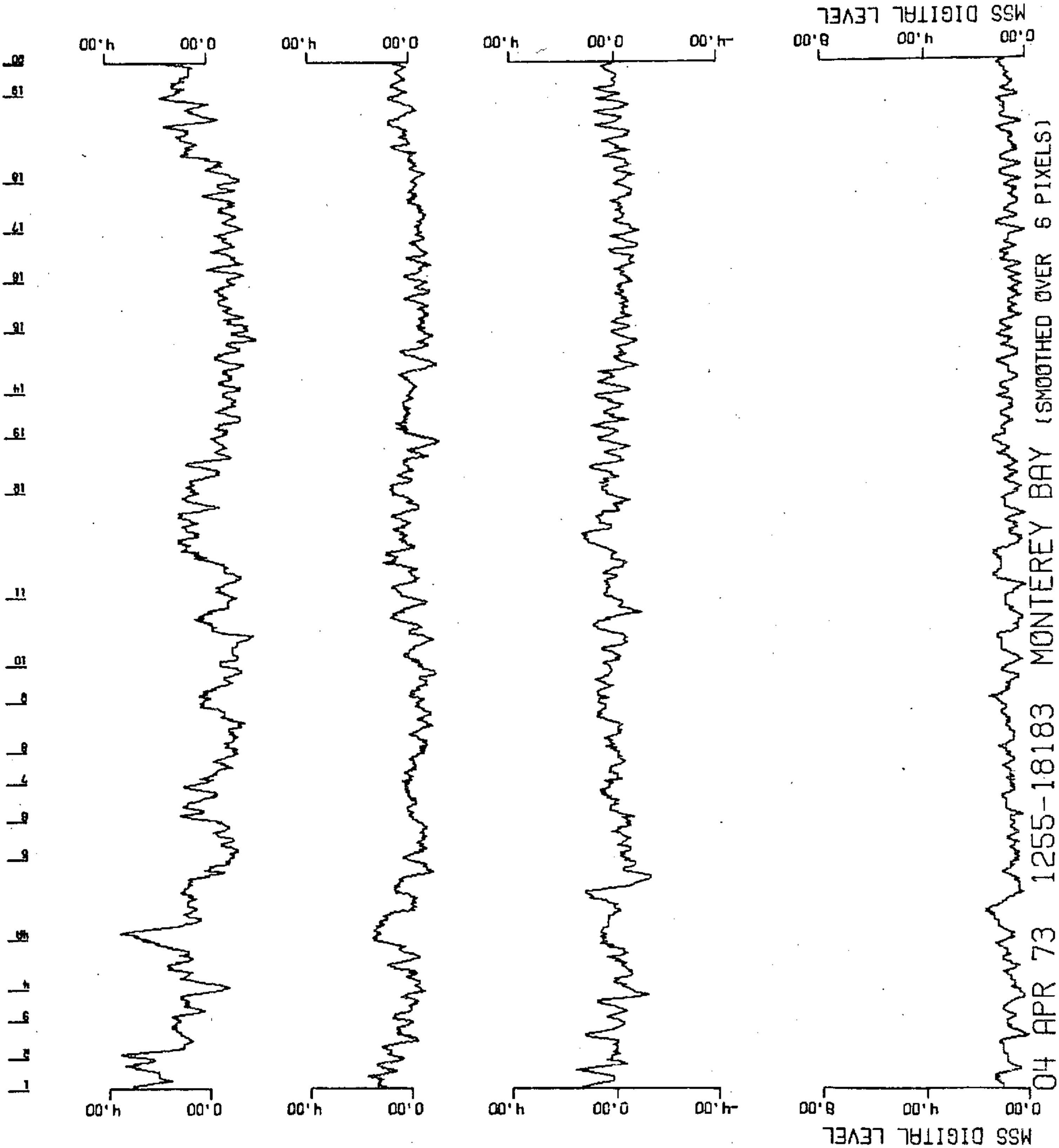
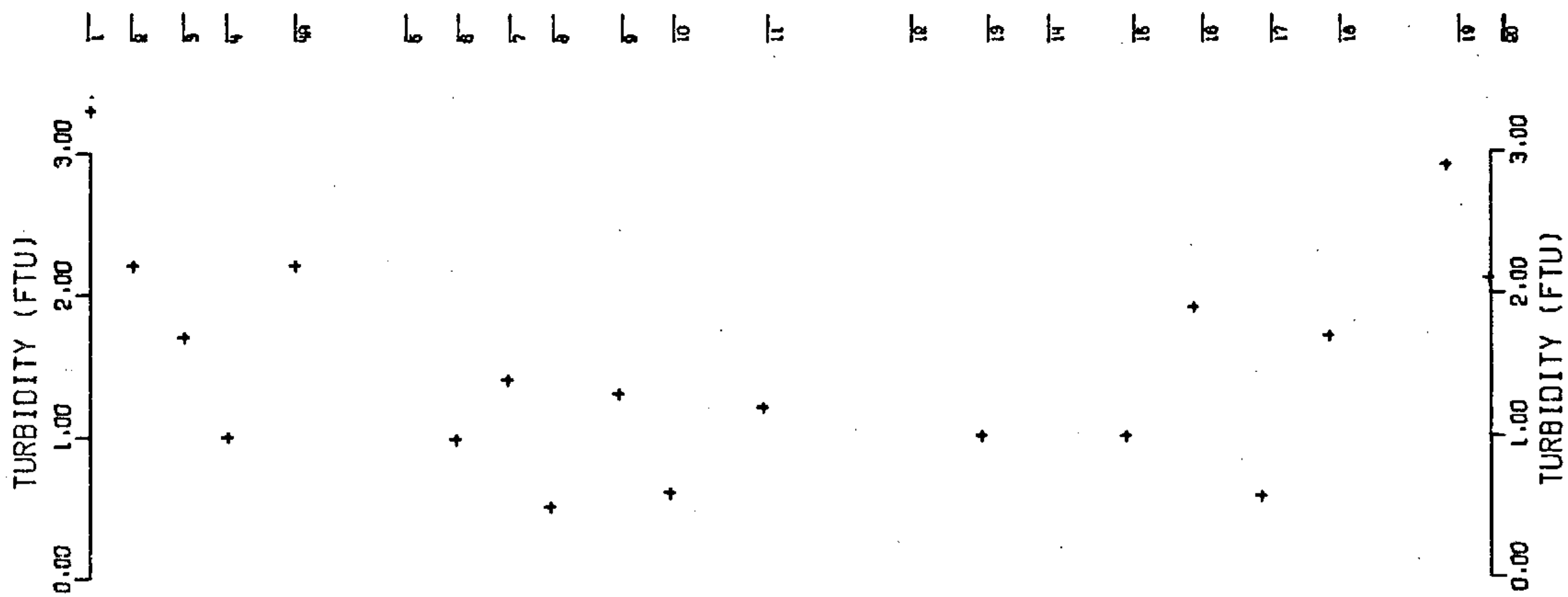


Figure A-43b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6,
COMPARED WITH BAND 7 RADIANCE
MONTEREY BAY - 4 APRIL 1973



<u>Figure A-44</u>

WATER SURFACE TURBIDITY PROFILE
MONTEREY BAY - 4 APRIL 1973

04 APR 73

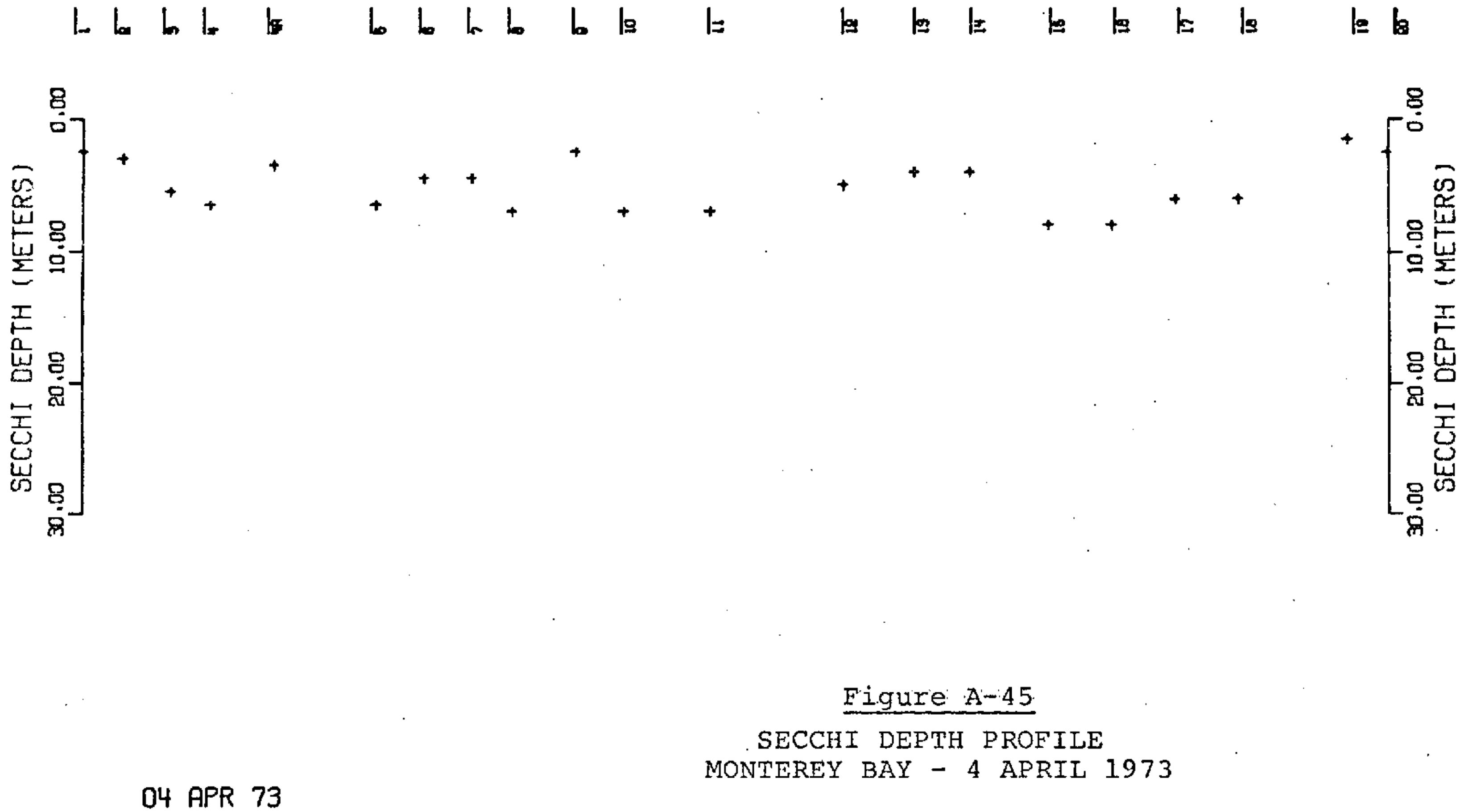


Figure A-45

SECCHI DEPTH PROFILE
MONTEREY BAY - 4 APRIL 1973

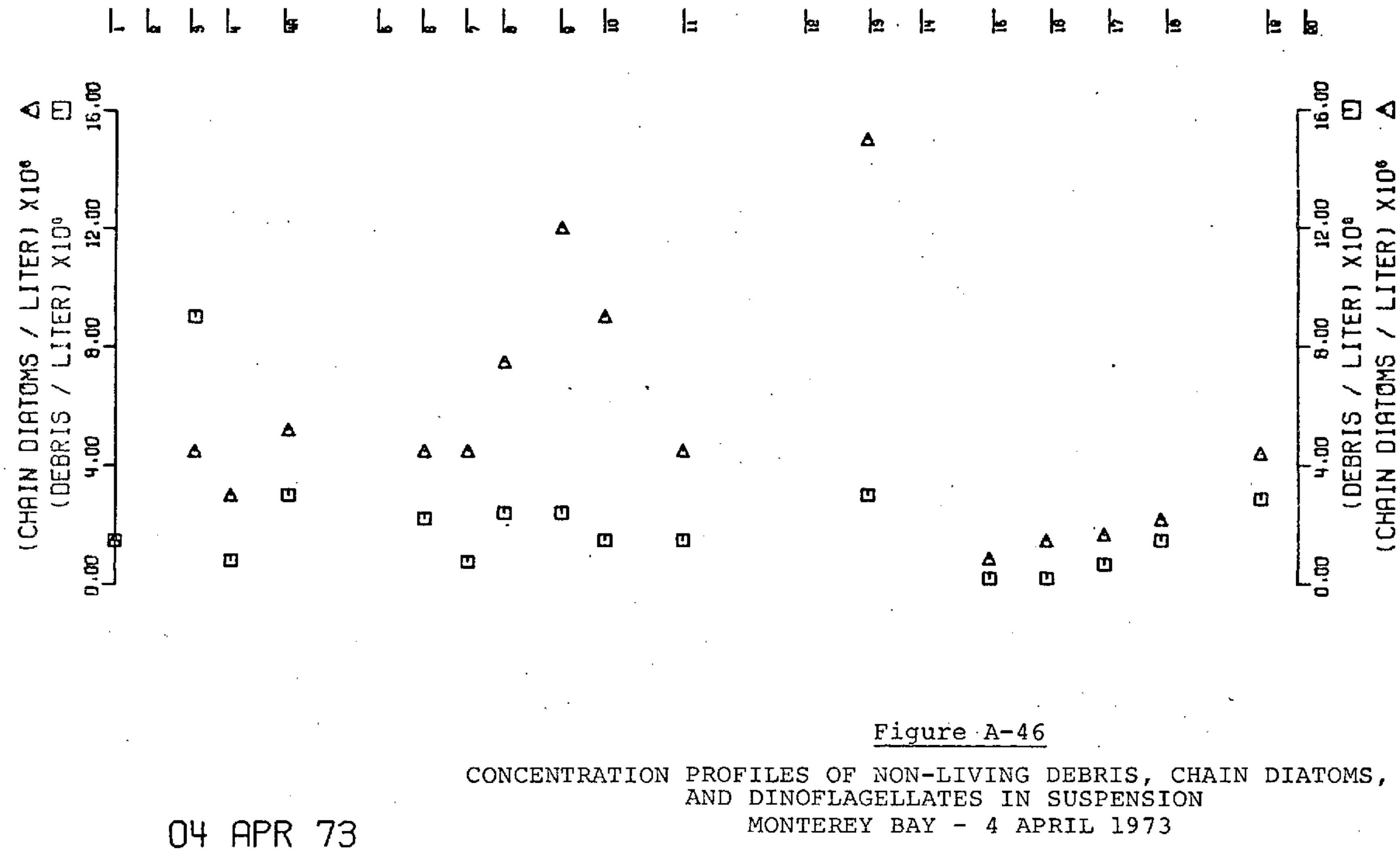


Figure A-46

CONCENTRATION PROFILES OF NON-LIVING DEBRIS, CHAIN DIATOMS, AND DINOFLAGELLATES IN SUSPENSION
MONTEREY BAY - 4 APRIL 1973

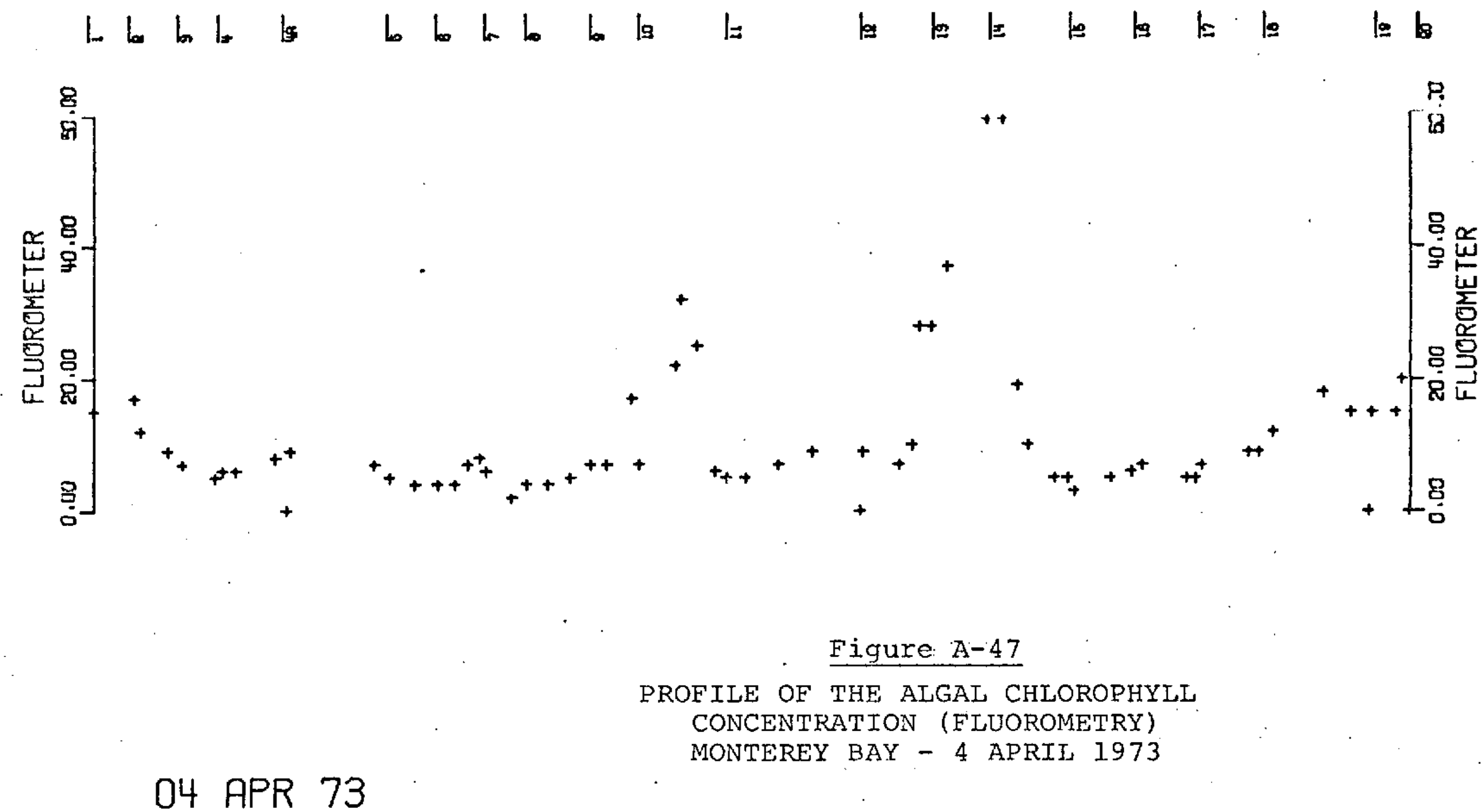


Figure A-47

PROFILE OF THE ALGAL CHLOROPHYLL
CONCENTRATION (FLUOROMETRY)
MONTEREY BAY - 4 APRIL 1973

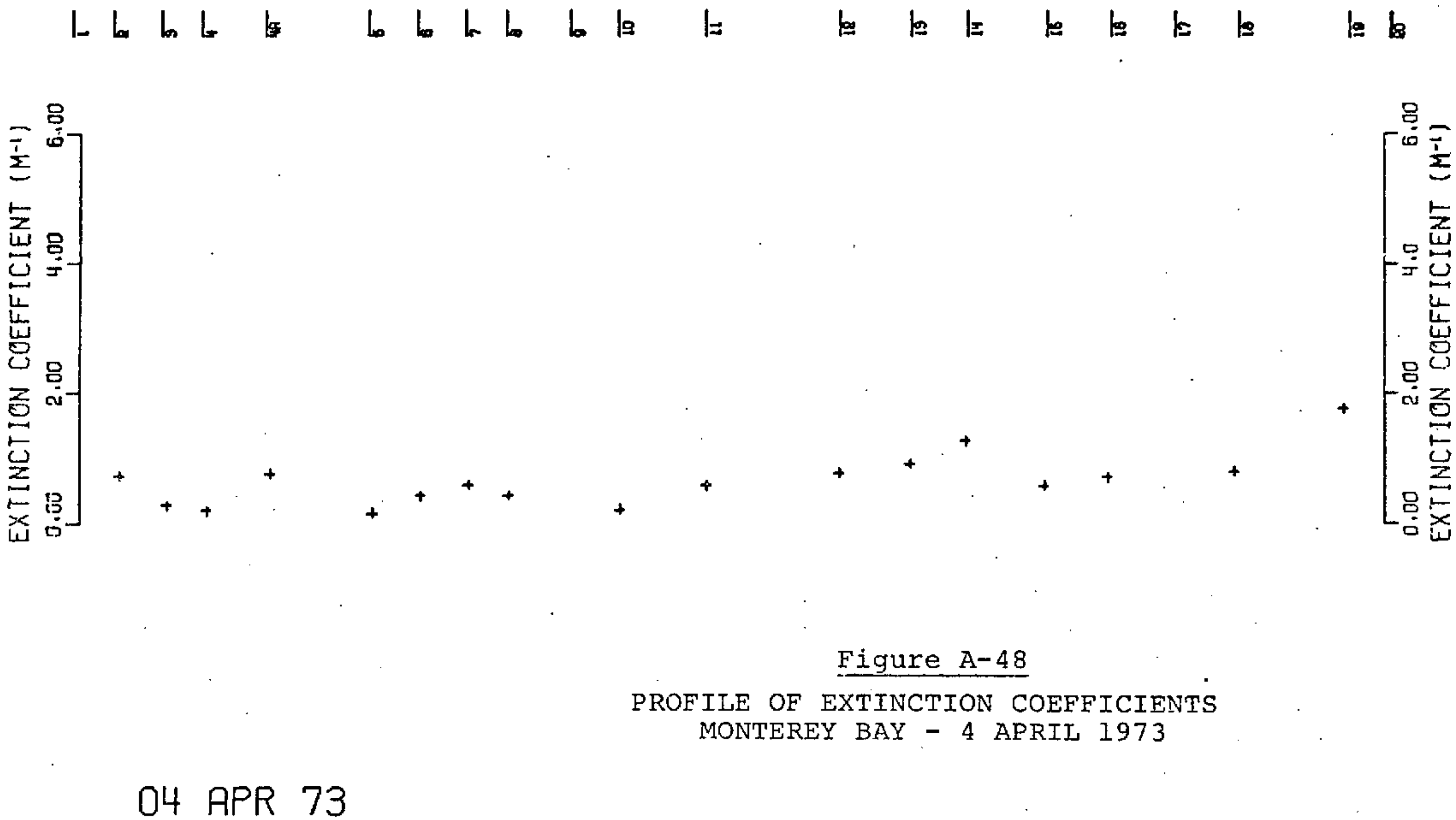


Figure A-48

PROFILE OF EXTINCTION COEFFICIENTS
MONTEREY BAY - 4 APRIL 1973

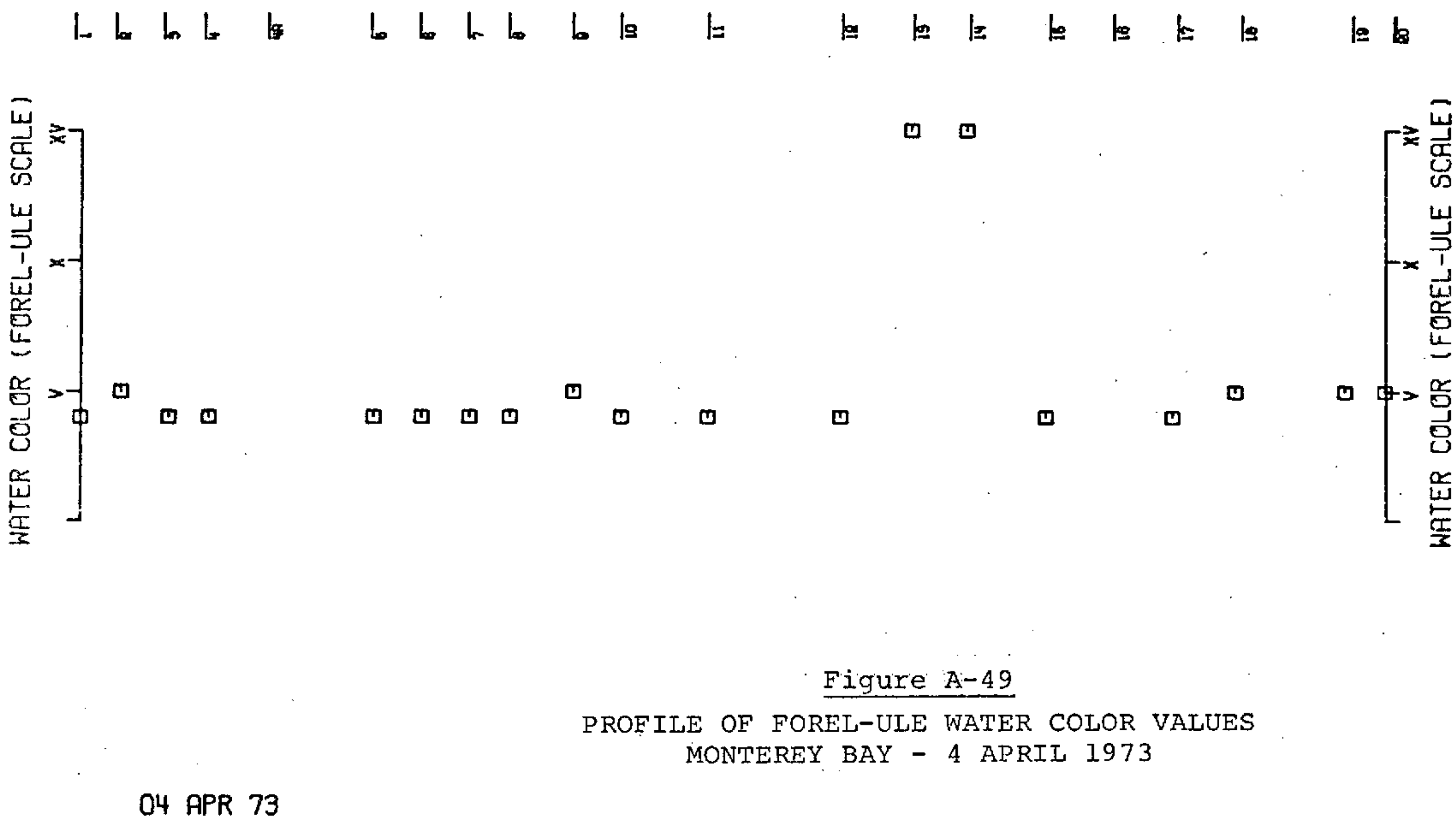


Figure A-49

PROFILE OF FOREL-ULE WATER COLOR VALUES
MONTEREY BAY - 4 APRIL 1973

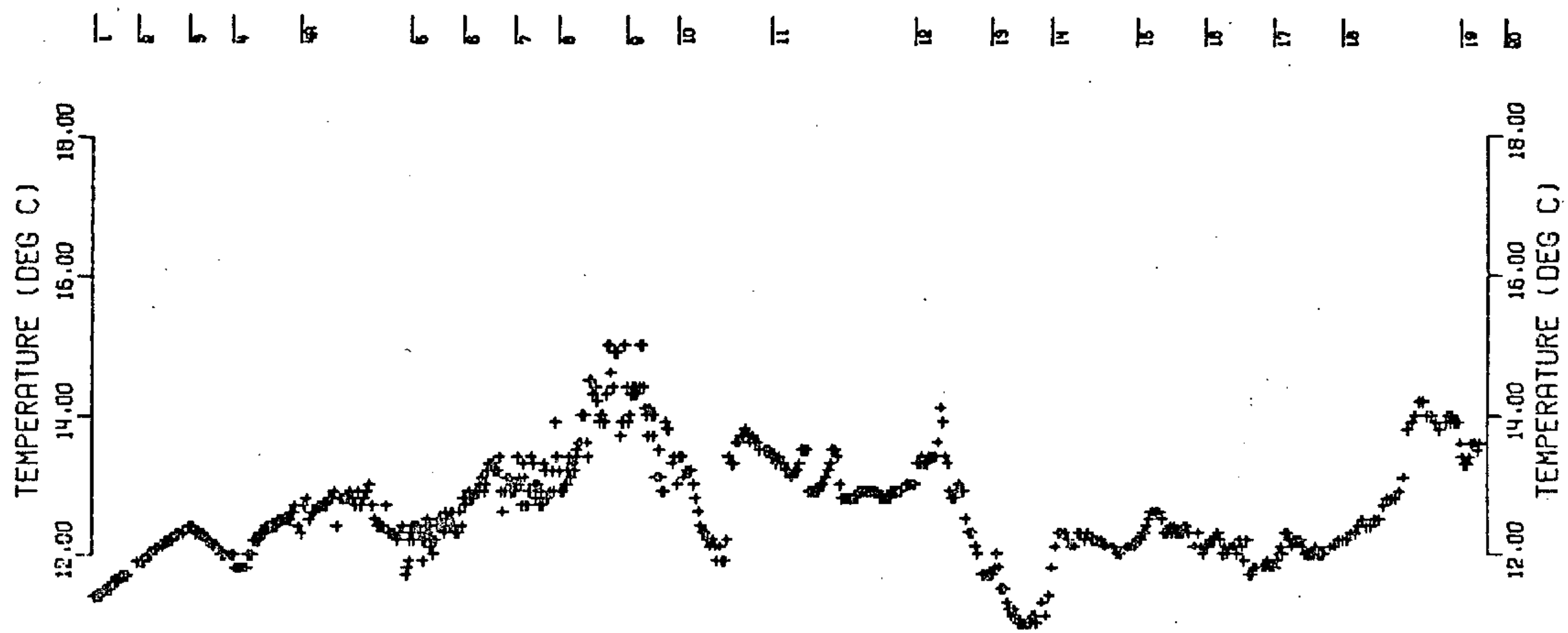


Figure A-50

SURFACE WATER TEMPERATURE PROFILE
MONTEREY BAY - 4 APRIL 1973

04 APR 73

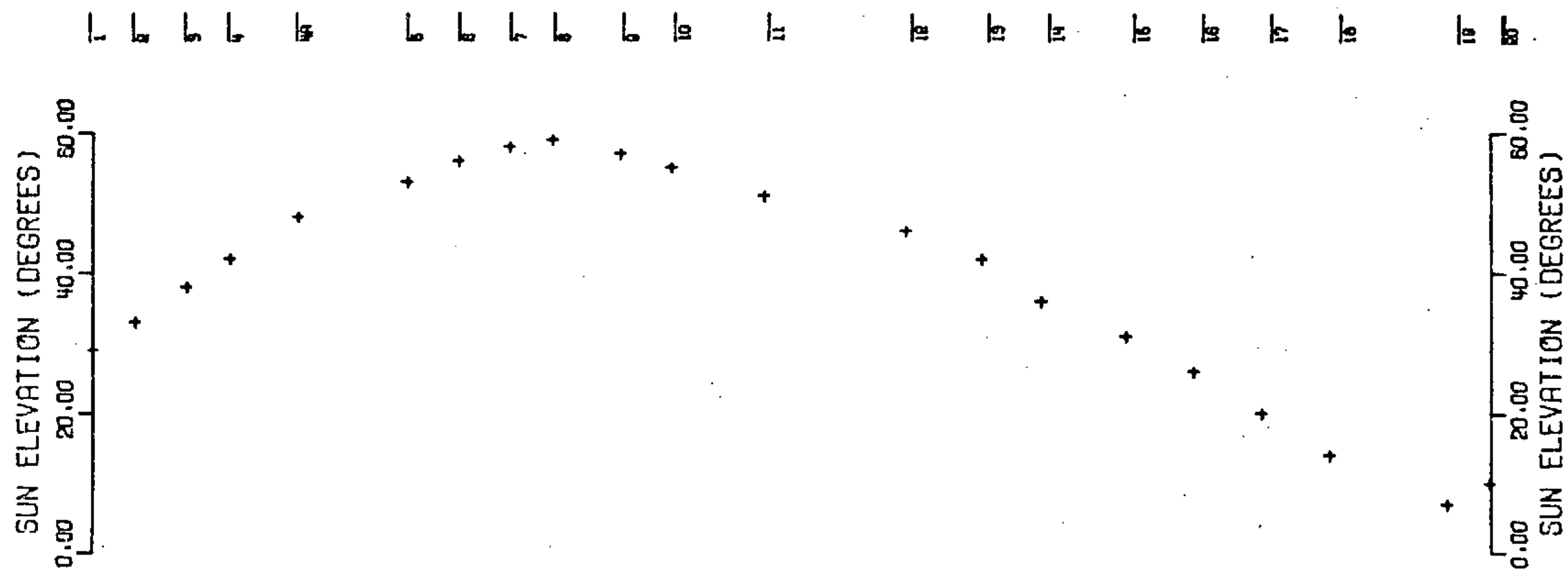


Figure A-51

SUN ELEVATION PROFILE
MONTEREY BAY - 4 APRIL 1973

04 APR 73

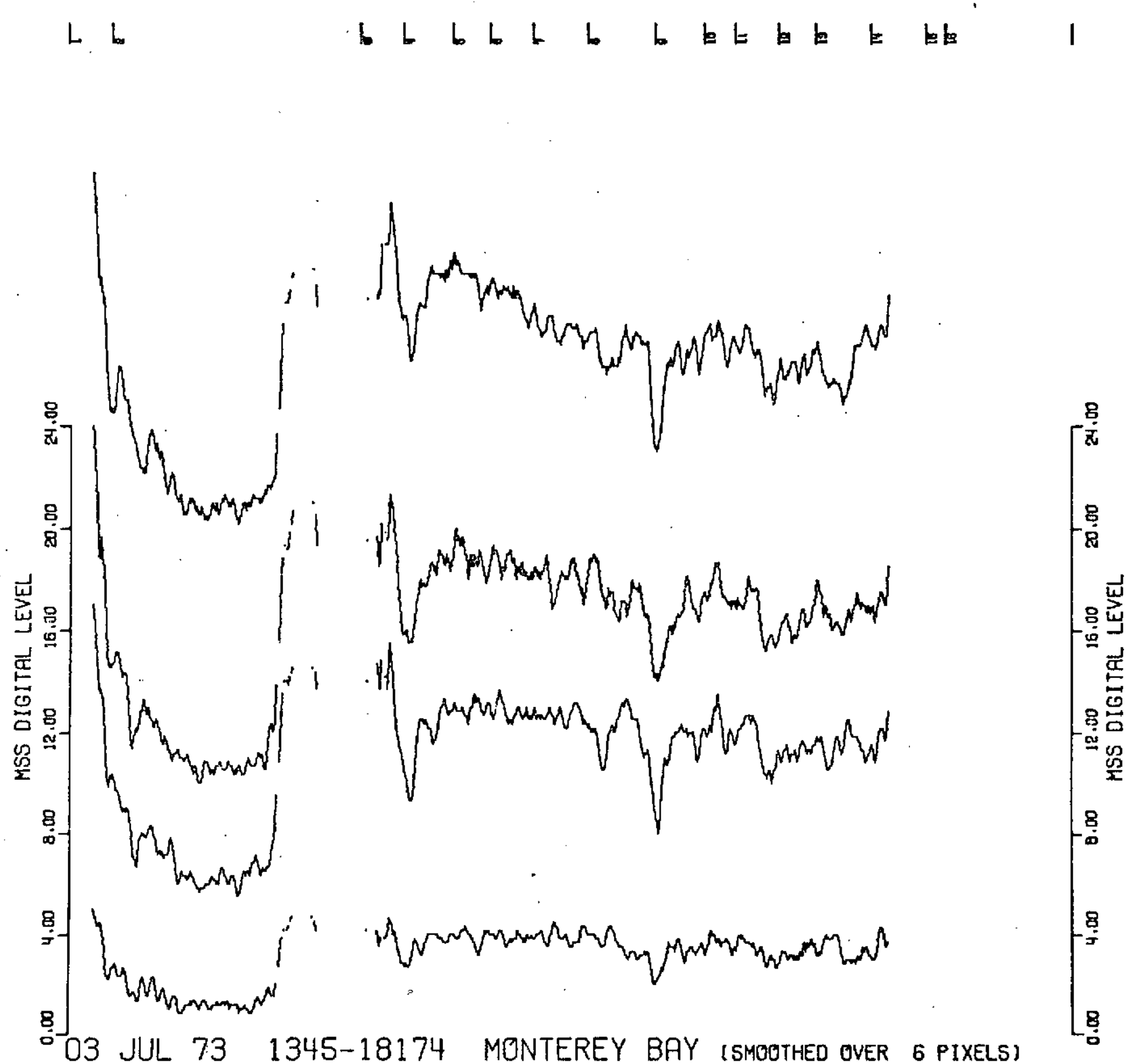


Figure 52a

RADIANCE PROFILES, BANDS 4-7
MONTEREY BAY - 3 JULY 1973

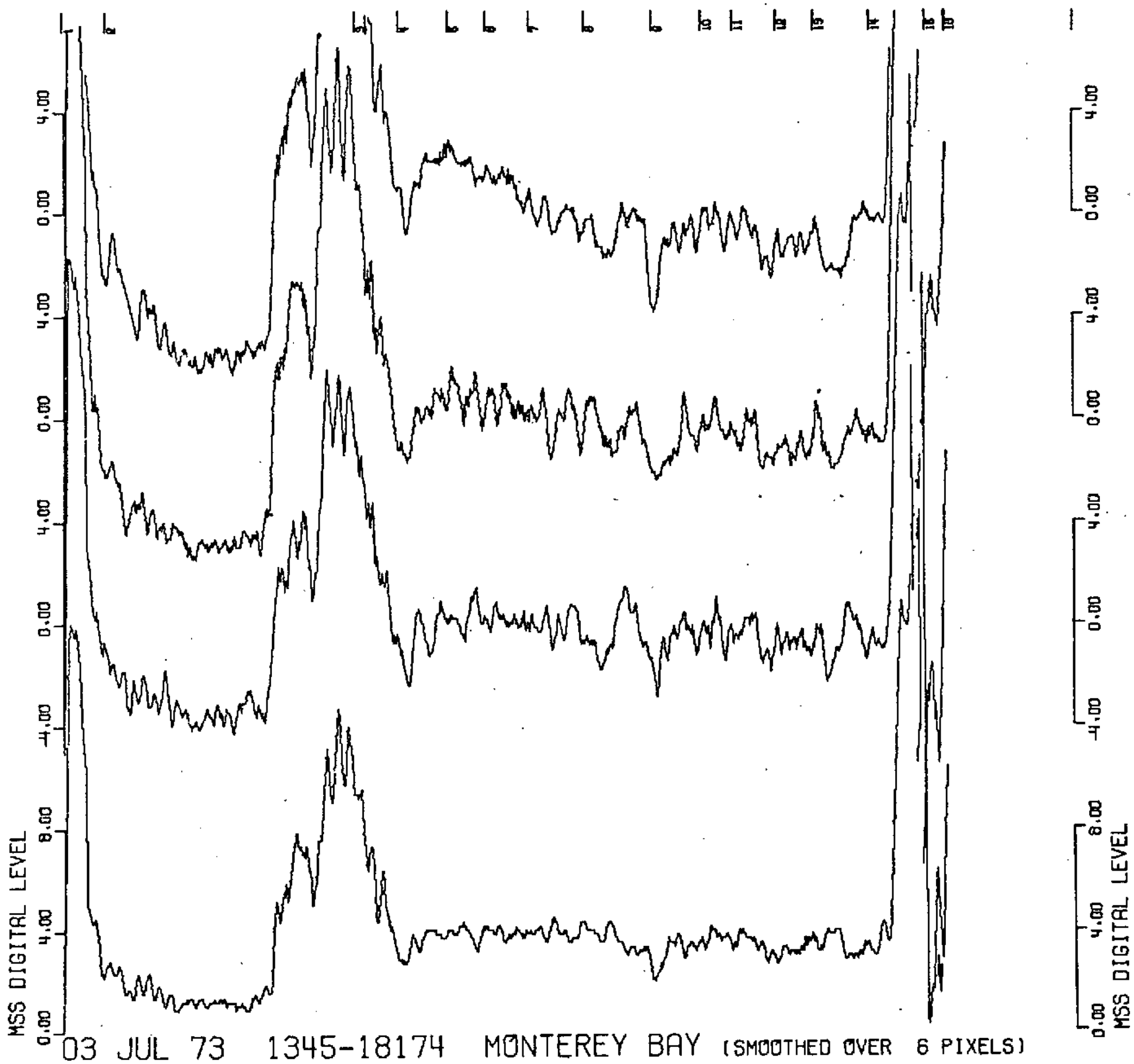


Figure A-52b
SUPPRESSED RADIANCE PROFILES, BANDS 4-6,
COMPARED WITH BAND 7 RADIANCE
MONTEREY BAY - 3 JULY 1973

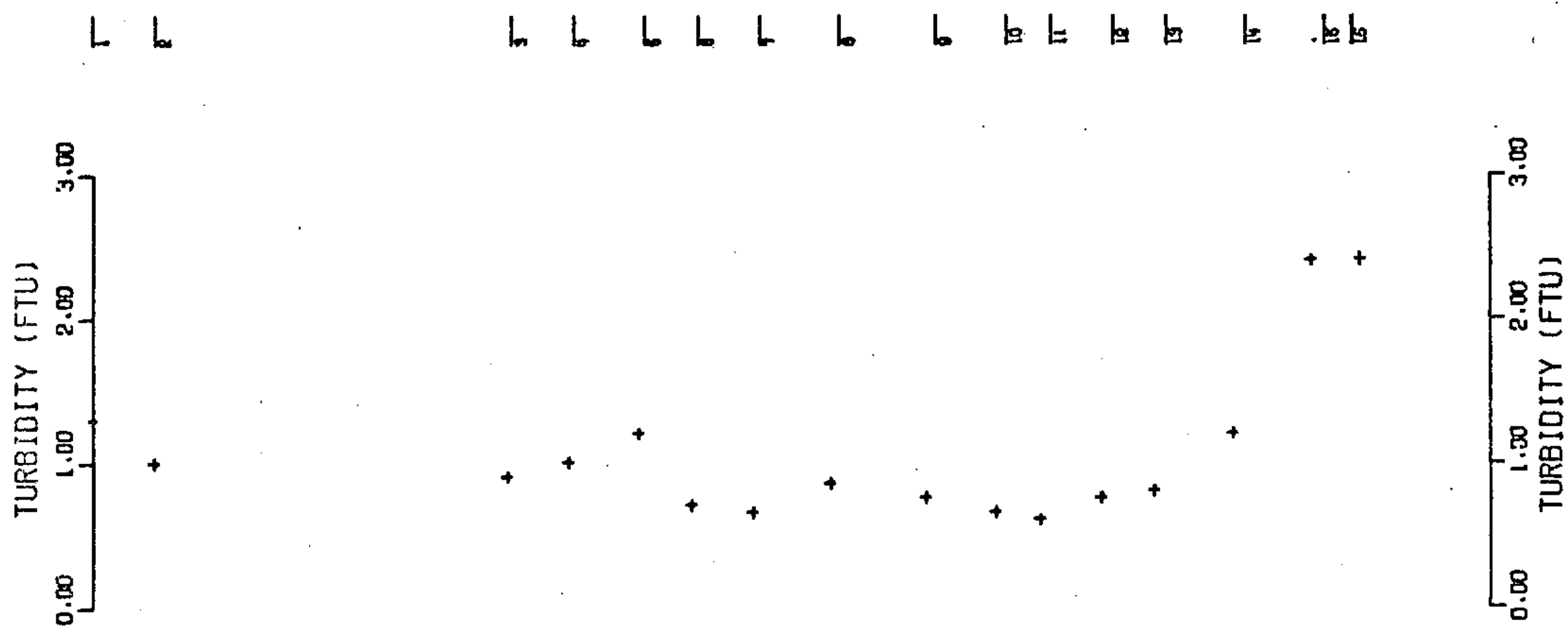
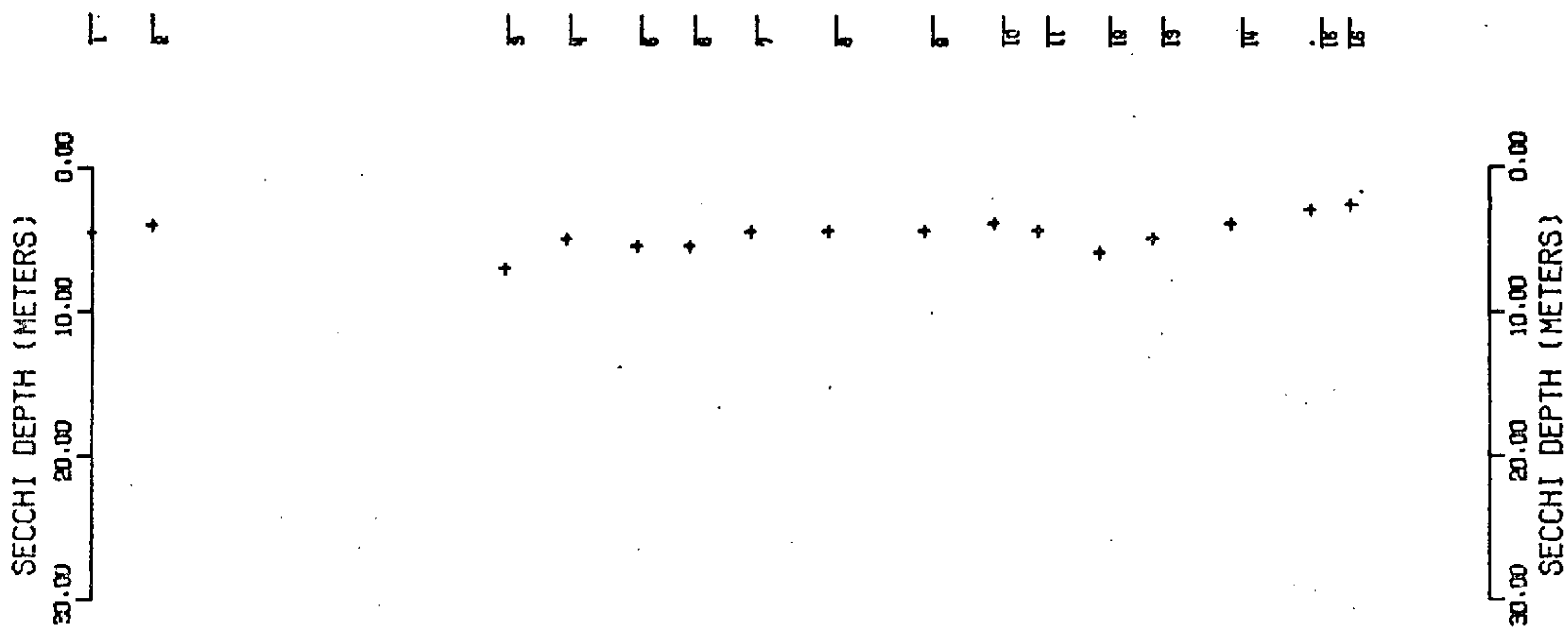


Figure A-53

WATER SURFACE TURBIDITY PROFILE
MONTEREY BAY - 3 JULY 1973

03 JUL 73



03 JUL 73

Figure A-54

SECCHI DEPTH PROFILE
MONTEREY BAY - 3 JULY 1973

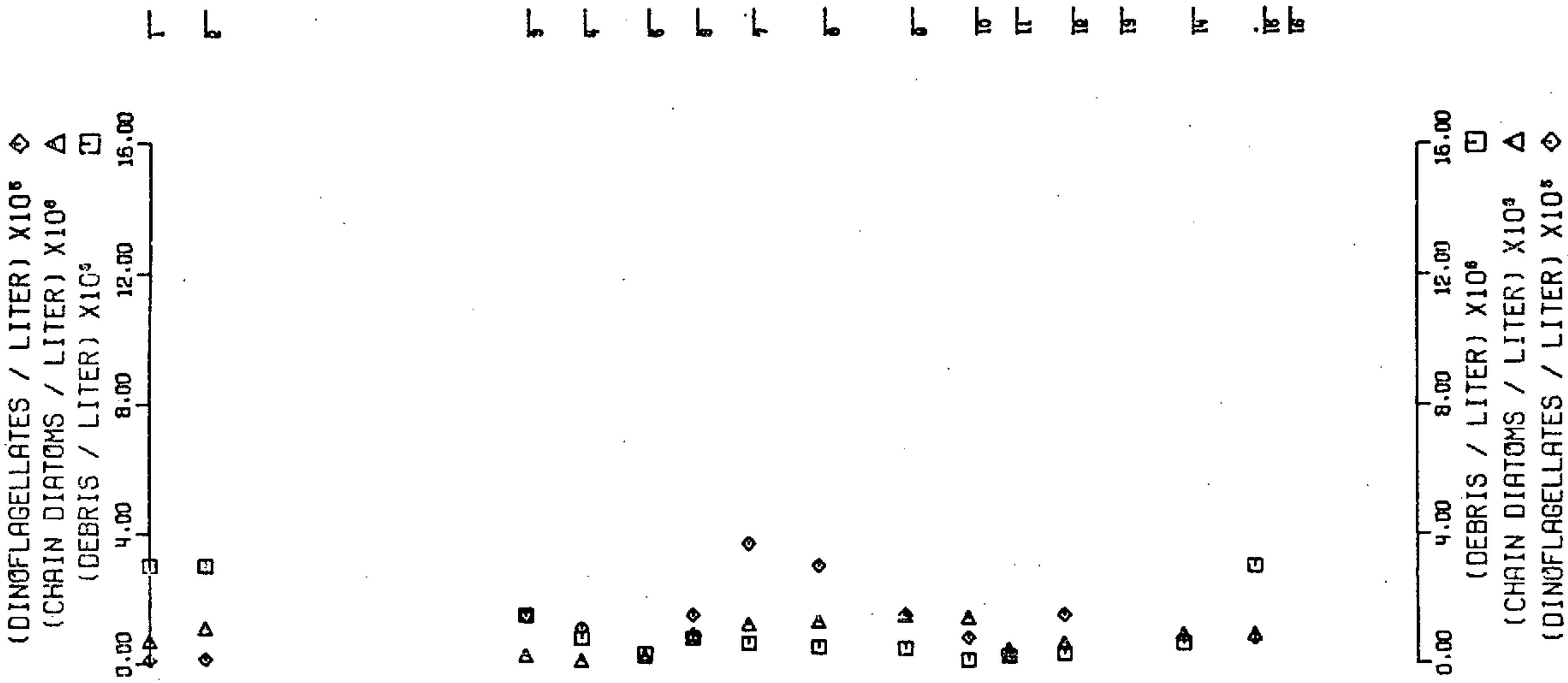


Figure A-55

CONCENTRATIONS OF NON-LIVING DEBRIS, CHAIN DIATOMS,
AND DINOFLAGELLATES IN SUSPENSION
MONTEREY BAY - 3 JULY 1973

03 JUL 73

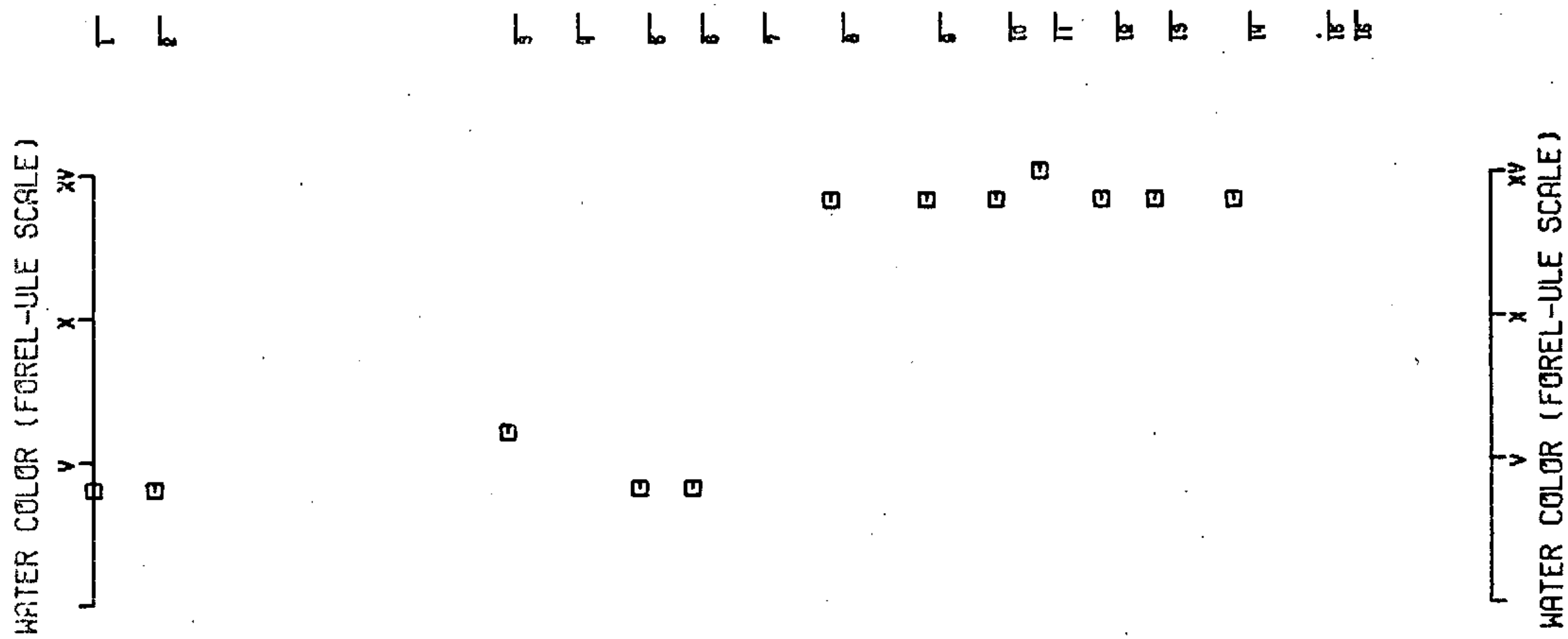


Figure A-56

PROFILE OF FOREL-ULE WATER COLOR VALUES
MONTEREY BAY - 3 JULY 1973

03 JUL 73

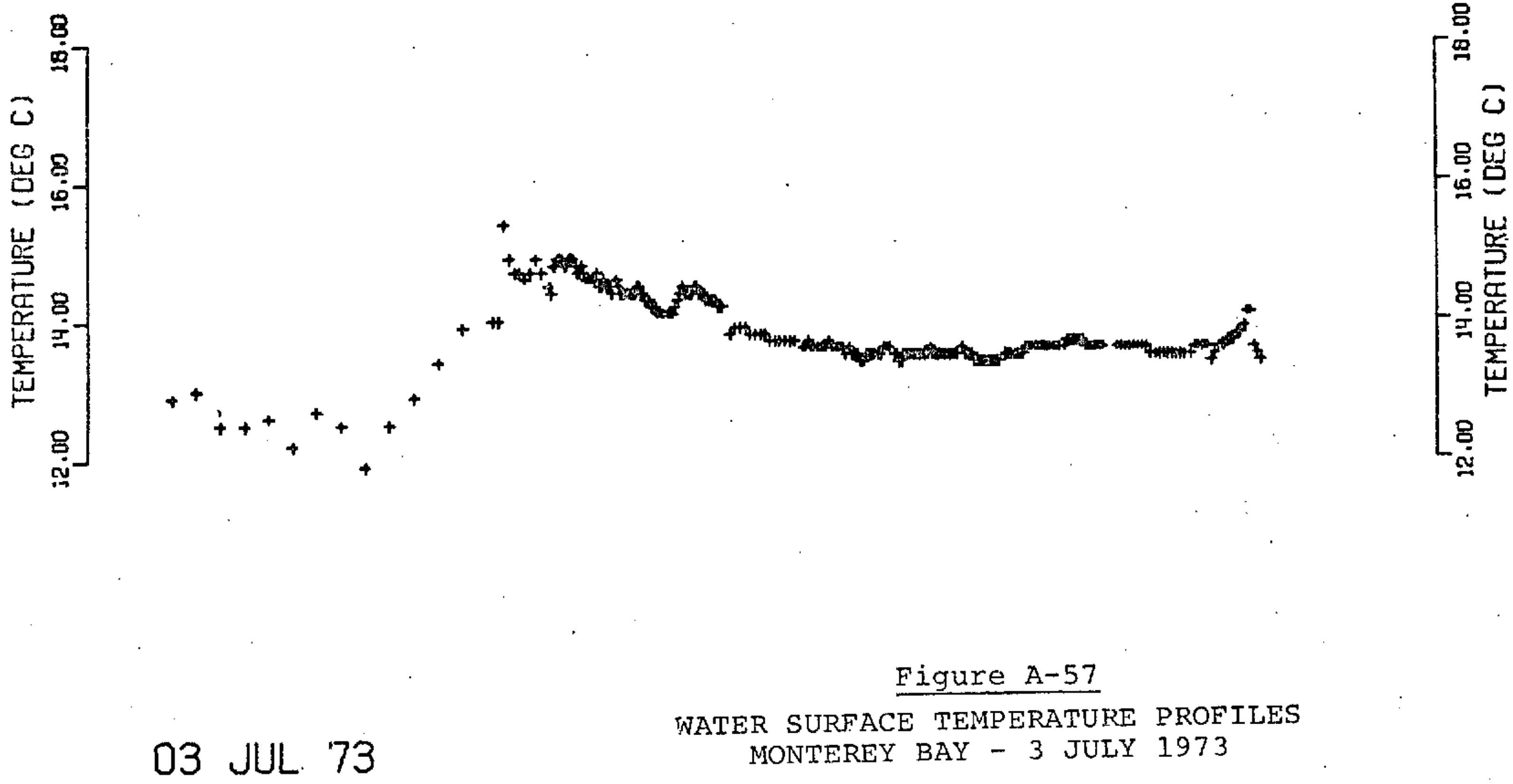


Figure A-57

WATER SURFACE TEMPERATURE PROFILES
MONTEREY BAY - 3 JULY 1973

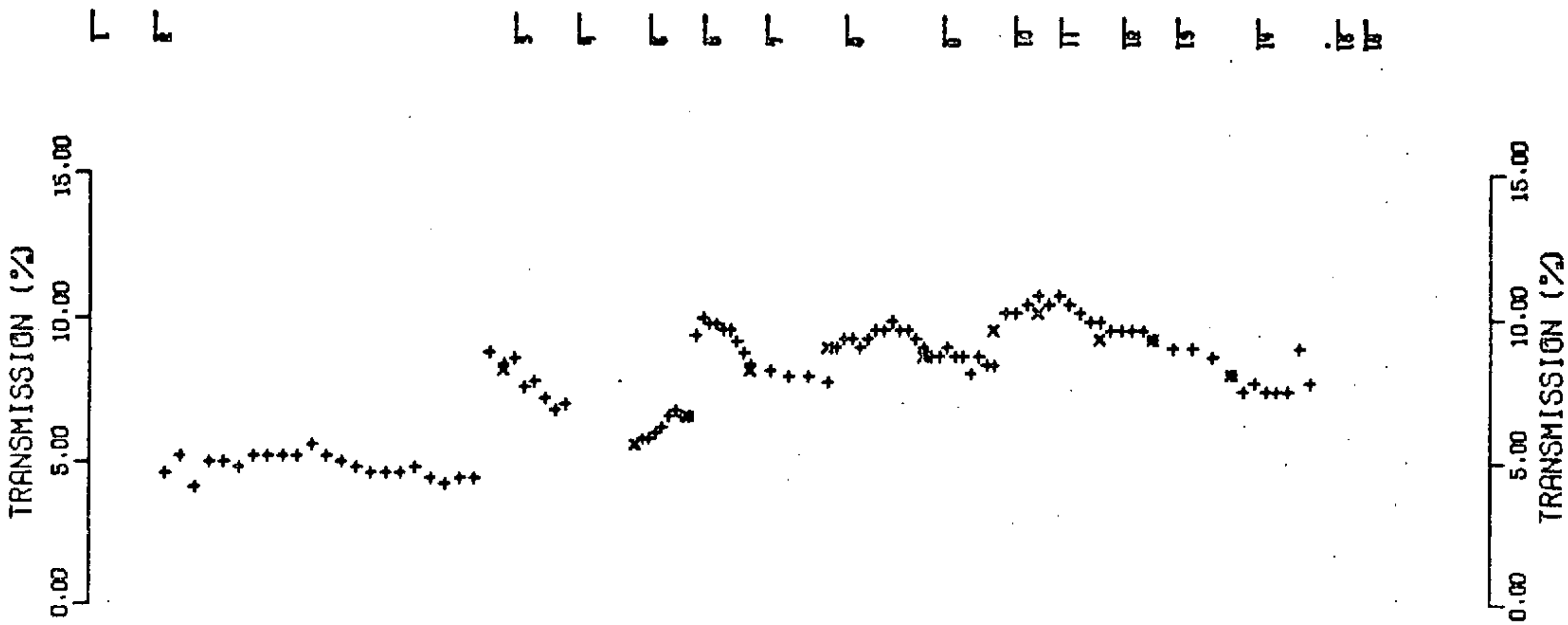


Figure A-58

PERCENTAGE PROFILES OF LIGHT TRANSMITTANCE
THROUGH SEA WATER
MONTEREY BAY - 3 JULY 1973

03 JUL 73

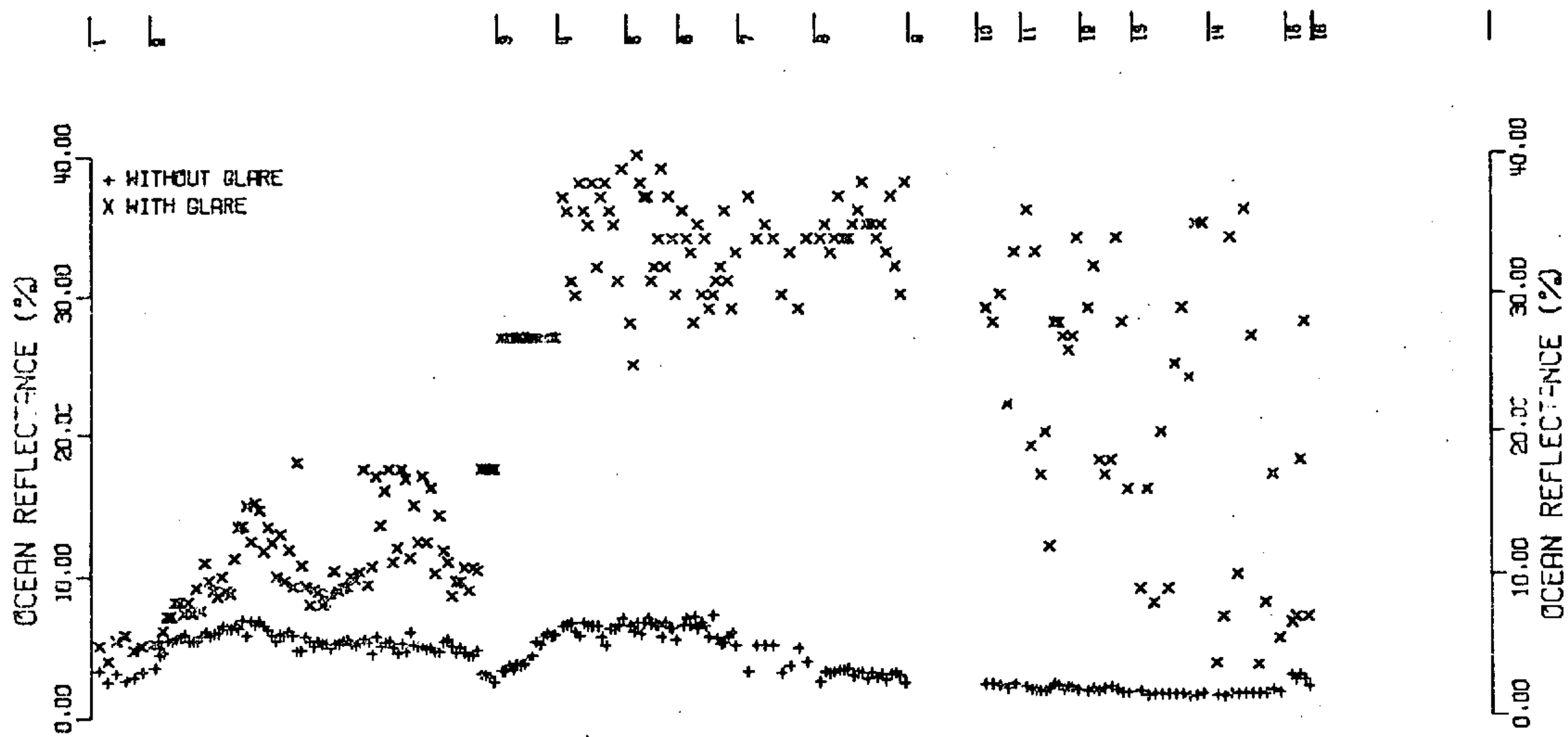


Figure A-59

PROFILE OF OCEAN REFLECTANCE - WITH AND WITHOUT GLARE
(UPPER AND LOWER SET OF POINTS RESPECTIVELY)
MONTEREY BAY - 3 JULY 1973

03 JUL 73

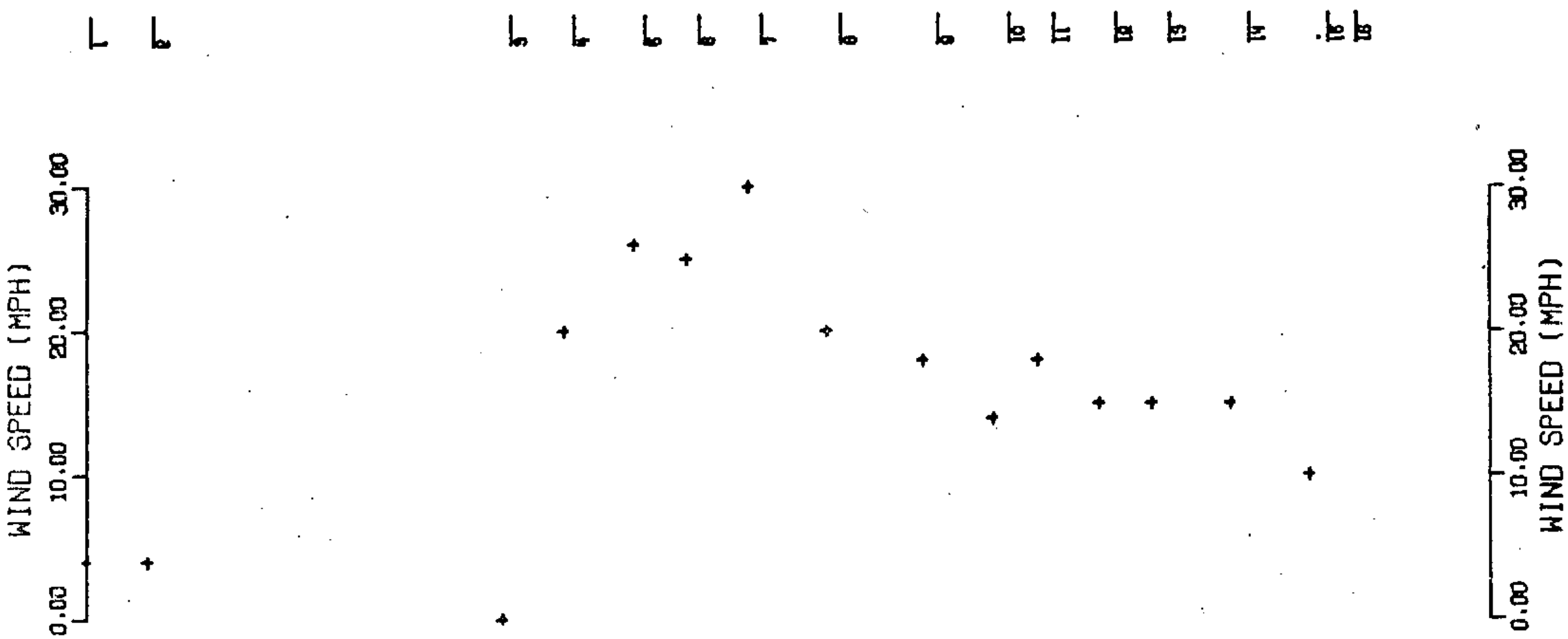
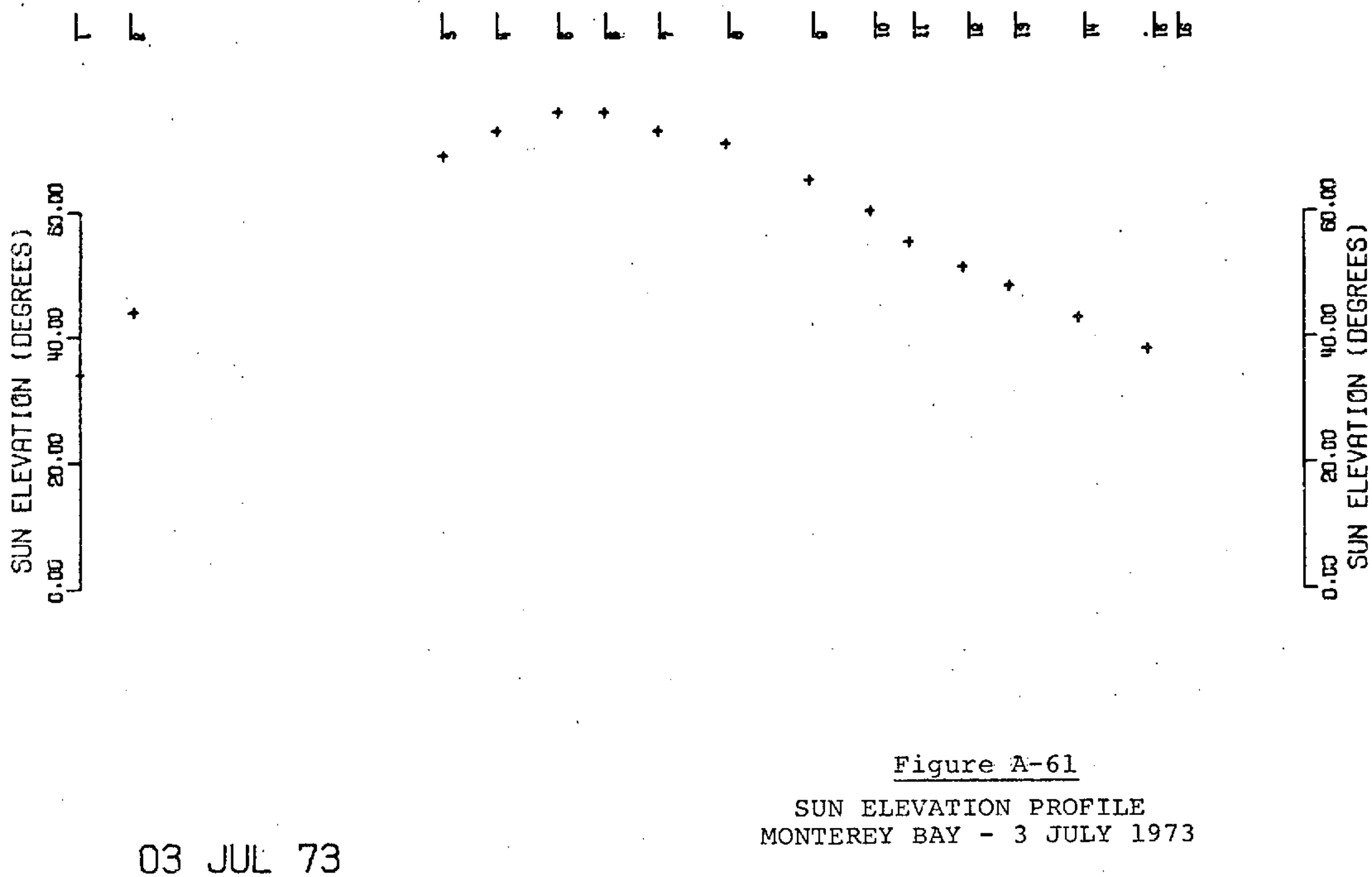


Figure A-60

WIND SPEED PROFILE
MONTEREY BAY - 3 JULY 1973

03 JUL 73



<u>Figure A-61</u>

SUN ELEVATION PROFILE
MONTEREY BAY - 3 JULY 1973

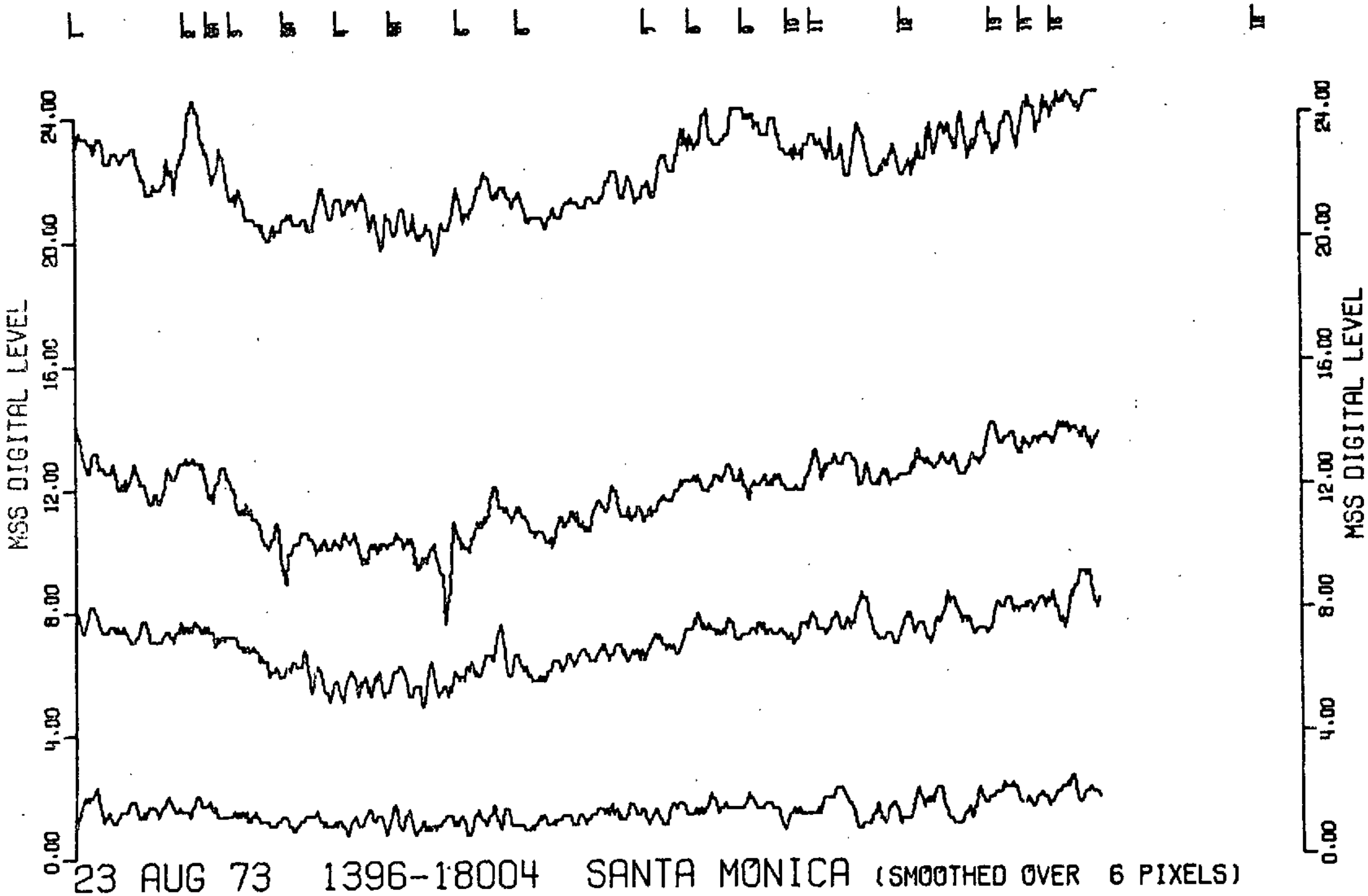


Figure A-62a

RADIANCE PROFILES, BANDS 4-7
SANTA MONICA BAY - 23 AUGUST 1973

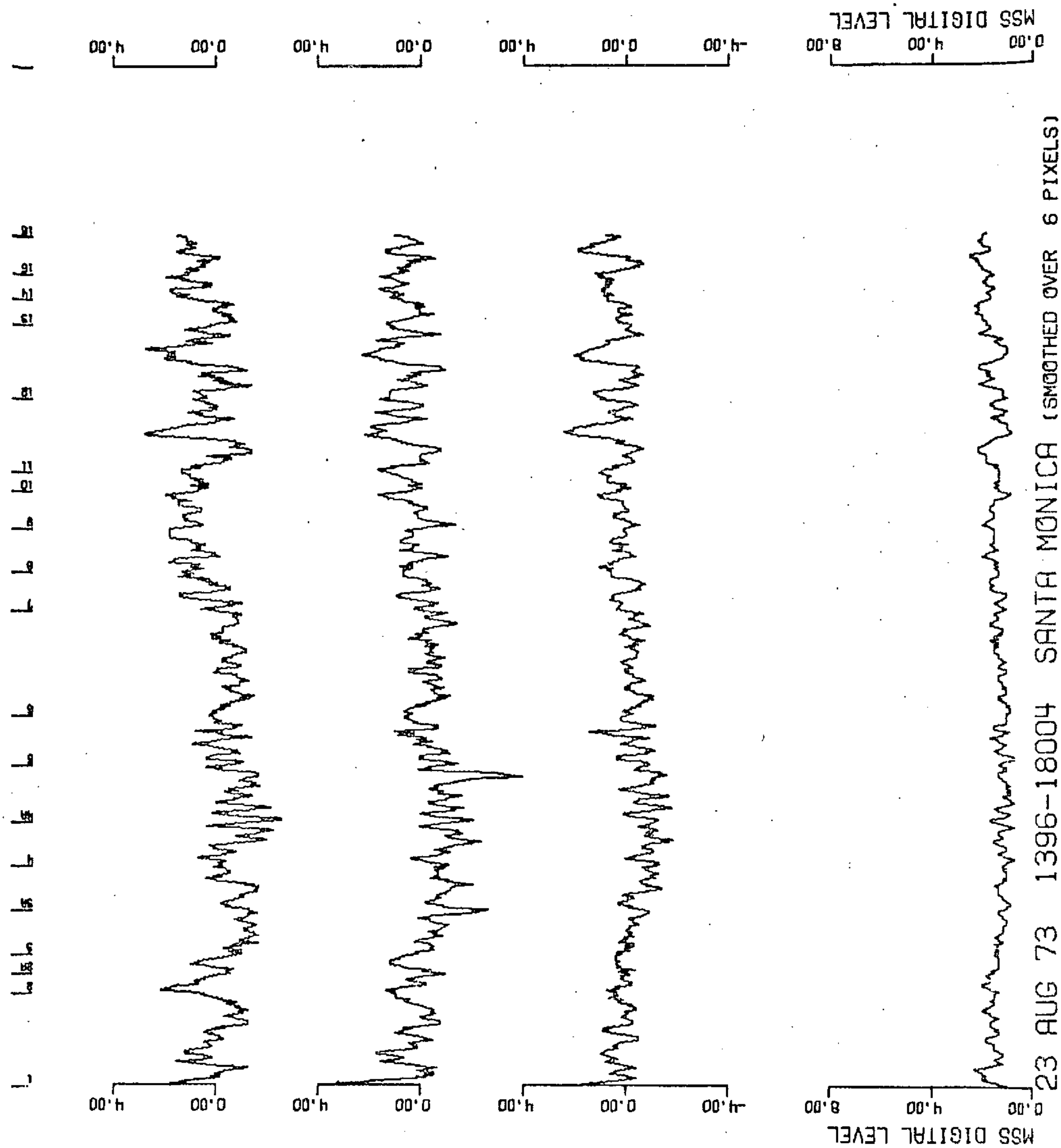


Figure A-62b

SUPPRESSED RADIANCE PROFILES, BANDS 4-6,
COMPARED WITH BAND 7 RADIANCE
SANTA MONICA BAY - 23 AUGUST 1973

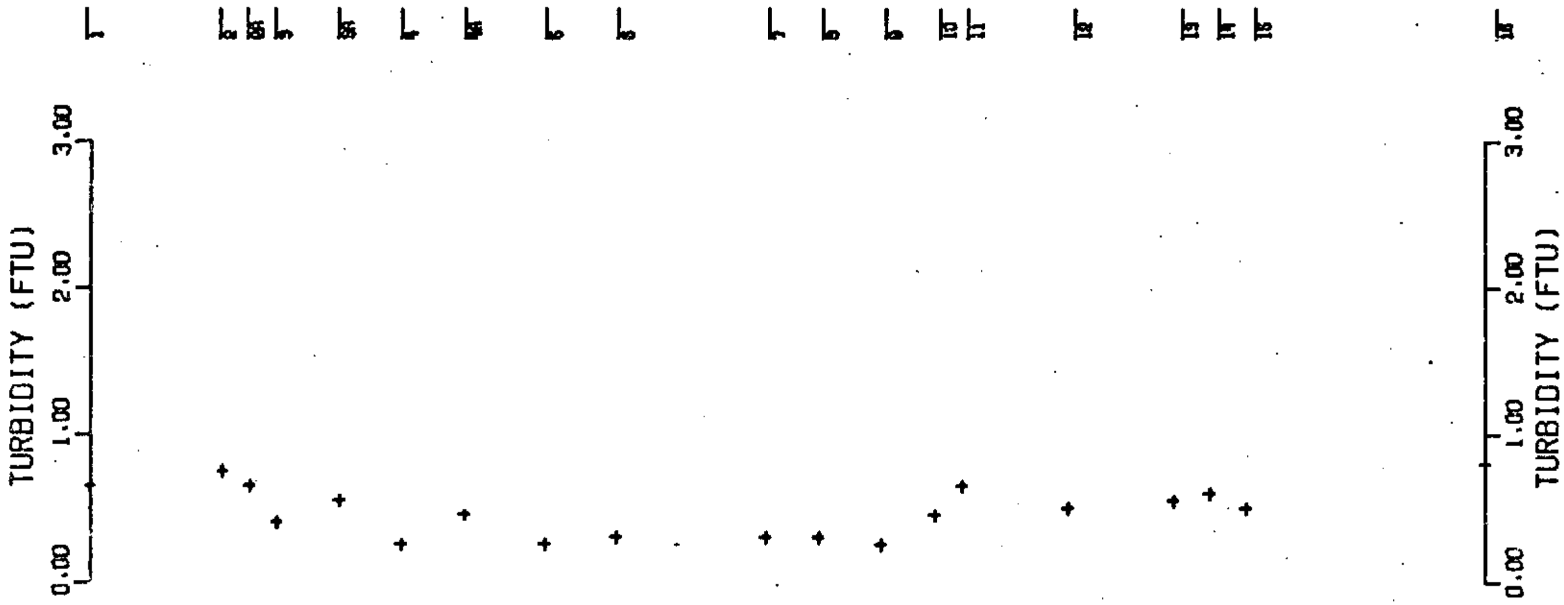


Figure A-63

WATER SURFACE TURBIDITY PROFILE
SANTA MONICA BAY - 23 AUGUST 1973

23 AUG 73

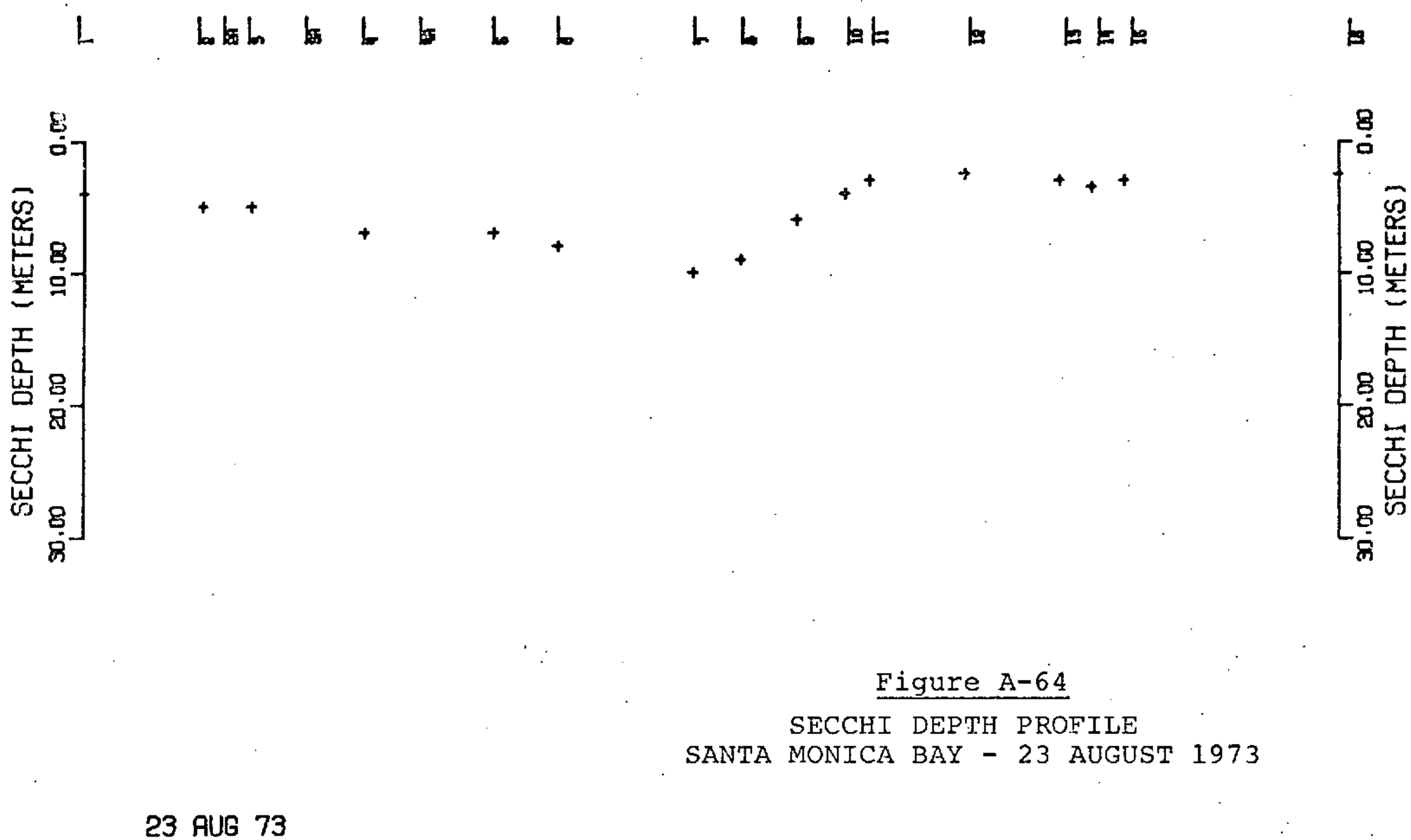


Figure A-64

SECCHI DEPTH PROFILE
SANTA MONICA BAY - 23 AUGUST 1973

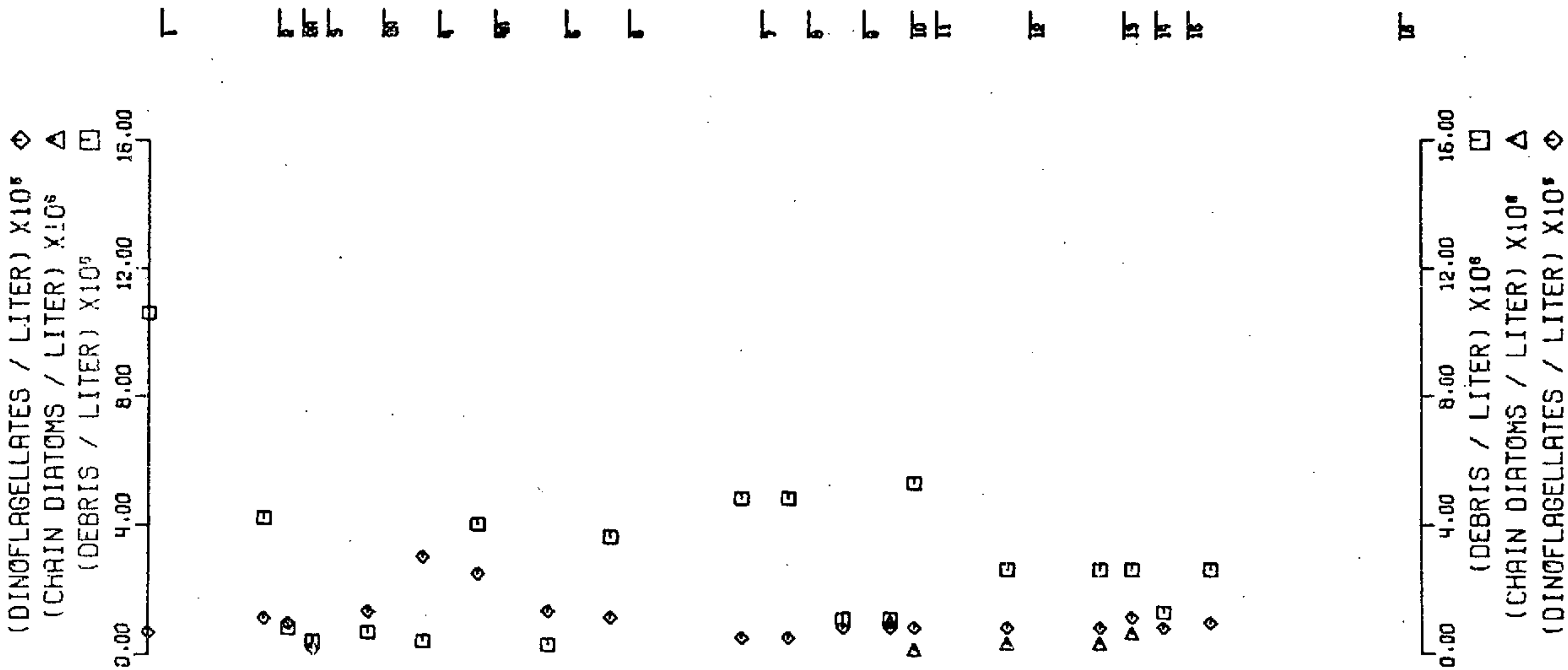
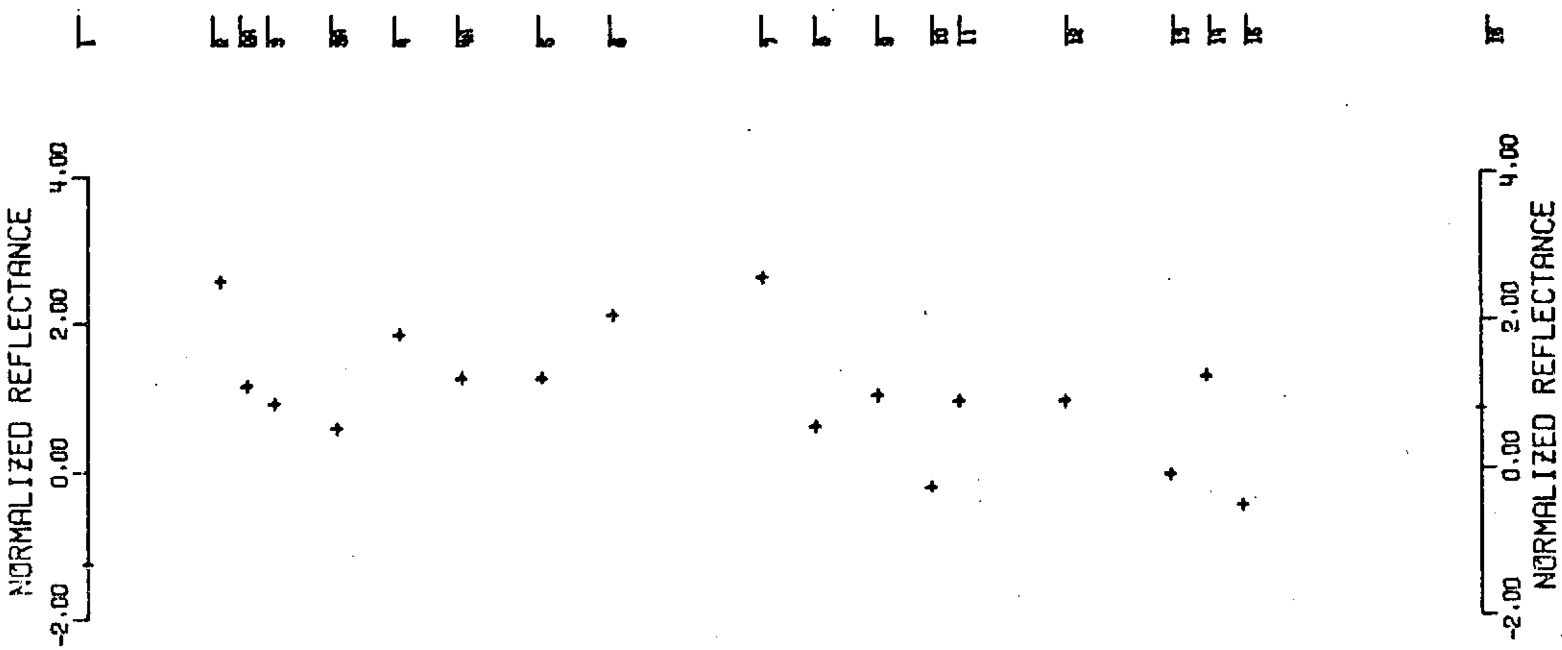


Figure A-65

CONCENTRATION PROFILES OF NON-LIVING DEBRIS, CHAIN DIATOMS, AND DINOFLAGELLATES IN SUSPENSION SANTA MONICA BAY - 23 AUGUST 1973

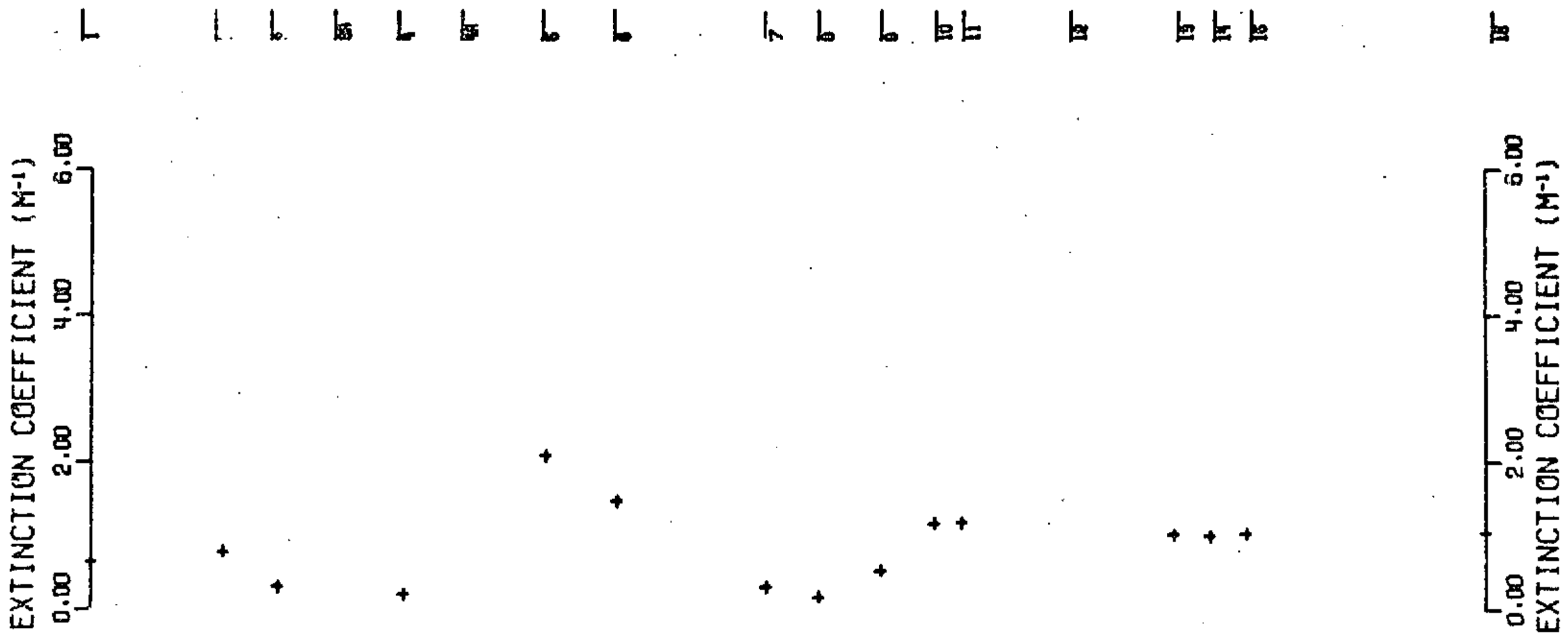
23 AUG 73



23 AUG 73

Figure A-66

PROFILE OF NORMALIZED REFLECTANCE
SANTA MONICA BAY - 23 AUGUST 1973



23 AUG 73

Figure A-67

PROFILE OF EXTINCTION COEFFICIENTS
SANTA MONICA BAY - 23 AUGUST 1973

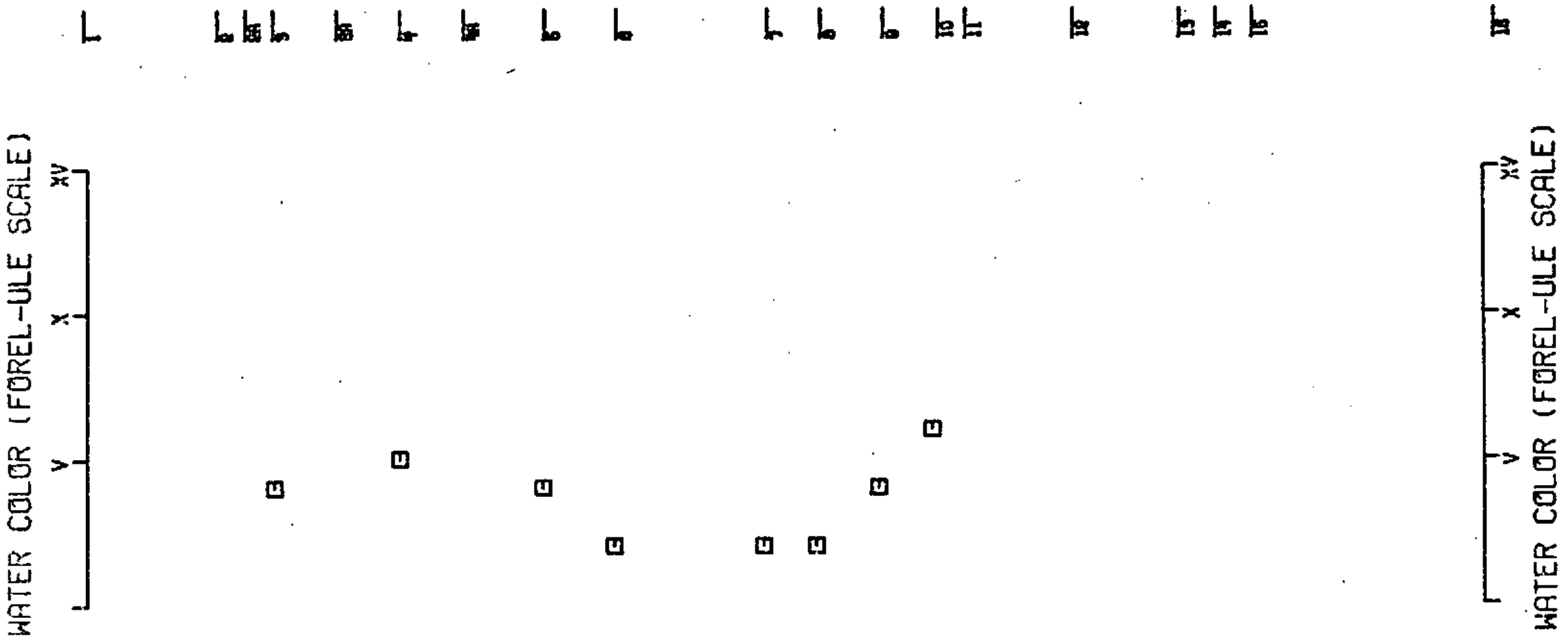
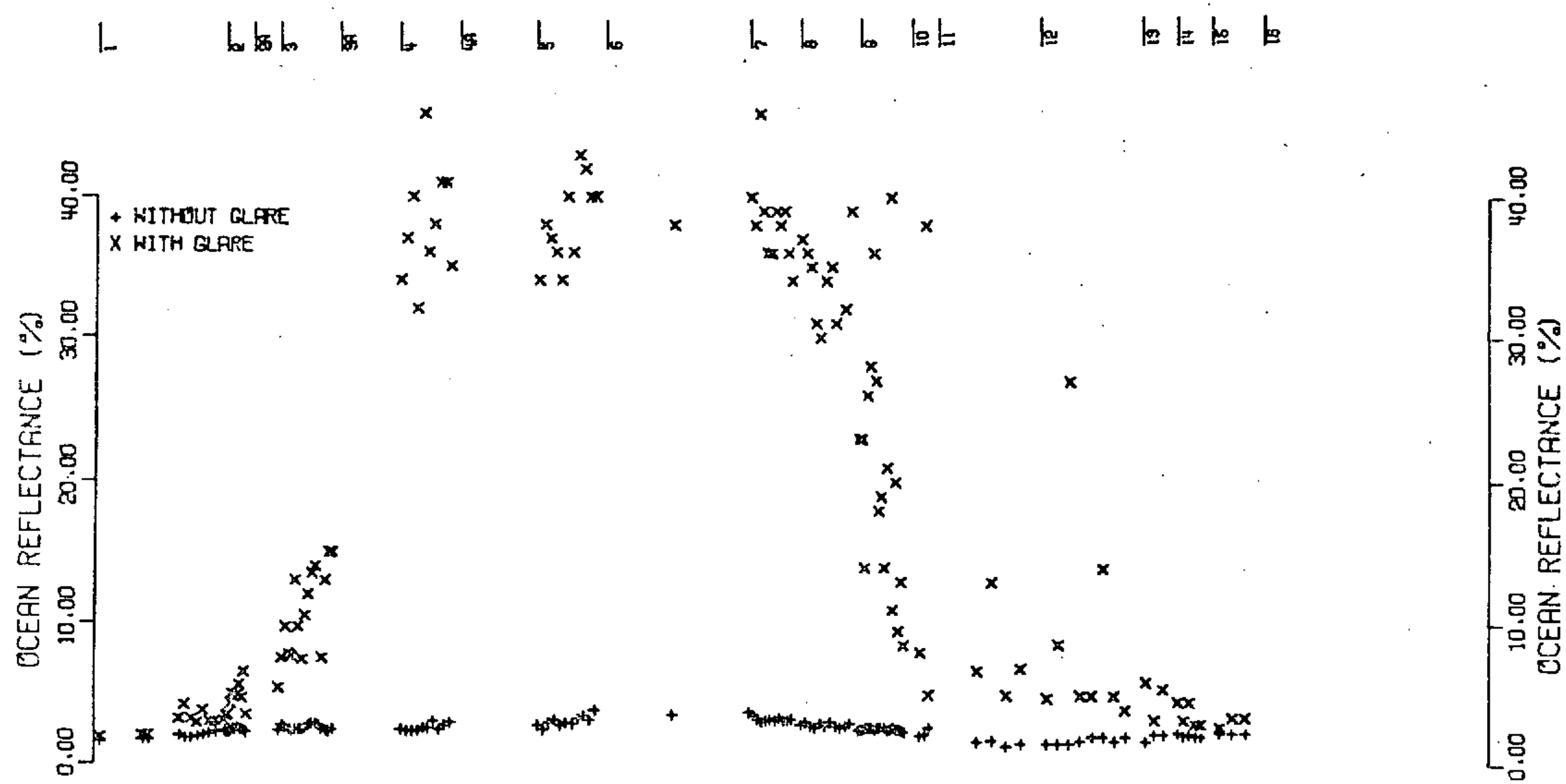


Figure A-68

PROFILE OF FOREL-ULE WATER COLOR VALUES
SANTA MONICA BAY - 23 AUGUST 1973

23 AUG 73



23 AUG 73

Figure A-69

PROFILE OF OCEAN REFLECTANCE - WITH AND WITHOUT GLARE
(UPPER AND LOWER SET OF POINTS RESPECTIVELY)
SANTA MONICA BAY - 23 AUGUST 1973

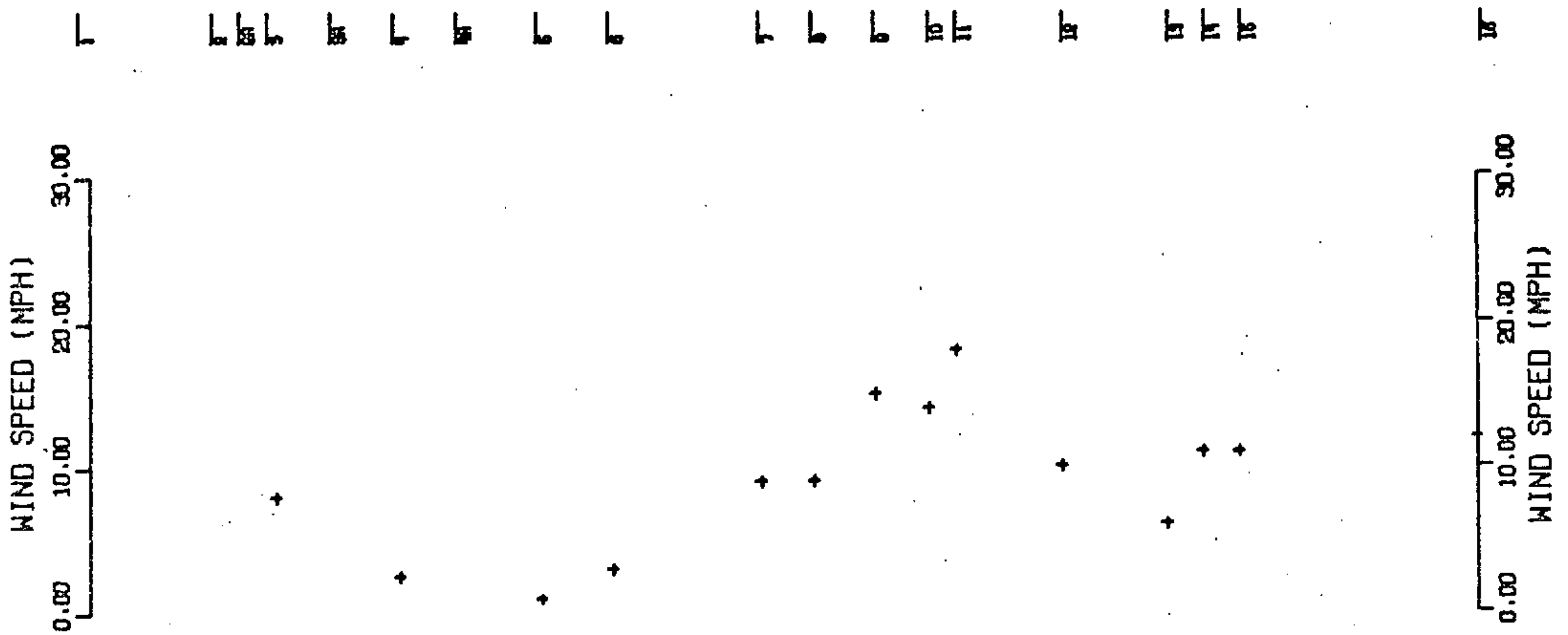


Figure A-70

WIND SPEED PROFILE
SANTA MONICA BAY - 23 AUGUST 1973

23 AUG 73

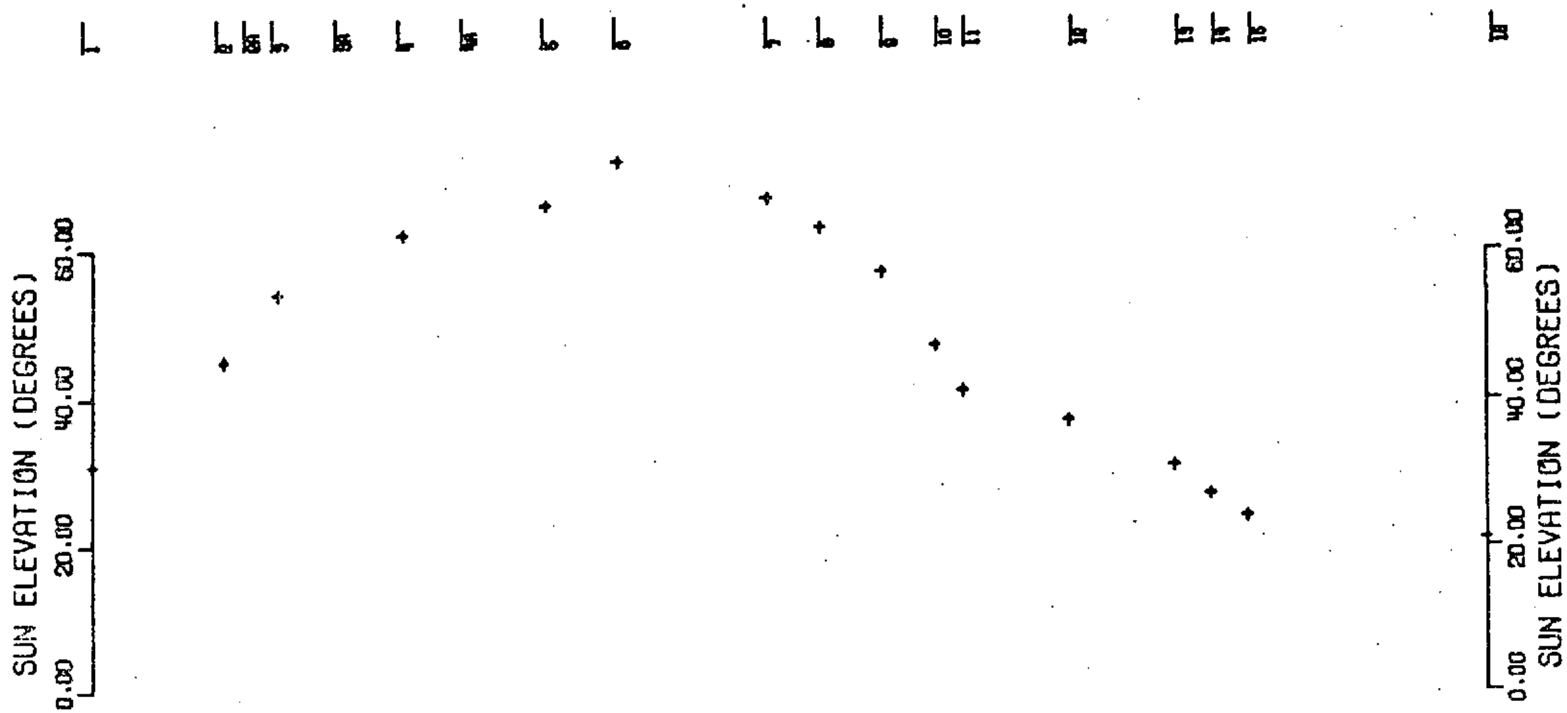


Figure A-71

SUN ELEVATION PROFILE
SANTA MONICA BAY - 23 AUGUST 1973

23 AUG 73

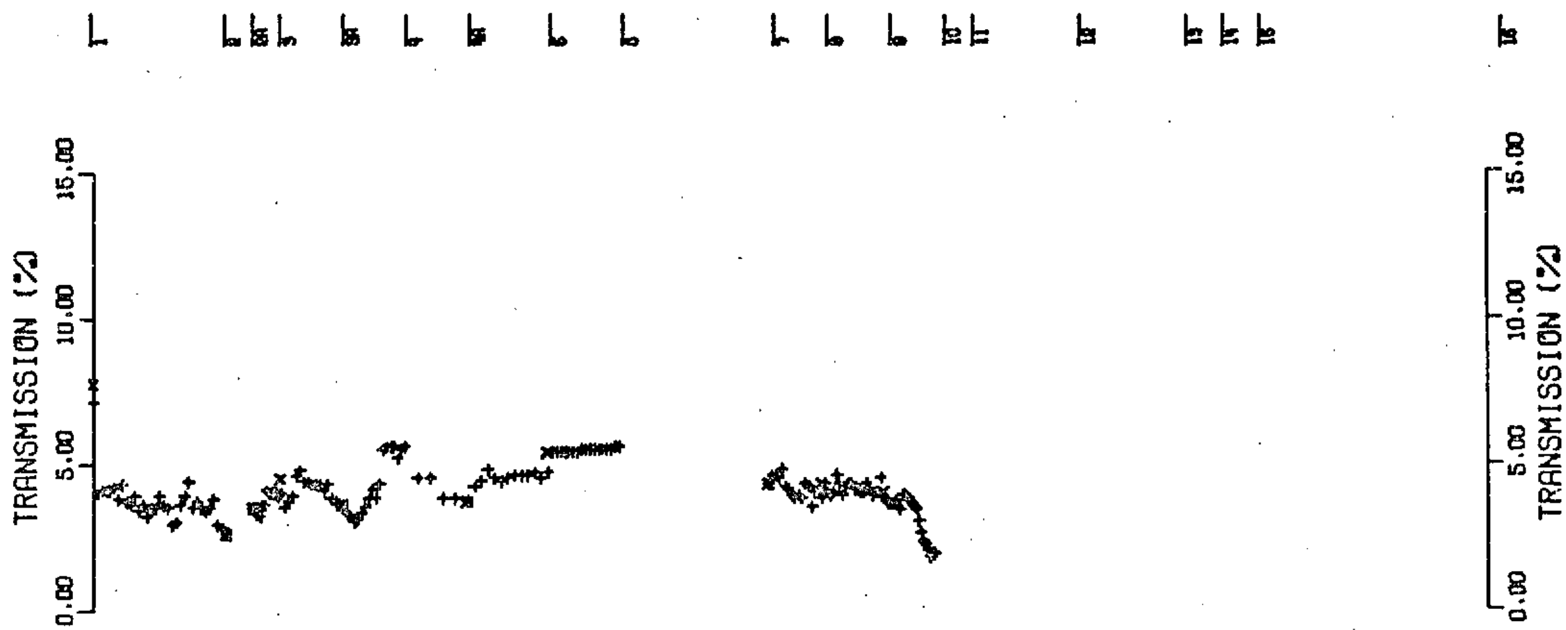


Figure A-72

PERCENTAGE PROFILE OF LIGHT TRANSMITTANCE
THROUGH SEA WATER
SANTA MONICA BAY - 23 AUGUST 1973

23 AUG 73

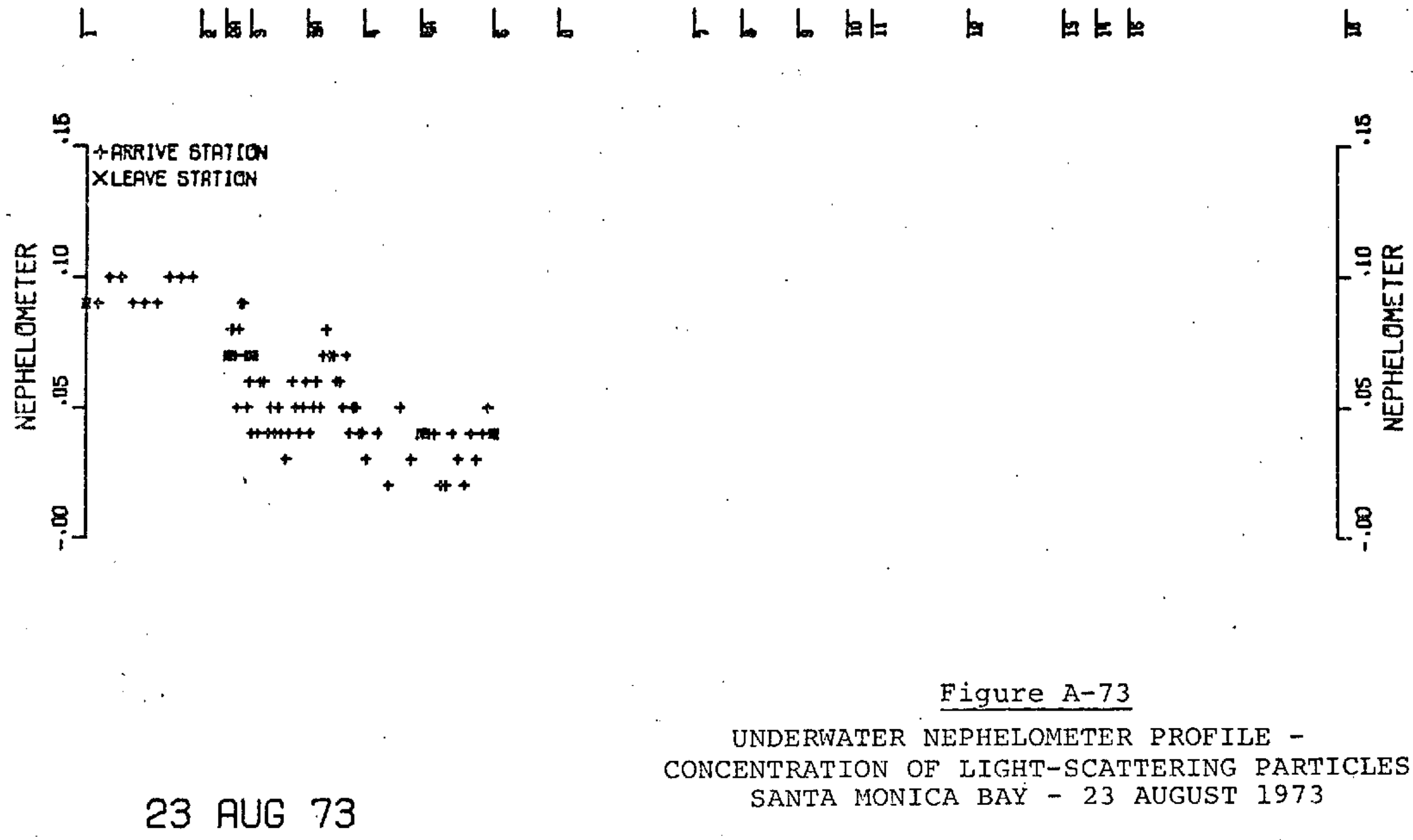


Figure A-73

UNDERWATER NEPHELOMETER PROFILE -
CONCENTRATION OF LIGHT-SCATTERING PARTICLES
SANTA MONICA BAY - 23 AUGUST 1973

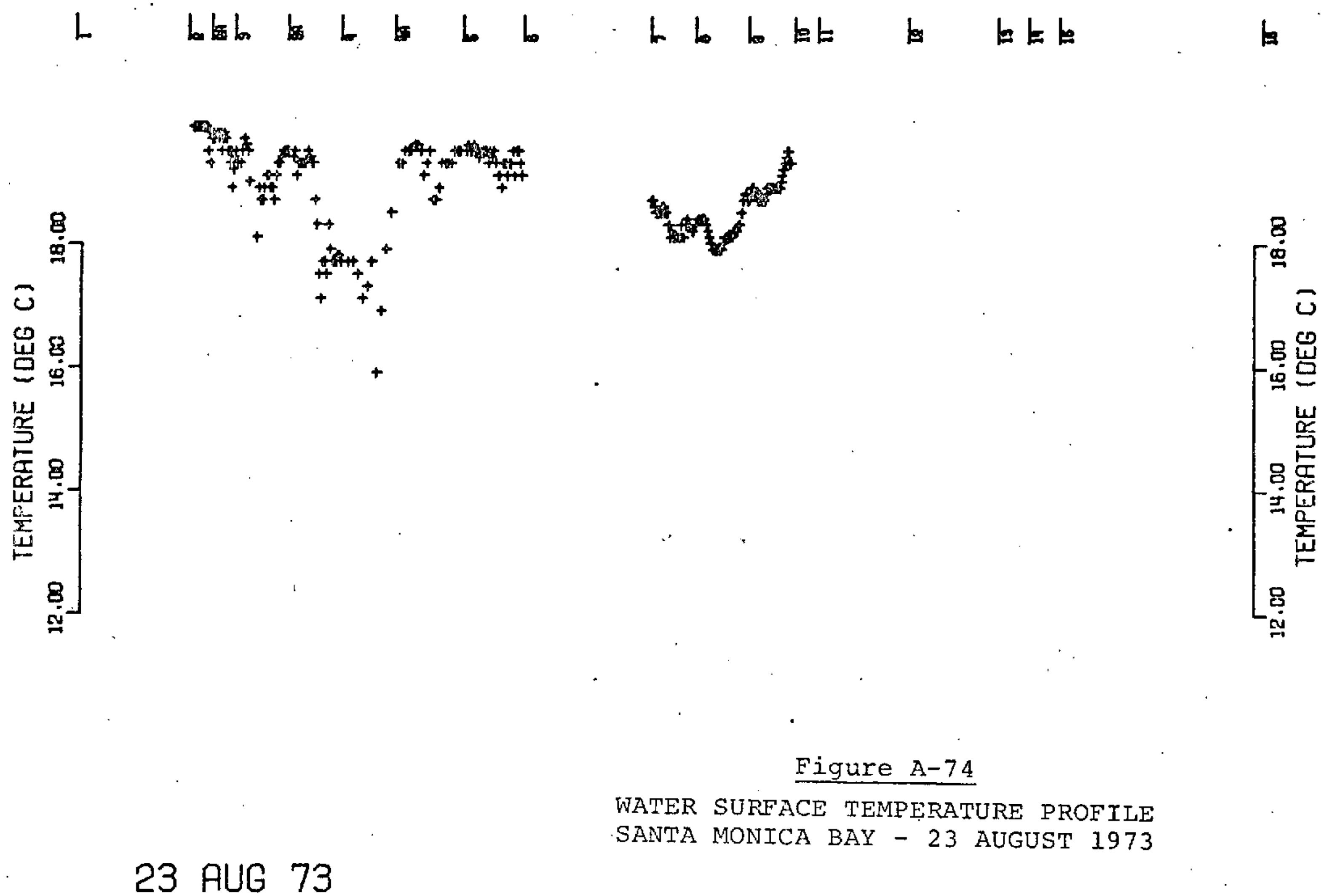


Figure A-74

WATER SURFACE TEMPERATURE PROFILE
SANTA MONICA BAY - 23 AUGUST 1973

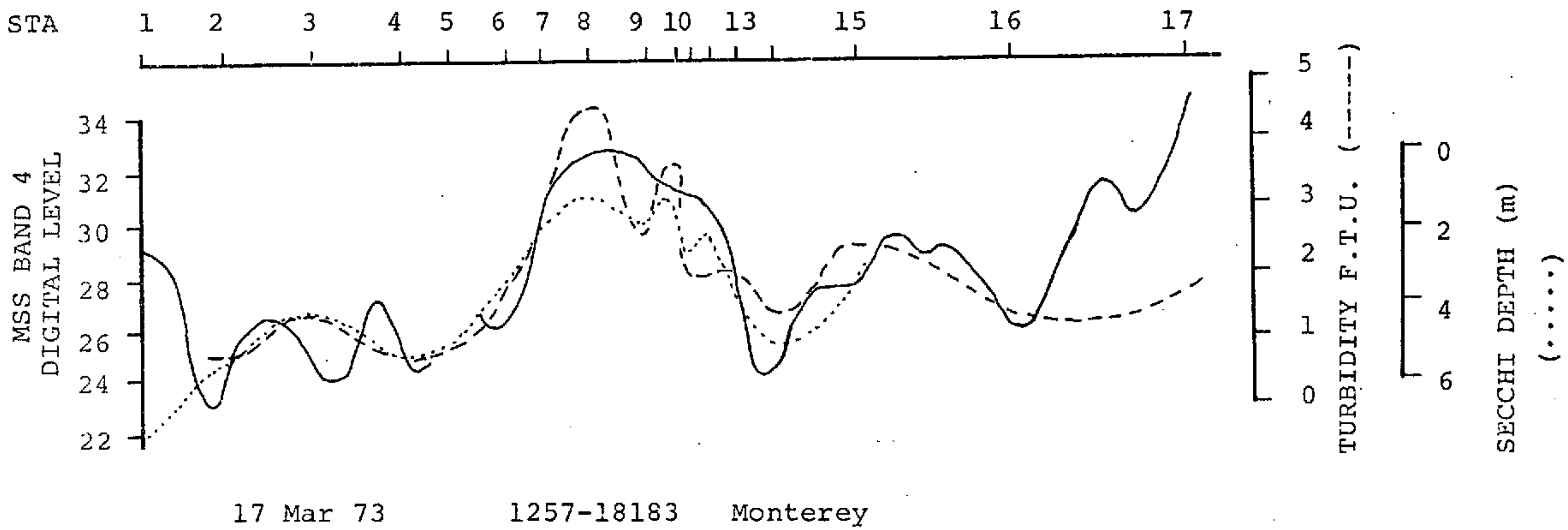


Figure A-75

EXAMPLE OF CORRELATION BETWEEN
RADIANCE AND OCEAN TRUTH PARAMETERS

Table A-1 WEATHER, ATMOSPHERE, AND SEA STATE OBSERVATIONS

Area Santa Barbara Date 25 February 1973 ERTS Image I.D. 1217-18074

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0900	120°	28°	75%	4-6	190°	0	--	14.9	15	82	1.5	14	2.4
2	0930	120	34	"	"	190	0-1	WSW	14.8	18.5	82	4	12	1.1
3	0952	125	37	"	"	210	0	--	14.8	---	--	14	--	0.46
4	1007	135	38	Slight Haze	"	"	"	--	14.4	16.5	--	15	3	0.25
5	1021	140	41	100%	"	"	0	--	14.8	---	--	15	"	0.20
6	1036	140	43	"	"	"	"	--	14.8	---	--	18	"	0.20
7	1055	150	43	"	"	"	0-1	SE	14.5	17	--	15	"	0.20
8	1109	160	46	"	"	"	6	SE	14.4	16.5	--	16	3	0.30
9	1123	165	47	"	"	235	6-7	ESE	14.3	16.5	--	16	3	0.15
10	1137	170	48	"	"	255	8	ESE	14.3	---	--	17	1	0.15
11	1202	180	47	"	2-3	220	0	---	14.8	---	--	22	"	0.20
12	1222	180	48	"	2-3	220	6	ESE	15	18.5	--	19	"	0.12
13	1255	195	47	"	4-6	210	7	ESE	15.4	16.5	--	12	4	0.85
14	1322	190	45	"	"	"	3	SE	15.5	17	--	11	5	1.0
15	1415	215	39	"	"	"	6	"	15.9	--	--	16	1	0.25
16	1442	225	34	"	"	"	7	"	15.0	--	--	22	1	0.30
17	1504	225	30	"	"	270	6	W	15.4	17	--	9	4	1.1
18	1525	240	27	"	"	"	7	"	16.0	16.5	--	11	4	0.4
19	1542	230	25	"	"	"	5	"	15.4	---	--	12	3	0.60

Table A-1 Continued
Page 2

Area Santa Barbara Date 15 March 1973 ERTS Image I.D. 1235-18075

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0830	100°	29°	100%	2-3	260°	0-1	SW	12.5	15	72	4	4	1.2
2	0902	090	35	"	"	"	0	--	12.8	"	"	4.5	"	1.2
3	0932	135	39	"	"	"	0	--	13.3	"	"	11	"	0.40
4	1005	115	44	"	"	"	5	SE	13	15.3	"	12	3	0.34
5	1033	--	54	"	"	"	7	"	13.6	16.5	63	9	"	0.43
6	1054	130	50	"	2-4	"	7	"	13.7	19.5	--	10	"	0.33
7	1110	180	53	"	"	"	7-10	"	13.8	18.5	--	9	"	0.62
8	1130	210	54	70	"	"	8-10	"	13.8	"	65	11	"	0.31
9	1158	180	55	100	"	"	2	"	13.1	"	--	14	"	0.28
10	1217	220	55	"	"	"	7-10	S	13.8	"	--	14	"	0.55
11	1304	215	53	"	"	"	10	SE	14.5	"	61	12	"	0.20
12	1332	270	50	"	0-2	"	10	S	13.6	"	61	7	6	0.73
13	1418	"	43	"	"	270	0-1	SE	14.4	19.5	58	14	3	0.23
14	1511	"	35	"	"	260	7-8	W	14.8	21	69	11	"	0.31
15	1627	--	19	"	"	270	8-10	"	14.2	19.5	84	--	"	0.22
16	1711	250	10	"	"	"	10	"	14.4	18.5	--	9	"	0.37
17	1757	--	1	"	3-5	"	12	"	14.2	16.5	--	--	--	0.37
18	1846	--	--	--	0-2	"	10	"	14.3	15	--	--	--	0.28
19	1930	--	--	--	--	--	--	--	--	--	--	--	--	0.46

Table A-1 Continued
Page 3

Area Monterey   Date 17 March 1973   ERTS Image I.D. 1237-18183

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Temperatures Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0820	100°	26°	Scattered 80%	0-2	270°	12-14	NW	12.9	10.5	80	7	5	0.96
2	0837	90	29	30	2-4	"	12-14	"	13.0	10.5	"	5	"	0.86
3	0857	100	30	40	"	"	12	"	13.2	"	--	4	"	1.6
4	0908	100	34	20	"	"	12-15	"	"	"	80	5	"	0.9
5	0918	105	34	100	"	"	0-4	W	13.2	"	"	--	"	1.0
6	0927	110	36	90	"	"	10	"	13.5	11	"	3	8	2.0
7	0936	115	32	95	0-2	"	5	"	13.4	11.5	"	2	10	2.9
8	0949	115	41	80	2-4	"	0-5	"	"	12	"	1	10	4.6
9	0959	120	42	70	"	"	0-2	"	"	12	"	2	12	2.6
10	1014	"	43	60	"	"	"	"	13.3	13	"	1	12	3.8
11	1021	--	--	"	"	"	"	"	13.3	13	"	2.5	6	2.0
12	1029	--	--	"	"	"	"	"	13.7	14.5	"	2	6	2.0
13	1034	125	47	70	"	"	"	"	13.6	"	"	3.5	3	2.1
14	1048	--	43	100	"	"	14	"	13.3	"	"	5	"	1.5
15	1107	--	49	40	"	"	14-16	"	13.4	"	"	3	"	2.5
16	1134	--	--	25	"	"	18-22	"	13.4	13.5	"	--	"	1.4
17	1214	--	--	10	4-6	"	22-24	"	12.7	13.5	"	--	"	1.6

Table A-1 Continued
Page 4

Area Santa Monica   Date 1 April 1973   ERTS Image I.D. 1252-18021

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0900	100°	40°	100%	4-6	270°	7-8	W	14.6	16	88	3.5	4	1.8
2	0920	100	44	"	"	"	15-18	"	"	"	"	"	"	2.7
3	0945	110	47	"	"	"	10-15	"	"	18	"	4	"	1.5
4	1006	120	52	"	"	"	15-18	"	13.8	15.5	"	8	"	0.7

Small craft warnings posted, cruise terminated.

Table A-1 Continued
Page 5

Area Santa Barbara Date 2 April 1973 ERTS Image I.D. 1253-18075

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0936	120°	46°	100%	1.5	225°	5	W	11.3	18.5	50	4.5	4	1.1
2	0957	"	50	"	1-2	225	0-5	Var.	10.9	"	39	7	"	0.72
3	1019	"	53	"	1-2	240	0	---	11.3	"	54	8.5	"	0.47
4	1037	"	56	"	2-3	240	7	WSW	11.3	"	"	"	"	0.50
5	1056	135	58	"	2-3	250	5-10	WSW	11.2	16	70	"	"	0.45
6	1115	145	60	"	2-4	260	10-14	W	11.5	15	63	7.5	"	0.60
7	1132	150	61	"	3-5	270	20	"	11.4	13.5	82	7.0	"	0.55
8	1152	160	61	"	3-6	270	20-25	"	11.5	14	66	7	"	0.80
9	1210	175	62	"	"	280	20-22	"	"	"	68	"	"	0.70
10	1228	180	61	"	"	275	20	"	"	"	64	"	"	0.69
11	1248	185	59	"	2-3	285	20	WNW	11.4	"	--	"	"	0.63
12	1315	210	56	"	2	280	20-25	WNW	12.1	--	68	"	"	0.36
13	1340	220	52	"	1-2	250	10	WSW	12.7	18.5	36	8	"	0.65
14	1425	220	45	"	1	250	8	"	12.3	18.5	46	9	"	0.46
15	1454	235	40	"	"	255	10-15	"	12.4	17	51	7.5	"	0.65
16	1512	235	36	"	"	290	12-15	W	12.0	17	46	6.5	"	0.57
17	1528	240	32	"	2-3	265	15-25	"	12.2	14.5	67	--	"	1.0
18	1548	240	29	"	2-4	270	10-18	"	12	14.5	72	7.0	"	0.52
19	1607	250	26	"	"	"	15	"	11.9	14	75	5	"	0.90
20	1625	240	22	"	"	"	15	"	11.8	14	--	4	"	0.90
21	1649	250	17	"	"	265	10-15	"	12.0	--	--	3.5	"	0.70
22	1714	255	12	"	2	315	10-15	NNW	---	14.5	67	4.5	"	0.80
23	1734	260	8	"	2-3	315	25	NNW	---	15.5	52	4.0	"	0.72

Table A-1 Continued
Page 6

Area Monterey   Date 4 April 1973   ERTS Image I.D. 1255-18183

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0814	105°	29°	100%	Ripple	--	0-1	S	10.5	13.5	--	2.5	4	3.3
2	0840	105	33	"	2-3	270°	3-4	ESE	11.8	16	59	3	5	2.2
3	0906	115	38	"	"	"	4-5	E	12.4	16.5	64	5.5	4	1.7
4	0927	110	42	"	"	"	0	--	12.0	16.5	64	6.5	"	1.0
4a	1002	120	48	"	5	"	"	--	12.2	18	69	3.5	"	2.2
5	1039	125	53	"	2-3	"	"	--	11.9	"	65	6.5	"	--
6	1108	136	56	"	1-2	"	"	--	12.3	"	69	4.5	"	0.98
7	1138	143	58	"	1-2	"	"	--	12.8	16.5	69	4.5	"	1.4
8	1214	164	59	"	0-1	"	"	--	12.6	18	65	7	"	0.53
9	1256	185	57	"	10-11	"	"	--	13.5	16.5	65	2.5	5	1.3
10	1322	204	55	"	1-2	"	1-3	W	13.5	18.5	68	7	4	0.57
11	1352	205	51	"	"	250	7-9	WSW	13.6	15.5	76	7	"	1.2
12	1420	219	46	"	"	255	6-8	"	13.0	16	66	5	"	--
13	1453	228	42	"	"	270	6-8	"	11.9	18	72	4	15	1.0
14	1526	228	36	"	"	270	8-12	"	11.1	15.5	70	4	15	--
15	1553	227	31	"	2-3	275	14-16	"	12.2	15.5	66	8	4	1.0
16	1620	238	26	"	"	"	13-15	--	12.2	16	63	8	--	1.9
17	1648	240	20	"	"	"	10-12	W	12.0	15	--	6	4	0.57
18	1716	242	14	"	2-4	275	0	--	11.9	16	67	6	5	1.7
19	1810	253	07	"	2-3	280	6-8	SSW	13.6	15.5	70	1.5	"	2.5
20	1829	245	01	"	1-2	270	4-6	SSE	13.5	14	88	2.5	"	2.1

Table A-1 Continued
Page 7

Area Monterey   Date 15 June 1973   ERTS Image I.D. 1327-18180

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humi-dity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbi-dity (FTU)
1	0922	75°	43°	100%	3-4	270	0	--	--	14.5	78	2.5	5	2.0
2	1146	120	68	"	3-5	270	10	W	--	11.5	88	8	4	0.52
3	1225	135	75	"	3-5	255	20	"	--	"	"	10	--	0.40
4	1301	190	77	"	3-6	260	21	"	--	"	"	11	4	0.45
5	1344	195	74	"	"	255	20	WSW	--	"	"	8	5	0.52
6	1410	210	71	"	"	270	22	W	--	"	"	7	6	1.3
7	1440	230	66	"	"	270	26	W	--	"	"	7	6	0.82
8	1526	235	58	"	2-3	235	18	WSW	--	"	"	5	4	1.4
9	1600	240	51	"	2	240	18	"	--	"	"	6	6	1.3
10	1624	250	45	"	1-2	"	7-8	"	--	14.5	83	6	"	1.1
11	1655	260	39	"	2-3	"	10	"	--	14.5	"	4.5	"	1.1
12	1724	260	33	"	2-3	255	18-20	"	--	11.5	"	4	"	0.97
13	1800	270	26	"	3-6	270	25	W	--	"	87	6	"	1.1
14	1835	270	20	"	4-6	270	24	W	--	"	83	4	"	1.0

Table A-1 Continued
Page 8

Area Monterey Date 3 July 1973 ERTS Image I.D. 1345-18174

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0853	60°	34°	---	1-2	255°	3-5	Var.	--	16	100	4.5	4	1.3
2	0947	70	44	Low Fog	1-2	255	3-5	Var.	--	13.5	82	4.0	4-5	1.0
3	1152	110	69	---	1	210	0	---	--	17	--	7.0	6	0.9
4	1225	110	73	100%	1-1.5	240	20	WSW	--	17	100	5.0	---	1.0
5	1255	155	76	---	1-2.5	250	26	"	--	15	88	5.5	4	1.2
6	1323	175	76	100%	1.5-2.5	255	25	"	--	16.5	93	5.5	4	0.7
7	1354	195	73	---	3-4	265	30	"	--	16	100	4.5	---	0.65
8	1413	210	71	---	"	265	20	"	--	15.5	93	4.5	14	0.85
9	1445	225	65	---	"	245	18	"	--	15.5	88	4	14	0.75
10	1515	230	60	---	2-3	255	14	"	--	15	94	4.5	15	0.65
11	1540	235	55	---	2-3	"	18	"	--	14.5	94	6	14	0.65
12	1558	245	51	---	3-4	"	15	"	--	"	88	4.5	14	0.60
13	1615	"	48	---	"	"	"	"	--	"	94	5	"	0.75
14	1640	"	43	---	"	"	"	"	--	"	88	4	"	0.80
15	1701	255	38	100	"	"	10	"	--	15.5	94	3	--	1.2
16	----	---	--	---	---	---	--	--	--	---	--	2.5	--	2.4

Table A-1 Continued

Area Santa Monica Date 23 August 1973 ERTS Image I.D. 1396-18004

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Temperatures Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0915	90°	31°	10,000 ft.	2-3	240°	0	---	18.5	20	72	4	Green-Brown	0.65
2	1011	100	45	"	2-3	"	0	---	20.2	19.5	78	5	Green-Brown	0.75
3	1048	105	54	"	3-4	"	8	WSW	19.3	21	84	5	4-5	0.40
4	1140	120	62	"	"	"	2.5	"	17.3	20.5	85	7	5-6	0.25
5	1208	135	66	"	"	"	0-1	"	18.9	20	85	7	4	0.25
6	1236	150	72	"	"	"	0-5	"	17.9	19	82	8	2	0.30
7	1327	165	67	"	"	"	9	"	18.4	20.9	83	10	2	0.30
8	1404	210	63	"	"	"	"	"	18.0	20	72	9	2	0.30
9	1437	210	57	"	1-2	250°	15	"	18.6	20	90	6	4	0.25
10	1539	225	47	100%	1-2	240°	12-16	"	---	20	90	4	6	0.45
11	--	255	41	10,000 ft.	2-3	275°	18	WNW	18.5	20	90	3	Green-Brown	0.65
12	1630	260	37	"	3-4	240°	10	W	18.5	20	90	2.5	"	0.50
13	1655	265	31	"	2-3	"	6	"	18.3	20.1	80	3.5	"	0.55
14	1712	265	27	"	3-4	"	10-12	"	18.5	20.1	"	3.5	"	0.60
15	1730	255	24	"	3-4	"	11	"	18.3	20.1	"	3	"	0.50
16	1740	250	21	"	1-2	"	12	WSW	---	20	"	2.5	"	0.80

Table A-1 Continued
Page 10

Area Santa Barbara   Date 24 August 1973   ERTS Image I.D. 1397-18062

Sta.	Arrival Time	Sun Az.	Sun Elev.	Vertical Visibility	Wave Height (ft)	Wave Dir.	Wind Speed (mph)	Wind Dir.	Temperatures Water (°C)	Air (°C)	Humidity (%)	Secchi Depth (m)	Water Color Forel-Ule	Turbidity (FTU)
1	0918	80°	35°	100%	4-6	260°	10	E	18	19	100	5	6	0.5
2	1015	90	45	100	4-6	260	5	E	18.5	18.5	74	6	8	0.7
3	1031	90	50	100	---	260	6	--	18.5	19.5	84	7	4	0.65
4	1046	100	52	100	4-6	260	5	E	18.5	19.5	88	10	3	0.35
5	1102	110	54	100	3-4	240	2	E	18.5	19	89	13	3	0.20
6	1128	120	58	100	4-6	240	0	--	18.5	19	89	10	2	0.25
7	1202	--	63	100	2-4	240	2	WSW	18.5	19.5	89	13	3	0.25
8	1232	145	61	100	3-4	240	5-6	SW	18.5	19	84	10	6	0.20
9	1249	155	67	100	4-6	240	12	WSW	17	17	94	11	3	0.30
10	1310	165	67	100	4-6	240	16	WSW	16	16	94	9	3	0.25
11	1330	70	66	100	4-6	240	14	WSW	15.8	16.5	96	9	6	0.40
12	1505	222	54	100	4-6	---	22	W	16.5	18.5	75	--	8	0.45
13	1530	240	49	100	4-6	265	26	W	16	15.8	94	9	5	0.30
14	1552	245	45	100	4-6	265	19	WSW	16.5	17	93	9	14	0.20
15	1618	235	40	---	3-5	240	17	WSW	17	18	87	9	3	0.35
16	1645	240	34	---	2-3	225	14	WSW	18.5	16	87	9	4	0.15
17	1707	210	30	---	2-3	220	0	---	18.5	19	85	8	5	0.20
18	1735	250	25	---	1-2	200	0	---	18.8	19.5	88	5	5	0.35

Table A-2

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara   Date 25 February 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	480	500	495	490	480	470	470	470
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some	some						
10-100μ	15,600	4,500	760	150	780	241	320	240
>100μ	150	18	7	few	78	20	20	
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	4,680			150	few	20		
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella	few	few	few	few	19		26	19
Biddulphia								
Bacteriastrum	1,180	1,500	few	770	470	400	400	400
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary				390				
DINOFLAGELLATES								
Ceratium	78	450	450		235	few	240	80
Peridinium	26	15			few	few		
Dinophysis	8	15		few		few		few
Gonyaulux	26							
Prorocentrum					few			
OTHER								
Irridescent Flakes	10	30	300	150	100	300	70	60
Silicoflagellate				few				few
Tintinnid		few						
Radiolarian								

Table A-2 Continued

Page 2

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 25 February 1973

Cruise Station	9	10	11	12	13	14	15	16
Volume Filtered (ml)	495	485	475	485	460	435	490	480
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	600	620	960	770	9,800	5,200	600	600
>100μ	7	40	40	77	82	17		
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	76		few	few				
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella	38	10			few			
Biddulphia								
Bacteriastrum	300	78	318	310	164	86	140	78
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary			few		16		few	
DINOFLAGELLATES								
Ceratium	300	78	318	77	41	few	few	
Peridinium			few		few			
Dinophysis	76		few					
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes	60	30	60	30	30	60	40	10
Silicoflagellate			15	few				
Tintinnid						few		
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 25 February 1973

Cruise Station	17	18	19					
Volume Filtered (ml)	460	480	450					
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some							
10-100μ	2,500	944	1,300					
>100μ	16	15						
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros		40	83					
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella		20	few					
Biddulphia								
Bacteriastrum	160	314	250					
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	27							
DINOFLAGELLATES								
Ceratium	few	157						
Peridinium		few						
Dinophysis		few						
Gonyaulux								
Prorocentrum	few	few						
OTHER								
Irridescent Flakes	160	20	8,000					
Silicoflagellate								
Tintinnid	few							
Radiolarian								

FILTERED SUSPENDED MATERIALS
OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 15 March 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some	some						
10-100μ	24,000	20,000	12,000	6,000	15,000	15,000	15,000	18,000
>100μ	75	75	15	75	few	few	few	37
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	7	12	150	150	150	150	150	220
Skeletonema	7		39	150	37	37	37	150
Thalassiosira			7	220	400	400	400	few
Thalassiothrix		15	300	900	20,000	20,000	20,000	150
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia			75	24	450		150	
Eucampia								
Thalassionema			7,500		75,000			
CENTRIC DIATOMS								
Large, solitary		7		22		22	22	150
DINOFLAGELLATES								
Ceratium	7	7	24	few		few	few	few
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 15 March 1973

Cruise Station	9	10	11	12	13	14	15	16
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	6,000	18,000	6,000	18,000	3,000	3,000	3,000	18,000
>100μ	few	15		few				
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	400	300	300	75	1,200	400	400	75
Skeletonema	75				75	18	18	18
Thalassiosira		75,000	75,000	150	220	75	75	75
Thalassiothrix	150	45	45		220	220	220	75
Stephanopyxis							few	
Schroderella				few				
Biddulphia								
Bacteriastrum								
Nitzschia	150				220	150	150	
Eucampia				few				
Thalassionema								
CENTRIC DIATOMS								
Large, solitary		75	75	75		7	7	
DINOFLAGELLATES								
Ceratium	7		few			few	37	few
Peridinium								
Dinophysis								few
Gonyaulux	7					few		
Prorocentrum						few		
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 15 March 1973

Cruise Station	17	18	19					
Volume Filtered (ml)	500	500	500					
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	9,000	1,200	750					
>100μ								
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	220	750	750					
Skeletonema			220					
Thalassiosira	75							
Thalassiothrix	600	400	400					
Stephanopyxis								
Schroderella								
Biddulphia			75					
Bacteriastrum		2,250	220					
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary			600					
DINOFLAGELLATES								
Ceratium	few							
Peridinium								
Dinophysis								
Gonyaulux		few						
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 17 March 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ							some	some
10-100μ	10,500	10,500	10,500	7,000	10,000	10,000	10,000	12,000
>100μ	few	few	few					
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	750	600	150	750	5,000	450	450	300
Skeletonema	220	450	150	750	600	220	220	150
Thalassiosira	75	75	220	220	37	24	24	37
Thalassiothrix	15	15		7	few			
Stephanopyxis	7				7	few	few	
Schroderella		7						
Biddulphia	7	7	7	7	few	7	7	
Bacteriastrum								
Nitzschia						few		
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	75	37		150		75		
DINOFLAGELLATES								
Ceratium		7	few	few				few
Peridinium				few			few	
Dinophysis			7	25	15	few	few	
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 17 March 1973

Cruise Station	9	10	11	12	13	14	15	16	17
Volume Filtered (ml)	500	500	500	500	495	500	500	460	500
ALGAL DEBRIS	Values in Particles/l x 10^3								
<10μ	some	some	some		12,000	12,000	12,000	13,000	13,000
10-100μ	10,000	15,000	10,000	10,000	1,500	1,500	1,500	1,500	1,500
>100μ						few		few	
CHAIN DIATOMS	Values in Organisms/l x 10^3								
Chaetoceros	450	450	300	750	340	300	220	220	75
Skeletonema	150	150	900	300	750	600	220	150	15
Thalassiosira	37	37			75	37			15
Thalassiothrix	few	few							
Stephanopyxis					few	few			few
Schroderella									
Biddulphia			few	few	few	few			
Bacteriastrum									
Nitzschia	few					150			few
Eucampia									
Thalassionema									
CENTRIC DIATOMS									
Large, solitary			few		few			few	
DINOFLAGELLATES									
Ceratium				few	few		few	few	
Peridinium									
Dinophysis				few		18		few	
Gonyaulux									
Prorocentrum									
OTHER									
Irridescent Flakes									
Silicoflagellate									
Tintinnid									
Radiolarian				few					

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Monica Date 1 April 1973

Cruise Station	1	2	3	4				
Volume Filtered (ml)	500	500	500	500				
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	9,000	9,000	5,000	3,000				
10-100μ								
>100μ								
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros			75	1,500				
Skeletonema								
Thalassiosira								
Thalassiothrix			few					
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia			37	150				
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary								
DINOFLAGELLATES								
Ceratium			few					
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 2 April 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some							
10-100μ	27,000	450	3,000					
>100μ				18	18	37	18	18
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	1,500	75	450	1,800	1,800	3,000	1,200	1,500
Skeletonema	1,200	75	75	1,500	1,500	220	220	300
Thalassiosira	450	1,200	150	1,500	1,500	750	few	
Thalassiothrix	1,500	600	1,500	1,200	1,200	1,500	1,500	900
Stephanopyxis	few	few	few			few	75	
Schroderella	few	few	18			few	150	220
Biddulphia	15	few				few		
Bacteriastrum								
Nitzschia		75		75		220		450
Eucampia			few					
Thalassionema	few			few			few	few
CENTRIC DIATOMS								
Large, solitary	few			few				few
DINOFLAGELLATES								
Ceratium								
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 2 April 1973

Cruise Station	9	10	11	12	13	14	15	16
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								3,000
10-100μ		75	75	400	75	75	750	1,500
>100μ	18			75			75	150
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	1,500	1,500	1,500	1,200	600	1,200	750	750
Skeletonema	300	300	300	300	300	300	300	400
Thalassiosira					300		600	150
Thalassiothrix	900	900	900	900	2,100	1,800	2,400	2,400
Stephanopyxis		few	few	few	75	75	150	150
Schroderella	220	220	220	220		few	75	75
Biddulphia		300	300	300	300		300	
Bacteriastrum								
Nitzschia	450	900	900	900	1,800		75	
Eucampia								
Thalassionema	few				few	75		7
CENTRIC DIATOMS								
Large, solitary	few	few	few					7
DINOFLAGELLATES								
Ceratium								
Peridinium						few		
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 2 April 1973

Cruise Station	17	18	19	20	21	22	23	
Volume Filtered (ml)	405	500	435	490	500	500	479	
ALGAL DEBRIS	Values in Particles/l x 10³							
<10μ								
10-100μ	900	400						
>100μ	90		43	43	few	few	few	
CHAIN DIATOMS	Values in Organisms/l x 10³							
Chaetoceros	1,500	1,000	1,000	1,000	1,200	1,200	1,200	
Skeletonema	1,300	2,000	2,000	600	600	2,000	2,000	
Thalassiosira		75	860		150	860	860	
Thalassiothrix	2,400	2,400	3,400	600	600	3,400	3,400	
Stephanopyxis	600	600	few	44	75	75	75	
Schroderella	75	few	few	75	220	220	220	
Biddulphia			15					
Bacteriastrum								
Nitzschia	500		350		600			
Eucampia								
Thalassionema		18						
CENTRIC DIATOMS								
Large, solitary		few						
DINOFLAGELLATES								
Ceratium								
Peridinium					few			
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

Table A-2 Continued

Page 13

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	1	1A*	2	2A	3	3A	3B	4
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	a lot	some	some	some				
10-100μ	1,500	1,500	3,000	18,000	9,000	9,000	750	750
>100μ	18	7	75					
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros						few		
Skeletonema	1,500	1,200	1,200	1,200	4,500	4,500	3,000	3,000
Thalassiosira					few			
Thalassiothrix			few		few	few		
Stephanopyxis								
Schroderella								
Biddulphia			few	few			75	
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema			few					
CENTRIC DIATOMS								
Large, solitary	75	75		35	15		few	few
DINOFLAGELLATES								
Ceratium								
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum					few			
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

* A capital letter indicates samples taken between stations.

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	4A*	4B	4C	4D	4a	4aA	4aB	5
Volume Filtered (ml)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ					some	some	a lot	
10-100μ	740	740	740	1,500	3,000	3,000	1,500	2,250
>100μ				few		few	few	few
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	few	few	few	few				
Skeletonema	1,500	2.200	2,200	300	5,200	5,200	2,900	4,500
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia	4	4				few		few
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	35	35	few	few	37		12	75
DINOFLAGELLATES								
Ceratium								
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

* A capital letter indicates samples taken between stations.

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	6-1m*	6-5m	6A**	7-1m	7-5m	7A	8-1m	8-5m
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ					some			
10-100μ	2,200	750	750	750	3,000	750	2,400	1,500
>100μ	few	7	7	7	7	few		
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros								
Skeletonema	4,500	9,000	7,500	4,500	3,000	3,000	7,500	12,000
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia				7	few	few		few
Bacteriastrum								
Nitzschia					few			
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	75	300	75	7				
DINOFLAGELLATES								
Ceratium				few				
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid							few	
Radiolarian								

* 1m indicates sample depth in meters.

** A capital letter indicates samples taken between stations.

Table A-2 Continued

Page 16

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	8A*	9-1m**	9-5m	9A	10-1m	10-5m	10A	11
Volume Filtered (ml)	500	500	500	500	500	250	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	1,200	2,400	4,400	3,000	1,500	3,000	750	1,500
>100μ			1,200			few		
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros					few	50		
Skeletonema	7,500	1,200	15,000	9,000	9,000	7,200	7,500	4,500
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia	few			few				
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	few	75		few	few			few
DINOFLAGELLATES								
Ceratium	few				few			
Peridinium	few					few	few	few
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid	few	15		few				150
Radiolarian								

* A capital letter indicates samples taken between stations.

** 1m indicates sample depth in meters.

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay   Date 4 April 1973

Cruise Station	11-5m*	12-5m	13H**	13-1m	13-5m	13A***	14-5m	15-1m
Volume Filtered (ml)	250	250	1,000	500	1,000	1,000	250	1,000
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	3,000	1,800	300	3,000	3,000	3,000	1,800	180
>100μ	50	30		25	25	25	75	few
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros								37
Skeletonema	24,000	7,500	5,900	15,000	7,400	7,400	18,000	880
Thalassiosira								
Thalassiothrix								few
Stephanopyxis								
Schroderella								
Biddulphia		few						few
Bacteriastrum								
Nitzschia								few
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary		few	few				few	7
DINOFLAGELLATES								
Ceratium								few
Peridinium								few
Dinophysis								
Gonyaulux								
Prorocentrum								few
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								few
Radiolarian								

* Depth of Sample

** Sample Taken Through Hull Intake Pipe

*** Samples Taken Between Stations are Indicated by a Capital Letter.

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	15-5m*	16-1m	16-5m	16A**	17-1m	17-5m	17A	17B
Volume Filtered (ml)	250	1,000	250	1,000	1,000	1,000	1,000	1,000
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	1,500	180	900	740	740	3,000	1,030	1,480
>100μ		few	50	7	7	300	37	70
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros			few	few	few		few	
Skeletonema	2,400	1,480	2,400	1,700	1,700	1,800	1,030	2,200
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia							few	
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary		7	few	few		few	few	
DINOFLAGELLATES								
Ceratium		few		few	few			
Peridinium		few	few	few	7			
Dinophysis								
Gonyaulux								
Prorocentrum		few						
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid				13	13			
Radiolarian								

* 1m indicates sample depth in meters.

** A capital letter indicates sample taken between stations.

Table A-2 Continued

Page 19

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	18-1m*	18-5m	18A**	18B	18C	19	19A	19B
Volume Filtered (ml)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ				some	a lot	a lot	a lot	a lot
10-100μ	1,480	2,400	740	3,000	2,200	2,900	2,900	2,900
>100μ	70	150	3	15	90			9
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros		few	few		few			
Skeletonema	2,200	2,400	800	2,200	2,200	4,400	4,400	2,200
Thalassiosira								
Thalassiothrix		few						
Stephanopyxis								
Schroderella								
Biddulphia				few				
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema		few						
CENTRIC DIATOMS								
Large, solitary		few	few	37		15	15	15
DINOFLAGELLATES								
Ceratium					few			
Peridinium		few						
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								few
Radiolarian								

* 1m indicates sample depth in meters.

** A capital letter indicates samples taken between stations.

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 4 April 1973

Cruise Station	20-1m*	20-5m						
Volume Filtered (ml)	1,000	250						
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	a lot							
10-100μ	2,900	9,000						
>100μ	9	few						
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros								
Skeletonema	2,200	9,000						
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia	few	few						
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary		150						
DINOFLAGELLATES								
Ceratium								
Peridinium								
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid								
Radiolarian								

* lm indicates sample depth in meters.

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 15 June 1973

Cruise Station	1	2	3	4	5 *	7	10	11
Volume Filtered (ml)								
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some						a lot	a lot
10-100μ		750	21,000	21,000	6,000	375	3,750	3,750
>100μ		37	few	few	few	few		few
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	150	150	150	150	few			
Skeletonema	1,125	1,125	450	450		220	300	300
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia	few	few			few			
Bacteriastrum								
Nitzschia						75		
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	few	few	few	few		1,000	37	37
DINOFLAGELLATES								
Ceratium							few	few
Peridinium			few	few	few		few	few
Dinophysis					few		few	few
Gonyaulux			few	few				
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate					75			
Tintinnid					37			
Radiolarian							few	

* No data for Stations 6, 8, & 9.

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 15 June 1973

Cruise Station	12	13 *						
Volume Filtered (ml)								
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	a lot	a lot						
10-100μ	3,750	3,750						
>100μ								
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	75	75						
Skeletonema	750	750						
Thalassiosira	few	few						
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary								
DINOFLAGELLATES								
Ceratium	few	few						
Peridinium	few	few						
Dinophysis								
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate								
Tintinnid	few	few						
Radiolarian								

* No Data for Station 14

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 3 July 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	3,000	3,000	1,500	750	300	750	600	450
>100μ								
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	450	220		18	37	150	600	18
Skeletonema	220	400	220	18	37	470	150	600
Thalassiosira		300				150	75	300
Thalassiothrix		18						
Stephanopyxis		7						
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia	7	150	37	75	150	150	450	400
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	150	300	75		7	18	15	
DINOFLAGELLATES								
Ceratium								
Peridinium	7	7	75	75		75	150	150
Dinophysis		7	75	37		75	220	150
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate						few		
Tintinnid								
Radiolarian								

Table A-2 Continued

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Monterey Bay Date 3 July 1973

Cruise Station	9	10	11	12	13	14	15	
Volume Filtered (ml)	500	500	500	500	500	500	500	
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	450	few	220	300	2,250	600	3,000	
>100μ			few					
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	600	300	150	75	150	150	150	
Skeletonema	600	750	220	150	300	220	150	
Thalassiosira	300	150		220	75	450	150	
Thalassiothrix				few				
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia		150	75	150	75	75	400	
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	150	150	400		150	300	750	
DINOFLAGELLATES								
Ceratium	7		few		few			
Peridinium	75	75	18	75	75		75	
Dinophysis	75			75	75			
Gonyaulux								
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate			few	150	222	222	18	
Tintinnid						7		
Radiolarian								

Table A-2 Continued

Page 25

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Monica Date 23 August 1973

Cruise Station	1	2	2A*	3	3A	4	4A	5
Volume Filtered (ml)	570	570	570	570	570	570	570	570
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	10,500	4,200	800	400	600	330	4,000	330
>100μ	132	21	few	few	66	66	33	16
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	few					few		
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum						few	few	
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary						few		
DINOFLAGELLATES								
Ceratium	16	16	13	6	33	33	66	16
Peridinium	16	16	16			16	33	16
Dinophysis	13	33	21	6	66	130	66	33
Gonyaulux	13	13	13				16	
Prorocentrum	10	33	33	6	33	130	66	66
OTHER								
Irridescent Flakes								
Silicoflagellate					few	few		few
Tintinnid								
Radiolarian			few					

* A capital letter indicates samples taken between stations.

Table A-2 Continued

Page 26

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Monica Date 23 August 1973

Cruise Station	6	7	8	9	10	11	12	13
Volume Filtered (ml)	570	570	570	570	570	570	570	570
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ							some	some
10-100μ	3,600	4,800	4,800	1,050	1,050	5,300	2,600	2,600
>100μ	13	7	7	few	few	few	66	few
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	few				100	13	33	33
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary								
DINOFLAGELLATES								
Ceratium	16	7	7	13	13	13	13	13
Peridinium	16	7	7	22	22	22	22	13
Dinophysis	33	11	11	13	13	13	13	13
Gonyaulux	16	11	11	33	33	33	33	33
Prorocentrum	33	13	13					7
OTHER								
Irridescent Flakes								
Silicoflagellate	few			few	few	few		
Tintinnid								
Radiolarian				few	few	few		

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Monica Date 23 August 1973

Cruise Station	14	15	16					
Volume Filtered (ml)	570	570	570					
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ	some	some	some					
10-100μ	2,600	1,300	2,600					
>100μ	few	7	13					
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	66							
Skeletonema								
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary								
DINOFLAGELLATES								
Ceratium	13	13	16					
Peridinium	13	13	33					
Dinophysis	13	13	16					
Gonyaulux	66	33	33					
Prorocentrum	7	7						
OTHER								
Irridescent Flakes								
Silicoflagellate	few							
Tintinnid								
Radiolarian								

Table A-2 Continued

Page 28

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 24 August 1973

Cruise Station	1	2	3	4	5	6	7	8
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ			some					
10-100μ	10,000	400	450	750	380	250	300	200
>100μ							few	
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	37	600	75	400	450	300	300	75
Skeletonema		few		7		300	300	15
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary					7			7
DINOFLAGELLATES								
Ceratium	7	7	7	7	7	7	7	7
Peridinium	7	7	75	75	75	75	75	75
Dinophysis	15	15	15	15	15	15	15	15
Gonyaulux	75	75	75	15	15	15	15	15
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate	5							
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 24 August 1973

Cruise Station	9	10	11	12	13	14	15	16
Volume Filtered (ml)	500	500	500	500	500	500	500	500
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	4,500	3,000	18,000	3,000	3,000	3,000	1,800	1,500
>100μ								
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	750	750	750	2,400	2,400	750	220	300
Skeletonema				150	150	200		150
Thalassiosira			12					
Thalassiothrix		7	12				7	
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia							7	
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary	15		7			37	37	
DINOFLAGELLATES								
Ceratium	7	7			7			
Peridinium	7	7		25	25	15	15	24
Dinophysis	15	15	7	7	7	15	15	24
Gonyaulux	15	15	7	15	15	15	15	24
Prorocentrum								
OTHER								
Irridescent Flakes								
Silicoflagellate	some							7
Tintinnid								
Radiolarian								

FILTERED SUSPENDED MATERIALS

OPTICAL MICROSCOPE ANALYSIS

Cruise Area Santa Barbara Date 24 August 1973

Cruise Station	17	18						
Volume Filtered (ml)	500	500						
ALGAL DEBRIS	Values in Particles/l x 10^3							
<10μ								
10-100μ	3,000	2,250						
>100μ	few							
CHAIN DIATOMS	Values in Organisms/l x 10^3							
Chaetoceros	600	75						
Skeletonema	150							
Thalassiosira								
Thalassiothrix								
Stephanopyxis								
Schroderella								
Biddulphia								
Bacteriastrum								
Nitzschia								
Eucampia								
Thalassionema								
CENTRIC DIATOMS								
Large, solitary								
DINOFLAGELLATES								
Ceratium		75						
Peridinium	15	7						
Dinophysis	15	75						
Gonyaulux	15							
Prorocentrum	15	220						
OTHER								
Irridescent Flakes								
Silicoflagellate	15	15						
Tintinnid								
Radiolarian								

APPENDIX B

IMAGE CATALOG

As the study progressed, the number and type of image products increased rapidly. In addition, numerous orders for specific NDPF products were initiated and in some cases, duplicated. Data retrieval of an individual product became more difficult as the size of the product file increased. To alleviate this bottleneck, a computer oriented image catalog was set up. Its format was kept simple, but it provided at a glance, the status of all products for any of the areas of interest. It included information on all orders initiated, including the date of the order. This allowed reordering of the product after an abnormally long period. As NDPF did not routinely acknowledge requests for products, requests not honored were assumed to have died in the system and were reinitiated after 120 days. As a new image description was added to the catalog, the missing products were immediately flagged. Unwanted products are shown in the catalog by an X. Designating a product as not wanted turned off the missing product flag. Updating was performed when the number of changes grew large. The catalog is included as Appendix B of the report and shows the final status of the image file.

NASA-ERTS IMAGE CATALOG 01/31/74 PAGE 1

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
MONTEREY							
1002-18134-4	7/25/72	1	2	1	1	X	
1002-18134-5	7/25/72	1	2	1	1	1	
1002-18134-6	7/25/72	1	2	1	1	0	
1002-18134-7	7/25/72	1	2	1	1	0	
S. MONICA							
1018-18010-4	8/10/72	1	1	0 525	X	X	
			9X9 POS ON ORDER SINCE 525				******
1018-18010-5	8/10/72	1	1	0 525	X	1	
			9X9 POS ON ORDER SINCE 525				******
1018-18010-6	8/10/72	1	1	0 525	X	0	
			9X9 POS ON ORDER SINCE 525				******
1018-18010-7	8/10/72	1	1	0 525	X	0	
			9X9 POS ON ORDER SINCE 525				******
S. BARBARA							
1019-18064-4	8/11/72	0 525	1	1	X	X	
			70MM POS ON ORDER SINCE 525				******
1019-18064-5	8/11/72	0 525	1	1	X	1	
			70MM POS ON ORDER SINCE 525				******
1019-18064-6	8/11/72	0 525	1	1	X	0	
			70MM POS ON ORDER SINCE 525				******
1019-18064-7	8/11/72	0 525	1	1	X	0	
			70MM POS ON ORDER SINCE 525				******
MONTEREY							
1021-18172-4	8/13/72	1	1	1	1	X	
1021-18172-5	8/13/72	1	1	1	1	1	
1021-18172-6	8/13/72	1	1	1	1	0	
1021-18172-7	8/13/72	1	1	1	1	0	
S. MONICA							
1036-18010-4	8/28/72	1	1	1	X	X	
1036-18010-5	8/28/72	1	1	1	X	1	
1036-18010-6	8/28/72	1	1	1	X	0	
1036-18010-7	8/28/72	1	1	1	X	0	
S. BARBARA							
1037-18064-4	8/29/72	1	1	1	1	X	
1037-18064-5	8/29/72	1	1	1	1	1	
1037-18064-6	8/29/72	1	1	1	1	0	
1037-18064-7	8/29/72	1	1	1	1	0	

ABBREVIATIONS:

B/W	= Black and White
+ pos	= Positive
- Neg	= Negative
0,1,2,3...	= Number of Copies received
X	= Copy not Desired

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W
MONTEREY						
1039-18172-4	8/31/72	1	1	1	1	X
1039-18172-5	8/31/72	1	1	1	1	1
1039-18172-6	8/31/72	1	1	1	1	0
1039-18172-7	8/31/72	1	1	1	1	0
S. MONICA						
1054-18010-4	9/15/72	1	3	1	X	X
1054-18010-5	9/15/72	1	3	1	X	1
1054-18010-6	9/15/72	1	3	1	X	0
1054-18010-7	9/15/72	1	3	1	X	0
S. BARBARA						
1055-18064-4	9/16/72	1	3	1	X	X
1055-18064-5	9/16/72	1	2	1	X	1
1055-18064-6	9/16/72	1	3	1	X	0
1055-18064-7	9/16/72	1	2	1	X	0
MONTEREY						
1057-18172-4	9/18/72	1	1	1	1	X
1057-18172-5	9/18/72	1	1	1	1	1
1057-18172-6	9/18/72	1	1	1	1	0
1057-18172-7	9/18/72	1	1	1	1	0
S. MONICA						
1072-18010-4	10/ 3/72	1	2	1	X	X
1072-18010-5	10/ 3/72	1	2	1	X	1
1072-18010-6	10/ 3/72	1	2	1	X	0
1072-18010-7	10/ 3/72	1	2	1	X	0
NEWPORT B.						
1072-18012-4	10/ 3/72	1	1	X	X	X
1072-18012-5	10/ 3/72	1	1	X	X	1
1072-18012-6	10/ 3/72	1	1	X	X	0
1072-18012-7	10/ 3/72	1	1	X	X	0
S. BARBARA						
1073-18064-4	10/ 4/72	1	2	1	1	X
1073-18064-5	10/ 4/72	1	2	1	1	1
1073-18064-6	10/ 4/72	1	2	1	1	0
1073-18064-7	10/ 4/72	1	2	1	1	0

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. BARBARA WEST							
1074-18123-4	10/ 5/72	1	0 731	1	X	0	
			70MM NEG ON ORDER SINCE 731				******
			MISSING 9X9 B/W				******
1074-18123-5	10/ 5/72	1	0 731	1	X	0	
			70MM NEG ON ORDER SINCE 731				******
1074-18123-6	10/ 5/72	1	0 731	1	X	0	
			70MM NEG ON ORDER SINCE 731				******
1074-18123-7	10/ 5/72	1	0 731	1	X	0	
			70MM NEG ON ORDER SINCE 731				******
MONTEREY							
1075-16173-4	10/ 6/72	1	3	1	1	X	
1075-18173-5	10/ 6/72	1	3	1	1	1	
1075-18173-6	10/ 6/72	1	3	1	1	0	
1075-18173-7	10/ 6/72	1	2	1	1	0	
S. MONICA							
1090-18012-4	10/21/72	1	2	1	1	X	
1090-18012-4	10/21/72	1	2	1	1	X	
1090-18012-5	10/21/72	1	2	1	1	1	
1090-18012-6	10/21/72	1	2	1	1	0	
1090-18012-7	10/21/72	1	2	1	1	0	
NEWPORT B.							
1090-18015-4	10/21/72	1	1	X	X	X	
1090-18015-5	10/21/72	1	1	X	X	1	
1090-18015-6	10/21/72	1	1	X	X	0	
1090-18015-7	10/21/72	1	1	X	X	0	
S. BARBARA							
1091-18071-4	10/22/72	1	2	1	1	X	
1091-18071-4	10/22/72	1	2	1	1	X	
1091-18071-5	10/22/72	1	2	1	1	1	
1091-18071-6	10/22/72	1	2	1	1	0	
1091-18071-7	10/22/72	1	2	1	1	0	
S. BARBARA WEST							
1092-18123-4	10/23/72	1	2	1	X	X	
1092-18123-5	10/23/72	1	2	1	X	1	
1092-18123-6	10/23/72	1	2	1	X	0	
1092-18123-7	10/23/72	1	2	1	X	0	

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W		
MONTEREY NORTH								
1093-18173-4	10/24/72	1	0 801	0	0	0		
							70MM NEG ON ORDER SINCE 801	******
							MISSING 9X9 POS	******
							MISSING MAG TAPE	******
							MISSING 9X9 B/W	******
1093-18173-5	10/24/72	1	0 801	0	0	0		
							70MM NEG ON ORDER SINCE 801	******
							MISSING 9X9 POS	******
1093-18173-6	10/24/72	1	0 801	0	0	0		
							70MM NEG ON ORDER SINCE 801	******
							MISSING 9X9 POS	******
1093-18173-7	10/24/72	1	0 801	0	0	0		
							70MM NEG ON ORDER SINCE 801	******
							MISSING 9X9 POS	******
MONTEREY SOUTH								
1093-18176-4	10/24/72	0 525	0 525	0 525	0 525	0		
							70MM POS ON ORDER SINCE 525	******
							70MM NEG ON ORDER SINCE 525	******
							9X9 POS ON ORDER SINCE 525	******
							MAG TAPE ON ORDER SINCE 525	******
							MISSING 9X9 B/W	******
1093-18176-5	10/24/72	0 525	0 525	0 525	0	0		
							70MM POS ON ORDER SINCE 525	******
							70MM NEG ON ORDER SINCE 525	******
							9X9 POS ON ORDER SINCE 525	******
1093-18176-6	10/24/72	0 525	0 525	0 525	0	0		
							70MM POS ON ORDER SINCE 525	******
							70MM NEG ON ORDER SINCE 525	******
							9X9 POS ON ORDER SINCE 525	******
1093-18176-7	10/24/72	0 525	0 525	0 525	0	0		
							70MM POS ON ORDER SINCE 525	******
							70MM NEG ON ORDER SINCE 525	******
							9X9 POS ON ORDER SINCE 525	******
S. MONICA								
1108-18014-4	11/ 8/72	1	3	1	1	X		
1108-18014-4	11/ 8/72	1	3	1	1	X		
1108-18014-5	11/ 8/72	1	3	1	1	1		
1108-18014-6	11/ 8/72	1	2	1	1	0		
1108-18014-7	11/ 8/72	1	3	1	1	0		
NEWPORT B.								
1108-18020-4	11/ 8/72	1	1	1	X	X		
1108-18020-5	11/ 8/72	1	1	1	X	1		
1108-18020-6	11/ 8/72	1	1	1	X	0		
1108-18020-7	11/ 8/72	1	1	1	X	0		

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W
S. BARBARA						
1109-18073-4	11/ 9/72	1	1	1	1	X
1109-18073-5	11/ 9/72	1	1	1	1	1
1109-18073-6	11/ 9/72	1	1	1	1	0
1109-18073-7	11/ 9/72	1	1	1	1	0
MONTEREY						
1111-18181-4	11/11/72	1	2	1	1	X
1111-18181-5	11/11/72	1	2	1	1	1
1111-18181-6	11/11/72	1	2	1	1	0
1111-18181-7	11/11/72	1	2	1	1	0
S. MONICA						
1126-18015-4	11/26/72	1	1	1	1	X
1126-18015-5	11/26/72	1	1	1	1	1
1126-18015-6	11/26/72	1	1	1	1	0
1126-18015-7	11/26/72	1	1	1	1	0
S. BARBARA						
1127-18073-4	11/27/72	1	1	1	1	X
1127-18073-4	11/27/72	1	1	1	1	X
1127-18073-5	11/27/72	1	1	1	1	1
1127-18073-6	11/27/72	1	1	1	1	0
1127-18073-7	11/27/72	1	1	1	1	0
S.NICOLAS						
1127-18080-4	11/27/72	X	X	1	X	1
1127-18080-5	11/27/72	X	X	1	X	0
1127-18080-6	11/27/72	X	X	1	X	0
1127-18080-7	11/27/72	X	X	1	X	0
MONTEREY						
1129-18181-4	11/29/72	1	1	1	1	X
1129-18181-4	11/29/72	1	1	1	1	X
1129-18181-5	11/29/72	1	1	1	1	1
1129-18181-6	11/29/72	1	1	1	1	0
1129-18181-7	11/29/72	1	1	1	1	0
MONTEREY SOUTH						
1129-18183-4	11/29/72	1	1	1	X	1
1129-18183-5	11/29/72	1	1	1	X	0
1129-18183-6	11/29/72	1	1	1	X	0
1129-18183-7	11/29/72	1	1	1	X	0

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W
S. MONICA						
1144-18015-4	12/14/72	1	1	1	1	X
1144-18015-5	12/14/72	1	1	1	1	1
1144-18015-6	12/14/72	1	1	1	1	0
1144-18015-7	12/14/72	1	1	1	1	0
S. BARBARA						
1145-18073-4	12/15/72	1	1	1	1	X
1145-18073-5	12/15/72	1	1	1	1	1
1145-18073-6	12/15/72	1	1	1	1	0
1145-18073-7	12/15/72	1	1	1	1	0
MONTEREY						
1147-18181-4	12/17/72	1	1	1	X	1
1147-18181-5	12/17/72	1	1	1	X	0
1147-18181-6	12/17/72	1	1	1	X	0
1147-18181-7	12/17/72	1	1	1	X	0
S. MONICA						
1162-18013-4	1/ 1/73	1	1	1	1	1
1162-18013-5	1/ 1/73	1	1	1	1	1
1162-18013-6	1/ 1/73	1	1	1	1	0
1162-18013-7	1/ 1/73	1	1	1	1	0
NEWPORT B.						
1162-18020-4	1/ 1/73	1	1	1	X	X
1162-18020-5	1/ 1/73	1	1	1	X	1
1162-18020-6	1/ 1/73	1	1	1	X	0
1162-18020-7	1/ 1/73	1	1	1	X	0
S. BARBARA						
1163-18072-4	1/ 2/73	1	1	1	1	X
1163-18072-5	1/ 2/73	1	1	1	1	1
1163-18072-6	1/ 2/73	1	1	1	1	0
1163-18072-7	1/ 2/73	1	2	1	1	0
MONTEREY						
1165-18175-4	1/ 4/73	1	1	1	1	1
1165-18175-5	1/ 4/73	1	1	1	1	1
1165-18175-6	1/ 4/73	1	1	1	1	0
1165-18175-7	1/ 4/73	1	1	1	1	0

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W
S. MONICA NORTH						
1180-18013-4	1/19/73	1	1	1	1	X
1180-18013-5	1/19/73	1	1	1	1	1
1180-18013-6	1/19/73	1	1	1	1	0
1180-18013-7	1/19/73	1	1	0 525	1	0
			9X9 POS ON ORDER SINCE 525			******
S. MONICA						
1180-18015-4	1/19/73	1	1	1	1	1
1180-18015-5	1/19/73	1	1	1	1	0
1180-18015-6	1/19/73	1	1	1	1	0
1180-18015-7	1/19/73	1	1	1	1	0
S. BARBARA						
1181-18071-4	1/20/73	1	1	1	1	1
1181-18071-5	1/20/73	1	1	1	1	1
1181-18071-6	1/20/73	1	1	1	1	0
1181-18071-7	1/20/73	1	1	1	1	0
MONTEREY NORTH						
1183-18175-4	1/22/73	1	1	1	1	1
1183-18175-5	1/22/73	1	1	1	1	1
1183-18175-6	1/22/73	1	1	1	1	0
1183-18175-7	1/22/73	1	1	1	1	0
MONTEREY SOUTH						
1183-18182-4	1/22/73	1	1	1	1	1
1183-18182-5	1/22/73	1	1	1	1	1
1183-18182-6	1/22/73	1	1	1	1	0
1183-18182-7	1/22/73	1	1	1	1	0
S. MONICA NORTH						
1198-18015-4	2/ 6/73	1	1	1	X	1
1198-18015-5	2/ 6/73	1	1	1	X	0
1198-18015-6	2/ 6/73	1	1	1	X	0
1198-18015-7	2/ 6/73	1	1	1	X	0
S. MONICA SOUTH						
1198-18021-4	2/ 6/73	1	1	1	X	1
1198-18021-5	2/ 6/73	1	1	1	X	0
1198-18021-6	2/ 6/73	1	1	1	X	0
1198-18021-7	2/ 6/73	1	1	1	X	0

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. BARBARA							
1199-18073-4	2/ 7/73	1	1	1	X	1	
1199-18073-5	2/ 7/73	1	1	1	X	0	
1199-18073-6	2/ 7/73	1	1	1	X	0	
1199-18073-7	2/ 7/73	1	1	1	X	0	
MONTEREY							
1201-18181-4	2/ 9/73	1	1	1	X	1	
1201-18181-5	2/ 9/73	1	1	1	X	0	
1201-18181-6	2/ 9/73	1	1	1	X	0	
1201-18181-7	2/ 9/73	1	1	1	X	0	
S. MONICA							
1216-18020-4	2/24/73	0 625	0 625	0 625	0	0	
			70MM POS ON ORDER SINCE 625				******
			70MM NEG ON ORDER SINCE 625				******
			9X9 POS ON ORDER SINCE 625				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1216-18020-5	2/24/73	0 625	0 625	0 625	0	0	
			70MM POS ON ORDER SINCE 625				******
			70MM NEG ON ORDER SINCE 625				******
			9X9 POS ON ORDER SINCE 625				******
1216-18020-6	2/24/73	0 625	0 625	0 625	0	0	
			70MM POS ON ORDER SINCE 625				******
			70MM NEG ON ORDER SINCE 625				******
			9X9 POS ON ORDER SINCE 625				******
1216-18020-7	2/24/73	0 625	0 625	0 625	0	0	
			70MM POS ON ORDER SINCE 625				******
			70MM NEG ON ORDER SINCE 625				******
			9X9 POS ON ORDER SINCE 625				******
S. BARBARA							
1217-18074-4	2/25/73	1	1	1	1	1	
1217-18074-5	2/25/73	1	1	1	1	0	
1217-18074-6	2/25/73	1	1	1	1	0	
1217-18074-7	2/25/73	1	1	1	1	0	
MONTEREY							
1219-18182-4	2/27/73	0 711	0 711	0 711	0	0	
			70MM POS ON ORDER SINCE 711				******
			70MM NEG ON ORDER SINCE 711				******
			9X9 POS ON ORDER SINCE 711				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1219-18182-5	2/27/73	0 711	0 711	0 711	0	0	
			70MM POS ON ORDER SINCE 711				******
			70MM NEG ON ORDER SINCE 711				******
			9X9 POS ON ORDER SINCE 711				******
1219-18182-6	2/27/73	0 711	0 711	0 711	0	0	
			70MM POS ON ORDER SINCE 711				******
			70MM NEG ON ORDER SINCE 711				******
			9X9 POS ON ORDER SINCE 711				******
1219-18182-7	2/27/73	0 711	0 711	0 711	0	0	
			70MM POS ON ORDER SINCE 711				******
			70MM NEG ON ORDER SINCE 711				******
			9X9 POS ON ORDER SINCE 711				******

IMAGE ID	DATE	70MM +		70MM -		9X9 +	TAPE	9X9 B/W	
S. MONICA									
1234-18021-4	3/14/73	1		1		1	1	1	
1234-18021-5	3/14/73	1		1		1	1	1	
1234-18021-6	3/14/73	1		1		1	1	0	
1234-18021-7	3/14/73	1		1		1	1	0	
S. BARBARA									
1235-18075-4	3/15/73	1		1		1	1	1	
1235-18075-5	3/15/73	1		1		1	1	1	
1235-18075-6	3/15/73	1		1		1	1	0	
1235-18075-7	3/15/73	1		1		1	1	0	
MONTEREY									
1237-18183-4	3/17/73	1		1		1	1	1	
1237-18183-5	3/17/73	1		1		1	1	1	
1237-18183-6	3/17/73	1		1		1	1	0	
1237-18183-7	3/17/73	1		1		1	1	0	
S. MONICA									
1252-18021-4	4/ 1/73	1		1		1	1	1	
1252-18021-5	4/ 1/73	1		1		1	1	0	
1252-18021-6	4/ 1/73	1		1		1	1	0	
1252-18021-7	4/ 1/73	1		1		1	1	0	
NEWPORT B.									
1252-18023-4	4/ 1/73	1		1		1	X	1	
1252-18023-5	4/ 1/73	X		1		1	X	0	
1252-18023-6	4/ 1/73	1		1		1	X	0	
1252-18023-7	4/ 1/73	1		1		1	X	0	
S. BARBARA									
1253-18075-4	4/ 2/73	1		1		1	1	1	
1253-18075-5	4/ 2/73	1		1		1	1	0	
1253-18075-6	4/ 2/73	1		1		1	1	0	
1253-18075-7	4/ 2/73	1		1		1	1	0	
MONTEREY SOUTH									
1255-18190-4	4/ 4/73	0	813	0	813	0	1	0	
			70MM POS ON ORDER SINCE 813						******
			70MM NEG ON ORDER SINCE 813						******
			MISSING 9X9 POS						******
			MISSING 9X9 B/W						******
1255-18190-5	4/ 4/73	0	813	0	813	0	1	0	
			70MM POS ON ORDER SINCE 813						******
			70MM NEG ON ORDER SINCE 813						******
			MISSING 9X9 POS						******
1255-18190-6	4/ 4/73	0	813	0	813	0	1	0	
			70MM POS ON ORDER SINCE 813						******
			70MM NEG ON ORDER SINCE 813						******
			MISSING 9X9 POS						******
1255-18190-7	4/ 4/73	0	813	0	813	0	1	0	
			70MM POS ON ORDER SINCE 813						******
			70MM NEG ON ORDER SINCE 813						******
			MISSING 9X9 POS						******

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. MONICA NORTH							
1270-18021-4	4/19/73	1	0 813	0	0	0	
			70MM NEG ON ORDER SINCE 813				******
			MISSING 9X9 POS				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1270-18021-5	4/19/73	1	0 813	0	0	0	
			70MM NEG ON ORDER SINCE 813				******
			MISSING 9X9 POS				******
1270-18021-6	4/19/73	1	0 813	0	0	0	
			70MM NEG ON ORDER SINCE 813				******
			MISSING 9X9 POS				******
1270-18021-7	4/19/73	1	0 813	0	0	0	
			70MM NEG ON ORDER SINCE 813				******
			MISSING 9X9 POS				******
S. MONICA SOUTH							
1270-18023-4	4/19/73	1	1	1	0	1	
			MISSING MAG TAPE				******
1270-18023-5	4/19/73	1	1	1	0	0	
1270-18023-6	4/19/73	1	1	1	0	0	
1270-18023-7	4/19/73	1	1	1	0	0	
S. BARBARA							
1271-18075-4	4/20/73	1	1	1	0 813	1	
			MAG TAPE ON ORDER SINCE 813				******
1271-18075-5	4/20/73	1	1	1	0	0	
1271-18075-6	4/20/73	1	1	1	0	0	
1271-18075-7	4/20/73	1	1	1	0	0	
MONTEREY NORTH							
1273-18183-4	4/22/73	1	1	1	1	1	
1273-18183-5	4/22/73	1	1	1	1	1	
1273-18183-6	4/22/73	1	1	1	1	0	
1273-18183-7	4/22/73	1	1	1	1	0	
MONTEREY SOUTH							
1273-18185-4	4/22/73	1	1	1	1	1	
1273-18185-5	4/22/73	1	1	1	1	1	
1273-18185-6	4/22/73	1	1	1	1	0	
1273-18185-7	4/22/73	1	1	1	1	0	

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
NEWPORT B.							
1287-17564-4	5/ 6/73	1	1	1	X	1	
1287-17564-5	5/ 6/73	1	1	1	X	0	
1287-17564-6	5/ 6/73	1	1	1	X	0	
1287-17564-7	5/ 6/73	1	1	1	X	0	
S. MONICA NORTH							
1288-18020-4	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1288-18020-5	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
1288-18020-6	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
1288-18020-7	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
S. MONICA SOUTH							
1288-18022-4	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1288-18022-5	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
1288-18022-6	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******
1288-18022-7	5/ 7/73	0 813	0 813	0 813	0	0	
			70MM POS ON ORDER SINCE 813				******
			70MM NEG ON ORDER SINCE 813				******
			9X9 POS ON ORDER SINCE 813				******

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. BARBARA							
1289-18074-4	5/ 8/73	1	1	1	1	1	
1289-18074-5	5/ 8/73	1	1	1	1	0	
1289-18074-6	5/ 8/73	1	1	1	1	0	
1289-18074-7	5/ 8/73	1	1	1	1	0	
MONTEREY NORTH							
1291-18182-4	5/10/73	1	1	1	1	1	
1291-18182-5	5/10/73	1	1	1	1	1	
1291-18182-6	5/10/73	1	1	1	1	0	
1291-18182-7	5/10/73	1	1	1	1	0	
MONTEREY SOUTH							
1291-18184-4	5/10/73	1	1	1	1	1	
1291-18184-5	5/10/73	1	1	1	1	1	
1291-18184-6	5/10/73	1	1	1	1	0	
1291-18184-7	5/10/73	1	1	1	1	0	
S. MONICA NORTH							
1306-18015-4	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1306-18015-5	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1306-18015-6	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1306-18015-7	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
S. MONICA SOUTH							
1306-18021-4	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1306-18021-5	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1306-18021-6	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1306-18021-7	5/25/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******

IMAGE ID	DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. BARBARA							
1307-18073-4	5/26/73	1	1	1	1	1	
1307-18073-5	5/26/73	1	1	1	1	1	
1307-18073-6	5/26/73	1	1	1	1	0	
1307-18073-7	5/26/73	1	1	1	1	0	
MONTEREY							
1309-18181-4	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1309-18181-5	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1309-18181-6	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1309-18181-7	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
MONTEREY							
1309-18183-4	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
			MISSING MAG TAPE				******
			MISSING 9X9 B/W				******
1309-18183-5	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1309-18183-6	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
1309-18183-7	5/28/73	0 919	1	0	0	0	
			70MM POS ON ORDER SINCE 919				******
			MISSING 9X9 POS				******
S. MONICA NORTH							
1324-18014-4	6/12/73	1	1	1	X	1	
1324-18014-5	6/12/73	1	1	1	X	0	
1324-18014-6	6/12/73	1	1	1	X	0	
1324-18014-7	6/12/73	1	1	1	X	0	

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   IMAGE ID       DATE    70MM +    70MM -     9X9 +    TAPE     9X9 B/W

S. BARBARA
  1325-18072-4   6/13/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
                                 MISSING MAG TAPE                        ******
                                 MISSING 9X9 B/W                         ******
  1325-18072-5   6/13/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
  1325-18072-6   6/13/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
  1325-18072-7   6/13/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******

MONTEREY
  1327-     0-4  6/15/73    0         0          0         0          0
                                 MISSING 70MM POS                        ******
                                 MISSING 70MM NEG                        ******
                                 MISSING 9X9 POS                         ******
                                 MISSING MAG TAPE                        ******
                                 MISSING 9X9 B/W                         ******
  1327-     0-5  6/15/73    0         0          0         0          0
                                 MISSING 70MM POS                        ******
                                 MISSING 70MM NEG                        ******
                                 MISSING 9X9 POS                         ******
  1327-     0-6  6/15/73    0         0          0         0          0
                                 MISSING 70MM POS                        ******
                                 MISSING 70MM NEG                        ******
                                 MISSING 9X9 POS                         ******
  1327-     0-7  6/15/73    0         0          0         0          0
                                 MISSING 70MM POS                        ******
                                 MISSING 70MM NEG                        ******
                                 MISSING 9X9 POS                         ******

S. MONICA  NORTH
  1342-18012-4   6/30/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
                                 MISSING MAG TAPE                        ******
                                 MISSING 9X9 B/W                         ******
  1342-18012-5   6/30/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
  1342-18012-6   6/30/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
  1342-18012-7   6/30/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******

S. MONICA  SOUTH
  1342-18015-4   6/30/73    0  919    1          0         0          0
                                 70MM POS ON ORDER SINCE  919            ******
                                 MISSING 9X9 POS                         ******
                                 MISSING MAG TAPE                        ******
```

				MISSING 9X9 B/W					******
1342-18015-5	6/30/73	0	919	1	0	0		0	
				70MM POS ON ORDER SINCE			919		******
				MISSING 9X9 POS					******
1342-18015-6	6/30/73	0	919	1	0	0		0	
				70MM POS ON ORDER SINCE			919		******
				MISSING 9X9 POS					******
1342-18015-7	6/30/73	0	919	1	0	0		0	
				70MM POS ON ORDER SINCE			919		******
				MISSING 9X9 POS					******

```
   IMAGE ID        DATE     70MM +    70MM -      9X9 +      TAPE      9X9 B/W


S. BARBARA
  1343- .   0-4    7/ 1/73    0          0          0          0          0
                                    MISSING 70MM POS                             ******
                                    MISSING 70MM NEG                             ******
                                    MISSING 9X9 POS                              ******
                                    MISSING MAG TAPE                             ******
                                    MISSING 9X9 B/W                              ******
  1343-     0-5    7/ 1/73    0          0          0          0          0
                                    MISSING 70MM POS                             ******
                                    MISSING 70MM NEG                             ******
                                    MISSING 9X9 POS                              ******
  1343-     0-6    7/ 1/73    0          0          0          0          0
                                    MISSING 70MM POS                             ******
                                    MISSING 70MM NEG                             ******
                                    MISSING 9X9 POS                              ******
  1343-     0-7    7/ 1/73    0          0          0          0          0
                                    MISSING 70MM POS                             ******
                                    MISSING 70MM NEG                             ******
                                    MISSING 9X9 POS                              ******

MONTEREY   NORTH
  1345-18174-4     7/ 3/73    0   919    1          0          1          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
                                    MISSING 9X9 B/W                              ******
  1345-18174-5     7/ 3/73    0   919    1          0          1          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
  1345-18174-6     7/ 3/73    0   919    1          0          1          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
  1345-18174-7     7/ 3/73    0   919    1          0          1          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******

MONTEREY   SOUTH
  1345-18181-4     7/ 3/73    0   919    1          0          0          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
                                    MISSING MAG TAPE                             ******
                                    MISSING 9X9 B/W                              ******
  1345-18181-5     7/ 3/73    0   919    1          0          0          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
  1345-18181-6     7/ 3/73    0   919    1          0          0          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
  1345-18181-7     7/ 3/73    0   919    1          0          0          0
                                    70MM POS ON ORDER SINCE   919                ******
                                    MISSING 9X9 POS                              ******
```

IMAGE ID		DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
S. MONICA								
1360-	0-4	7/18/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1360-	0-5	7/18/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1360-	0-6	7/18/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1360-	0-7	7/18/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
S. BARBARA								
1361-	0-4	7/19/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1361-	0-5	7/19/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1361-	0-6	7/19/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1361-	0-7	7/19/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******

IMAGE ID		DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
MONTEREY								
1363-	0-4	7/21/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1363-	0-5	7/21/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1363-	0-6	7/21/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1363-	0-7	7/21/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
S. MONICA								
1378-18005-4		8/ 5/73	1	1	1	0	0	
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1378-18005-5		8/ 5/73	1	1	1	0	0	
1378-18005-6		8/ 5/73	1	1	1	0	0	
1378-18005-7		8/ 5/73	1	1	1	0	0	
S. BARBARA								
1379-	0-4	8/ 6/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1379-	0-5	8/ 6/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1379-	0-6	8/ 6/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1379-	0-7	8/ 6/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******

IMAGE ID		DATE	70MM +	70MM -	9X9 +	TAPE	9X9 B/W	
MONTEREY								
1381-	0-4	8/ 8/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
				MISSING MAG TAPE				******
				MISSING 9X9 B/W				******
1381-	0-5	8/ 8/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1381-	0-6	8/ 8/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******
1381-	0-7	8/ 8/73	0	0	0	0	0	
				MISSING 70MM POS				******
				MISSING 70MM NEG				******
				MISSING 9X9 POS				******