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VOLUME IV-4 INSTRUMENTATION DRAFT FINAL REPORT

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INSTRUMENTATION

4.1 INTRODUCTION

This chapter gives the technical descriptions of data-gathering instrumentation and systems utilized in the Marine Review Committee Experiment at San Onofre.

4.2 IRRADIANCE AND TEMPERATURE INSTRUMENTS

4.2.1 Combination Instruments

For the continuous monitoring of light irradiance and temperature, ECO-M has designed and fabricated three types of instruments:

- 1) Dual Light Irradiance (I/I)
- 2) Dual Temperature (T/T)
- 3) Irradiance and Temperature (I/T)

All of these instruments provide continous monitoring by recording data every hour in digital loggers. The light intensity values during the sampling period (1 hour) are digitized and stored in a shift register. Every hour during the recording cycle, the number from the shift register is stored under the proper address in EPROM and the shift register is reset to zero. The resulting recording represents integrated values of light intensity for each hour of operation, expressed in microEinsteins/m²/Hr, (μ E/m²/Hr). The temperature sensing system stores absolute values in degrees centigrade in EPROM, which represents the actual temperature at the time of recording. The instruments operate for several weeks (42 days maximum) and provide a maximum of 1024 data points for each channel.

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After recovery of the instruments from the ocean, the EPROMS are removed from their underwater housings and the stored data transferred via a microprocessor-controlled EPROM reader to an MRC computer.

The computer-stored data are then reviewed, calibrated and identified. Results are then transferred into the MRC data base. The accuracy and specifications of the system are as follows:

Basic Instrument:

Sampling Rate:	Selectable 1/2 - 24 Hrs
Number of Channels:	2 each
Storage Capacity:	1,024 for each channel
Clock Accuracy:	0.003%
Power Comsumption:	0.01 watts max.

Light Integrator:

Count Rate: Accuracy: 140 counts/μa Hr <u>+</u>1% @ 25μa +5% @ 0.1μa

Temperature:

Accuracy:

0.1 °C

where $1 \mu E = 6.02 \times 10^{17}$ photons and $1 \mu a = 280 \mu E/m^{-2}/sec$.

4.2.2 Irradiance Instrument Characteristics

For the MRC experiment, LI-COR LI-192S Underwater Quantum Sensors are used. The LI-192S is a cosine collector (flat sensor) with a relative energy response proportional to the wavelength of the incident light being measured. The actual sensor spectral response profile is compared with an ideal quantum sensor response profile in Figure 4-2-1 (Roemer & Hoagland, 1976).



Spectral Response, from Roemer and Hoagland, 1976.

PERCENT RELATIVE RESPONSE

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The sensor measures the quantum irradiance, Q, which is the number of photons absorbed per square meter per second for any wavelength in its response region from 400 to 700 nm. Ideally, the response of the sensor is defined by

$$Q = A/hc \int_{400}^{700} H(\lambda) \lambda d\lambda \qquad (1)$$

where h is Planck's constant (6.624 x 10^{-27} erg sec), c is the speed of light (3.0) x 10^8 m sec⁻¹), A is a conversion factor for counts to Einsteins, H (λ) is the incident irradiance, and λ is the wavelength of the irradiance.

The absolute calibration of the spectral response of the LI-COR sensor is +5 percent. A source of error in the instrument response is the change in measured irradiance with the angle of observation shown in Figure 4-2-2. A calibration factor for the instrument sensitivity, which depends on the optical properties unique to the geometry of each sensor, is determined by LI-COR and recalibrated yearly. An immersion-effect correction, determined for each sensor, adjusts the underwater response of the instrument for energy loss at the air-water interface, and depends on the refractive properties of the interface. A small source of error in irradiance measurements which is difficult to correct, is the wavelength dependence of the immersion-effect. It was noted by Smith (1969) that for an accurate measurement of total irradiance between 400 and 700 nm, the spectral properties of the water being measured must be considered when calculating the immersion-effect correction. Total estimated error due to the sensor is +15 percent.

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4.2.3 Measurements of Irradiance and Temperature Profiles

Temperature profiles are conducted with the use of ECO-M designed and fabricated digital field instruments. The dual thermistor-type probes, internally compensated, provide reliable temperature readings with an accuracy of $\pm 0.1^{\circ}$ C readable in real numbers on a liquid crystal display.

The new irradiance profile instruments are also designed and manufactured by ECO-M and provide two independent readings: one under water at a given depth, the other an ambient light level on board the vessel.

The sensor for underwater measurements is attached to a balanced, weighted fixture to assure that the sensor element is parallel with the surface of the sea and the deck sensor is placed on a gimbal to provide a relatively stable position for surface ambient light measurement. The display units (liquid crystal) provide numerical values for irradiance measurements in (μ E).

During cruises, when the vessel assumes the proper position at a station, the light/temperature sensing unit and a precision depth transducer are lowered to a discrete depth to record temperature, depth, and light level underwater together with light level at the sea surface. As the sensor unit is lowered or raised the profile is accomplished.

Data from each profile are recorded, transferred via keypunch to the MRC computer and entered into the proper data base file.

Units are also available to take either temperature or irradiance profiles separately.

Profile Instrument Specifications:

Sampling Rate:	Continuously	
Number of Channels:	4	
Power Consumption:	1 watt	
Accuracy:		
Temperature:	0.1 [°]	
Irradiance:	15%	
Depth:	10%	

4.3 CURRENT AND WAVE INSTRUMENTS

4.3.1 Current Measurements

During this study we used two different types of current meters. From 1977 to 1984, we used Davis-Weller vector-averaging instruments. These instruments sample two orthogonal velocity components of the horizontal vector field through the use of two sets of rotors mounted at right angles to each other (Figure 4-3-1). The velocity components measured by each rotor are continuously vector-averaged and these averaged values are recorded at pre-programmed intervals on a 4channel cassette tape. Orientation data from the Fluxgate magnetic compass is acquired simultaneously. In addition, temperature is monitored with a pressure-case-embedded thermistor.

The data base is checked for errors such as transients, spikes, or other faults. These are corrected and the data then analyzed.

The specifications of the Davis-Weller current meter areas are as follows.

Sampling Rate:	8	minutes
Number of Channels:	4	

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Deployment Period:4-6 weeksTiming Accuracy:100 ppmPower Consumption: $\simeq 48W/deployment$ Threshold: $\simeq .5$ cm/sec

Since January 1985, we have used the Inter-Ocean model S-4. The S-4 is an electro-magnetic spherical current meter that is about the size of a basketball. It is self-contained, has no proturding sensors or external moving parts, resulting in a low-drag instrument that is easy to deploy, maintain, and recover. It is well-suited for taut line moorings to depths of 1000 meters. The S-4 housing is fabricated from glass-filled cycloaliphalic epoxy which has high strength, is dimensionally stable and corrosion proof. The exposed metal is titanium, making up the load bearing shaft and sensor electrodes. This combination of materials provides excellent protection against corrosion.

Currents are measured by creating a magnetic field and sensing the voltage induced by the movement of water through the field. Current vectors can be measured at programmable intervals and vector averaged immediately, i.e. north and east components of the current are computed and stored. Data are recorded in a non-volatile solid state memory at established intervals. Retrieval of data is accomplished through a serial port in the current meter by using a portable computer.

The specifications of the S-4 current meter are given below.

Type:	Electro-Magnetic, 2 axis		
Range:	0-350 cm/sec		
Resolution:	0.2 cm/sec		
Accuracy:	<u>+</u> 1 cm/sec		
Vertical Response:	True cosine response (internally		
	software corrected with tilt option)		

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Schematic diagram of the Davis-Weller Vector Averaging Current Meter. Two sets of fans, especially designed to operate with a flat cosine response, are mounted at 90° to each other on a common vertical axis. Four optical sensors, located in the fan hubs, are assimetrically mounted to read each of the two rotating encoding discs, thereby providing rate and direction of rotation information.

Figure 4-3-1 Davis-Weller Vector Averaging Current Meter

4.3.2 Wave Measurements

From 1981 through December 1986 we measured wave climate at a station maintained offshore of SONGS Unit 1. The station is located approximately 800 m upcoast from Unit 1 near the offshore end of the songs Unit 3 diffuser. The measuring instrument is at a water depth of 12 m and at 1 meter above bottom.

During this period, we used three different types of wave climate instruments, all with sensors that measure the wave induced pressure at the level of the sensor. Table 4-3-1 lists the names of the sensors and the periods of deployment.

TABLE 4-3-1

Name of Wave	Deployment	
Climate Instrument	Period	
S101	JUN81 - DEC83	
ECO1	JAN84 - APR85	
MOS4	APR85 - DEC86	

In the following pages, we will discuss the 3 systems:

1. The S101 is a system which incorporates a pressure sensor and an electromagnetic current meter to measure pressure and orthogonal components of current velocities. The system activates every 12 hours for approximately 34 minutes and samples every 2 seconds giving 1024 data points per recording interval. The velocity components are measured with respect to the current meter coordinate axis which is defined by the position of the measuring electrodes. Subsequently, the components are rotated to the u, v axis of the MRC Coordinate System in which positive u is in the direction 108° magnetic and positive v is in the direction 18° magnetic. The data are stored on 2 cassettes fitted inside the underwater package.

The data on the cassettes are transcribed to a 9-track tape readable by a digital computer system for storage and retrieval for further analysis. Every 34 minutes the pressure time series was Fourier transformed. The Fourier coefficients of the surface elevation n are obtained by applying the frequency dependent depth correction given by the linear wave theory frequency which can be studied to about 0.3 Hz. At frequencies higher than this, small amounts of noise may be amplified into large sea surface variations.

The total variance $\langle \eta^2 \rangle$ of the surface displacement is obtained for each recording period by summing the variance in the frequency range 0.02 - 0.3 Hz. A significant wave height is then obtained from the following formula:

 $H_{S} = 4(\langle \eta^{2} \rangle)^{1/2}$

The root-means-square wave height is calculated from

$$H_{\rm rms} = (8 < \eta^2 >)^{1/2}$$

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To estimate the mean direction of the observed wave field, the cospectral values between pressure and the two velocity components must be calculated. The mean direction α can be determined from these values by the formula:

$$\tan \alpha = C_{pv}(f) / C_{pu}(f)$$

where $C_{pv}(f)$ is the cospectral value between pressure and longshore velocity and $C_{pu}(f)$ is the cospectral value between pressure and onoffshore velocity at a frequency f. The cospectral values at the peak frequencies were used to calculate α so that the direction given represents the direction of the wave having a period at which maximum energy occurred. This period where maximum wave energy occurred is defined as the wave period estimate (T). Since the velocity components have been expressed in the MRC Cartesian Coordinate System, the directions given are measured in degrees counterclockwise to the positive v axis which is in the direction 108° magnetic. The coastline is oriented such that 030° magnetic is directed onshore. Therefore, for $\alpha = 78^{\circ}$, surface waves would be heading directly onshore. For $\alpha > 78^{\circ}$, the waves would be coming onshore from a downcoast direction, and for $\alpha < 78^{\circ}$, surface waves would be coming onshore from an upcoast direction.

The root-mean-square wave velocity U_{rms} is calculated from the following equation:

$$U_{\rm rms} = \sqrt{\frac{2 < \eta^2 > *(2\pi / T)}{\sinh (2\pi h / L)}}$$

where h is the water depth (h=12m) and L is the wave length.

The wave length is calculated by solving the following equation in

$$L = \frac{gT^2}{2\pi} \tanh (2\pi h/L)$$

where g is the acceleration of gravity.

2. The ECOl is a simplified wave-recorder designed by ECOSystems. This instrument reads pressure every two seconds for about half an hour, several times a day, but it computes wave statistics in situ and stores these instead of the pressure reading. Before each main recording period, the instrument reads for a few minutes and computes and stores a trial mean pressure p^* . It then takes about 1000 instantaneous pressure readings p_i and accumulates the sums of $(p_i - p^*)$ and $(p_i - p^*)^2$, and also the number of times $(p_i - p^*)$ changes sign. After the last reading, it computes and stores the mean pressure $\overline{p} = (p_i - p^*) + p^*$, the variance $\overline{p'^2} = (\overline{p_i} - p^*)^2 - (\overline{p} - p^*)^2$ an estimate of the period T given by the recording time divided by half the number of sign changes in the $(p_i - p^*)$.

Knowing the distance $(h-z \sim 50 \text{ cm})$ of the instrument above the bottom, the mean pressure $\overline{p} = z$, the variance $\overline{p'^2}$, and the period T, the following quantities are computed from the recorded statistics:

•The total water depth h is the fixed depth h_m below MLLW plus the tide height, so the variations of h over time provide a tide record.

•The propagation parameter kh = 2π / L , given by kh tanh kh = $4\pi^2h/gT^2$, (L is the wavelength);

•The variance of surface displacement $\langle \eta^2 \rangle = p'^2 \cosh^2 kh$;

•The variance of wave-orbital velocity near the bottom $\overline{u^2} = (4\pi^2 T^2) < \eta^2 > \cosh^2 kh.$

We would like to point out that the analysis techniques adapted for this instrument give approximate results for the actual wave climate conditions. Secondly the estimation of wave period from the number of zero crossings of $(p_i - p^*)$ is certainly subject to more uncertainties than the method of choosing the highest peak from the computed wave spectrum. 3. Since April 1985 we have used the S-4 Inter Ocean Current Meter (MOS4) displayed 1 m off the bottom and programmed to measure wave pressure and horizontal wave velocity (2-components). The measurements have been carried out every 12 hours for 17 minutes, with a sample rate of 1 sample/sec.

Every 17 minutes the pressure time series is Fourier transformed and the sea surface elevation spectrum is obtained from the wave pressure spectrum using the Linear Wave theory. The analysis techniques for this sensor are analagous to the one adapted for S101.

The specification of the fitted pressure sensor is as follows:

Range	0-1000 dBar
Resolution	l dBar
Accuracy	+ 0.25% full scale

4.4 SALINITY INSTRUMENTS

4.4.1 Conductivity, Temperature and Depth Meter

The equipment used for measuring conductivity, temperature and depth is a miniature "Salinity, Temperature, Depth" Probe (Model STD-12) manufactured by Applied Microsystems, Inc. The STD-12 is a small, easy to deploy instrument, ruggedly constructed of 6061-T6 aluminum, with other external fittings of 316 stainless steel. The aluminum parts are hard anodized and protected with antifouling epoxy paint. The physical size is 4" (10.2 cm) diameter, and 26.8" (67.5 cm) long. A sacrificial zinc anode is attached to ensure season after season of corrosion free operation. The salinity is not measured directly but is calculated using the conductivity, temperature and pressure measurements. The "Temperature" sensor is a fast response microbead thermistor mounted in a stainless steel capilliary tube, designed for pressure insensitive measurements. Special laboratory aging techniques ensure repeatable measurements within $\pm 0.01^{\circ}$ C over a range of -5 to $\pm 35^{\circ}$ C for periods exceeding one year.

A patented "Conductivity" sensor, manufactured by Applied Microsystems, is another feature designed into the STD-12. This four electrode device demonstrates excellent long-term stability, and high precision in areas of extreme fouling. Careful design considerations in both the electrode positioning and excitation circuitry results in the cell having wide dynamic range; ie. from distilled water to 50 ppt salinity. The accuracy of the conductivity measurements are ±.01 mS/cm and resolution +.003 mS/cm.

The pressure sensor used in this instrument is a monolithic semiconductor strain gauge. On command the STD-12 reads the ambient atmospheric pressure from the depth sensor and corrects the surface reading of pressure to zero depth, which is typically accurate to 0.1% of full scale (with a selected range of 0-100 psi).

Data are collected in a solid state memory of 60K RAM. Seven thousand six hundred forty-eight scans maximum can be stored per deployment.

Output/input and power-up is accomplished via two "double contact" underwater connectors. Communication with the on-board computer is provided with an adaptor for conversion to standard RS-232A format data. However, the signal from the instrument to the adaptor requires only two polarity independent wires.

4.5 SESTON FLUX INSTRUMENTS

4.5.1 Seston Traps

The seston traps (sometimes called sediment traps) are rigid plastic tubes 2.5 cm in inside diameter and 30 cm long, closed at the bottom and open at the top, mounted vertically in the water. The rate of accumulation of seston in the traps is measured as the height of accumulated seston in mm divided by the accumulation time in days. This variable is called seston flux F (mm/day), and does actually represent the net mean volume flux (volume per unit area per unit time) of particles through the mouth of the tube.

In still water, the mean downward seston flux for particles in a particular range of size would be given by F = SC, S being the settling rate and C the mean ambient volume concentration for particles in that range. In the presence of horizontal velocities due to waves and currents, though, turbulence generated at the mouth of the tube produces some exchange of water between the tube and the outside, and seston accumulates at the bottom by the combined processes of water exchange and settling-out of seston from the water in the tube, as well as by seston simply falling through the water at the mouth.

The exchange of water involves water entering the tube with the ambient seston concentration C, and an equal flow of water leaving the tube with a lower concentration C' because some seston has settled out of this water during its residence in the tube. Calling the mean exchange-rate E, we can write the total flux into the tube as

$$F = SC + E(C-C')$$
, or $F = SC\{1+(E/S)(C-C')/C\}$

The factor (C-C')/C goes from zero for $E/S \rightarrow \infty$ (non-settling particles) to one for $E/S \rightarrow 0$ (particles settling very fast compared to the exchange-rate). We can suppose roughly that $(C-C')/C \sim (aS/E)$

for large E/S, with a on the order of 1, giving $F \sim (1+a)$ SC for the slowest-settling particles. For the fastest-settling particles, we have $F \sim SC$ in any case; in between, with S comparable to E , we have something intermediate, with some dependence on E for any given S . Overall, we can bracket F between one and a few times SC for any size of particle, with variations due to varying E confined to this range.

This simple theory of open-tube traps is generally supported by the flume experiments of Gardner (Journal of Marine Research, <u>38</u>, <u>1</u>, 1980), which showed F within <u>+</u> 50% or less of SC for inorganic particles with a range of diameters up to about .02 mm, corresponding to $S \leq .02$ cm/sec. This upper settling-rate was on the same order as the lengths of the traps divided by the residence-times of dyed water in the traps, which gave a rough measure of the exchange-rates E.

The variable F measured by seston traps, then, is an index of seston volume concentration, weighted by settling-rate so that it selects strongly against finer and less dense particles, with some uncertainty due to variations in E with varying ambient watervelocity.

The reported values of F for a given deployment and station are the means of three (occasionally two) tubes mounted at the same height about 2 m apart.

If the accumulated seston approaches the top of the tube, the turbulence can wash some of it out, and the net collection rate slows and ultimately stops. This should be kept in mind in considering results in which measured seston flux exceeds about 20 mm/day over a deployment longer than 10 days.

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4.5.2 Seston Pumps

The seston pump is an instrument developed by ECO-M to collect samples of seawater with the contained seston at regular intervals over a period of several days at a fixed location. The samples are accumulated in a single container; the average seston concentration over the period of deployment, and other average properties of the water, are found by laboratory analyses of the composite sample.

Samples are collected by a calibrated peristaltic pump which collects 3 ml per revolution. A crystal-controlled cycle timer produces any specified number of revolutions at specified timeintervals ranging by octaves from 15 minutes to 16 hours. The sample container holds 4 liters, and is filled in 10 days at a pumping rate of 16 ml per hour.

Both organic and inorganic seston can dissolve and precipitate to some extent in the course of a few days in the sample container, even when bacteria are killed by sodium azide. The development of the instrument has required experimentation and testing of the stability of suspended and dissolved matter in the container, besides tests of mechanical reliability. These tests will be described together with the results of field deployments through the latter half of 1986 when the field data are finally established in the new data base DBSESTON.

4.6 ANALYTICAL CHEMISTRY INSTRUMENTATION

4.6.1 Continuous Flow Analyzer

The Continuous Flow Analyzer (CFA) is a multipurpose, modular analytical instrument which can perform several and various analyses concurrently. The basic analytical principle utilized by this instrument is colorimetry or the measurement of the absorbance of light (at a defined wave length through a defined path length) as it passes through a color solution. This type of analysis relies on our ability to combine or react the chemical in question with another reagent to produce a colored solution. The intensity of this color will be proportional to the concentration of the unknown. By comparison with known standards the concentration of the unknown can be deduced. Figure 4-6-1 shows a basic functional diagram of the CFA.

The CFA consists of four basic modular components. The first is a proportioning pump which draws samples, standards and reagents at precise flow rates through transmission tubing. These reagents are then pumped to the manifolds where the samples and reagents are combined at specific junctions and precise times as determined by the required analysis. It is at this point where the solutions develop the specific color characteristic required by colormetric analysis. This colored solution now flows through the colorimeters where the intensity (absorbance) of the solution is measured. Data is recorded continuously via the colorimeter to strip chart recorders.

The CFA operated by ECOSystems is manufactured by Scientific Instruments Corporation and consist of the following modular components: one AS-100 sampler; one AP-200 peristaltic pump; two manifold catridges (one for $NO_3 + NO_2$ and NO_2 analysis, and one for NH_4 analysis); three AC-200 Continuous Flow Colorimeters (one for each nitrogen nutrient) and two Non-Linear strip chart recorders (a dual pen and single pen).





The entire unit was placed in transport box constructed by ECOSystems which allowed for easy transport to and set up in the lab aboard ship.

4.6.1.1 In Situ Nutrient Analysis

The CFA is used on a regular basis for in situ determination of NO_3 , NO_2 and NH_4 over depth. For this purpose the CFA is placed aboard ship and transported to the study area. Water samples are then pumped from depth to the ship where a continuous sample is withdrawn from a flow cell before discharged overboard.

4.6.1.2 Discrete Nutrient Analysis

In the laboratory the CFA is routinely used for the determination of NO_3 , NO_2 and NH_4 in seawater samples collected in the study area and transported back to ECOSystems. All analytical operations are identical to field use, except that the AS-100 sampler is used for delivery of sample instead of the in situ flow cell. Analysis of discrete samples is done to check and calibrate in situ sampling and also for monitoring nitrogen levels at various KEP stations.

4.6.2 Fluorometer

Fluorometric analysis is done for a number of variables including chlorophyll, phaeophytin and dye concentration. The instrument used for this type of analysis is known as a fluorometer and operates on the principle that a fluorescent molecule will absorb light at one wavelength and almost instantly emit light at a new and longer wave length. The color of the emitted light (or its emmission spectra) is independent of the excitation wavelength and its intensity depends on the number of photons of light which the fluorescent material absorbs per unit of time. Thus, the intensity of the emitted light is: 1.) proportional to the concentration of the fluorescent material present, and 2.) has a characteristic excitation

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spectrum. By proper selection of excitation and emission filters a high degree of fluorescent material selectivity may be achieved. Calibration is accomplished by preparation of appropriate standards in the laboratory and then comparing the intensity of emitted fluorescence of the unknown to known.

4.6.2.1 Discrete Chlorophyll and Phaeophytin Analysis

Chlorophyll and its degredation product, phaeophytin, are routinely determined from discrete water samples taken from the study area and transported to ECOSystems. In the lab, they are extracted from the sample using a 90% acetone solution. Then they are measured fluorometrically using known standards. ECOSystems had used a Turner III Fluorometer until the end of 1985 at which time it was replaced with a Turner Designs Model 10-000.

4.6.2.2 In Situ Chlorophyll Analysis

Fluorometric analysis can also be adapted for in situ chlorophyll determination. To accomplish this the fluorometer is fitted with a flow-through cuvette through which is pumped a continuous stream of seawater. The chlorophyll in this water will fluoresce and a quantative measurement can be calculated from this value. Discrete samples, however, must be taken during the in situ measurement and returned to the lab for analysis. Using the discretes to calibrate the in situ measurement produces an accurate measurement of in situ chlorophyll. Pheaeophytin cannot be measured in situ using the continuously flow method.

4.6.2.3 Chlorophyll and Phaeophytin in Sediment Analysis

The determination of chlorophyll and phaeophytin in sediments is also routinely performed by ECOSystems. This type of fluorometric analysis is no different than that used for discrete water samples except that the chlorophyll and phaeophytin is extracted from sediment sample rather than water.

4.6.2.4 Tracing of Fluorescent Materials

A number of water soluable dyes, such as rhodamine, fluorescence and lissamine, exhibit fluorescent properties. ECOSystems has conducted a number of water mass tracing and dilution ratio experiments in the study area using fluorescence dyes by tracking the distribution of dye using the fluorometer. This is achieved by pumping seawater through the fluorometer (with a flow-through cuvette) from depth using a submersible pump. The fluorescence of the sample is recorded continuouly and the data is calibrated against known standards.

4.6.3 Nephelometer

When light passes through a liquid containing suspended solids, a portion of this light is deflected from its original path at the refractive index discontinuities between the liquid and solid particles. A nephelometer is an instrument which measures the amount of light deflected (in our case, 90° from the incident light beam). In nephelometry, each discontinuity acts independently. If there are no suspended solids, no light is scattered, and the nephelometer reads zero. As the solids content increases, the scattered light increases proportionately, yielding a linear relationship between reading and concentration. This relationship holds until a significant fraction of the scattered light is scattered twice or more. Eventually, as the solids content gets very high, the system will go "blind" as no light can penetrate to the area where the light detector views the scattered light. Nephelometry is related to turbidimetry (which measures forward scatter of light) and its analogous parent, transmissivity (which measures absorbance of light). From a practical point, however, it is a much more practical field instrument as it has greater sensitivity, linear response, and is not strongly effected by dissolved colored materials.

ECOSystems uses a Turner Designs Model 10-000 fluorometer, adapted with a 10-033 Continuous Flow Nephelometry Kit for its nephelometric studies.

4.6.3.1 Turbidity Measurements

These studies were carried out using the nephelometer on board ship in the continuous-flow mode. Seawater is pumped to the instrument from a depth using a submersible pump and hose assembly, through the nephelometer, then discharged overboard. Data is recorded continuously using strip chart recorders then calibrated by comparison to know standards made in the lab.

4.6.4 Spectrophotometer

Spectrophotometric analysis is performed using a Bausch and Lomb Spectronic 710 spectrophotometer. This instrument is a single beam UV-visible spectrophotometer which provides photometric readout in % transmittance, absorbance or concentration. The instrument is provided with interchangeable radiation sources, including a deuterium discharge tube for the lower wavelengths and a tungsten filament lamp for the visible region. The radiation wavelength is selected by means of a Littron prism; by adjusting the position of the prism, light of the desired wavelength can be focused on the sample cell. The amount of light transversing the cell (transmittance or optical density) is measured using a phototube and photomultiplier.

4.6.4.1 Analysis of Particulate Organic Carbon in Sediment

ECOSystems routinely performs POC analysis using the spectrophotometer. In this analysis, organic carbon is oxidized using a sulfuric acid potassium dichromate solution. This solution changes color during the oxidation process and this color change (measured on the spectrophotometer) is directly proportional to the concentration of POC in a sample. By comparison to known standards the concentration in an unknown sample may be determined.

4.6.5 Ion-Analyzer

ECOSystems uses ammonia-selective electrodes in conjunction with a high input impedance ph/mV meter for the determination of nitrogen in sediment samples. The electrode functions by sensing ammonia gas in equilibrium with ammonia in solution which diffuses across a semipermeable lipophilic membrane on the electrode which separates an internal electrolyte from the sample solution. The amount of ammonia that diffuses through the membrane depends on the partial pressure of ammonia and is proportional to the concentration of ammonia in solution. The ammonia passes through the membrane, dissolves in the internal filling solution of the electrode and reacts reversibly with the water, via

$$\mathrm{NH}_3 + \mathrm{H}_2\mathrm{O} = \mathrm{NH}_4 + \mathrm{OH}.$$

The relationship between the concentration of ammonia and the concentrations of ammonium ion and hydroxide ion is expressed by

(NH₄) (OH) ------ = constant . (NH₃)

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Since the internal solution contains a level of ammonium ion that is high enough to be considered constant, the equation reduces to:

The potential of the internal pH element of the electrode varies with OH concentration according to the Nernst equation:

$$E = E^{\circ} + 2 - 3 - \frac{10}{n_{F}} \log (OH)$$

Where E is the potenial;

 E^{o} is a constant which is the sum of several potenials in the system;

R is the gas constant;

T is temperature in degrees Kelvin;

n is the charge on the ion, and

F is the Faraday.

The high input impedance mV meter measures the potenial difference between the electrodes which will be proportional to the ammonia concentration.

4.6.5.1 Analysis of Particulate Organic Nitrogen in Sediment

PON analysis is done at ECOSystems using ion-selective electrode instruments. The PON sample is first subjected to a chemical treatment (low-level Kjeldahl digestion) which converts the PON to ammonia. The ammonia concentration is then determined using an ammonia electrode. This data can then be calibrated using known

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standards and the amount of PON in the original sample can be calculated.

4.6.6 Non-dispersive Infrared Analyzer

This instrument measures organic carbon using the principle of infrared spectrophotometry. This type of instrument operates on the principle common to all spectra photometers, which is the measurement of absorption of light (at a known wave length) as it passes through a solution. TOC analyzers basically automate the chemical processing (conversion of organic carbon to carbon dioxide), measurement of absorbance (infrared gas analyzer) and data reduction.

An Oceanography International Model 524-B Total Organic Carbon System is used for the organic carbon measurements performed by ECO-M. The system operates by conversion of organic carbon to carbon dioxide and then measures the absorbance of the carbon dioxide in the infrared region of the spectrum. By comparison to known standards, the unknown amount of organic carbon can be determined.

4.6.6.1 Analysis of Particulate Organic Carbon in Sediment

Particulate Organic Carbon (POC) in sediment samples is routinely determined by using the Non-dispersive Infrared Analyzer. Sediment samples are digested by using phosphoric acid and potassium persulfate which converts the organic carbon to carbon dioxide. The amount of CO₂ generated is measured by using infrared absorption and comparing it against known standards.

4.6.6.2 Analysis of Dissolved Organic Carbon in Seston

To determine the level of Dissolved Organic Carbon (DOC) in seston samples, the samples are filtered through 0.2 micron glass fiber filters to remove the particulate material. The filtered

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seawater is then subject to standard organic carbon to carbon dioxide chemistry and the amount of carbon dioxide generated is measured by using infrared absorption. Comparison to known standards allows calculation of organic carbon in the original sample.

4.6.7 Elemental Analyzer

Elemental analysis is accomplished using a Perkin Elmer Model 240C elemental Analyzer. This type analysis involves the complete combustion of a sample in a pure oxygen environment. The combustion product of carbon, nitrogen and hydrogen will be respectively carbon dioxide, various oxides of nitrogen, and water. This mixture is then analyzed by passage through a series of three high-precision thermal conductivity (TC) detectors.

Between the first pair of TC cells is a moisture trap. As the sample passes through, water is removed. The differential signal obtained before and after the trap reflects the water content and therefore the amount of hydrogen in the sample.

A similar measurement is made for carbon by using a carbon dioxide trap between a second pair of TC cells. The remaining gas now consists of helium (the carrier gas) and nitrogen. this gas passes through a conductivity cell, the output of which is compared to that of a reference cell where pure helium flows to give the nitrogen concentration.

4.6.7.1 C:H:N Analysis of Kelp Blades

The blade samples are furnished to ECO-M by members of KEP. Each sample is dried and ground into a powder. The powder is then sent to a subcontracting laboratory where the analysis is performed on a Hewlett-Packard Carbon-Hydrogen-Nitrogen (CHN) analyzer for the percentage of each desired element. ECOSystems subcontracted kelp blade C:H:N analysis to MicAnal of Tucson, Arizona. The analysis is done using the elemental analyzer described above. ECOSystems prepared the kelp blades for analysis by drying, and then grinding the dry blades to a fine powder. These samples were then shipped to Mic Anal for analysis.

4.7 CHECK AND MAINTENANCE OF SYSTEMS

Prior to use, all instruments are cleaned, dissembled and inspected for electronic problems, corrosion, water leakage, and all other possible problems as appropriate to the various systems in use.

The instruments are then subjected to the following procedures where appropriate:

- 1. Battery packs are recharged or replaced.
- 2. Electronics are recalibrated using bench simulators.
- 3. Sensors, probes, compasses and similar devices are recalibrated and results documented.
- 4. Rubber seals, gaskets and "O" rings are replaced.
- 5. Reassembled instruments are operated for a minimum of 24 hours in a simulated environment to verify proper operation. During this time, external power is used. The chips of the EPROMS from this test are programmed into our computer and results verified. If satisfactory, the unit is connected to an internal battery source, voltages are rechecked under power, the storage medium is properly identified and inserted into the instrument, and a final physical check is performed with the power off. The unit is then ready for operation.

Measuring devices are calibrated at bi-monthly intervals on a rotating basis. Information gathered during the test are recorded on a printed inspection card and later logged in a separate log book.

Figure 4-7-1 depicts the quality control procedures utilized in our operations.

INSTRUMENT QUALITY CONTROL

FLOW DIAGRAM



Figure 4-7-1 INSTRUMENT QUALITY CONTROL PROCEDURES

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4.8 **REFERENCES**

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