FINAL REPORT CONTRACT CHESDIV PW-2820: NEAR SHORE CHEMICAL PARAMETER INVESTIGATION

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PURPOSE: To determine whether (1) significant variations occur in chemical parameters affecting corrosion in the open coastal waters of a single climatic province, and (2) such parameters can be measured using a S.C.U.B.A. diver operated system.

BACKGROUND: Metal corrosion is the result of many complex chemical reactions. These reactions are sensitive in varying degrees to environmental parameters. For example, factors such as temperature, oxygen concentration, and pH have a major effect on the rate and direction of metal oxidation reactions. Ambient light would have a much smaller effect.

The oceans are generally considered well-mixed bodies, but near shore the nature of the bottom and the effect of wave action have a large effect on water chemistry. Thus, different corrosion behavior would be expected in tropical coastal regions than would be anticipated for similar arctic sites.

Chemical variations within a single, open, coastal, climatic region will be investigated during this project. The work will involve sampling chemical oceanographic parameters near the bottom in locations within the Temperate Zone. The selected unsheltered California locations will be exposed to the Pacific Ocean at sites duplicating those that might be used for cable runs to the sea. If these initial results show that the parameter variations are sufficiently large to have a significant effect on cable protection design, later work can be devoted to the effect of adjacent fresh water sources and regions of stagnation. This later work will be done with equipment made or purchased specifically for chemical corrosion parameter measurement.

PROCEDURE: Temperature, dissolved oxygen, pH, sulfide, conductivity, salinity, depth, depth of sensors, ambient light, and Eh will be measured perpendicular to shore from the low tide line to a depth of no more than 100 feet, or for a distance of from 300 - 500 yards off shore. The purpose of this work is to sample the region where cable protection and stabilization devices might be used - not to reach great depths or get far off shore. The sensors will be held as near the bottom as practical and, if possible, occasional *in situ* surface sediment chemical parameters will also be measured.

SITES: Sites for the study will be on unprotected coastline away from the contaminating effect of fresh water inputs or regions of stagnation:

1. Pacific Ocean Coast, Punta Banda Peninsula, south of Ensenada, Baja California, Mexico.
2. Pacific Ocean Coast, La Jolla, southern California, USA.

DELIVERABLES & SCHEDULE: Data are presented in the form of (1) a map of each site showing the tracks, and (2) computer generated graphs of the measured parameters as functions of distance from the shore. A brief discussion (3) of the methods, sources of error, and accuracy of the results is also provided.

OPERATIONS: The instrumentation used in the investigation consists of an underwater environmental monitor (Conti, 1972) attached to a Farallon diver propulsion vehicle model DPV-MK 111 (Figures 1 a & b). A brief description of the environmental monitor is attached in Appendix 1. The following procedure was used during the monitoring runs:

(A) The monitor and the propulsion vehicle were carried independently to the beach by two people together with the diving gear. The system was assembled by means of a quick release mechanism on the beach as close to the water as the breakers would allow.

(B) The recording and measuring systems of the monitor were turned on 10 minutes prior to the dive to allow time for the electronics and for the chemical sensors to reach an equilibrium status.

(C) A fully equipped diver grabbed the system by the propulsion vehicle nozzle and backed in the water dragging the system until both diver and system were waterborne.

(D) The diver assumed the normal traveling position behind the system and headed offshore through the surf using the propulsion vehicle.

(E) Past the surf zone, a dive was made to the bottom which was thereafter followed on a compass course provided by the compass mounted on the propulsion vehicle. Occasional detours were required to avoid kelp or large rocks.

(F) After one half hour, the diver with the system surfaced vertically. At the surface a bearing was taken and a course set for the return trip.

(G) Return to the beach was performed by riding the surf as far as possible to the beach. The diver then turned the system 180° and dragged it on the beach by walking backward. The system was then switched off, disassembled and carried away.

(H) Water samples were taken at the beginning and at the end of each for calibration.

SURVEYS:

Punta Banda Survey

This survey was done on April 9, 1973 in the Pacific Ocean off the coast of the Punta Banda Peninsula, Baja California, Mexico. A map of the general area is shown in Fig. 2. More detailed maps are shown in Fig. 3: these maps were taken from aerial photographs as no detailed maps of the area are available. Fig. 3 shows also the survey course. The monitor was turned on at 1051 HRS and turned off at 1201 HRS. One hour of record is shown in Fig. 4:

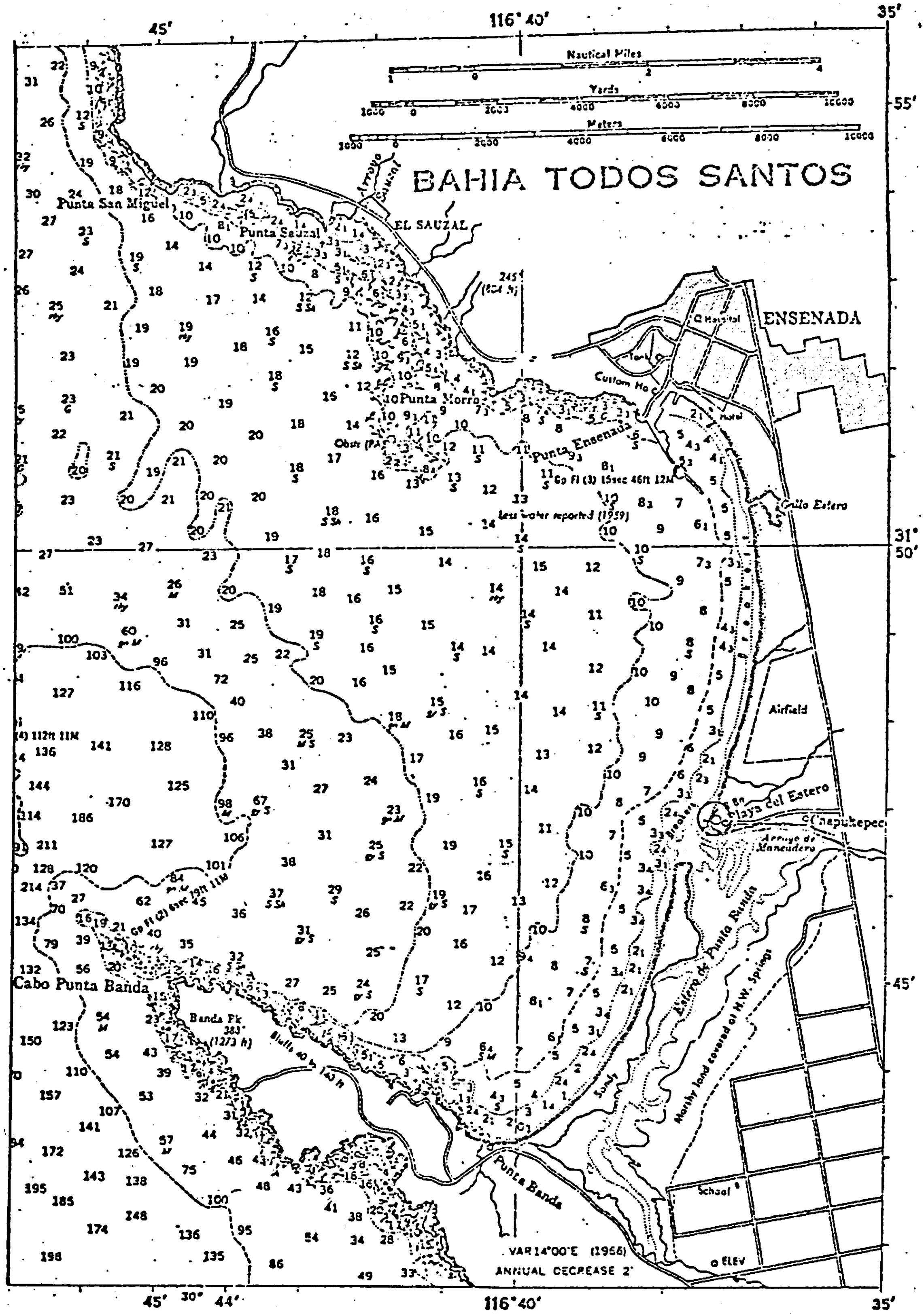


FIG. 2 GENERAL AREA OF PUNTA BANDA SURVEY (FROM BRITISH ADMIRALTY CHART NO. 2885).

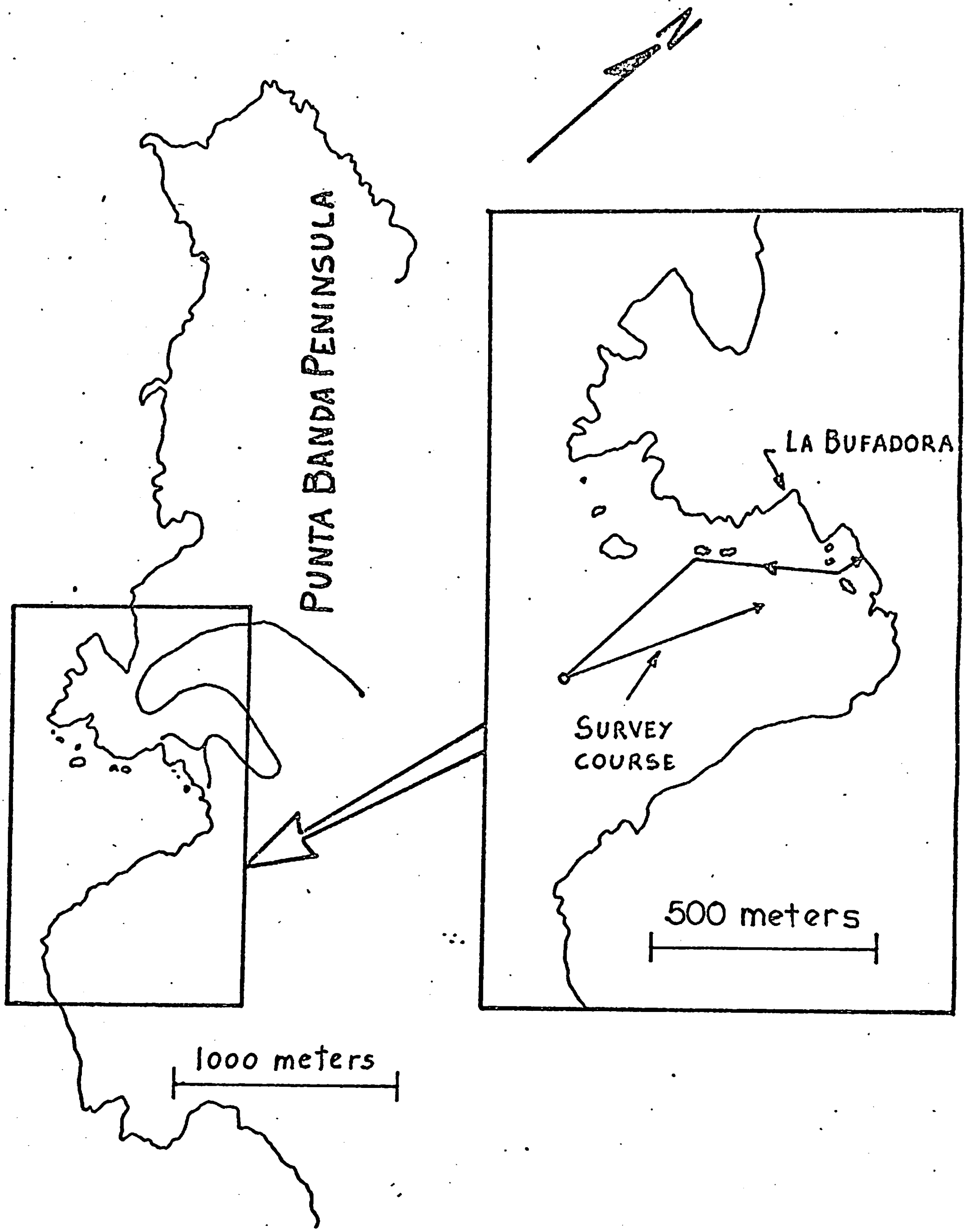


FIGURE 3: DETAILED MAPS OF PUNTA BANDA SURVEY

the record corresponding to the times when the system was dragged in and out of the water has been deleted. The bottom in this area is alternatively sandy, very rocky and covered with kelp forest. The estimated distribution along the survey course was 40% sand, 40% rocks and 20% kelp. The kelp forest was not avoided but instead a course was chosen in order to avoid collision and entanglement with the kelp stalks. Any bottom irregularity was followed as closely as possible. It is estimated that the distance of the monitoring sensors from the bottom was at all times between 0.2 and 1.0 meters. The average speed was maintained at 1.0 knots. During the return trip, a record navigational check on the surface was made. The positioning of the surfacing points was made by triangulation with landmarks. The estimated positioning error is ± 25 meters. Visibility was 10-12 feet. Sea conditions were calm with an open water swell 2 - 4 feet high and breakers on the beach 2 -3 feet high.

The following preliminary considerations can be made on the records of Fig. 4.

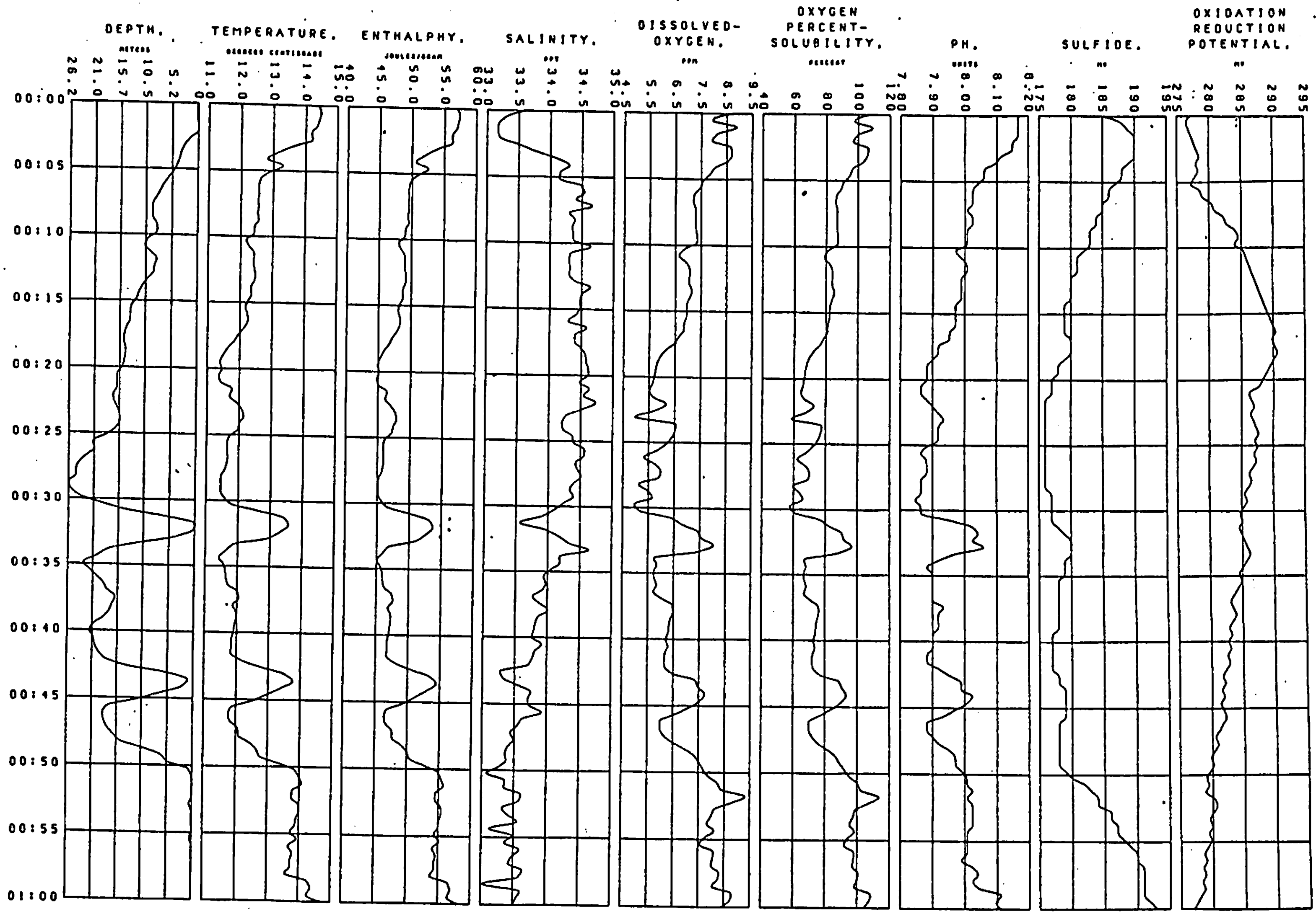
Depth: This record shows the depth of the monitory system. The main features are the two surfacing periods and the ruggedness of the sea floor.

Temperature: A temperature variation of 4°C was detected between surface and bottom. The record suggests a uniform stratification of temperature between surface and bottom waters.

Enthalpy: This record follows the record of temperature without substantial variations.

Salinity: This record shows that the first part of the survey course, which ran through and around kelp beds and awash boulders, is characterized by high salinity with respect to the waters at the center of the cove.

Dissolved Oxygen and Oxygen Percent Solubility: This parameter shows variations



	DEPTH	TEMPERATURE	ENTHALPHY	SALINITY	DISSOLVED-OXYGEN	OXYGEN PERCENT-SOLUBILITY	PH	SULFIDE	OXIDATION REDUCTION POTENTIAL
MEAN-VALUE.	10.81	12.61	49.81	33.99	6.95	82.95	7.97	181.19	283.25
STANDARD-DEVIATION.	7.99	.94	3.77	.47	1.01	13.44	.08	4.85	3.84
UNITS.	METERS	DEGREES CENTIGRADE	JOULES/GRAM	PPT	PPM	PERCENT	UNITS	MV	MV

FIGURE 4: ENVIRONMENTAL RECORD OF PUNTA BANDA SURVEY

PUNTA BANDA.

consistent with depth, indicating a stratification of dissolved oxygen with higher concentrations at the surface.

pH: The pH variations during the survey were contained within .2pH units and show a stratification similar to DO and temperature or a reduction in pH with depth.

Sulfide Ion Concentration: This parameter is given in mV instead of p ion units because the concentration of $S^=$ is extremely low ($pS^= > 20$) and beyond the range of the electrode, which is reasonable in the presence of free oxygen.

Oxidation-Reduction Potential: The variations of this parameter, along the entire survey course, are contained within 20mV. These variations are well within the accuracy of the sensor (± 20mV).

La Jolla Survey

The second survey was done on April 11, 1973 in the Pacific Ocean off the coast of La Jolla, southern California.

A map of the area is shown in Fig. 5 with the bathymetry of the ocean floor and the course taken during the monitoring run. The run started from the beach of La Jolla Cove. The bottom in this area is relatively rocky with generous kelp growth close to shore and it becomes sandy with occasional kelp beyond the 10 meter contour. The run lasted approximately one hour. Good visibility (5-7 meters) and a relatively smooth bottom allowed the diver to follow a straight course and return, after surfacing at the farther-most point, along the same course (within an estimated ± 20 meters). Sea conditions were calm with long swells 1-2 feet high. The speed was maintained constant throughout the survey run at about 1 knot. One hour of record is shown in Fig. 6. As in the preceding survey record, the beginning and the end of the record which are characterized by zero depth, are relative to surface

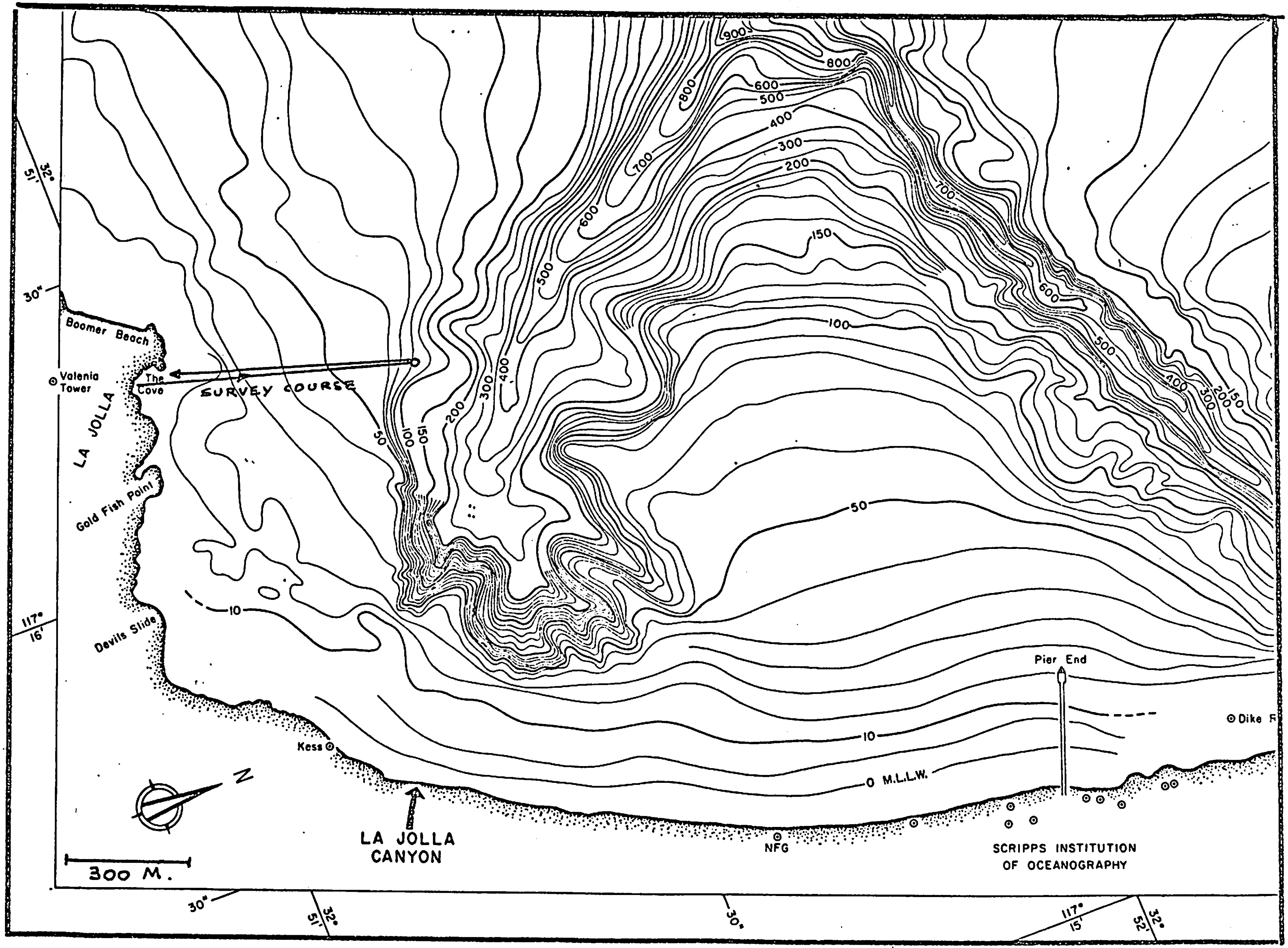


FIGURE 5: LOCATION OF LA JOLLA SURVEY

measurements and are influenced by turbulence and occasional exposure of the sensor package. The following preliminary considerations can be made on the records of Fig. 6.

Depth: The main feature of this record is the surfacing period in the middle of the run. This point represents also the furthest point reached and a 180° inversion of the course.

Temperature: The decrease in temperature with depth suggests a uniform temperature stratification.

Enthalpy: This record is similar to the temperature record as expected for non-estuarine conditions.

Salinity: Apart from large variations at the surface due to turbulence and sensor exposure, the variations of salinity along the survey course were about .5ppt which is high for open ocean conditions, but not unusual for near shore conditions.

Dissolved Oxygen and Oxygen Percent Solubility: The record indicates a substantial decrease of this parameter with depth. This is consistent with the assumption of high aeration of surface waters and a relatively stable water stratification (density gradient due to temperature gradient).

pH: As in the Punta Banda survey the record of pH shows variations of about ± .2 pH units with a decrease with depth implying stratification.

Sulfide Ion Concentration: This record also is similar to the record obtained in Punta Banda and indicates extremely low concentration in $S^{=}$.

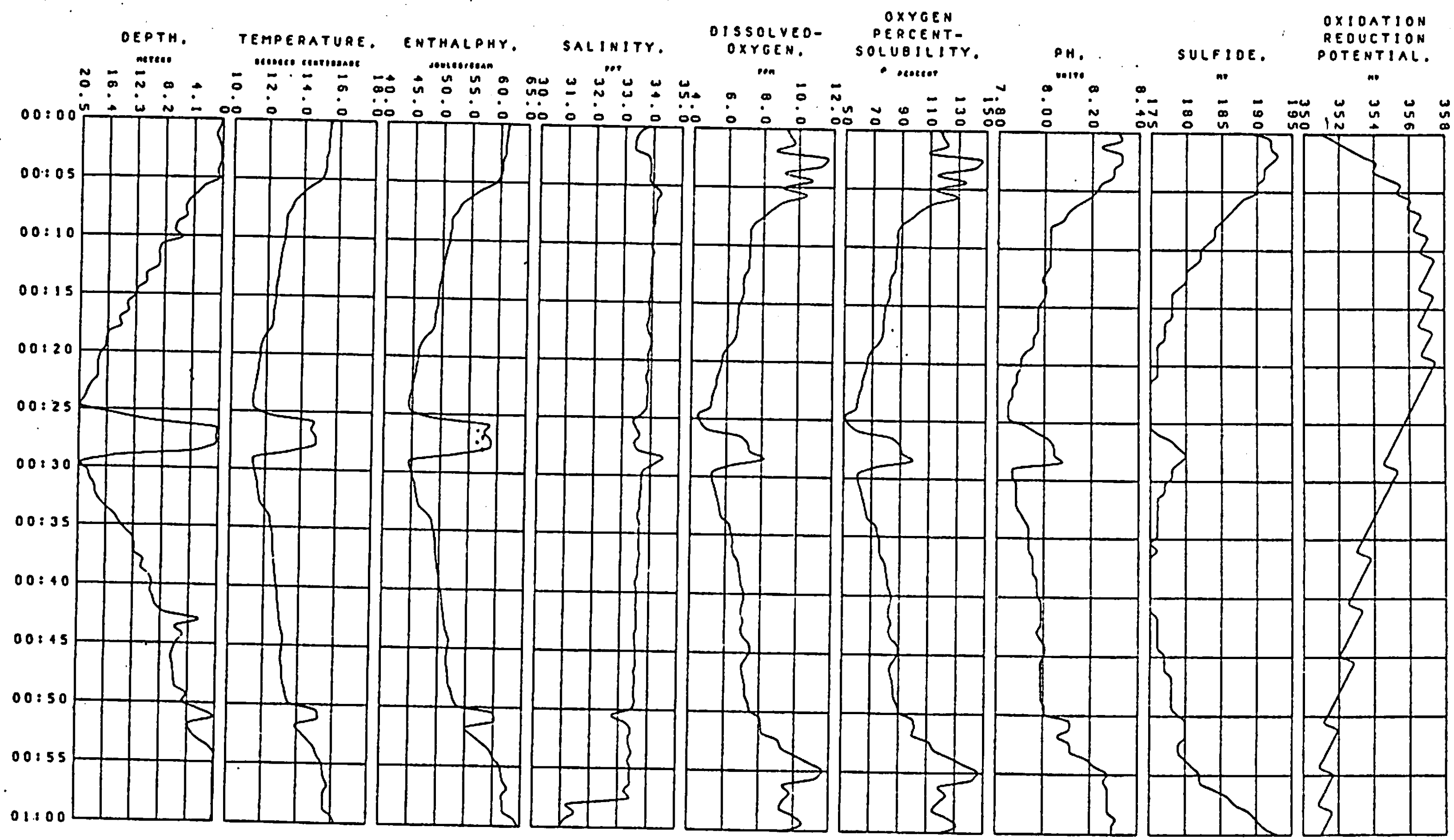
Oxidation-Reduction Potential: The range of variations shown by this record is very small (10 mV) and well below the accuracy of the sensor (± 20 mV). Therefore these variations can be attributed to instrumental drift.

CONCLUSIONS:

(1) Measurable variations in the corrosion significant parameters of

FIGURE 6: ENVIRONMENTAL RECORD OF LA JOLLA SURVEY

LA JOLLA.



	DEPTH	TEMPERATURE	ENTHALPHY	SALINITY	DISSOLVED-OXYGEN	OXYGEN PERCENT-SOLUBILITY	PH	SULFIDE	OXIDATION REDUCTION POTENTIAL
MEAN-VALUE.	8.25	13.31	52.64	33.60	7.45	90.20	8.04	180.01	354.18
STANDARD-DEVIATION.	8.56	1.41	5.68	.57	1.71	23.05	.14	5.35	2.14
UNITS.	METERS	DEGREES CENTIGRADE	JOULES/GRAM	PPT	PPM	PERCENT	UNITS	MV	MV

temperature, dissolved oxgyen, pH are demonstrated to be inversely related to depth in depths of water less than 100 feet at two sites in open coastal waters of the temperate eastern Pacific. Thus depth stratification is evident and is maintained even with the high mixing potential produced by the rigorous surf conditions of the Pacific. That is to at least to 100 feet the value of these parameters cannot be assumed equal to surface values and must be measured in place.

In addition the Punta Banda survey suggests that the presence of a rocky bottom and kelp forest further influences linity where for the other environments measured salinity was essentially uniform and well-mixed.

(2) The system used in this survey operated satisfactorily under all circumstances without failures. The diver was able to familiarize himself with the equipment very quickly and a survey could be performed with minimum physical effort. Launching and beaching of the monitoring system was performed easily by the diver in the presence of moderate surf. Calibration of the sensor was performed by taking water samples at known locations for later laboratory analysis. The data presented in Figures 4 and 6 can be considered accurate within the specifications of the monitoring system (Appendix 1).

(3) Accordingly, based on the above items (1) and (2) we believe that discrete surveys are necessary and operationally feasible for each projected or existing cable entry sites to provide data for a cable protection design program.

<u>REFERENCES:</u>

Conti, U., 1972, "Study of an Underwater Towable Environmental Monitor", Ph.D. thesis, University of California, Berkeley.

APPENDIX 1

Engineering Geoscience
University of California
Institute of Marine
Resources

TOWED UNDERWATER ENVIRONMENTAL MONITOR

The underwater environmental monitoring system is composed of a towed vehicle housing a number of physical and chemical sensors and related electronic package.

1) The vehicle has the following characteristics:

Speed	:	1-8 knots
Operating depth	:	3 to 100 feet
Operating mode	:	a) Bottom contouring 10 to 50 feet off the bottom. b) Constant depth 3 to 100 feet.
Body diameter	:	9 inches
Length	:	54 inches
Wing span	:	40 inches
Material	:	Plexiglass and fiberglass reinforced polyester
Weight in air	:	110 pounds
Buoyancy	:	6 pounds.
Towing cable type	:	$\frac{1}{4}$ inch polypropylene rope

The basic configuration of the vehicle is that of an airplane (Fig. 1) with forward fixed wings and rear movable elevators. The bottom of the vehicle is kept free from appendages to minimize the damage in case of contact with the bottom during towing. This configuration was selected to give high lift to drag ratio and high percentage of payload. The vehicle is constructed of plexiglass and fiberglass reinforced polyester. Wings, elevators and rudder are cast reinforced polyester. The tail section is hand laid fiberglass and polyester with an average thickness of .750 inch. The central body

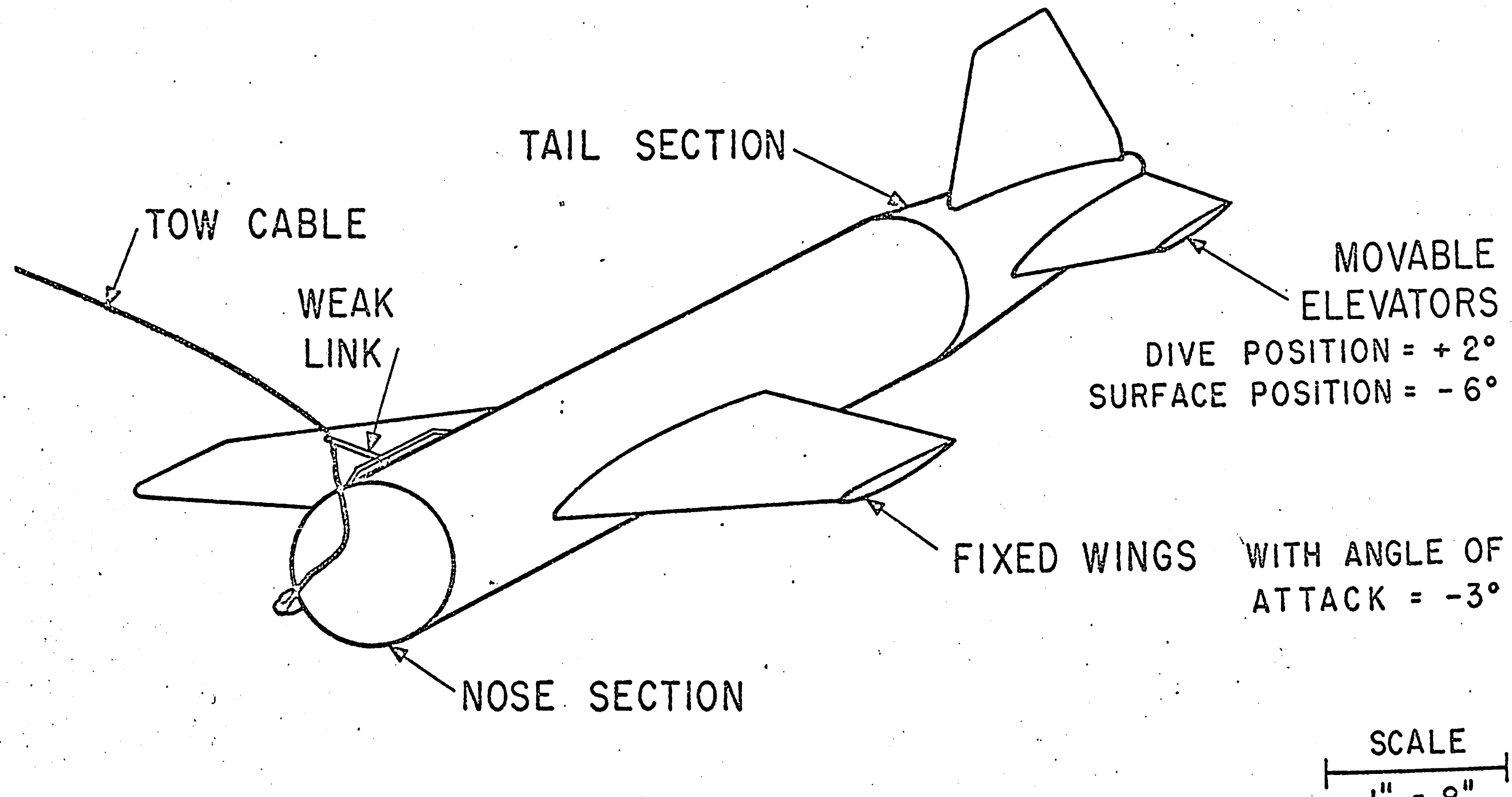

TAIL SECTION
TOW CABLE
WEAK LINK
MOVABLE ELEVATORS
DIVE POSITION = + 2°
SURFACE POSITION = - 6°
FIXED WINGS WITH ANGLE OF ATTACK = -3°
NOSE SECTION
SCALE
1" = 8"

FIGURE 1

is made of a plexiglass tube, 9 inch O.D. and with .500 inch wall thickness. The nose is solid plexiglass. The theoretical depth at which the vehicle will collapse is over 1000 feet. Visual inspection of the electronic package and a direct check of water leaks and mechanical malfunctions can be made through the transparent central body.

The two ends of the hull are easily detachable for changing the operating mode and servicing the electronic package. The tow cable is attached to the vehicle forward of the wings through a weak link. Should the vehicle hit the bottom or get entangled, the weak link will break and the cable will pull from the forwardmost point of the vehicle thus creating a surfacing momentum. The vehicle is capable of following two operating modes:

a) Constant Depth: The vehicle can be towed at a given constant depth within 6 inches, by setting the length of the towing cable. (Fig. 2a)

b) Constant Distance from the bottom (Bottom Contouring). (Fig. 2b) When the vehicle is set for this mode of operation, the distance from the bottom is measured with an echo sounder housed in the vehicle itself. This distance is compared electronically with a preset value. The sign of the difference establishes the position of the elevators either diving or surfacing the vehicle. This two position dynamic control system has the obvious advantage of simplicity versus a continuous-closed loop control system. Because the elevators do not move instantaneously and the vehicle requires some time to change vertical direction, the control system generates an oscillation of the vehicle along

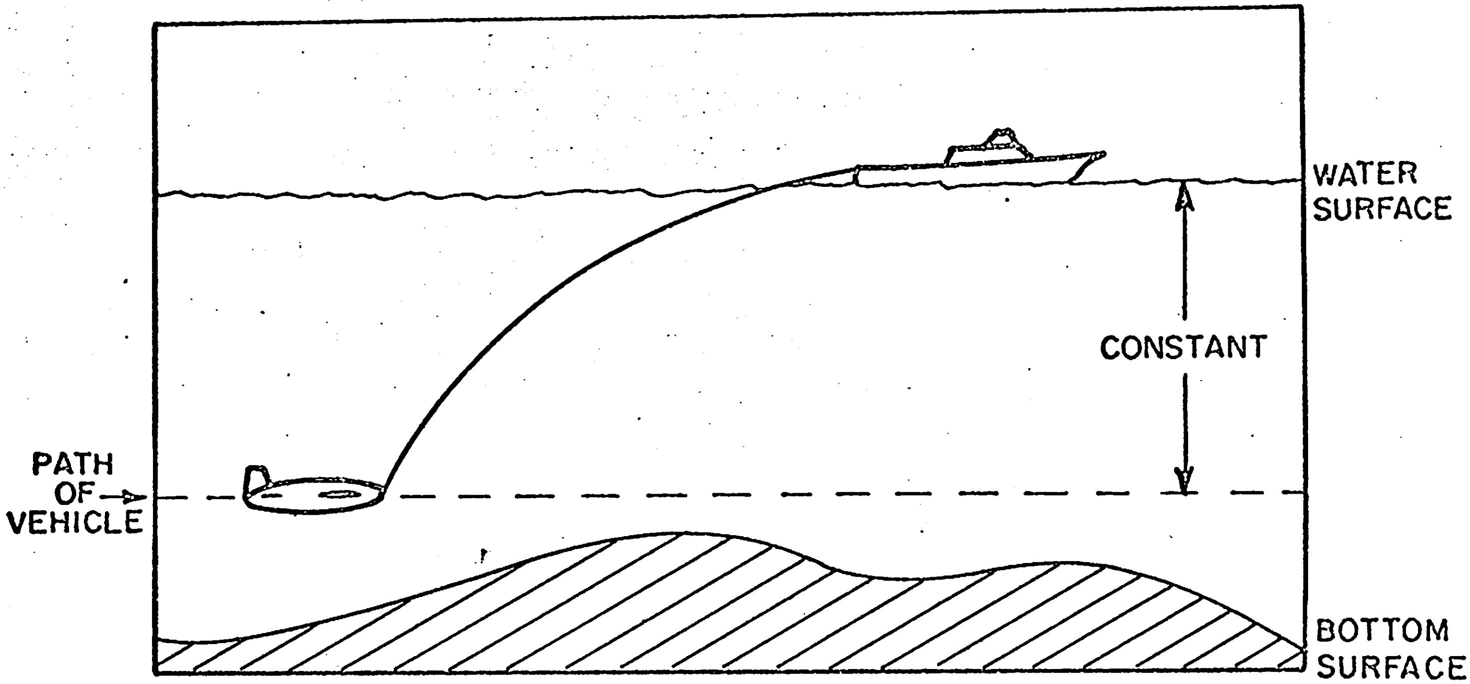


FIG. 2a CONSTANT DEPTH MODE

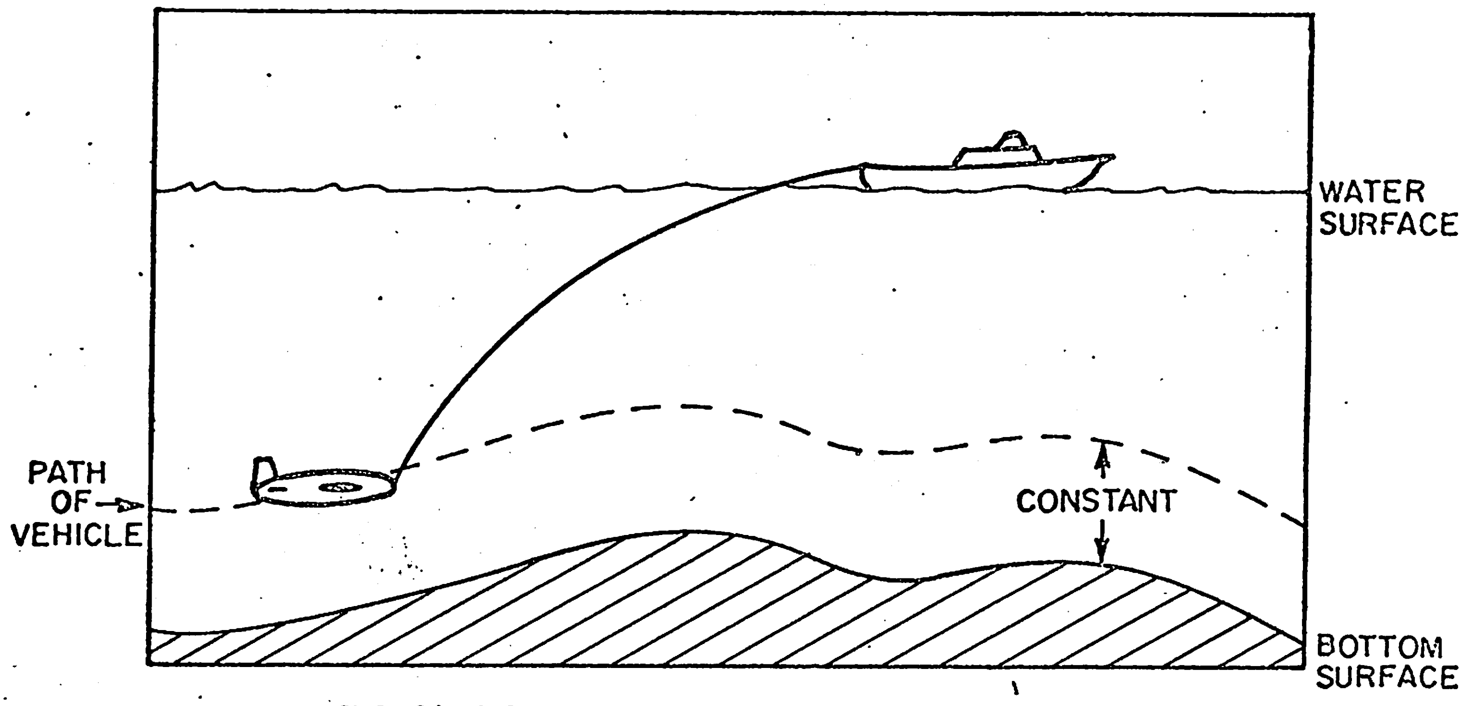


FIG. 2b BOTTOM CONTOURING MODE
(CONSTANT DISTANCE FROM THE BOTTOM)

the established path. This oscillation is contained within 5 feet and has a period of 10 to 15 seconds. (Fig. 3)

2) The physical and chemical sensors are grouped laterally outside the vehicle body behind the wings and the related electronic and recording package is housed inside the vehicle (Fig. 4). This package and the depth control system are powered with internal rechargeable batteries. The following parameters are measured and recorded by the system.

a) Depth with a pressure gage within ± 0.1 meters

b) Temperature with a compensated linear thermistor within ± .02° C

c) Conductivity with a four electrode A.C. system with an accuracy of ± 0.3%

d) Dissolved oxygen with a polarographic sensor within ± 1%

e), f) pH and Sulfide ion concentration with commercial ion selective electrodes and high impedance electrometers within ± 1 m V of the electrode voltage.

g) Eh (Reduction-Oxidation Potential) with a platinum - Ag-Ag Cl system within ± 20 mV

h) Ambient Light with two photocells for high and low illumination. This is not an absolute measurement but detects changes of ambient light within ± 1%

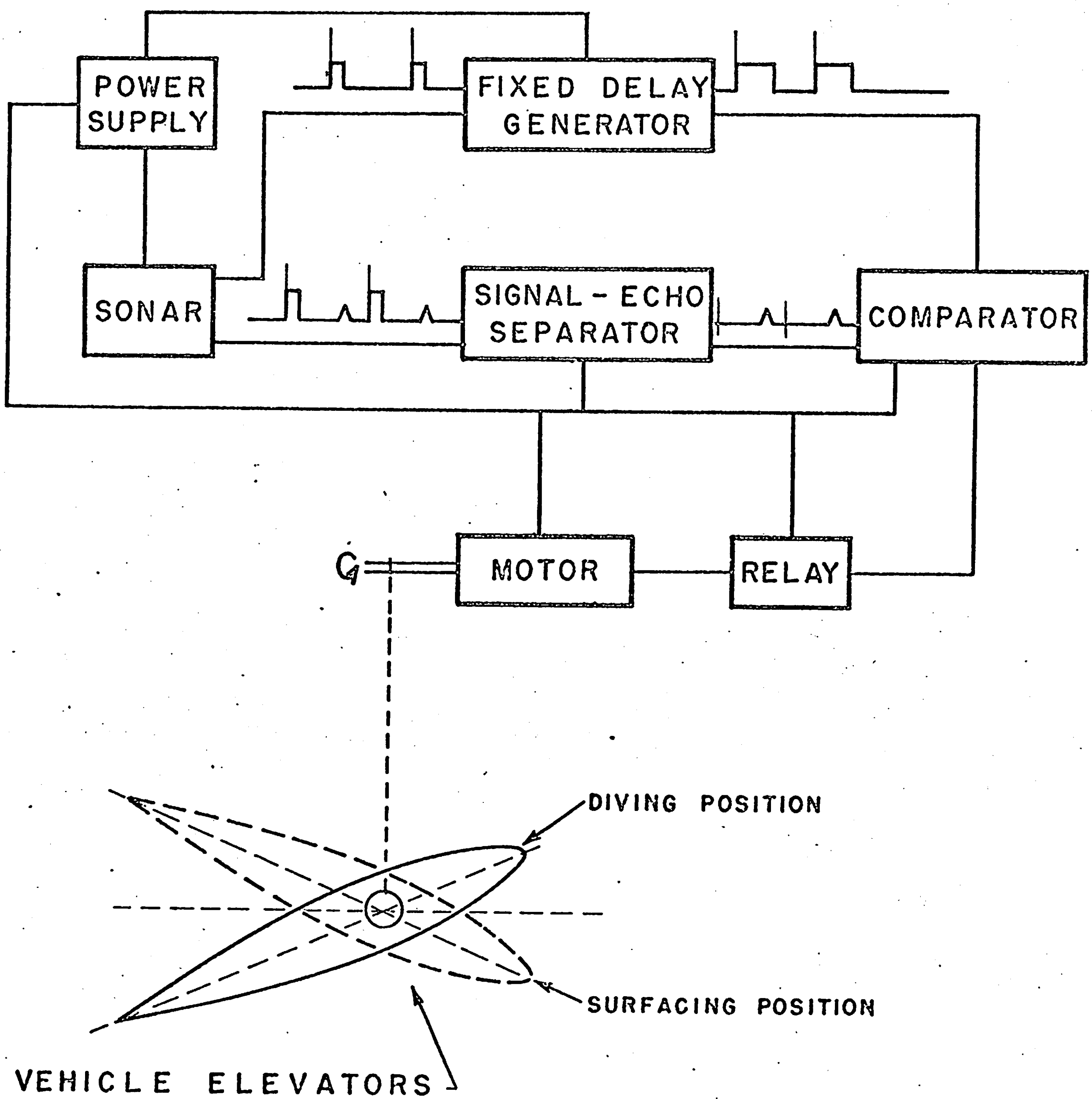
i) Internal Electronic Check

e) Time within ± 30 seconds

The ten parameters are scanned sequentially and the values in millivolts are displayed on a digital voltmeter. The data recording system consists of a 16 mm movie camera that takes single frame pictures of the digital voltmeter, a time display and a display of the

BLOCK SCHEMATIC OF DEPTH CONTROL SYSTEM
(BOTTOM CONTOURING MODE)

FIG. 3



type of parameter measured. This system has the greater accuracy of digital operation and is very easy to read. Furthermore, the operator can check the regular functioning of the sensor package by looking at the visual display through the transparent plexiglass wall of the vehicle before starting every run at sea and for calibration . A 50 foot film magazine contains 2000 frames that are equivalent to 2000 data points. After the film has been processed, the data are punched on computer cards. A computer program has been written to process the data to account for calibrations, temperature corrections and internal electronic drift. The data is them printed and plotted for easy interpretation.

The following table shows the final parameters, units and accuracies:

Parameter	Unit	Accuracy
Temperature	°C	± 0.02°C
Depth	Meters	± 0.1 meters
Salinity	PPT	± .3%
Dissolved Oxygen	PPT	± 1%
pH	pH units	± .02 pH units
Sulfide	pIon units	± 1%
Eh	mV	± 20 mV
Ambient Light	Arbitrary	± 1%
Time	Hours-Min.	± 30 sec.

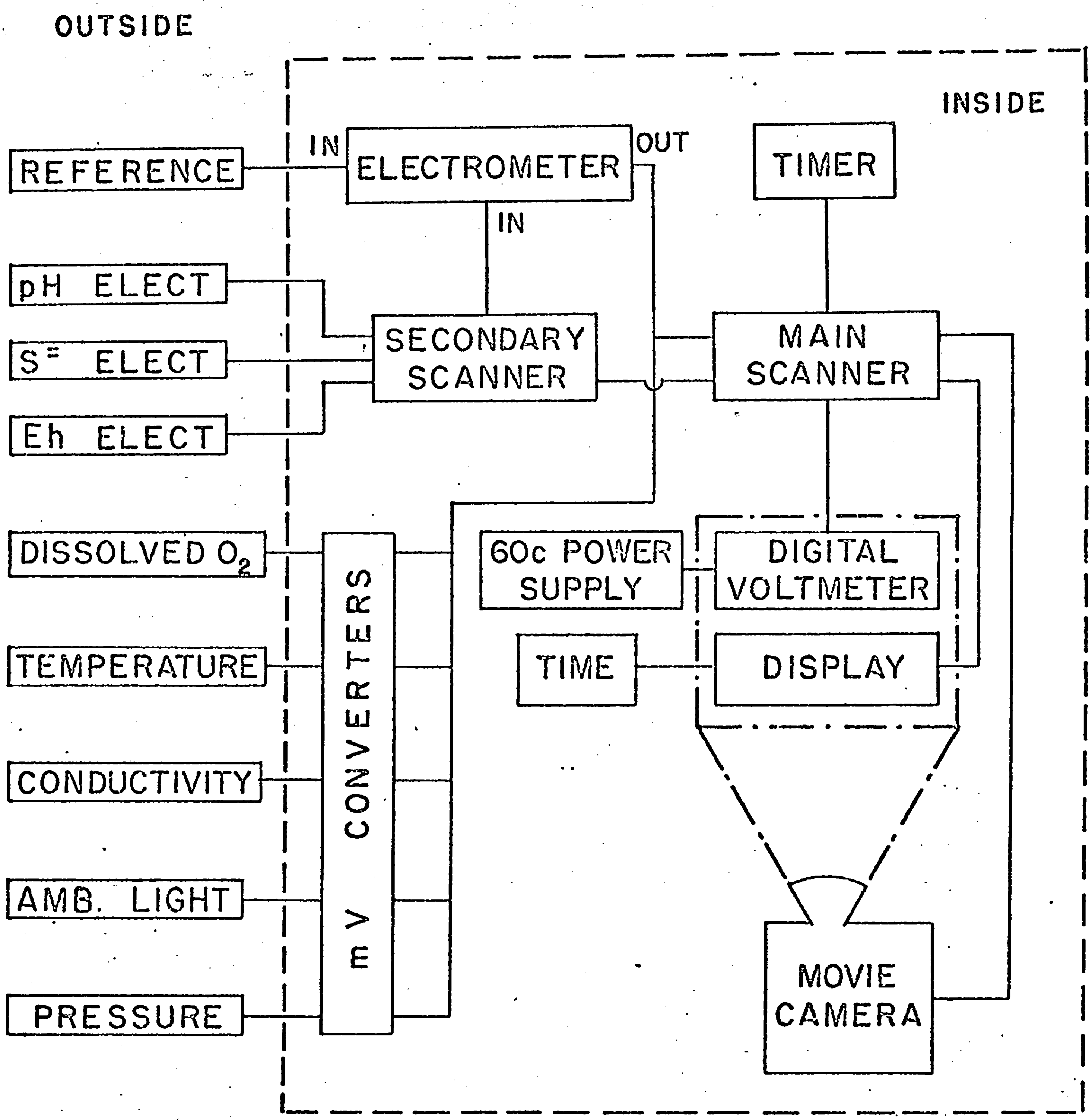

OUTSIDE
INSIDE
REFERENCE
IN
ELECTROMETER
OUT
IN
TIMER
pH ELECT
S= ELECT
Eh ELECT
SECONDARY SCANNER
MAIN SCANNER
DISSOLVED O2
TEMPERATURE
CONDUCTIVITY
AMB. LIGHT
PRESSURE
mV CONVERTERS
60c POWER SUPPLY
DIGITAL VOLTMETER
TIME
DISPLAY
MOVIE CAMERA

FIG. 4

To conclude, the system described proved to be very rugged, reliable and easy to operate even from a very small boat (10 foot rubber raft) in very shallow waters as in deeper ones.

The positioning of the vehicle is done by relating the position of the boat and the time recorded in the vehicle.

The system has been operated successfully by diver when the area was too small for towed operation.