INTERNAL CRUISE REPORT

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MV NAVICULA CRUISE - MIRAMICHI BAY, NEW BRUNSWICK

BY

C.L. AMOS, A.J. GIBSON, V. PARTRIDGE, A. ATKINSON and F. JODREY

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RODAC, ENVIRONMENTAL PROTECTION SERVICE
QUEEN SQUARE, 45 ALDERNEY DRIVE
DARTMOUTH, N.S. B2Y 2N6

JULY, 1994

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Sponsored by

Geological Survey of Canada
Atlantic Geoscience Centre
Bedford Institute of Oceanography
P.O.Box 1006, Dartmouth
Nova Scotia, B2Y 4A2

and

RODAC, Environmental Protection Service
Queen Square, 45 Alderney Drive
Dartmouth, Nova Scotia
B2Y 2N6

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1.0 CRUISE SUMMARY SHEET

SHIP.................	MV NAVICULA
CRUISE DATES.........	17 - 25 JUNE, 1994
CRUISE NUMBER........	94-350
CRUISE LOCATION......	Miramichi Bay, dump site B
SIDESCAN DATA........	12 hours
SEA CAROUSEL.........	15 stations
VAN VEEN GRABS.......	14
GRAVITY CORES........	13

SCIENTIFIC STAFF

C.L. AMOS............	Senior Scientist (G.S.C.)
A. ATKINSON..........	Electronics (G.S.C.)
J. GIBSON............	Biological sampling (Acadia U)
V. PARTRIDGE.........	Laboratory analyses (Acadia U)
F. JODREY............	Sediment sampling (G.S.C.)

MAJOR ACCOMPLISHMENTS

1. Completion of four (4) Sea Carousel stations at Miramichi Inner Bay Control site (Reach 22).

2. Completion of ten (10) Sea Carousel stations at Miramichi Inner Bay disposal site B.

3. Collection of thirteen (13) gravity cores, bulk samples and biological samples from each site.

3. Completion of sidescan sonar survey of Miramichi Bay navigation channel from Newcastle to M47.

4. Completion of sidescan mosaic of eastern and central Miramichi Bay disposal site B.

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3.0 BACKGROUND AND PURPOSE

3.1 GENERAL SCOPE

The mobility and stability of particulate material may be viewed as a continuum of scales. The largest form of instability we term mass movement, slumping or turbidity flows. Such movements often represent *catastrophic* events with a long return-interval, and are usually of large consequence. The energy to trigger and sustain these types of instabilities comes from short-lived geological events, such as earthquakes, and once mobile are subsequently sustained by the gravitational force. At the other end of the scale, we find instabilities in the form of particle-by-particle motion, commonly referred to as the *sediment transport phenomenon*. This form of sediment instability we view as *chronic* as it is often of low magnitude but may be continuous and long-lived. It is usually triggered by periodic events such as tidal currents or storm-generated waves, and is sustained by hydrodynamic forces (Dyer, 1989). This form of instability accounts for a greater volume of sediment motion, but is harder to detect. It is often overlooked as impacts are slow to develop, and often difficult to associate with a specific cause. It is precisely this type of sediment instability that dominates the coastal and estuarine environments of eastern Canada, **and it is the focus of this study**.

The sediment transport phenomenon may be characterized within three major groups of responses: (1) *non-cohesive sediment transport* (Middleton and Southard, 1984); (2) *cohesive sediment transport* (Dyer, 1986) and (3) *fluidized muds and beds* (Mehta, 1989). For non-cohesive sediment transport, the important parameters are:

3.1.1 the critical bed shear stress for traction

3.1.2 the traction rate as a function of applied bed shear stress

3.1.3 the critical bed shear stress for saltation/suspension

3.1.4 the distribution of suspended load and the total load concentration

3.1.5 the associated bed roughness and bedform pattern

3.1.6 the critical bed shear stress for upper plane bed sheet flow.

For cohesive sediments exhibing Bingham plastic behaviour the important parameters are:

3.2.1 the surface critical bed shear stress for erosion (cohesion)

3.2.2 the distribution of shear strength with depth in the sediment

3.2.3 the erosion rates as a function of excess bed shear stress

3.2.4 the critical water-column Reynolds stresses for incipient settling

3.2.5 the mass settling rates (as a function of concentration and grain size)

3.2.6 the rate of bed consolidation.

The third group falls between visco-elastic solids (soils or beds) and inviscid fluids (Newtonian behaviour). It typically encompasses moveable beds of bulk unit weights less than 1200 kg/m^3 (Terzaghi and Peck, 1967), fluid muds where hindered settling is prevalent (concentrations > 10 kg/m^3), newly formed deposits undergoing self-weight consolidation (dumped material), or organic rich gels. The response to an applied stress is typically called pseudo-plastic and may be either shear thinning or shear thickening (Faas, 1991). They have extremely low friction angles (no consolidation), yet may posses yield strength (organically bonded), and invariably sustain excess pore pressures that maintain the solid material in a state of suspension. Many sediments forming group (2) pass through this stage. Some sediment types pass through it quickly (non-reactive clays, inorganic silts); other sediments may remain in this stage for long periods of time (reactive clays, organic-rich silts). Fluid muds are characterized in terms of the strain rate as a function of applied stress (rheological properties), and have no yield strength by definition (Dyer, 1986). Gels, by contrast, are fluidized beds that possess a yield strength. **We know virtually nothing about natural gels or moveable beds, yet they are found in many estuaries (including the Miramichi Bay) and are extremely important in the dredging/dumping process as they may**

quickly become mobile (Brylinsky et al. 1992).

The forces that are applied to the sediment (cyclic or static) gravitational or hydrodynamic affect the way the sediment will respond. For example, the cyclic loading of a sediment will induce liquefaction more easily than will a static load of the same magnitude due to build up in pore pressures. Also wave action at the bed will induce a different form and rate of particle-by-particle transport than will a tidal current due to pressure gradients exerted by the strong wave accelerations and decelerations. In most cases, waves and steady currents act together to create a complex *combined flow* benthic boundary layer, and a complex time history of bed shear stresses. The nature of these bed stresses will in part dictate the way in which the sediment parameters will behave.

Thus we have a complex coupled system between sediment failure mode and the applied forces that result in failure. We often account for this coupling through the use of numerical models of sediment transport and sedimentation. Nominally, we attempt to define such a model by assigning values to 3.2.1 to 3.2.6 above and to the following parameters:

3.3.1 the spatial distribution in bathymetry

3.3.2 the spatial distribution in grain size

3.3.3 the time-series of spatial distribution of waves, tides, and storm currents

From these parameters, a solution of bed stability may be derived for natural or artificial conditions. Normally, such models are calibrated against known examples, and they are then used to extrapolate to the future. The output from such models are largely used in two ways:

- **environmental impact assessment**
- **engineering risk analysis**

With respect to the Miramichi Bay disposal site B two major sets of problems exist: (1) the proper characterization of sediment response under various types of bed shear stress application (3.2.1 to 3.2.6); and (2) the adequate definition of a realistic natural time-series for accurate prediction. The first set of problems is complex and is still poorly described in the literature; the second set of problems requires monitoring using standard oceanographic equipment and so is relatively straight-forward to solve, if expensive.

The first set of problems has been largely addressed in the past through flume experimentation with artificial sediments. Our experiences (Amos *et al.* 1988; Daborn *et al.* 1991), and those of others (reviewed in LISP-UK, 1992), demonstrate that results of such experiments are not always applicable to nature for the following reasons:

- **variations in grain size, mineralogy and texture**
- **effects of the shape, size and content of organic matter**
- **variations in pore water salinity, cation-exchange capacity and cation composition**
- **variations in depositional history, antecedent sediment loading, and consolidation history**
- **effects of bioturbation, biostabilization, and benthic feeding**
- **effects of exposure, temperature fluctuations, and freeze/thawing**
- **effects of man (dredging/dumping)**
- **the effects of turbid/fluid benthic boundary layers on turbulence suppression**
- **the effect of suspended particles (sand or flocs) on erodibility through bed impact**

We may move forward in both the applied and scientific aspects of sediment stability in the following manner: (1) by developing good numerical models that can realistically simulate the benthic bed shear stresses under complex combined flows; (2) by measuring the parameters of erosion or deposition under the full spectrum of flow conditions using *in situ* technologies; (3) by scrupuloulsy re-analysing field sediments under controlled conditions whereby each of the preceived important parameters are varied and eliminated by turn, thereby determining its contribution to sediment stability; and (4) by undertaking long-term measurements of the environmental forces responsible for the sediment instabilities.

Clearly this cannot be undertaken within the context of a single study. However, certain aspects are in more need of examination than others. For example, the study of non-cohesive sand transport under steady flows is well documented through fluvial and tidal studies, and can be predicted to within a factor of 2. Sand transport under waves and currents is more complex, but is advancing steadily through instrumentation on European and north American continental shelf studies. Our understanding of cohesive sediment behaviour may be viewed as poor under steady flows and virtually absent for a situation of combined (wave/current) flows. It is precisely in this area of endeavour that this cruise is addressed to. Specifically, it is **to undertake a detailed examination of the *in situ* cohesive sediment parameters at Miramichi Bay Disposal Site B and to determine the factors controlling these parameters.**

3.2 THE TECHNOLOGY

Major advances have recently been made in Canada with respect to the measurement of *in situ* cohesive sediment transport parameters. A suite of seabed instrumentation is available for the first time that provides reliable and scientifically acceptible data for the definition of seabed stability. Sea Carousel (Amos, Grant *et al.* 1992), SOBS (Amos, Ardiles *et al.* 1992), INSIST-II (Christian *et al.* 1990), SASW, Lancelot (Christian and Heffler, 1993), EXCALIBUR, and RALPH (Heffler, 1984) are working systems developed by Atlantic Geoscience Centre (AGC) that are capable of being used in the coastal marine environment, and have proven themselves through prior use. Others are in the process of development (DODO - an ultrasonic (2 MHz) downlooking sounder and profiler). Software for data downloading, plotting, and manipulation has also been developed, and the results are producing new and exciting insights into the science of seabed stability. The technology, instrument calibrations, data outputs and scientific conclusions form the basis of a series of papers or reports. **Within the context of this cruise we will focus on the field deployment of Sea Carousel.**

At the same time, a laboratory Carousel (the exact same dimensions as the Sea Carousel) has been developed jointly by Acadia University and Atlantic Geoscience Centre (AGC). The purpose of this Carousel is to rigorously evaluate the stress distribution within the Sea Carousel, and to undertake controlled studies on field samples for a comparison with the Sea Carousel results. Also, a straight, recirculating flume is being developed by Dalhousie University (DALFLEX). Comparisons will be made between this flume and the annular one on standardized beds. These flumes will provide a necessary adjunct to the field results.

3.3 THE STUDY

The main objectives of this study are as follows:

(1) **to calibrate the flow within Sea Carousel and the associated distribution of bed shear stresses.** This will be undertaken using the Lab Carousel using small-head electro-magnetic flow meters and hot-film plates. We will also evaluate the changes in bed shear stress and turbulence dampening resulting from increases in bed roughness due to the erosion process and due to changes in sediment concentration in the benthic layer. This is an essential step that allows us to link with confidence the fluid dynamics to the observed bed responses; a relationship essential to numerical prediction of dump site stability;

(2) **to compare the nature of erosion of standardised beds within the Lab Carousel against the same standardized beds with a more conventional straight flume (Dalflex).** This will help address concerns regarding the non-uniform distribution in bed shear stresses (as well as flow structure) in annular flumes;

(3) **to minimize and better-define dispersion from Sea Carousel.** All benthic flumes leak thereby losing material eroded from the bed. Unless accounted for, this loss induces errors in defining the rate of bed erosion and the depth of bed erosion. We have accounted for this in the past through numerical methods (Amos, Grant *et al.* 1992) while accepting this leakage. We now feel that this loss may be minimize, perhaps eliminated

through a process of *continuous pumping* from the Carousel. The purpose of this task is to define the rate and type of pumping that will minimized leakage at each increment of flow, and to define a more-precise algorithm of sediment loss;

(4) **to determine the effects of sediment colour on the sensitivity and range of Optical Backscatter Sensors (OBS's; Downing, 1983).** These OBS's are widely used to detect sediment in suspension on benthic tripods etc. SOBS uses 6 at varying heights above the seabed. It has long been known that the size of particles has a strong effect on the sensitivity of these sensors. Recently, however, we found that the black (reduced) muds of Miramichi Bay had an even larger effect on these sensors that did grain size. This effect, according to J. Downing (pers. comm., 1994) is unknown and has never been documented. In the case of dumped material, which is often highly reduced (and black in colour), this effect is very important, and large errors in predicted suspended sediment concentration may result.

(5) **to evaluate the effects of suspended particle concentration and size on the erodibility of seabed sediments.** Bagnold (1966) and Kamphuis (pers. comm.) suggest that the effects of momentum transfer (grain impact) between particles in suspension and the seabed can be greater than the viscous fluid forces in the erosion process. The transfer of forces to the bed increases with concentration and grain size, thus sand in suspension could influence greatly the erosion process and enhance mobilization of dumped material. It has been suggested that the threshold criterion for cohesive beds may be defined purely in terms of the *Shields Parameter for entrainment* of the material in suspension. We know that on most tidal flats fine-medium sand is transported over mud flats during storms, and to a lesser extent in fair-weather. We also have observations (J. Grant, unpublished data, 1992) of bedload transport and micro-ripples forming on mud flats. **So does grain impact play an important role in cohesive sediment mobilization ?** We have little data to solve this question. If it is true, then measurements of stability made under clear-water laboratory **or** field conditions may bear no

relationship to the actual process of seabed reworking. Thus, it is vitally important to determine these effects before accurate predictions of cohesive bed stability can be made. We propose, therefore, to use the Lab Carousel to develop a reference, standard bed using Miramichi dumped material. Thereafter to erode this bed with varying concentrations of sediment of differing sizes. We anticipate running 36 experiments at 6 starting concentrations and 6 sizes of material. A further six (6) experiments will be carried out using clear water to determine reproduceability and to establish a standard;

(6) **to monitor the sedimentation parameters of pre-disposed and post-disposed material at dump site B, in Miramichi Bay.** This will be undertaken through 14 deployments of Sea Carousel. This will capitalize on a recent study of this site survey before dumping, hours after dumping and days later (done for DPW) in order to examine the long-term rate of stabilization of a known dump. Also, to expand our understanding of the spatial distribution in sedimentation parameters around dumped and natural (control) sites for purposes of numerical simulation. At the same time, SOBS and DODO will be deployed in order to examine any natural resuspension rates from the natural and dumped sediments. The importance of this work is that we do not know the consolidation rates of freshly dumped material, so it is not possible to assess the stability of such material through time. We know (from our recent Miramichi work, 1993) that newly-dumped material is fluidized and easily eroded. We also know that 1-year old dumped material is stronger than the surrounding natural sediment and difficult to erode. **Thus we need to know the rate at which dumped material strengthening takes place.** A minimum of 10 deployments will take place at dump site B, Miramichi Bay (Figures 3.3.1 and 3.3.2), in order to evaluate dump material stability having suffered a winter season. Other deployments (10) will be undertaken at dump sites on an opportunity basis;

(7) **to collect large samples of natural and dumped material for laboratory analyses of sedimentation parameters under controlled conditions**. We hope to be able firstly to reproduce the Sea Carousel results;

secondly to undertake controlled experiments whereby we manipulate by turns (A) biological contribution; (B) consolidation times; (C) organic content; (D) pore water salinity; (E) sand in suspension; (F) emplacement rate; the factors influencing bed stability are complex and occur in concert in nature. Previous studies have attempted to use step-wise multiple regression analysis to explain erosion variance in terms of the measured animal/sediment parameters. The resulting relationships are non-intuitive, have no physical basis, and cannot be applied in a predictive fashion. Our approach is to vary each parameter in turn under laboratory conditions to determine the exact influence of each parameter (inverse or direct; linear, quadratic etc); in this fashion we will construct an algorithm defining bed stability that has a sound physical basis and can be used predictively, at least within the region of study. This will involve *circa* 100 tests in the flume. Parameters A to F will be varied over at least 6 levels in turn, and triplicate controls will be undertaken on control samples.

4.0 NAVIGATION

We navigated using the ship board Northstar® LC/GPS 800X. This navigation system combines the time delays of Loran-C with a Global Positioning System to derive position. It proved to be within 50 m of our docked position at Chatham Wharf, and was stable through time. The output from the Northstar was passed through a Raytheon Track Plotter and thereafter into the Simrad® sidescan sonar system for annotation on paper records. We were not able to log navigation fixes directly using AGCNAV as the codes transmitted by the Northstar system did not match those typical of GPS. The navigation for the sidescan survey of the channel was anticipated to be differential GPS, and was to be provided by Dept. of Public Works. The system, however, did not materialise.

5.0 SEABED SAMPLING

5.1 GRAB SAMPLING

A medium Van Veen grab was used to collect bulk samples of the seabed at each station. Two small syringe cores were collected from the surface of each grab for purposes of examining microfabric. The syringe cores were held vertically to prevent disturbance, and frozen onboard using dry ice. Small unit volumes of sediment were also collected from the sediment surface for CHN ratios, polysaccharides, and chlorophyll-a content. These were collected from three depths in each grab sample: 1, 8 and 15 cm. Thereafter, the bulk sample was retained for future analysis of resuspension and biostabilization within the Laboratory Carousel.

5.2 GRAVITY CORING

A wide-barrel AGC gravity corer was deployed at all sites. The corer was equipped with 50 lbs of lead and a 1 m long barrel (Plate 5.2.1). The barrel was equipped with a one-way value at the top (to prevent draw-out on removal) and a leaf core catcher at the base. The corer was allowed to free fall from 1 - 2 m above the seabed. The purpose was to obtain undisturbed samples of the sediment surface and about 0.6 to 0.8 m of the underlying material. Cores were held vertically, packed to prevent motion, and sealed with wax to prevent loss of moisture. The cores were collected for analysis of the major physical properties:

- o water content
- o grain size
- o bulk density
- o acoustic velocity
- o vane shear strength, and
- o sediment texture, lithology, and structure

The results of these analyses will be the subject of a future report.

5.3 BIOLOGICAL SAMPLING

Benthic invertebrate samples were collected at each site using a 15 x 15 cm Eckman grab sampler. The bulk sample was wet seived through a 710 μm sieve, and the retained macrofauna was stored for enumeration and identification of species. Chlorophyll-a was determined from sub-samples pumped from Sea Carousel throughout each deployment. A 60-ml syringe with a Swinnex® disk filter holder was used to extract the samples onto MSF GF75 borosilicate filters. Water temperature, salinity, and density was monitored at each site using an Applied Microsystems Ltd. EMP2000.

6.0 SIDESCAN SONAR

Sidescan mosaicking was undertaken using a Simrad MS992 system. The system works at frequencies of 120 and 320 kHz, and is fully digital. The incoming signals are displayed on a TDU 1200 graphic recorder and colour video monitor (Plate 6.1). All records were slant-range corrected and the water column was removed. Signals were digitized and logged with a Geoacoustics® SE880 Digitizer. A swath width of 100 m/channel was used throughout the survey. The system was deployed from the starboard side of the ship and towed about 10 m aft, at a height of 4 m above the seabed.

7.0 SEA CAROUSEL

Sea Carousel is a benthic annular flume capable of submarine monitoring of seabed erosion (Amos, Grant *et al.,* 1992). The annulus is 2 m in diameter, 0.3 m high and 0.15 m wide (Plate 7.1). It is equipped with three optical backscatter sensors to monitor water turbidity, a Marsh-McBirney® current meter to monitor azimuthal and vertical flow, a lid rotation sensor and an underwater camera that views the eroding bed through a window in the side of the annulus. The system is operated from the surface through an RS-232 communication link to a submerged data logger/controller. The digital driver motor is controlled by a similar link to a second computer. Real time video is monitored on a video display and logged on VHS tape (Plate 7.2).

Flow was induced by rotation of the lid, to which are attached eight paddles. Azimuthal flow was transformed to bed stress based on velocity gradients derived in a series of field tests. Bed stress was increased in the flume in a series of steps. Erosion rate was defined as the increase in suspended mass through time. Eroded depth was derived assuming constant areal erosion under the flume, and by measures of bulk density made at the site (*circa* 1300 kg/m^3). The profile of shear strength with depth was derived by assuming that the applied fluid shear stress (τ_o) is equivalent to the shear strength (τ_{ob}) of the sediment when erosion ceases, and that this strength is the critical value (τ_c) at which sediment at that depth will begin to be eroded $\tau_o = \tau_{ob} = \tau_c$. The critical shear stress for incipient erosion of the sediment surface is evaluated as the surface (z = 0) intercept of the best-fit line of shear strength versus depth. See Amos, Grant *et al.* (1992) for a detailed description of the methods and results.

8.0 RESULTS

8.1 CORES AND GRABS

Van Veen grabs and gravity cores were collected at 13 of the 14 stations. A summary table of these samples is given in Table 8.1.1. The grabs preserved the surface oxydised layer and showed highly-reduced organic-rich sediments beneath (Plates 8.1.1 and 8.1.2). The surface layer appeared to be very soft and "soupy". It was typically less than 1 cm thick. The reduced layer beneath was also very soft and appeared as a gel rather than as a plastic solid. No primary structures were evident in the sediment, nor was there evidence of significant reworking into lag layers. These findings suggest that little, if any, reworking of the seabed had taken place over the winter 1993/94. Table 8.1.2 is a summary of the suspended sediment sampling and biological sampling carried out during this study.

STATION #	CORE LENGTH (m)	GRAB SAMPLES	SYRINGE CORES
MIR1(001)	0.68	1	2
MIR2(002)	--	1	2

STATION #	CORE LENGTH (m)	GRAB SAMPLES	SYRINGE CORES
MIR3(003)	--	1	2
MIR4(004)	0.65	1	2
MIR5(005)	0.60	1	2
MIR6(006)	0.16(A); 0.90(B)	1	2
MIR7(007)	0.28	1	2
MIR8(008)	0.48(A); 0.68(B)	1	2
MIR9(009)	0.75	1	2
MIR10(010)	0.77	1	2
MIR11(011)	0.65	1	2
MIR12(012)	0.81	1	2
MIR13(013)	0.65	1	2
MIR14(014)	--	--	--

Table 8.1.1. A summary of seabed samples collected during the cruise. The numbers in brackets denotes the sample numbers.

ST #	SEA CAROUSEL		VAN VEEN		BENTH
	SSC	CHL*a*	CHL*a*	ORG	
MIR1	5	5	3	3	2
MIR1A	7	7	--	--	--
MIR2	12	12	3	3	2
MIR3	12	12	3	3	2
MIR4	11	11	3	3	2
MIR5	11	11	3	3	2
MIR6	9	9	3	3	2
MIR7	11	11	3	3	2
MIR8	12	12	3	3	2
MIR9	12	12	3	3	2
MIR10	12	12	3	3	2
MIR11	11	11	3	3	2
MIR12	12	12	3	3	2
MIR13	12	12	3	3	2
MIR14	--		--	--	--

Table 8.1.2. A summary of biological and water samples collected during this cruise (BENTH - Eckman benthic samples).

8.2 SEA CAROUSEL

Sea Carousel was deployed at fourteen (14) stations during this survey. Stations MIR1, MIR2, and MIR3 were occupied at the same control site as was occupied during the 1993 survey of Miramichi Bay (Amos *et al.* 1994) i.e. immediately north of the navigation channel along Reach 22. Stations MIR4 to MIR13 were located on the exclosure of Disposal site B, and re-occupied stations occupied in 1993. Thus 10 stations were located on material that was surveyed immediately upon disposal in 1993, and now approximately 1 year later. Station MIR14 was located at the control site in order to test a new method for evaluating seabed stability. A summary of the stations occupied by Sea Carousel is given in Table 8.2.1. The E.M. flow meter in Sea Carousel did not work, and so the azimuthal current velocity (U_y) has been determined from a laboratory calibration of flow against lid rotation (U_r):

$$U_y = 0.574 U_r \text{ m/s.}$$

The correlation between lid speed and motor rotation (arbitrary units) is shown in Figure 8.2.1. The plot is useful as the motor speed must be defined in the arbitrary units shown in the figure. The accuracy of lid rotation was evaluated against observed lid speed from video imagery. A linear relationship with a correlation coefficient of 1.0 was apparent (Figure 8.2.2) except that a constant of 0.11 was needed to convert lid rotation to units of m/s. There is a straight-line relationship between motor speed and azimuthal current (Figure 8.2.3) that held for all deployments and was subject to low scatter.

The accuracy of the predicted azimuthal current speed has been evaluated against measures of particle trajectories scaled in the high-resolution video tapes. The results are presented in Amos *et al.* (1994) and show a possible 5% overprediction at the highest speeds, and a good fit at lower speeds. Time-series plots of the Sea Carousel deployments are shown in Figures 8.2.4 to 8.2.19. The results were of good quality and clearly showed bed erosion at high current speeds. Current speed during MIR1 was limited due to mechanical difficulties, and so the station was repeated (MIR1a). Clearly evident in the time-series are (1) the onset of erosion at the second increment of flow, (2) the step-wise increases in SSC at each velocity increment after the onset of erosion, (3) the linear decrease in raw SSC with time within each increment, and (4) the asymptotic decay to a constant value in the corrected SSC (solid line, Figure 8.2.5). Type I erosion is clearly illustrated in Figure 8.2.8. Notice that this erosion Type prevails throughout the deployment, and that the final corrections SSC is *circa* 5000 mg/L. These results from the dump site are similar to those from the control site, and suggests that material disposed of in the summer of 1993 is now as stable as the surrounding, natural seabed.

Stations MIR6 (Figure 8.2.10) and MIR11 (Figure 8.2.16) show significantly higher resistences to erosion than the other stations, and is diagnostic of heterogeneity within the dump site. All sites possessed yield resistence and and behaviour under stress diagnostic of a consolidating bed. MIR14 (Figure 8.2.19) was occupied at the control site (as MIR1, MIR2, and MIR3). This station was undertaken to examine the magnitude of dispersal from the Carousel at differing current velocities and SSC's. Four increments of terminal velocity were selected. At the end of each interval the Carousel was lifted and moved so that it sat on a fresh seabed surface. As expected peak SSC increased with velocity. The raw SSC showed a distinct initial peak that was followed by rapid dispersal. The rate of dipersal shows an asymptotic decrease with time (and SSC). The corrected SSC also shows a peak at the onset of flow, followed by a decrease and finally a slow steady increase. This indicates that the correction we use is valid to first order, but may over-predict dispersal at low SSC's (< 500 mg/L) and under-predict SSC at high SSC's (> 2000 mg/L). Between these extremes, the correction factor appears to be accurate.

ST # (1994)	ST # (1993)	LAT.	LONG.	DEPTH (m)	TEMP (C)	SAL (ppt)	SAMP #
MIR1	MIR13	47 08.06	65 09.54	6.3	5.8	17.1	5
MIR1A	MIR13	47 08.14	65 09.40	6.3	5.8	17.1	7
MIR2	MIR13	47 08.09	65 09.47	6.1	6.0	16.3	12
MIR3	MIR13	47 08.12	65 09.40	5.8	--	--	12
MIR4	MIR7	47 06.99	65 10.17	5.0	6.0	20.5	11
MIR5	MIR18	47 06.82	65 10.29	6.0	5.7	20.7	11
MIR6	MIR19	47 06.85	65 10.24	5.8	5.7	20.8	9
MIR7	MIR9	47 06.85	65 10.18	5.2	--	--	11
MIR8	MIR10	47 06.90	65 10.26	5.2	--	--	12
MIR9	MIR15	47 07.02	65 10.13	5.3	6.5	21.1	12
MIR10	MIR16	47 07.04	65 10.14	5.3	6.0	21.5	12
MIR11	MIR11	47 06.89	65 10.23	4.8	6.4	18.3	11
MIR12	MIR8	45 06.85	65 10.28	5.3	--	--	12
MIR13	MIR20	47 06.87	65 10.31	5.6	--	--	12
MIR14	MIR13	47 08.02	65 09.40	5.3	--	--	--

Table 8.2.1 A summary table of the stations occupied by Sea Carousel. These stations are cross-referenced to those occupied during the 1993 survey of Disposal site B for comparative purposes.

The results show that bed erosion took place in all cases. This is evident by the steady increase in SSC with time. In Figure 8.2.20 are plotted the measured values of SSC against azimuthal current velocity for all stations. Note that the trends are very similar between stations with the exception of MIR6, MIR7, and MIR11. These latter three stations were significantly more resistant to erosion than the remaining ones. The full analysis of data from the Sea Carousel deployments will form the basis of a future report.

8.3 SIDESCAN

Sidescan records were collected of the entire navigation channel from Newcastle Wharf to channel marker M47. The records were of very good quality and showed a number of distinct seabed features including bedrock outcrops, dredger marks, single seabed targets, channel marker anchor weights, and fishing drag marks. There was evidence of infill of very soft muds within certain reaches of the channel. The margins of the channel were also very evident. In places, fish weirs and dock walls were recognizeable, and attested to the clarity of operation of the system. Also, the Highway # 8 bridge footings were clearly seen, as were the channel marker anchor weights. Navigation was not recorded digitally during this survey. However, latitude and longitude, taken from the ship's GPS system, were annotated automatically at 60 second intervals on the sidescan records. The navigation in the channel was noted to be off by up to 2 degrees. It is therefore not useable. However, the annotations of the channel markers evident on the sonar records can be used to position the survey line with precision.

Thirteen lines of dump site B were surveyed (Figure 8.3.1). Each line was approximately 2500 m long and spaced 200 m apart giving good coverage. Approximately 70% of the disposal site was surveyed. The westernmost part was inaccessible due to the shallow water depths (less than 3.5 m). In order to access the westermost lines, we surveyed during a rising or high tide. Hourly tidal predictions for the site are given in Table 8.3.1 and were produced by Canadian Hydrographic Service, Tidal Section (Table 8.3.1).

The exclosure region specified during the 1993 survey of Disposal Site B was also surveyed and showed clear evidence of spoil mounds. Most of these spoils showed well-defined boundaries as if no dispersal had taken place. We found little evidence of dumping outside the boundaries of the disposal site, and those spoils near the site margins were heavily reworked. The entire region showed evidence of flow-parallel current lineations aligned W-E, presumeably with the tidal currents. Also, there were signs of dragger marks located sporadically through the site.

9.0 ITINERARY

DATE/TIME(GMT)	OPERATION
18 May/1300	Leave BIO for Newcastle, N.B.
	check into Wharf Inn, Newcastle
	Meeting with crew of MV Navicula
	Offload equipment in Chatham warehouse
19 May/1100	Mobilization of equiment on MV Navicula
	winds strong
20 May/1100	Steaming to Miramichi Bay control site
20 May/1330	Station 1 (MIR1); grab sample 1; core 1;
	Sea Carousel station MIR1
20 May/1545	drifting off station
20 May/1620	Reoccupied station MIR1(A)
20 May/1730	core 1A
20 May/1757	Station 2 (MIR2); grab sample 2;
	Sea Carousel station MIR2
20 May/1830	Station 3 (MIR3); grab sample 3;
	Sea Carousel station MIR3
20 May/2045	Returning to Chatham Wharf
20 May/2330	Secured at Chatham Wharf
21 May/1100	Steaming for Miramichi Bay disposal site B
21 May/1250	Station 4 (MIR4); grab sample 4; core 4
21 May/1330	Sea Carousel station MIR4
	Difficulty encountered setting anchors
21 May/1700	Station 5 (MIR5); grab 5; core 5
21 May/1710	Sea Carousel station MIR5
21 May/1850	Station 6 (MIR6); grab 6; core 6
21 May/1905	Sea Carousel station MIR6
21 May/2000	Dragging anchors due to high winds
21 May/2015	Returning to Chatham Wharf
21 May/2315	Secured at Chatham Wharf
22 May/1100	Steaming for Miramichi Bay disposal site B
22 May/1230	Station 7 (MIR7); grab 7; core 7a
22 May/1310	Sea Carousel station MIR7
22 May/1620	Core 7b; problem with rollers on Carousel
22 May/1642	Station 8 (MIR8); grab 8; core 8
22 May/1845	Sidescan mosaic of dump site B
22 May/2100	Completed lines 1 to 7
	Returning to Chatham Wharf

22 May/2300	Secured at Chatham Wharf
23 May/1100	Meet Navicula at Newcastle Wharf
23 May/1130	Start sidescan survey of navigation channel
23 May/1500	Finished survey at marker M47
23 May/1545	Sea Carousel station MIR9
23 May/1650	Station 9 (MIR9); grab 9; core 9
23 May/1716	Station 10 (MIR10); grab 10; core 10
23 May/1730	Sea Carousel station MIR10
23 May/1910	Completing sidescan survey of dump site B
23 May/2100	Strong NE winds prevent survey of outer channel
23 May/2300	Secured at Chatham Wharf
24 May/1100	Demobilizing SE880 and sidescan
24 May/1200	Streaming for Miramichi Bay dump site B
24 May/1430	Station 11 (MIR11); grab 11; core 11
24 May/1504	Sea Carousel station MIR11
	Dragging anchors in strong tides
24 May/1630	Station 12 (MIR12); grab 12; core 12
24 May/1704	Sea Carousel station MIR12
24 May/1820	Station 13 (MIR13); grab 13; core 13
24 May/1849	Sea Carousel station MIR13
24 May/2030	Station 14 (MIR14)
24 May/2035	Sea Carousel station MIR14
24 May/2330	Returning to Chatham Wharf
25 May/0100	Secured at Chatham Wharf
25 May/1200	Demobilizing MV Navicula
25 May/1500	Loading equiment into vehicles
25 May/1700	Leave Newcastle for BIO

10.0 CONCLUSIONS AND RECOMMENDATIONS

The major objectives of this cruise were completed. About 5% of the program was abandoned due to inclement weather at the end of the cruise. The major achievements of the cruise are as follows:

1. Four (4) Sea Carousel stations were occupied at the Miramichi inner Bay control site, for comparison with three stations occupied during 1993 (see Amos *et al.* 1994).

2. Ten (10) Sea Carousel stations were occupied at the Miramichi inner Bay disposal site B at sites occupied

during 1993. These stations will allow an evaluation of the change in stability of disposal material over the winter 1993/94.

3. Gravity cores, bulk samples, and syringe cores were successfully collected at each site for analysis of physical properties. These properties will be compared to those determined at dump site B prior to and immediately subsequent to disposal of channel dredge material.

4. Biological sampling was carried out at each site. Analysis of macrofauna was performed on repetitive grab samples, chlorophyll was abstracted from both the Sea Carousel and from bulk samples to evaluate the contribution of biostabilization on disposal material.

5. Approximately 80% of the navigation channel was surveyed with sidescan (from Newcastle to marker M47). The sidescan showed a variety of features indicating that the channel morphology is complex and the seabed sediments are of mixed lithology.

6. Approximately 70% of Dump Site B was surveyed using sidescan. The survey encompassed the central and eastern end of the site. Results show that reworking of older disposal material has taken place, but that the 1993 disposed material showed little evidence of reworking.

7. The bulk samples and cores showed no evidence of a lag deposit suggestive of reworking and seabed winnowing. The inference is that the diposal site (within the exclosure of 1993) is stable.

8. The video records from Sea Carousel showed the water column to be clear to the bed. No fluid mud layers were detected.

9. The results from Sea Carousel were of good quality. Bed erosion took place in all cases. The nature of this erosion, and the magnitude of it requires further analysis.

11.0 REFERENCES

Amos, C.L., Van Wagoner, N.A. and Daborn, G.R. 1988. The influence of subaerial exposure on the bulk properties of fine-grained intertidal sediment from Minas Basin, Bay of Fundy. Estuarine, Coastal and Shelf Science 27: 1-13.

Amos, C.L., Grant, J., Daborn, G.R. and Black, K. 1992. Sea Carousel - a benthic annular flume. Estuarine, Coastal and Shelf Science 34: 557-577.

Amos, C.L., Daborn, G.R., Christian, H.A., Atkinson, A., and Robertson, A. 1992. In situ erosion measurements on fine-grained sediments from the Bay of Fundy. Marine Geology 108: 175-196.

Amos, C.L., Ardiles, B. and others. 1992. CSS Hudson and MV Septentrion cruise, Grande Baleine region, Hudson Bay. A multi-disciplinary survey of the coastal and nearshore regions. Geological Survey of Canada Open File Report 2603: 80p.

Amos, C.L., Tay, K-L., Hughes, M., Robertson, A. and Wile, B. 1993. Seabed stability at dump site B of St John Harbour, New Brunswick, using Sea Carousel. Geological Survey of Canada Open File Report : 22p.

Amos, C.L., Brylinski, M., Christian, H.A. and Daborn, G.R. 1994. Seabed stability, liquefaction and the development of fluid mud during dredging and dumping at Miramichi Inner Bay. Acadia Centre for Estuarine Research Publication No. 32: 347p.

Bagnold, R.A. 1966. An approach to the sediment transport problem from general physics. U.S. Geological Survey Professional Paper 4421: 37p.

Brylinsky, M., Gibson, J., Daborn, G.R., Amos, C.L. and Christian, H.A. 1992. Miramichi inner bay sediment stability study. Acadia Centre for Estuarine Research Publication 22: 53p.

Christian, H.A. 1993. In situ measurements of consolidation and permeability of soft marine sediments. Proceedings 4th Canadian Conference on Marine Geotechnical Engineering.

Christian, H.A. Gillespie, D., and Amos, C.L. 1990. Results of a new device to measure the in-situ shear strength of cohesive sediments, Minas Basin, Bay of Fundy. Abstracts of 13th International Sedimentological

Congress, Nottingham: p 91.

Christian, H.A. and Heffler, D. E. 1993. Lancelot - a seabed piezometric probe for geotechnical studies. Geo-Marine Letters 13: 189-195.

Daborn, G.R. and others. 1991. Littoral investigation of sediment properties (LISP) report. Acadia Centre for Estuarine Research Report 17: 239p.

Downing, J.P. 1983. An optical instrument for monitoring suspended particulates in ocean and laboratory. Proceedings of Oceans, 83. Publ. IEEE: 199-202.

Dyer, K. R. 1986. Coastal and Estuarine Sediment Dynamics. Publ.John Wiley & Sons: 342p.

Dyer. K.R. 1989. Sediment processes in estuaries: future research requirements. Journal of Geophysical Research 94: 14327-14339.

Faas, R.W. 1991. Rheological boundaries of mud: where are the limits? Geo-Marine Letters 11: 143-146.

Heffler, D. 1984. RALPH - an instrument to monitor seabed sediments. Current Research, PArt B, Geological Survey of Canada Paper 84-1B: 47-52.

LISP-UK, 1992. Littoral Investigation of Sediment Properties: A Proposal. Publ. Gatty Labs, St Andrews University, Scotland. Submitted to Land Ocean Interaction Study: 15p.

Mehta, A. J. 1989. On estuarine cohesive sediment suspension behaviour. Journal of Geophysical Research 94: 14303-14314.

Middleton, G.V. and Southard, J.B. 1984. Mechanics of sediment movement. Short Course No. 3. Publ. Society of Economic Paleontologists and Mineralogists: 401p.

PLATE 5.2.1

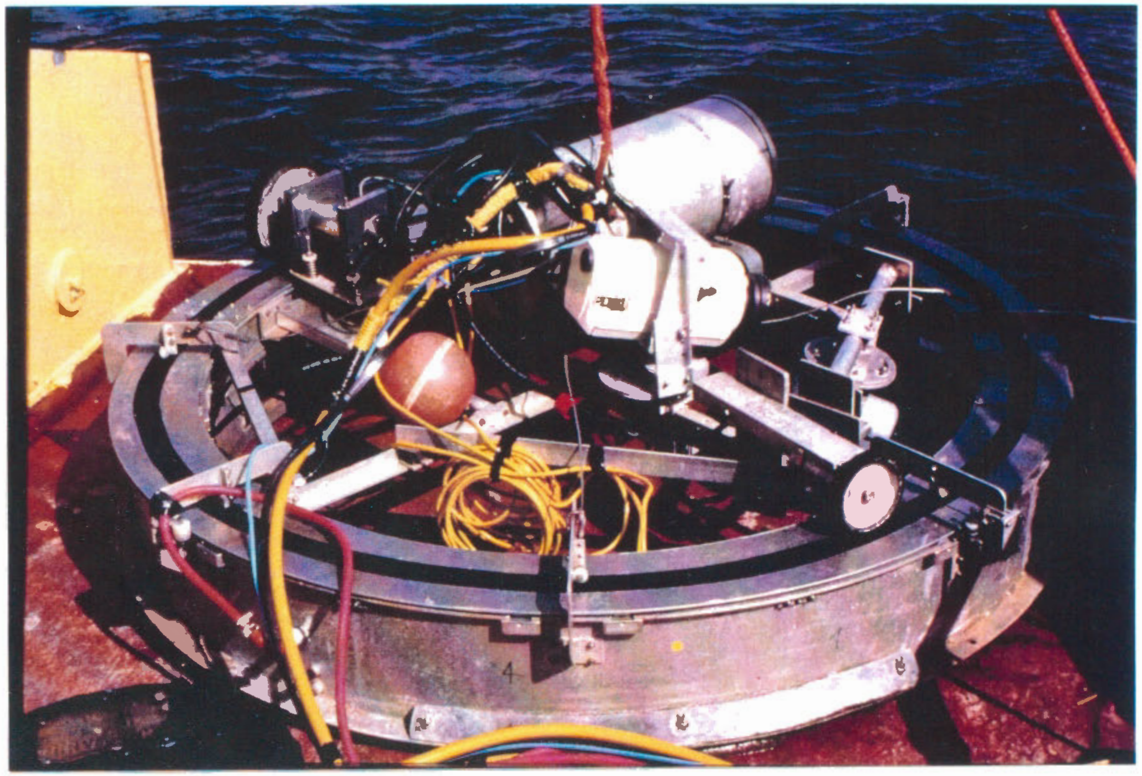


PLATE 7.1

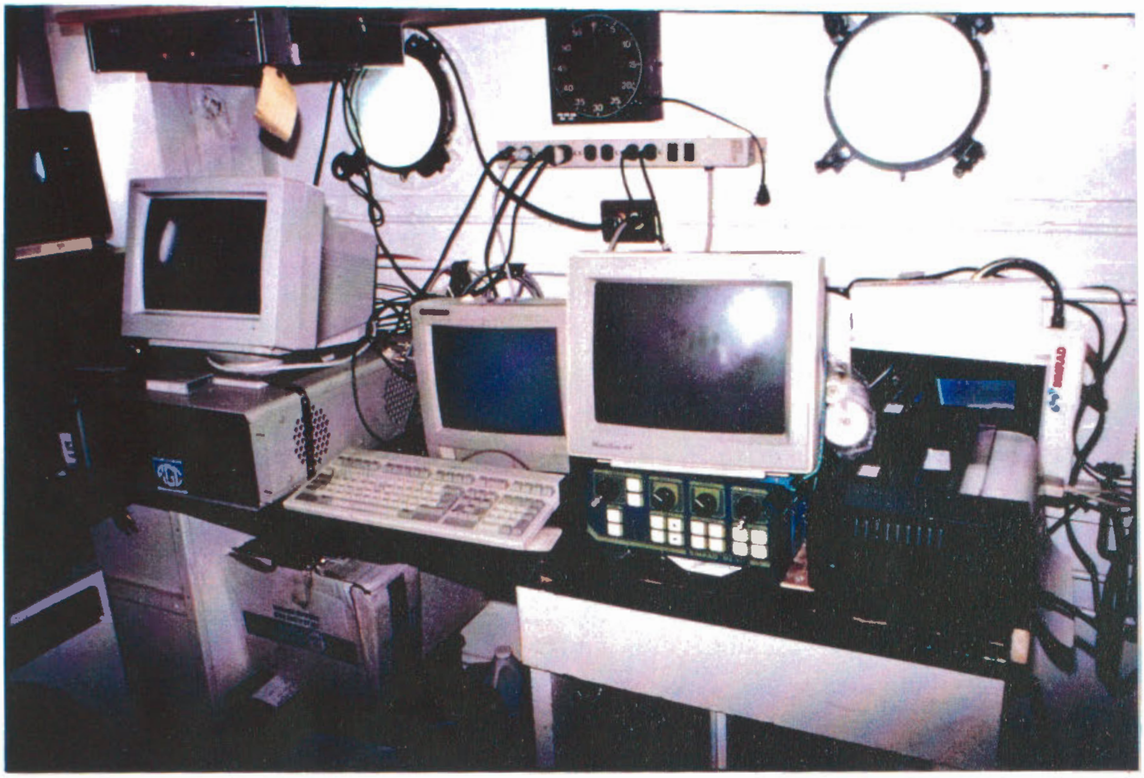


PLATE 6.1

PLATE 7.2

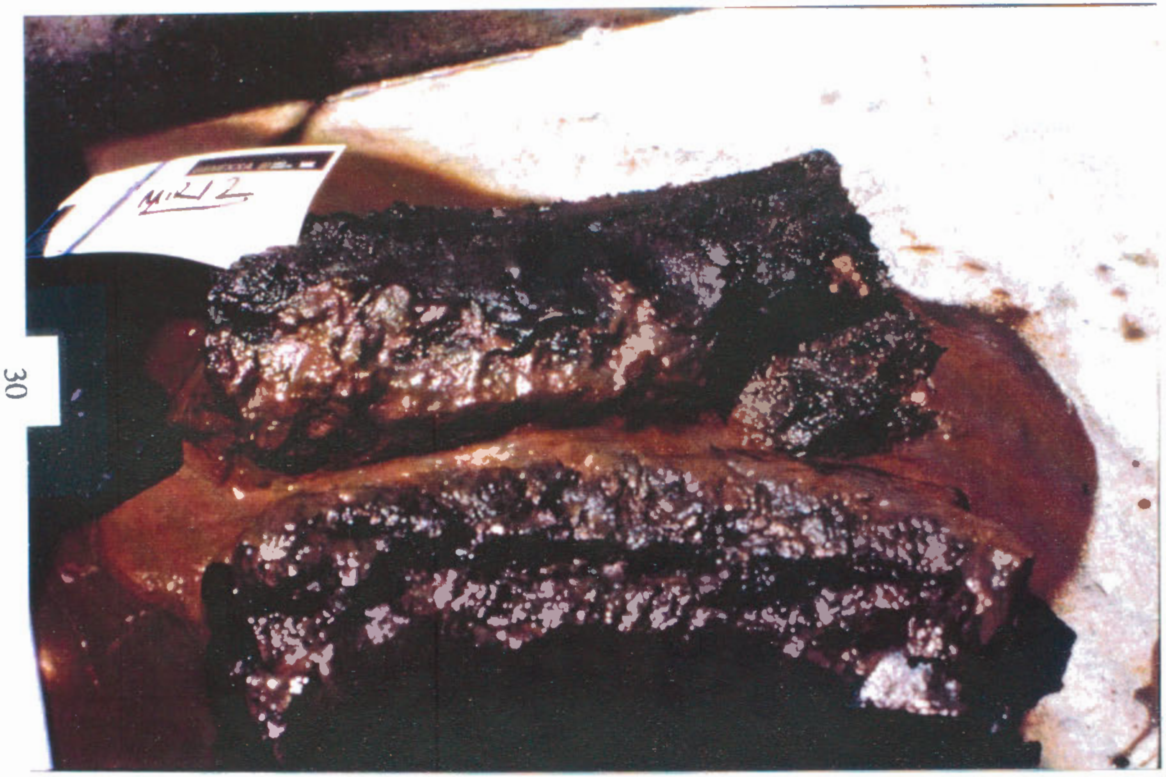


PLATE 8.1.1

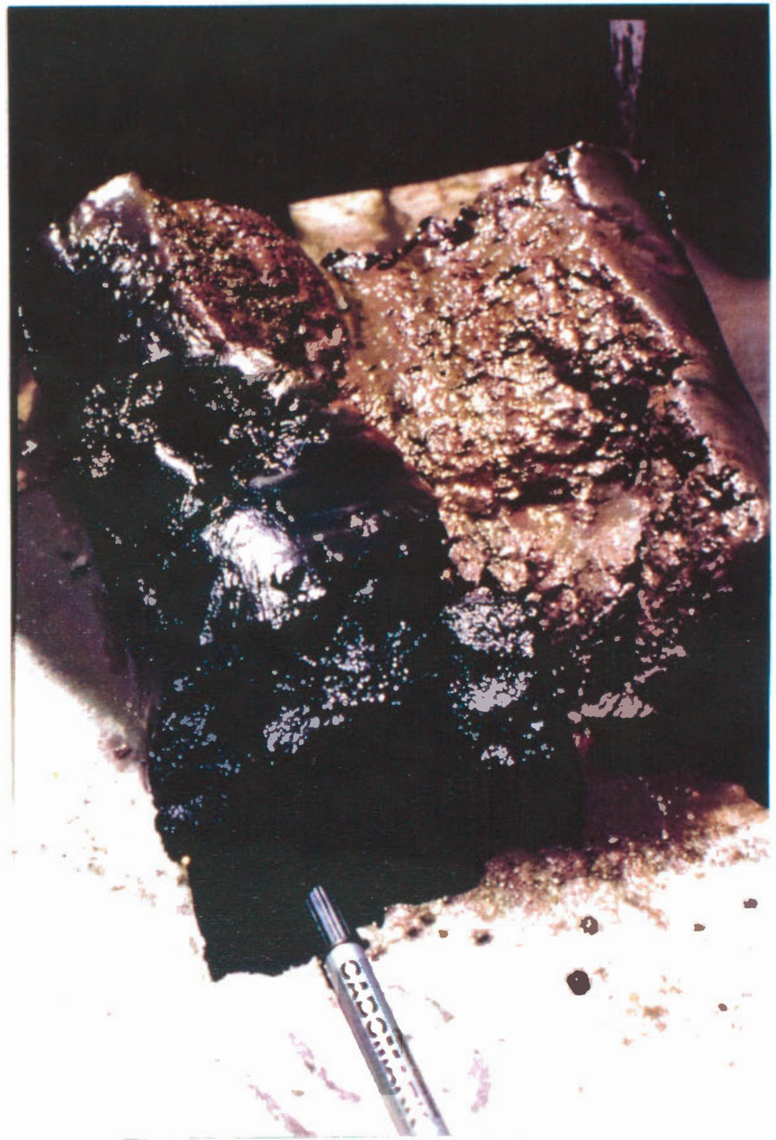
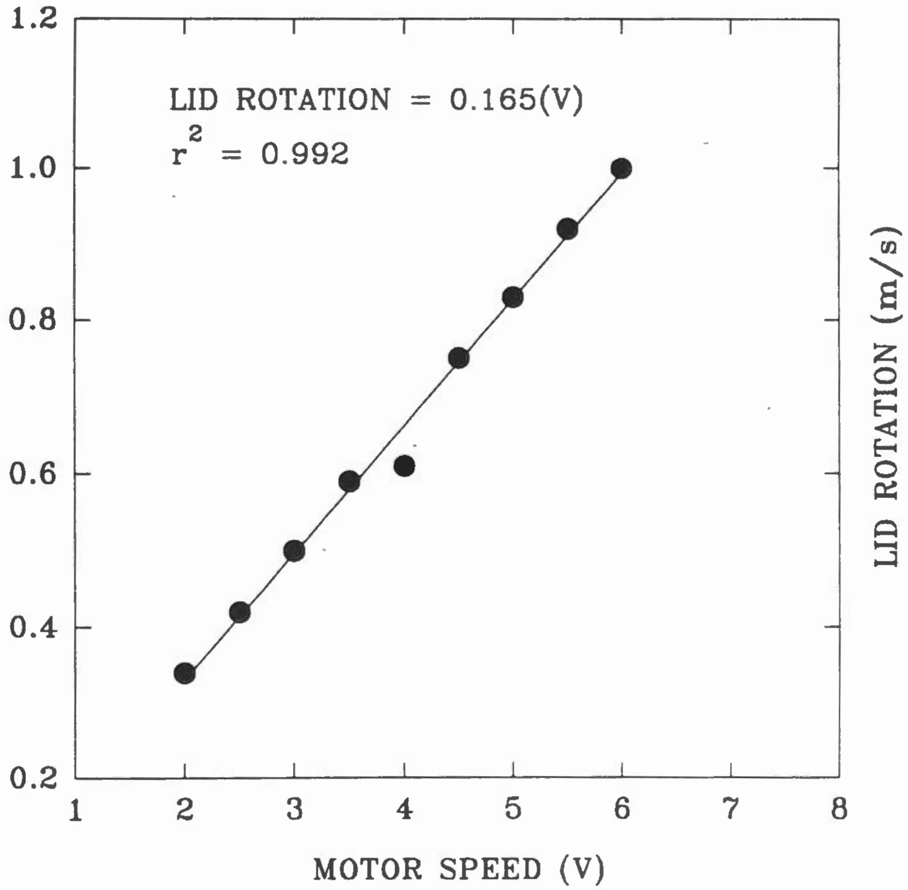


PLATE 8.1.2



LID ROTATION = 0.165(V)
r2 = 0.992
1.2
1.0
0.8
0.6
0.4
0.2
1
2
3
4
5
6
7
8
MOTOR SPEED (V)
LID ROTATION (m/s)

FIGURE 8.2.1

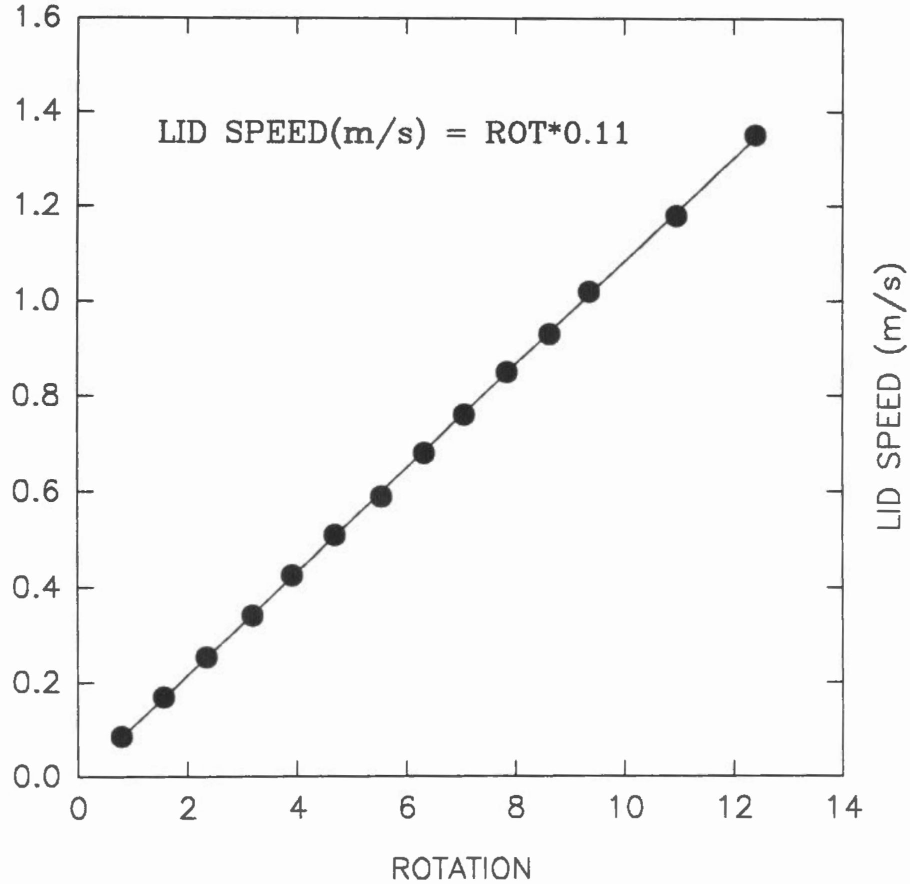
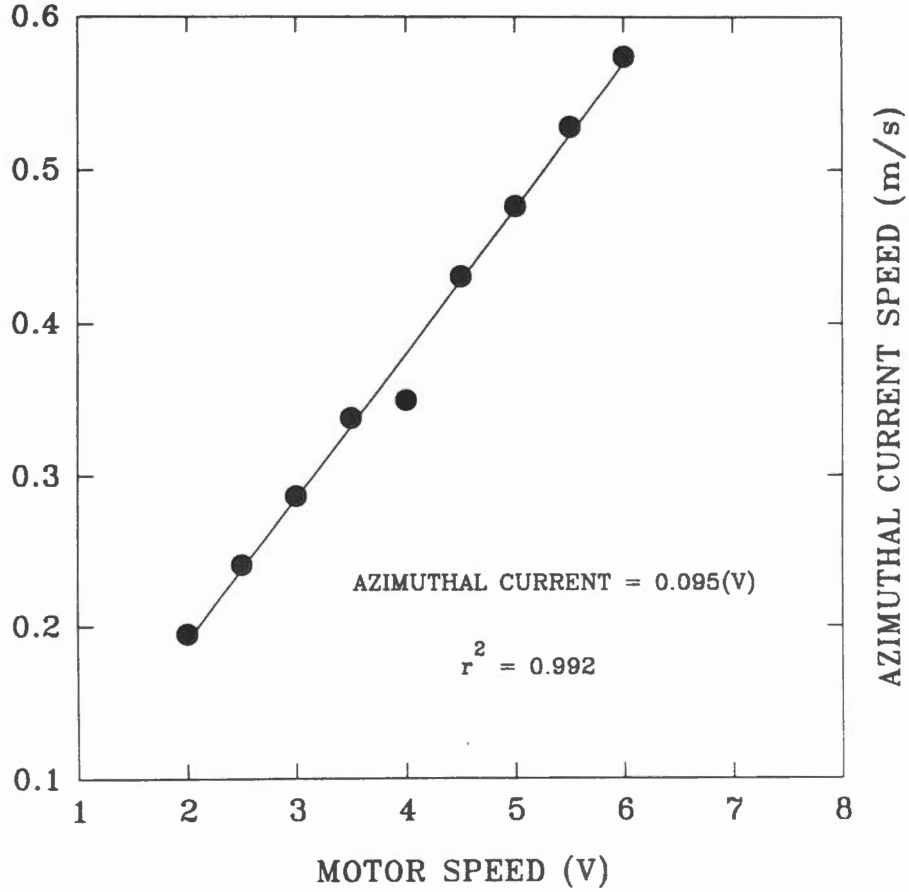

LID SPEED(m/s) = ROT*0.11
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
ROTATION
LID SPEED (m/s)

FIGURE 8.2.2



0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
8
MOTOR SPEED (V)
AZIMUTHAL CURRENT SPEED (m/s)
AZIMUTHAL CURRENT = 0.095(V)
r² = 0.992

FIGURE 8.2.3

8.2 4

SEA CAROUSEL – MIRAMICHI BAY

STATION MIR1 – 20 MAY, 1994

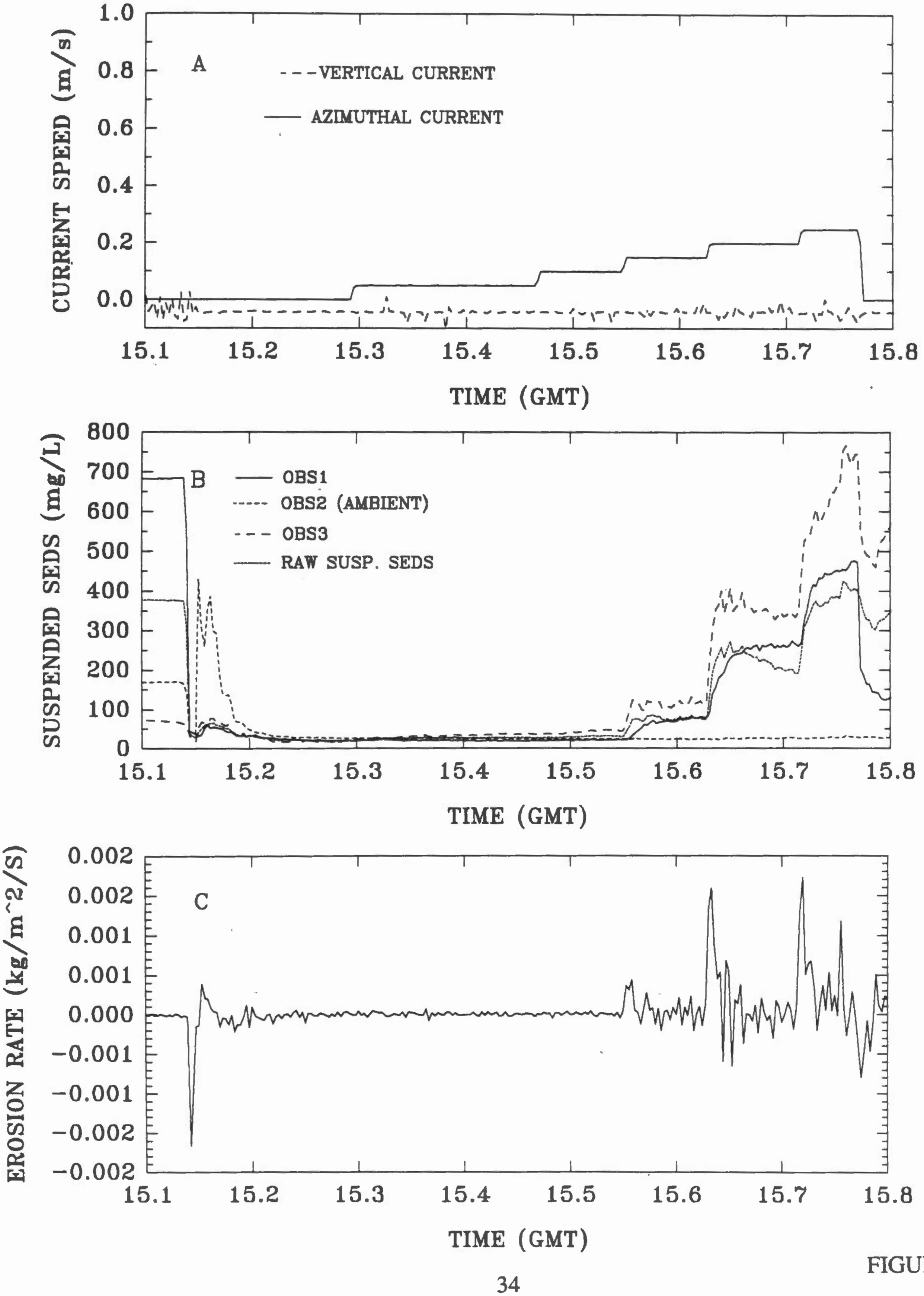


FIGURE 8.2.4

SEA CAROUSEL – MIRAMICHI BAY

STATION MIR1a – 20 MAY, 1994

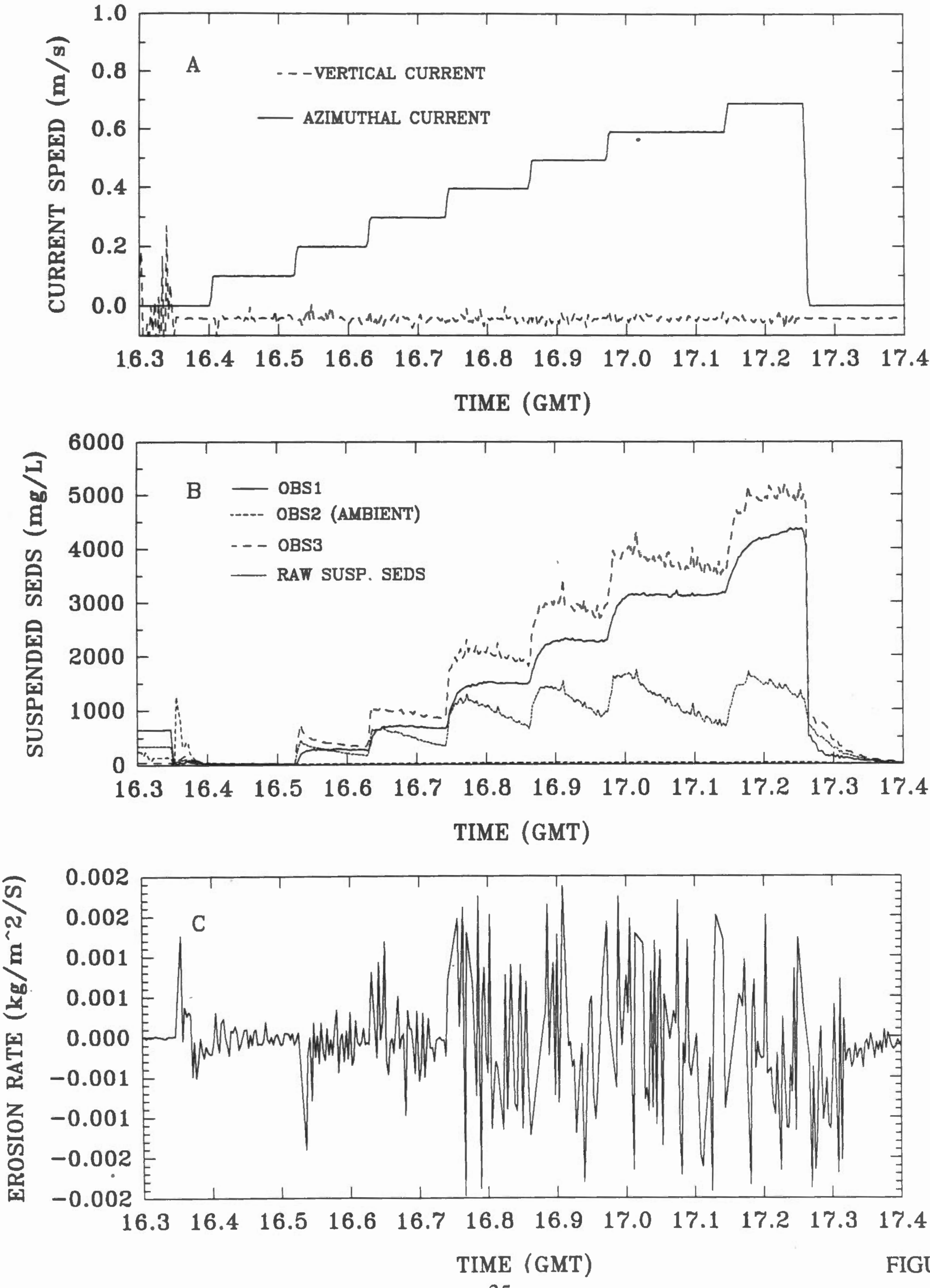


FIGURE 8.2.5

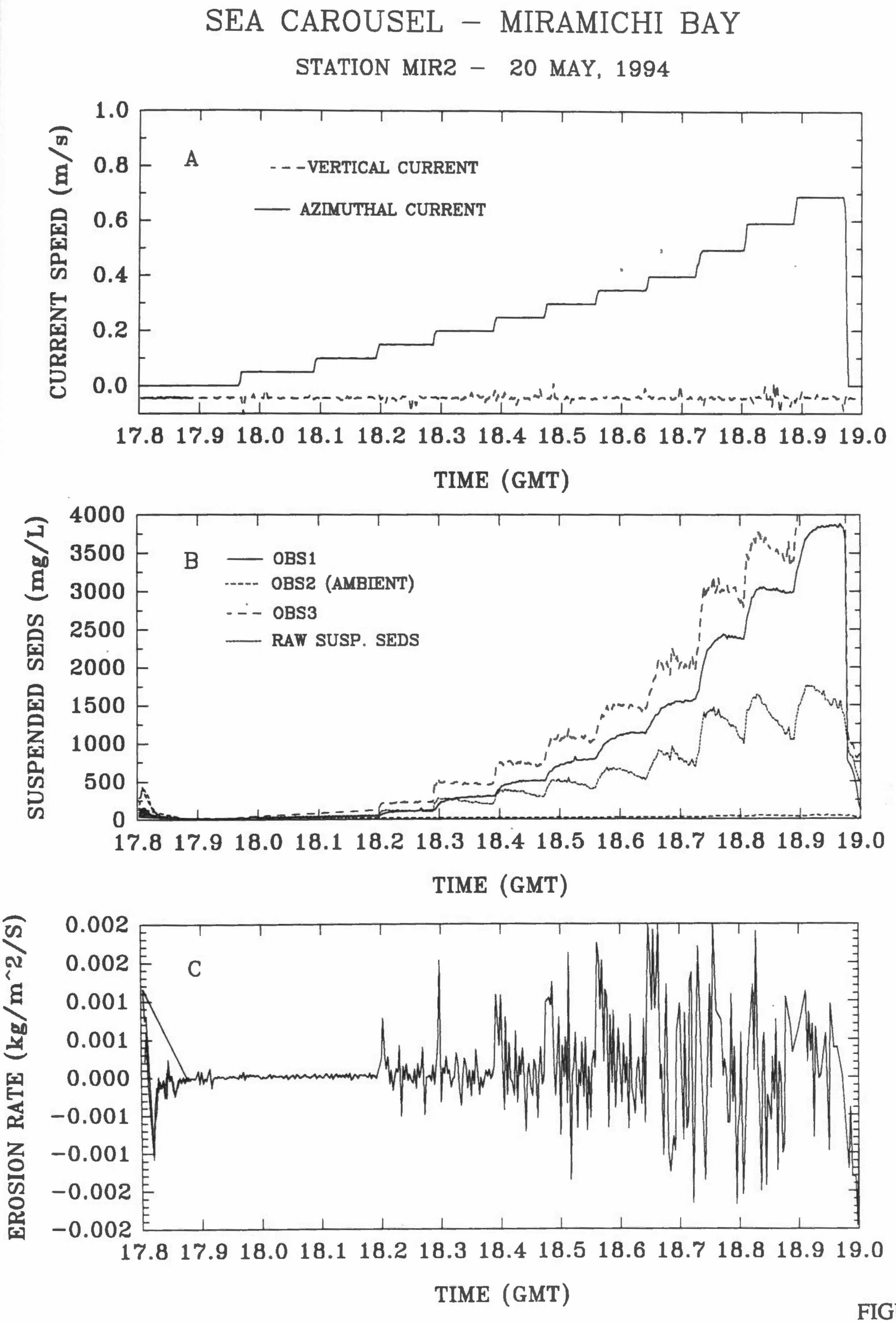

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR2 – 20 MAY, 1994
A
- - -VERTICAL CURRENT
—— AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0
TIME (GMT)
B
—— OBS1
----- OBS2 (AMBIENT)
- - - OBS3
—— RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.002
0.002
0.001
0.001
0.000
−0.001
−0.001
−0.002
−0.002
17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0
TIME (GMT)

FIGURE 8.2.6

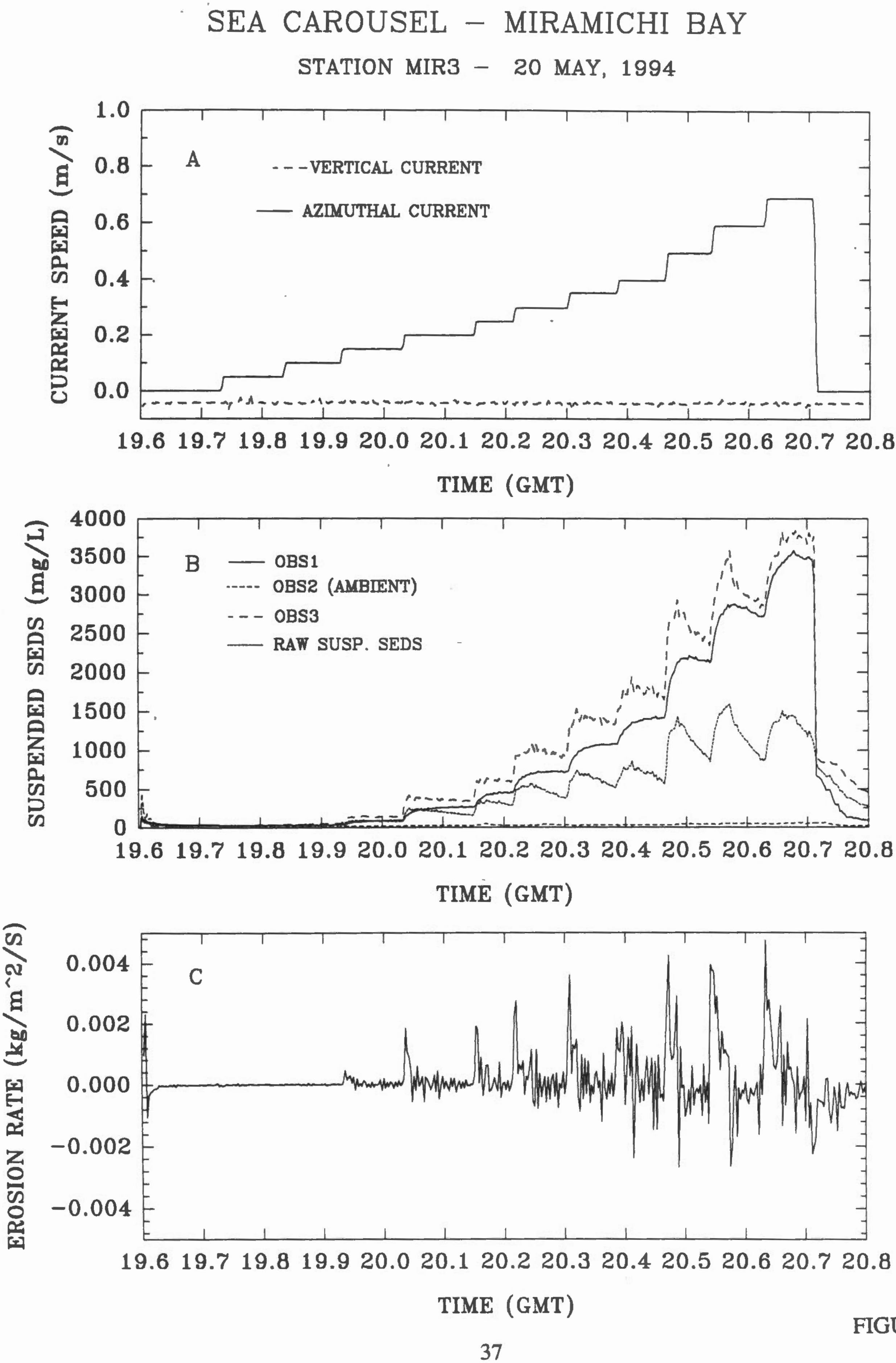
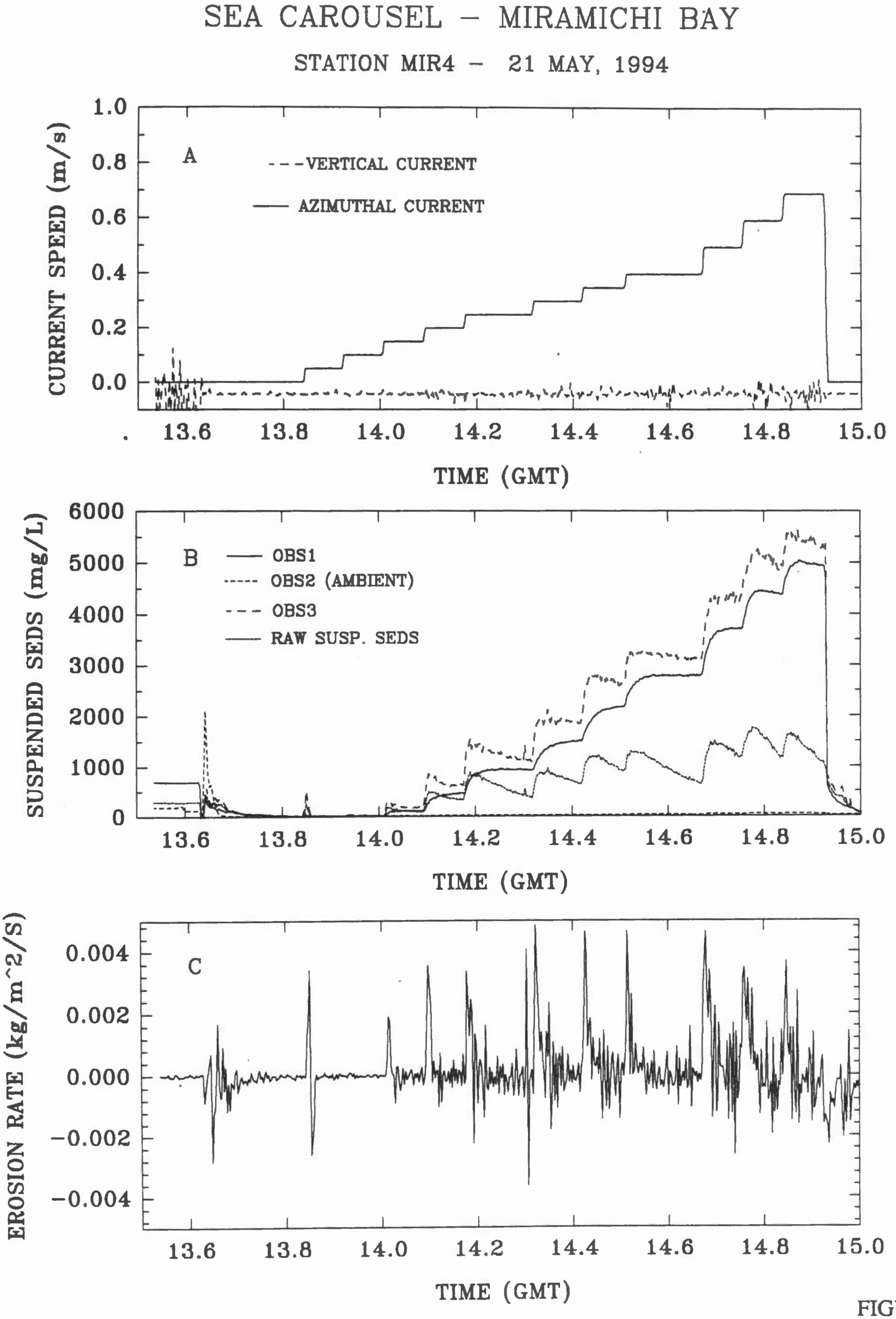
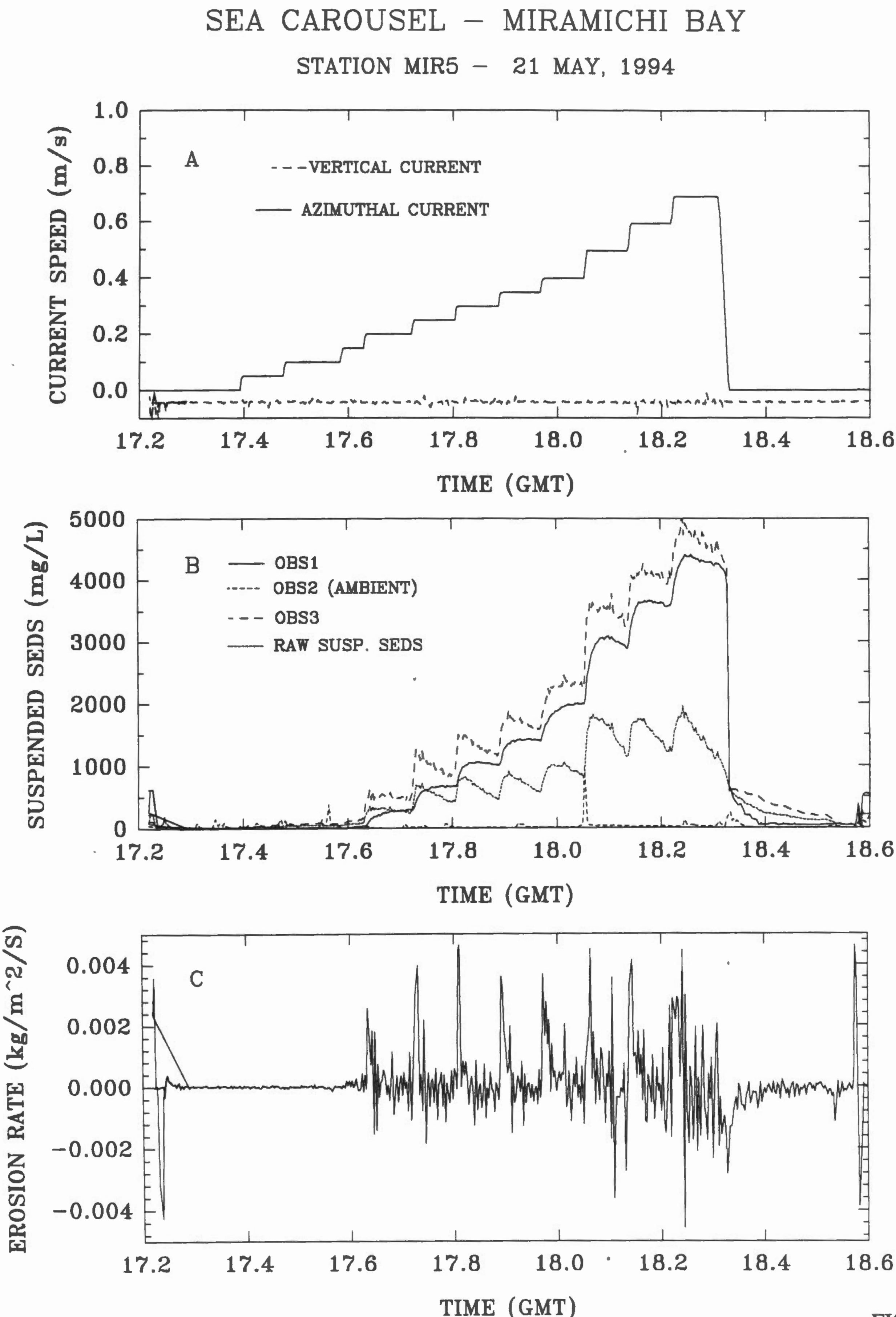

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR3 – 20 MAY, 1994
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
TIME (GMT)
19.6 19.7 19.8 19.9 20.0 20.1 20.2 20.3 20.4 20.5 20.6 20.7 20.8
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.004
0.002
0.000
−0.002
−0.004
TIME (GMT)

FIGURE 8.2.7



SEA CAROUSEL – MIRAMICHI BAY
STATION MIR4 – 21 MAY, 1994
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
13.6
13.8
14.0
14.2
14.4
14.6
14.8
15.0
TIME (GMT)
SUSPENDED SEDS (mg/L)
6000
5000
4000
3000
2000
1000
0
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
TIME (GMT)
EROSION RATE (kg/m^2/S)
0.004
0.002
0.000
−0.002
−0.004
C
TIME (GMT)

FIGURE 8.2.8



SEA CAROUSEL – MIRAMICHI BAY
STATION MIR5 – 21 MAY, 1994
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
17.2
17.4
17.6
17.8
18.0
18.2
18.4
18.6
TIME (GMT)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
5000
4000
3000
2000
1000
0
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.004
0.002
0.000
−0.002
−0.004
TIME (GMT)

FIGURE 8.2.9

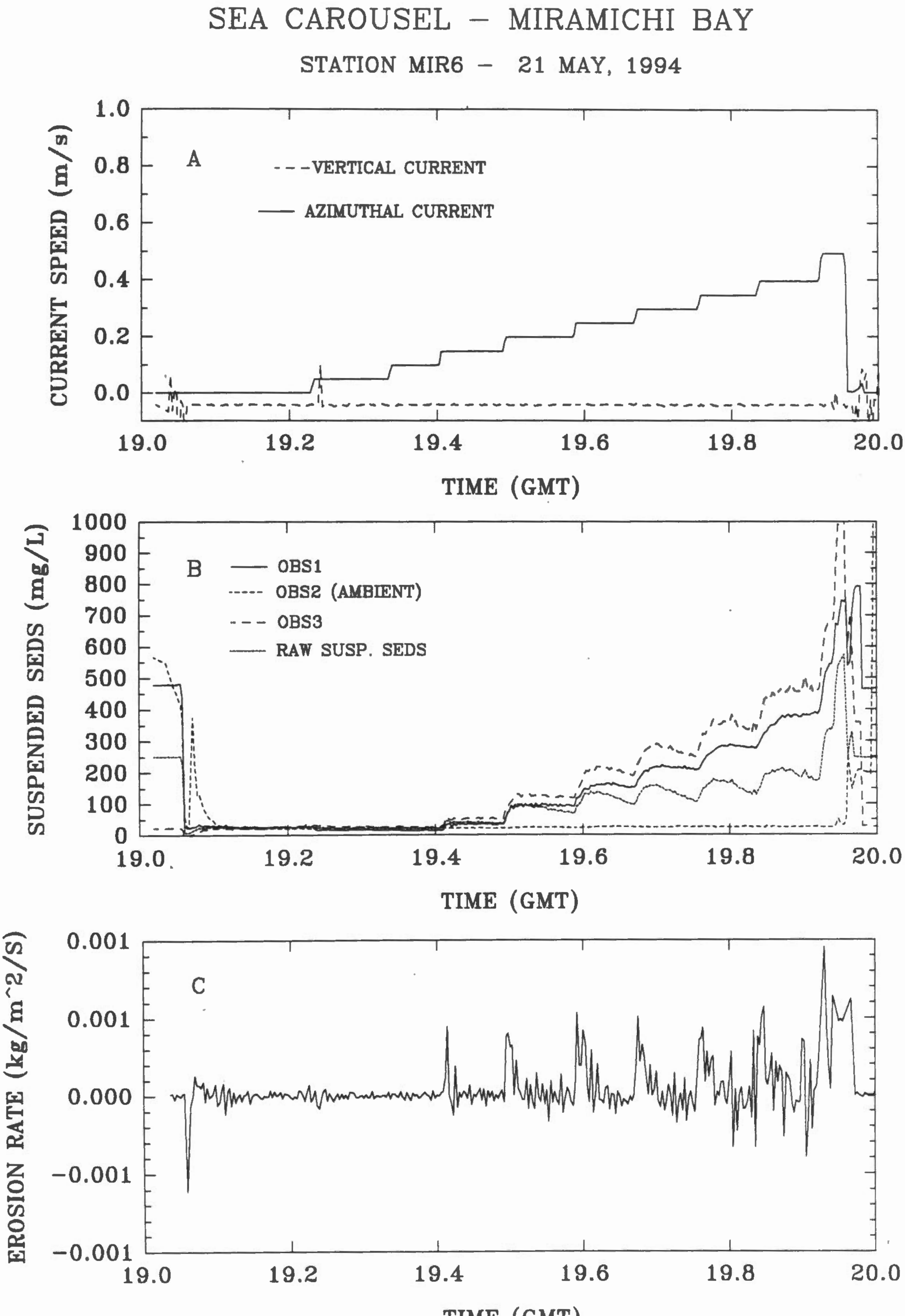

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR6 – 21 MAY, 1994
CURRENT SPEED (m/s)
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
1.0
0.8
0.6
0.4
0.2
0.0
19.0
19.2
19.4
19.6
19.8
20.0
TIME (GMT)
SUSPENDED SEDS (mg/L)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
1000
900
800
700
600
500
400
300
200
100
0
19.0
19.2
19.4
19.6
19.8
20.0
TIME (GMT)
EROSION RATE (kg/m^2/S)
C
0.001
0.001
0.000
−0.001
−0.001
19.0
19.2
19.4
19.6
19.8
20.0
TIME (GMT)

FIGURE 8.2.10

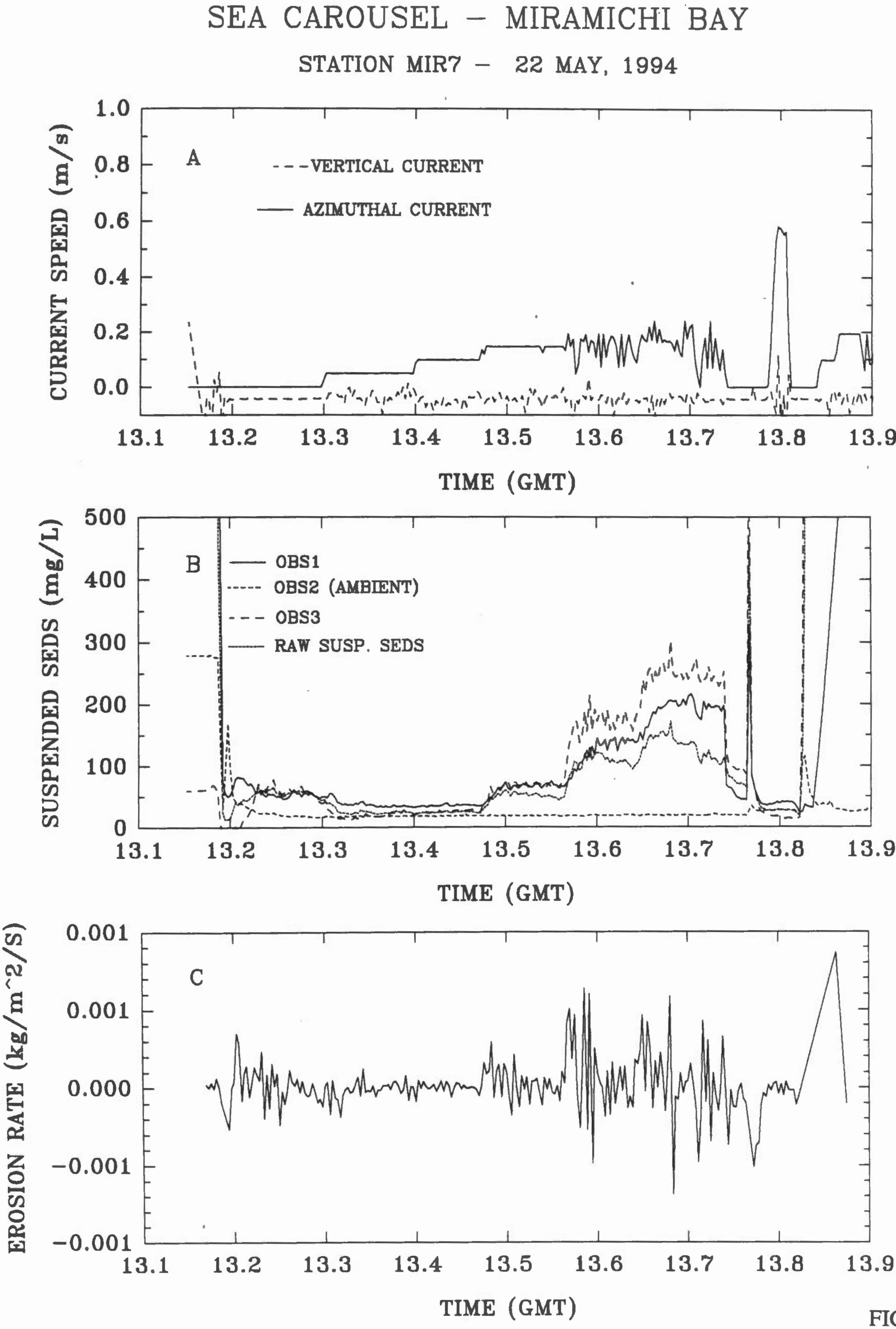

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR7 – 22 MAY, 1994
A
- - -VERTICAL CURRENT
—— AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
13.1
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
TIME (GMT)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
500
400
300
200
100
0
13.1
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.001
0.001
0.000
−0.001
−0.001
13.1
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
TIME (GMT)

FIGURE 8.2.11

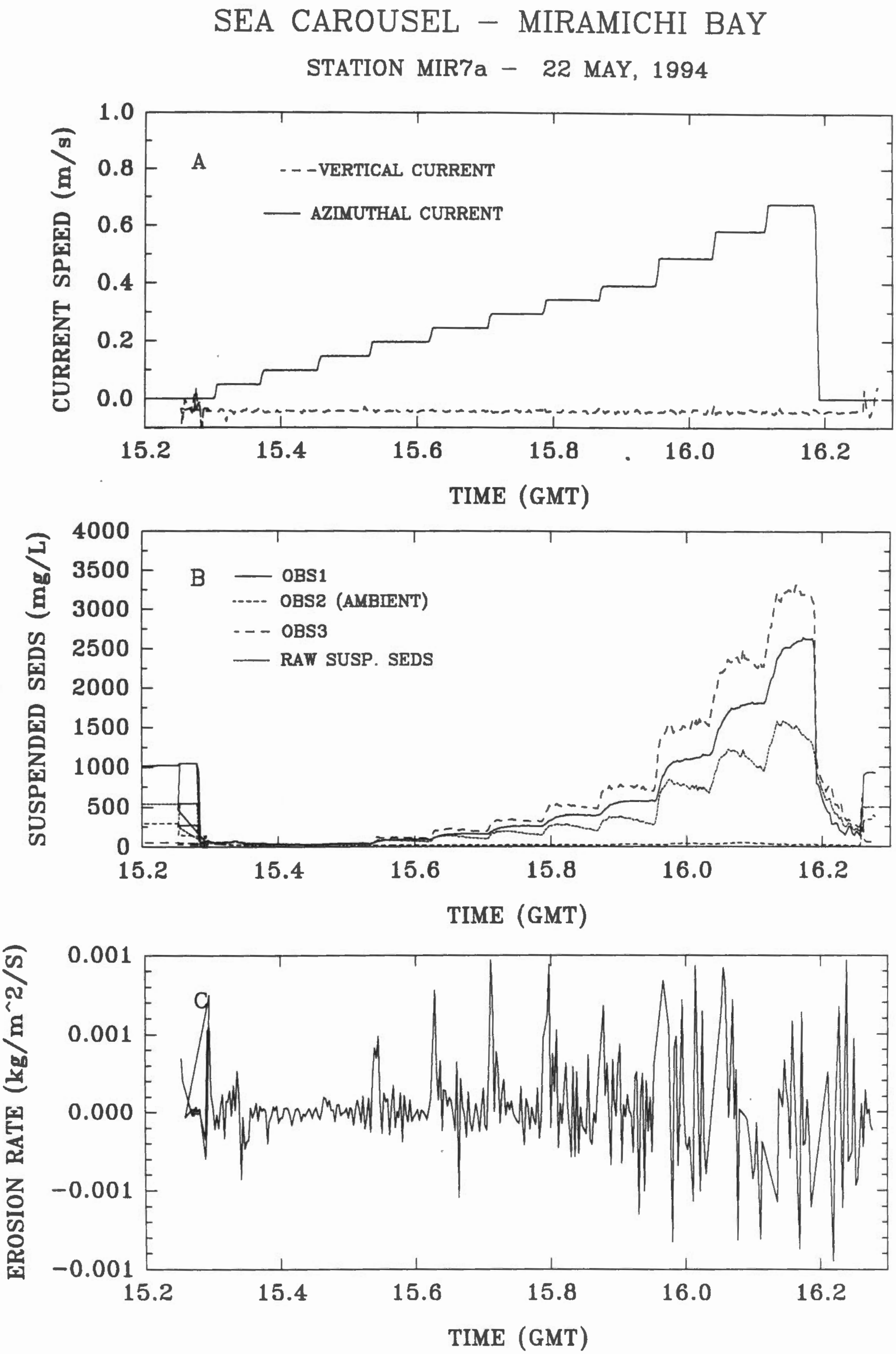

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR7a – 22 MAY, 1994
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
15.2
15.4
15.6
15.8
16.0
16.2
TIME (GMT)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
15.2
15.4
15.6
15.8
16.0
16.2
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.001
0.001
0.000
−0.001
−0.001
15.2
15.4
15.6
15.8
16.0
16.2
TIME (GMT)

FIGURE 8.2.12

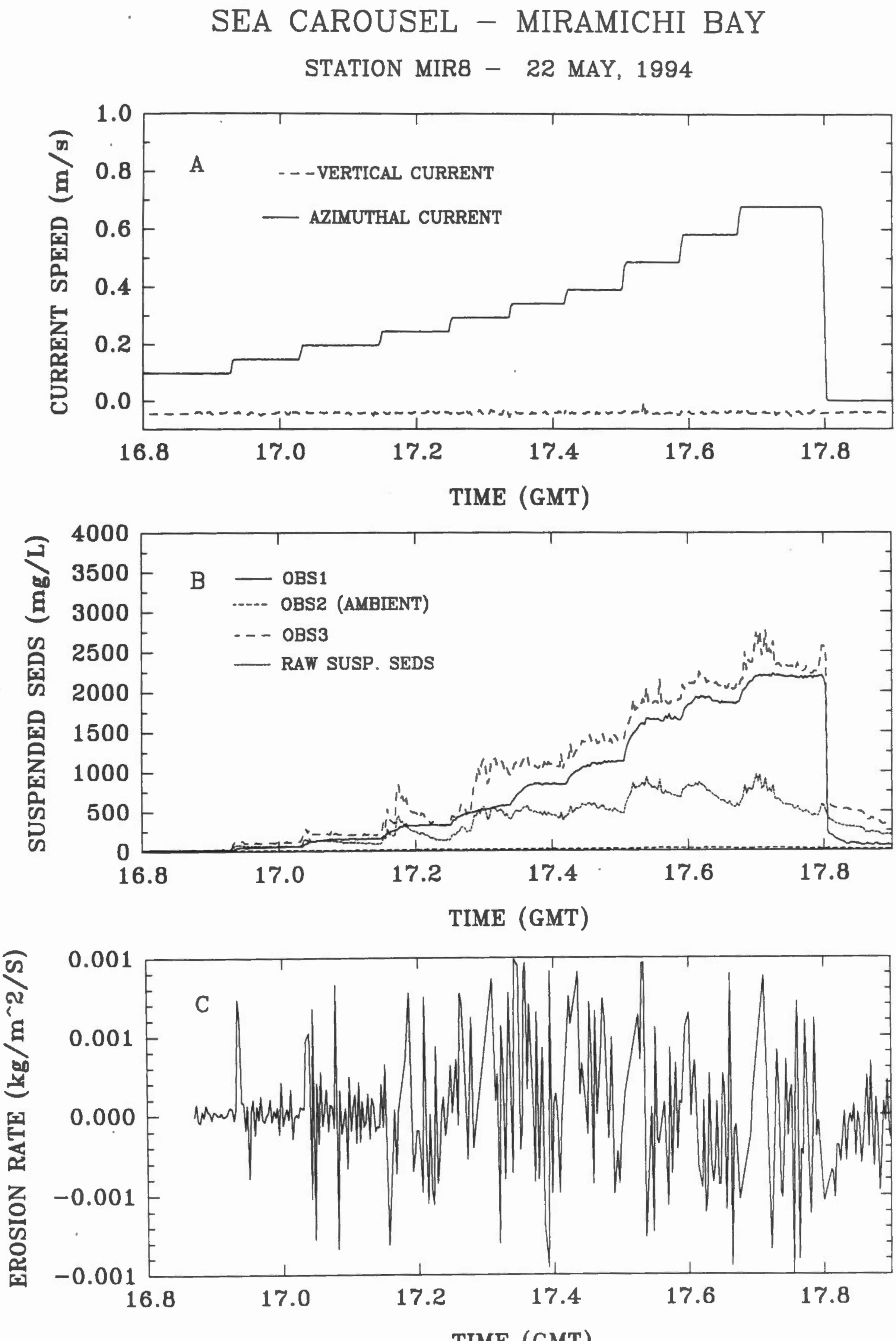
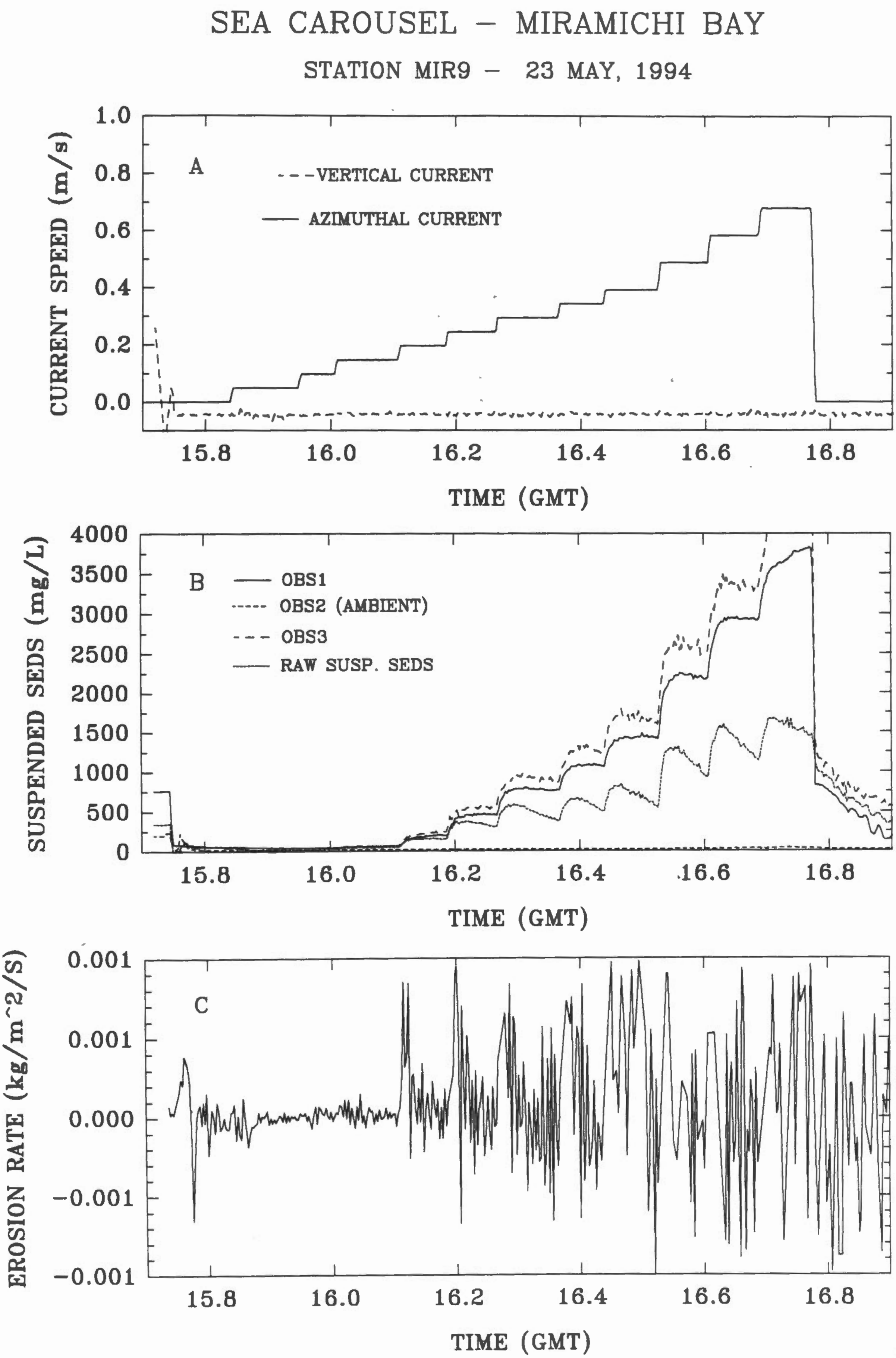

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR8 – 22 MAY, 1994
CURRENT SPEED (m/s)
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
1.0
0.8
0.6
0.4
0.2
0.0
16.8
17.0
17.2
17.4
17.6
17.8
TIME (GMT)
SUSPENDED SEDS (mg/L)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
4000
3500
3000
2500
2000
1500
1000
500
0
16.8
17.0
17.2
17.4
17.6
17.8
TIME (GMT)
EROSION RATE (kg/m^2/S)
C
0.001
0.001
0.000
−0.001
−0.001
16.8
17.0
17.2
17.4
17.6
17.8
TIME (GMT)

FIGURE 8.2.13



SEA CAROUSEL – MIRAMICHI BAY
STATION MIR9 – 23 MAY, 1994
A
- - -VERTICAL CURRENT
—— AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
15.8
16.0
16.2
16.4
16.6
16.8
TIME (GMT)
B
—— OBS1
----- OBS2 (AMBIENT)
- - - OBS3
—— RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
15.8
16.0
16.2
16.4
16.6
16.8
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.001
0.001
0.000
−0.001
−0.001
15.8
16.0
16.2
16.4
16.6
16.8
TIME (GMT)

FIGURE 8.2.14

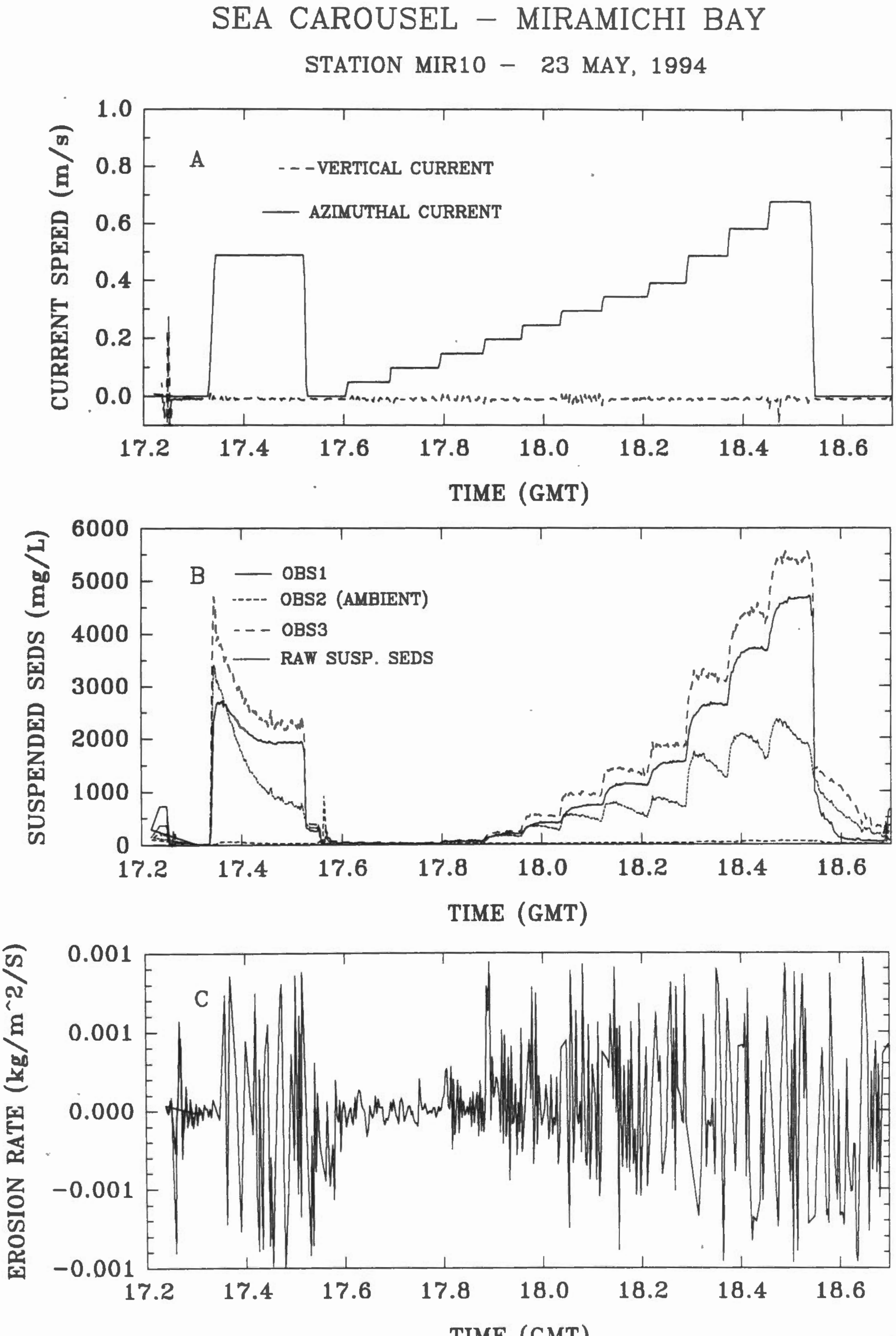
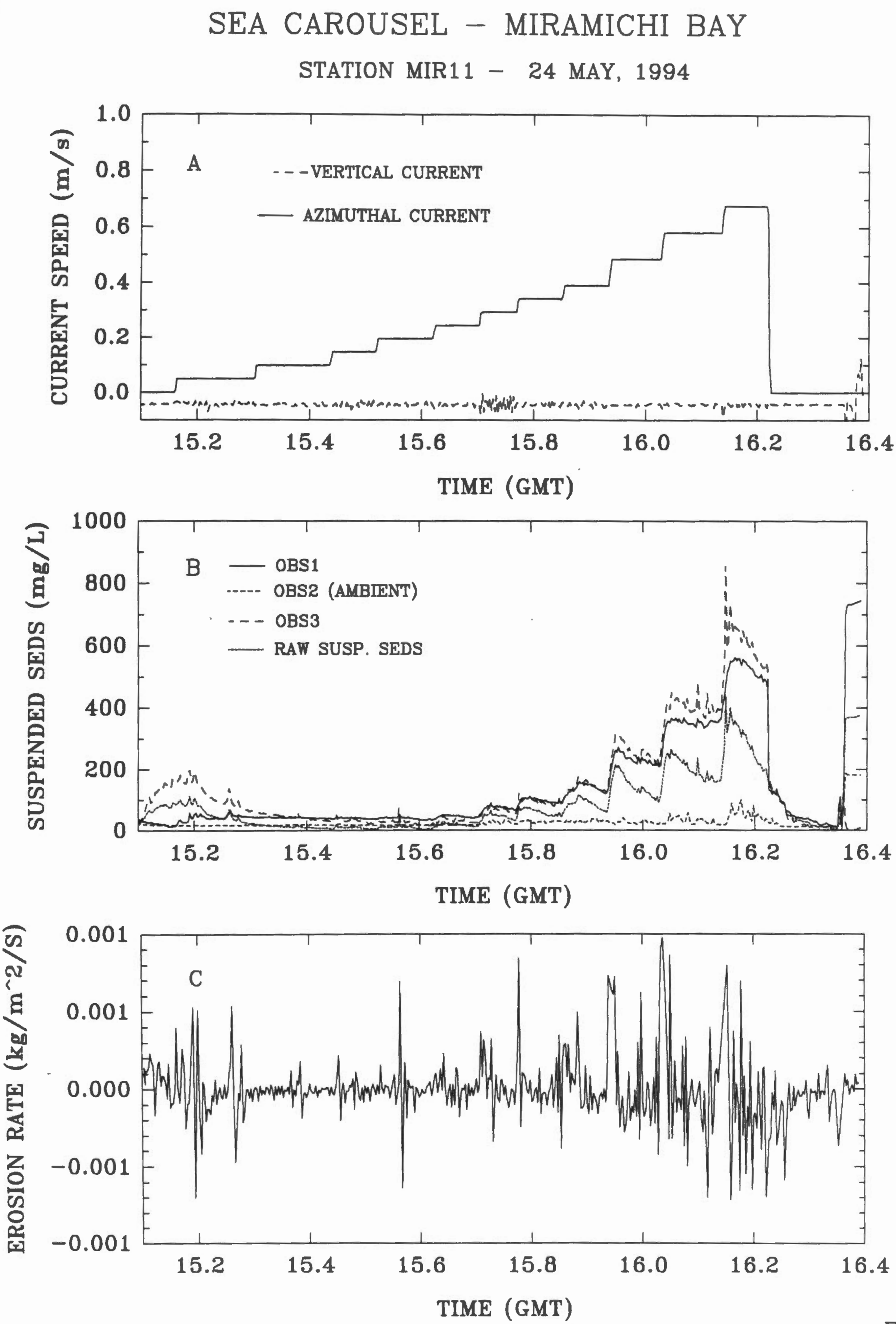

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR10 – 23 MAY, 1994
CURRENT SPEED (m/s)
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
1.0
0.8
0.6
0.4
0.2
0.0
17.2
17.4
17.6
17.8
18.0
18.2
18.4
18.6
TIME (GMT)
SUSPENDED SEDS (mg/L)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
6000
5000
4000
3000
2000
1000
0
TIME (GMT)
EROSION RATE (kg/m^2/S)
C
0.001
0.001
0.000
−0.001
−0.001
TIME (GMT)

FIGURE 8.2.15



SEA CAROUSEL – MIRAMICHI BAY
STATION MIR11 – 24 MAY, 1994
A
---VERTICAL CURRENT
AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
15.2
15.4
15.6
15.8
16.0
16.2
16.4
TIME (GMT)
B
OBS1
OBS2 (AMBIENT)
OBS3
RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
1000
800
600
400
200
0
15.2
15.4
15.6
15.8
16.0
16.2
16.4
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.001
0.001
0.000
−0.001
−0.001
15.2
15.4
15.6
15.8
16.0
16.2
16.4
TIME (GMT)

FIGURE 8.2.16

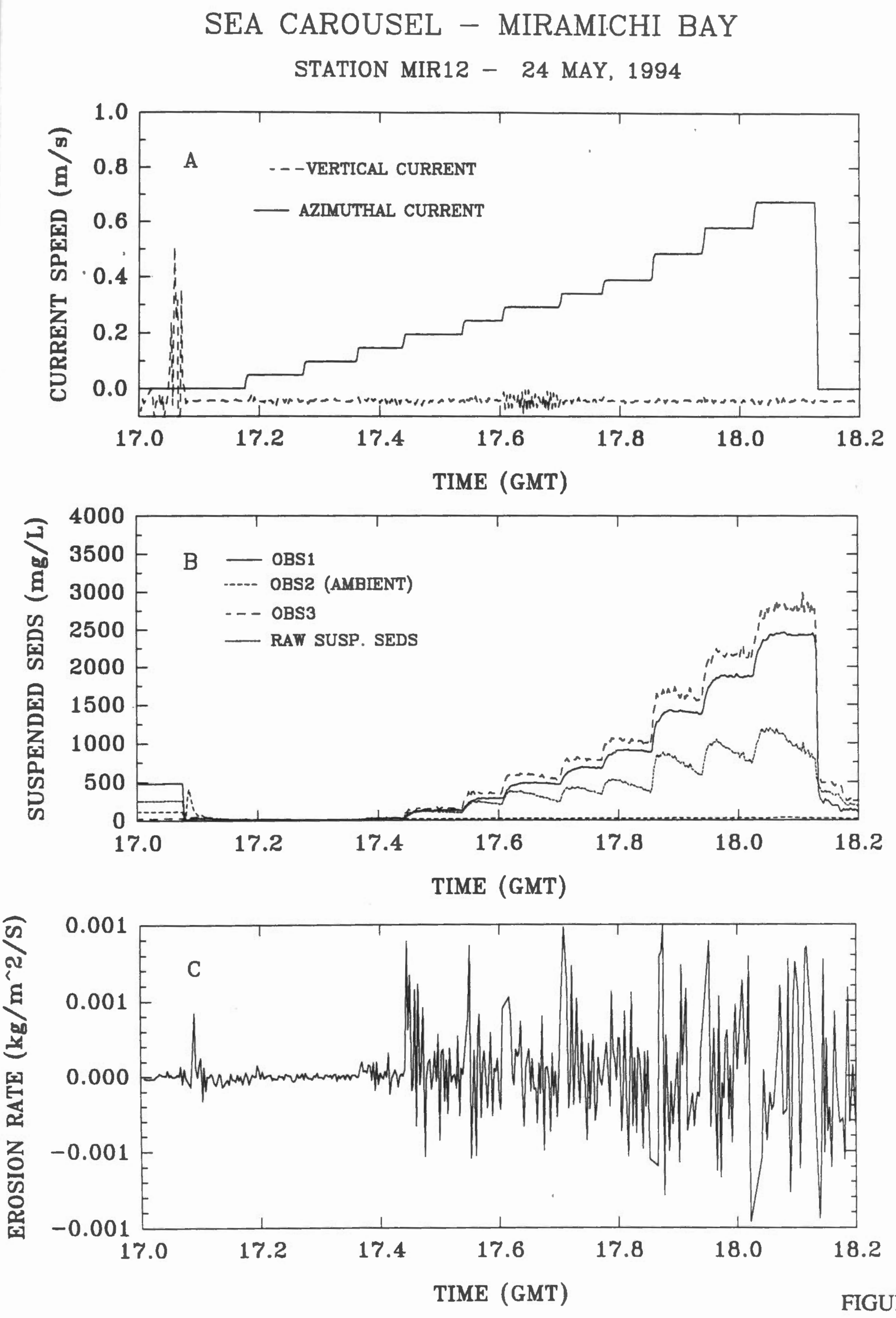

SEA CAROUSEL – MIRAMICHI BAY
STATION MIR12 – 24 MAY, 1994
A
---VERTICAL CURRENT
—— AZIMUTHAL CURRENT
CURRENT SPEED (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
17.0
17.2
17.4
17.6
17.8
18.0
18.2
TIME (GMT)
B
—— OBS1
----- OBS2 (AMBIENT)
- - - OBS3
—— RAW SUSP. SEDS
SUSPENDED SEDS (mg/L)
4000
3500
3000
2500
2000
1500
1000
500
0
17.0
17.2
17.4
17.6
17.8
18.0
18.2
TIME (GMT)
C
EROSION RATE (kg/m^2/S)
0.001
0.001
0.000
−0.001
−0.001
17.0
17.2
17.4
17.6
17.8
18.0
18.2
TIME (GMT)

FIGURE 8.2.17

SEA CAROUSEL – MIRAMICHI BAY

STATION MIR13 – 24 MAY, 1994

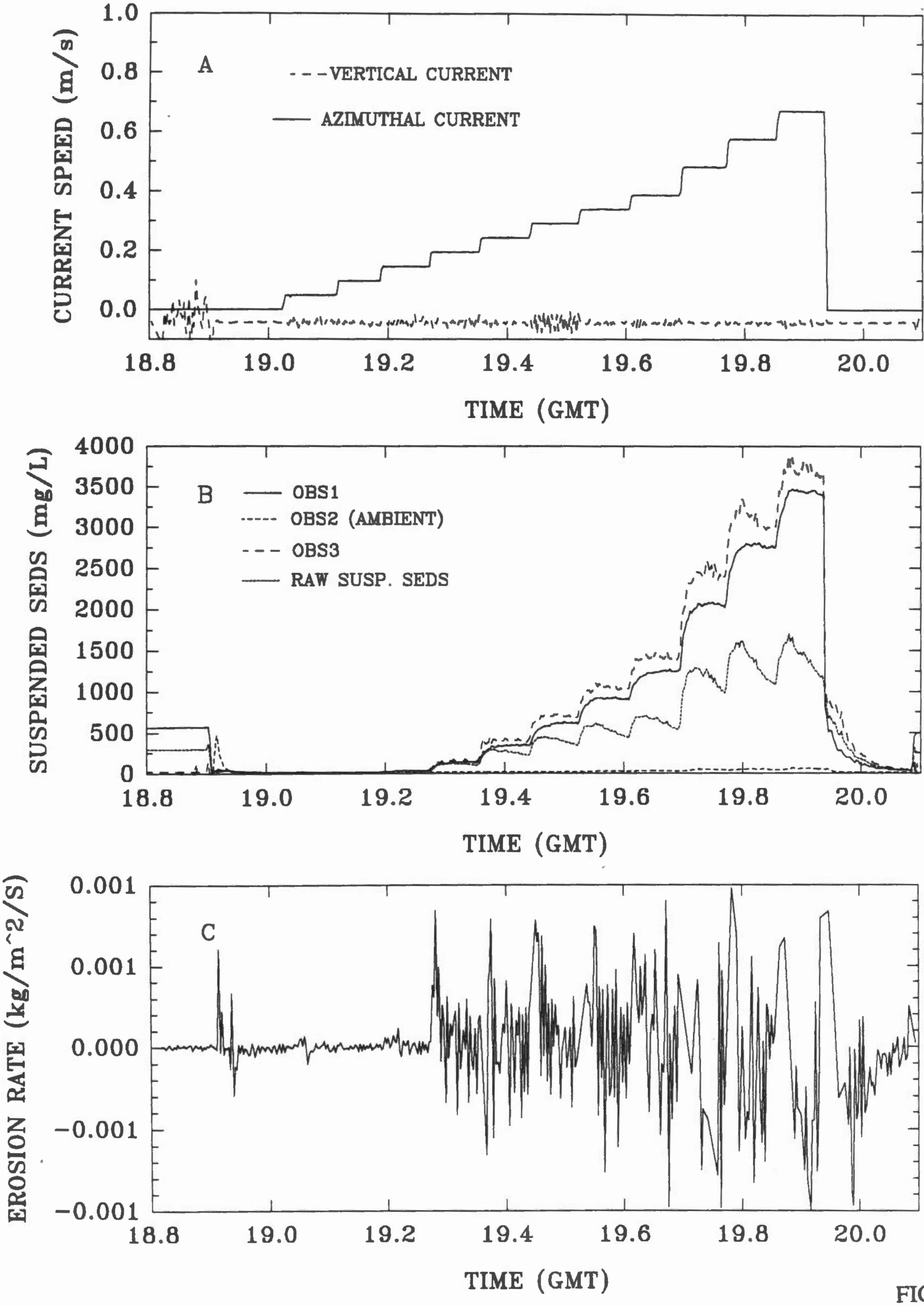


FIGURE 8.2.18

SEA CAROUSEL – MIRAMICHI BAY

STATION MIR14 – 24 MAY, 1994

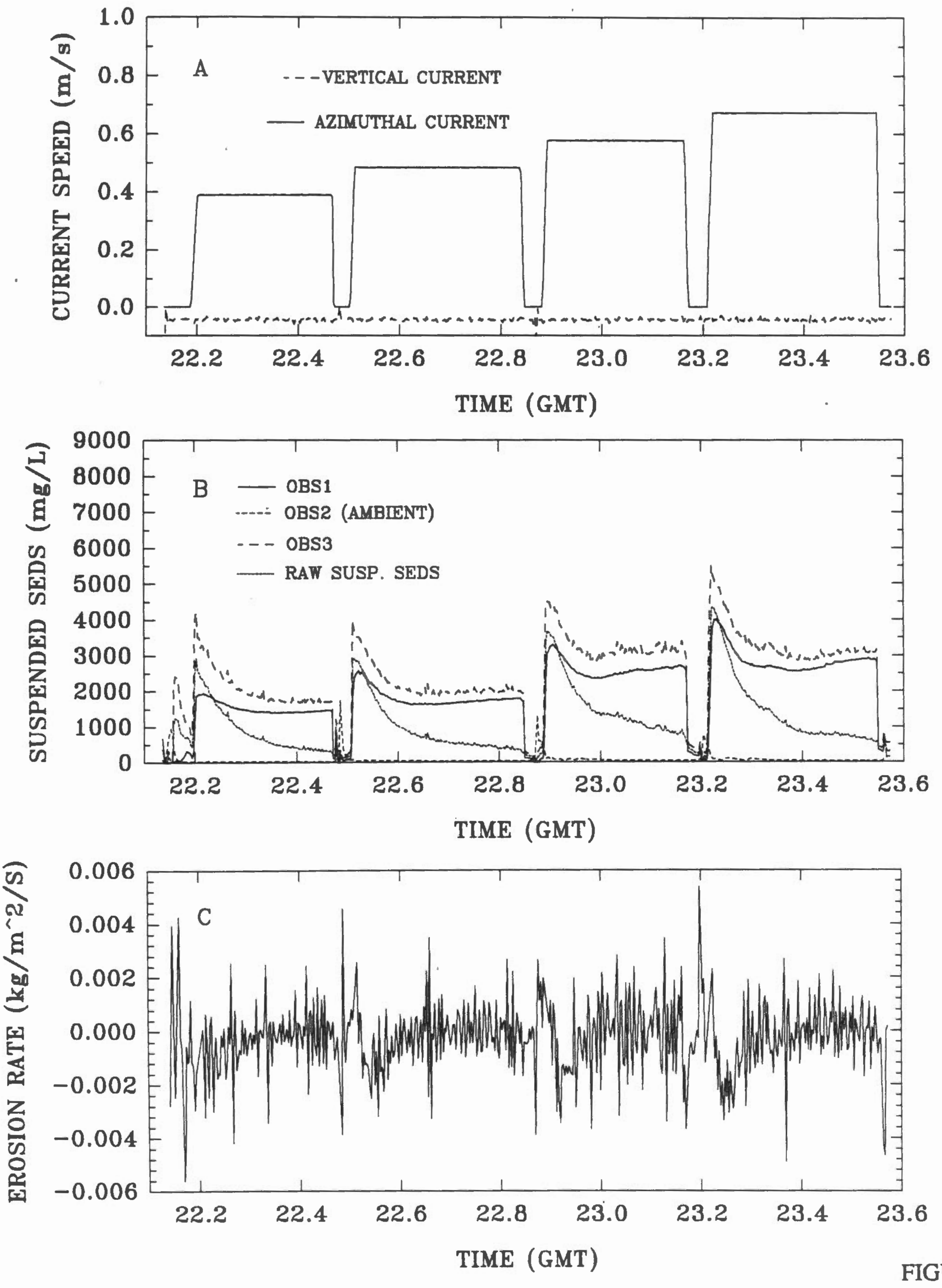


FIGURE 8.2.19

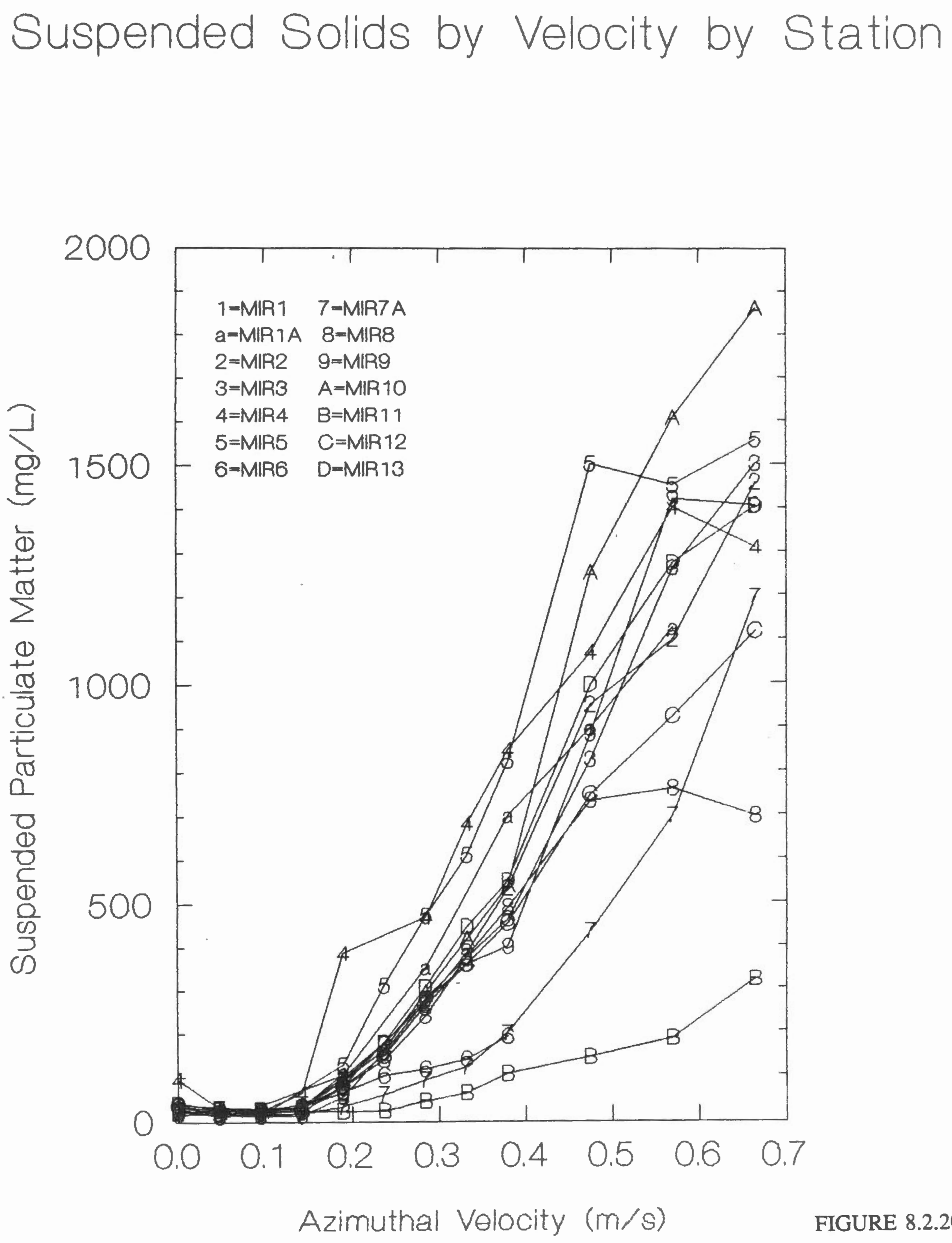

Suspended Solids by Velocity by Station
Suspended Particulate Matter (mg/L)
Azimuthal Velocity (m/s)
1=MIR1
7=MIR7A
a=MIR1A
8=MIR8
2=MIR2
9=MIR9
3=MIR3
A=MIR10
4=MIR4
B=MIR11
5=MIR5
C=MIR12
6=MIR6
D=MIR13
0
500
1000
1500
2000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

FIGURE 8.2.20

TIDAL SECTION, CHS ATLANTIC
(902) 426-3846

HOURLY PREDICTIONS FOR ROBICHAUD SPIT
LATITUDE= 47 15 LONGITUDE= 65 15 TIME ZONE= AST DT= 1.0000 HOURS

HEIGHTS ARE IN METRES REFERRED TO CHART DATUM

MAY 1994

DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 HOUR
15	0.5	0.6	0.7	0.9	1.1	1.3	1.4	1.4	1.3	1.1	0.9	0.7	0.5	0.4	0.4	0.4	0.4	0.6	0.7	0.7	0.7	0.7	0.6	0.5
16	0.5	0.5	0.6	0.7	0.9	1.1	1.3	1.4	1.3	1.2	1.0	0.8	0.6	0.5	0.4	0.4	0.4	0.5	0.6	0.7	0.8	0.7	0.7	0.6
17	0.5	0.5	0.5	0.6	0.7	0.9	1.1	1.2	1.3	1.2	1.1	0.9	0.8	0.6	0.5	0.4	0.4	0.4	0.5	0.7	0.8	0.8	0.8	0.7
18	0.6	0.5	0.5	0.5	0.5	0.7	0.8	1.0	1.1	1.2	1.1	1.0	0.9	0.7	0.6	0.5	0.4	0.4	0.4	0.6	0.7	0.9	0.9	0.9
19	0.8	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.9	1.0	1.1	1.1	1.0	0.8	0.7	0.5	0.4	0.4	0.4	0.5	0.6	0.8	0.9	1.0
20	1.0	0.9	0.8	0.7	0.5	0.5	0.4	0.5	0.6	0.8	0.9	1.0	1.0	0.9	0.8	0.7	0.5	0.4	0.4	0.4	0.5	0.7	0.9	1.0
21	1.1	1.1	1.0	0.9	0.7	0.6	0.4	0.4	0.4	0.5	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.5	0.4	0.4	0.4	0.6	0.8	1.0
22	1.2	1.3	1.3	1.1	1.0	0.8	0.6	0.4	0.3	0.3	0.4	0.6	0.7	0.9	0.9	0.9	0.8	0.7	0.5	0.4	0.4	0.5	0.6	0.9
23	1.1	1.3	1.4	1.4	1.2	1.0	0.8	0.5	0.3	0.2	0.3	0.4	0.5	0.7	0.8	0.9	0.9	0.8	0.7	0.5	0.4	0.4	0.5	0.7
24	0.9	1.2	1.4	1.5	1.4	1.3	1.0	0.8	0.5	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.9	0.8	0.6	0.5	0.4	0.4	0.5
25	0.8	1.0	1.3	1.5	1.6	1.5	1.3	1.0	0.7	0.5	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.8	0.7	0.6	0.5	0.4	0.4
26	0.6	0.8	1.1	1.4	1.6	1.6	1.5	1.2	1.0	0.7	0.5	0.2	0.2	0.2	0.3	0.5	0.7	0.8	0.8	0.8	0.7	0.6	0.5	0.5
27	0.5	0.7	0.9	1.2	1.5	1.6	1.6	1.4	1.2	0.9	0.7	0.4	0.2	0.2	0.2	0.4	0.6	0.7	0.8	0.8	0.8	0.7	0.6	0.5
28	0.5	0.5	0.8	1.0	1.3	1.5	1.6	1.5	1.3	1.1	0.9	0.6	0.4	0.2	0.2	0.3	0.4	0.6	0.7	0.8	0.8	0.7	0.7	0.6
29	0.5	0.5	0.6	0.8	1.1	1.3	1.5	1.5	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.2	0.4	0.5	0.7	0.8	0.8	0.8	0.7	0.7
30	0.6	0.5	0.5	0.7	0.9	1.1	1.3	1.4	1.4	1.3	1.1	0.9	0.7	0.5	0.4	0.3	0.3	0.5	0.6	0.7	0.8	0.8	0.8	0.7
31	0.7	0.6	0.6	0.6	0.7	0.9	1.1	1.2	1.3	1.2	1.1	1.0	0.9	0.7	0.5	0.4	0.4	0.4	0.6	0.7	0.8	0.9	0.8	0.8

TABLE 8.3.1

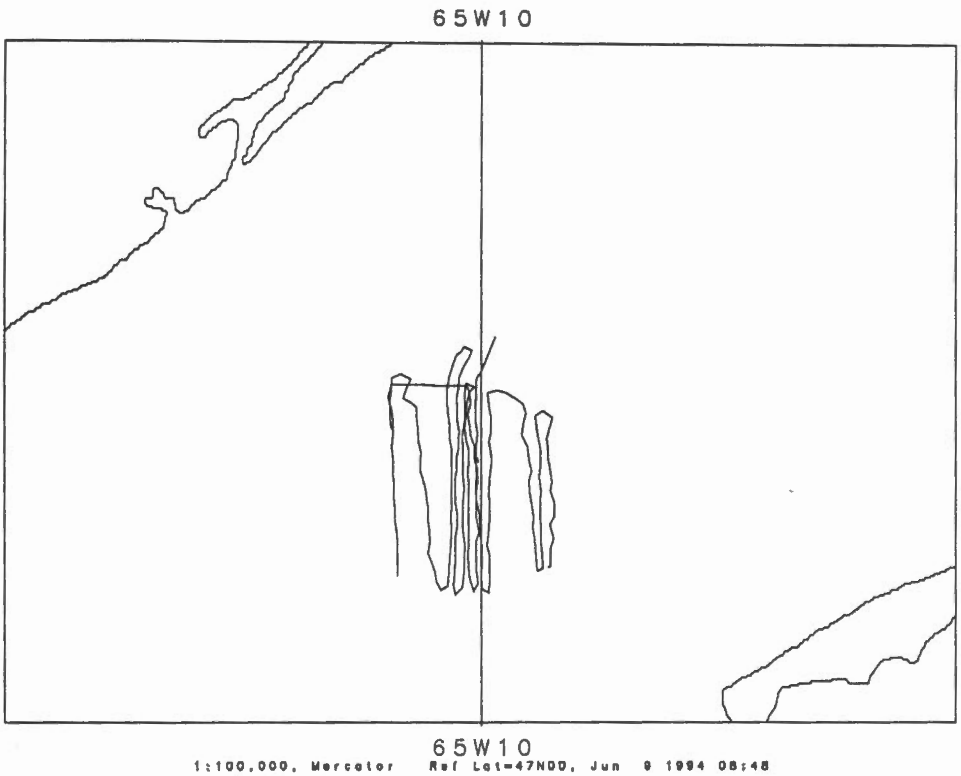


FIGURE 8.3.1A

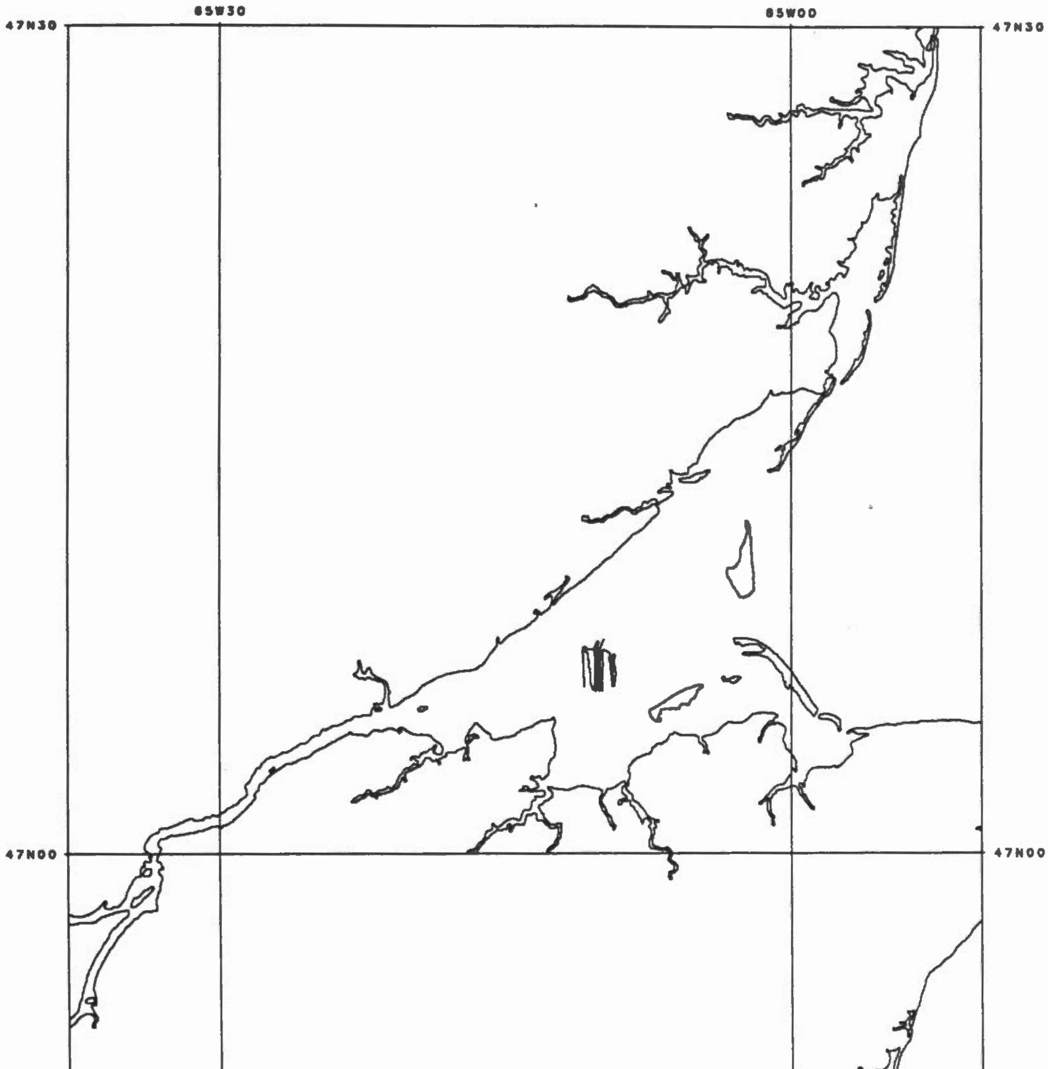


FIGURE 8.3.1B

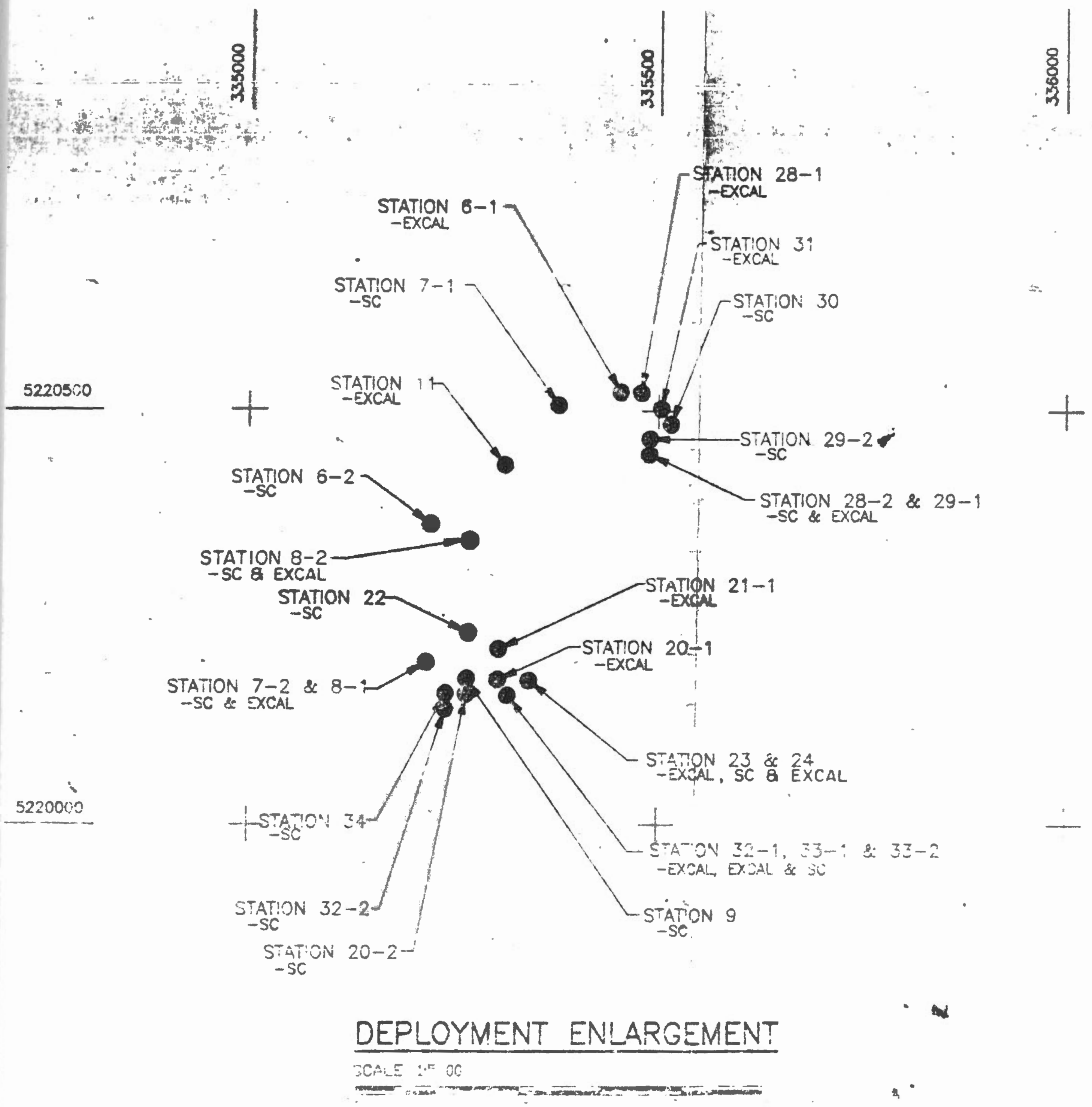

335000
335500
336000
5220500
5220000
STATION 28-1
-EXCAL
STATION 6-1
-EXCAL
STATION 31
-EXCAL
STATION 7-1
-SC
STATION 30
-SC
STATION 11
-EXCAL
STATION 29-2
-SC
STATION 6-2
-SC
STATION 28-2 & 29-1
-SC & EXCAL
STATION 8-2
-SC & EXCAL
STATION 22
-SC
STATION 21-1
-EXCAL
STATION 20-1
-EXCAL
STATION 7-2 & 8-1
-SC & EXCAL
STATION 23 & 24
-EXCAL, SC & EXCAL
STATION 34
-SC
STATION 32-1, 33-1 & 33-2
-EXCAL, EXCAL & SC
STATION 32-2
-SC
STATION 9
-SC
STATION 20-2
-SC
DEPLOYMENT ENLARGEMENT

FIGURE 8.3.2A

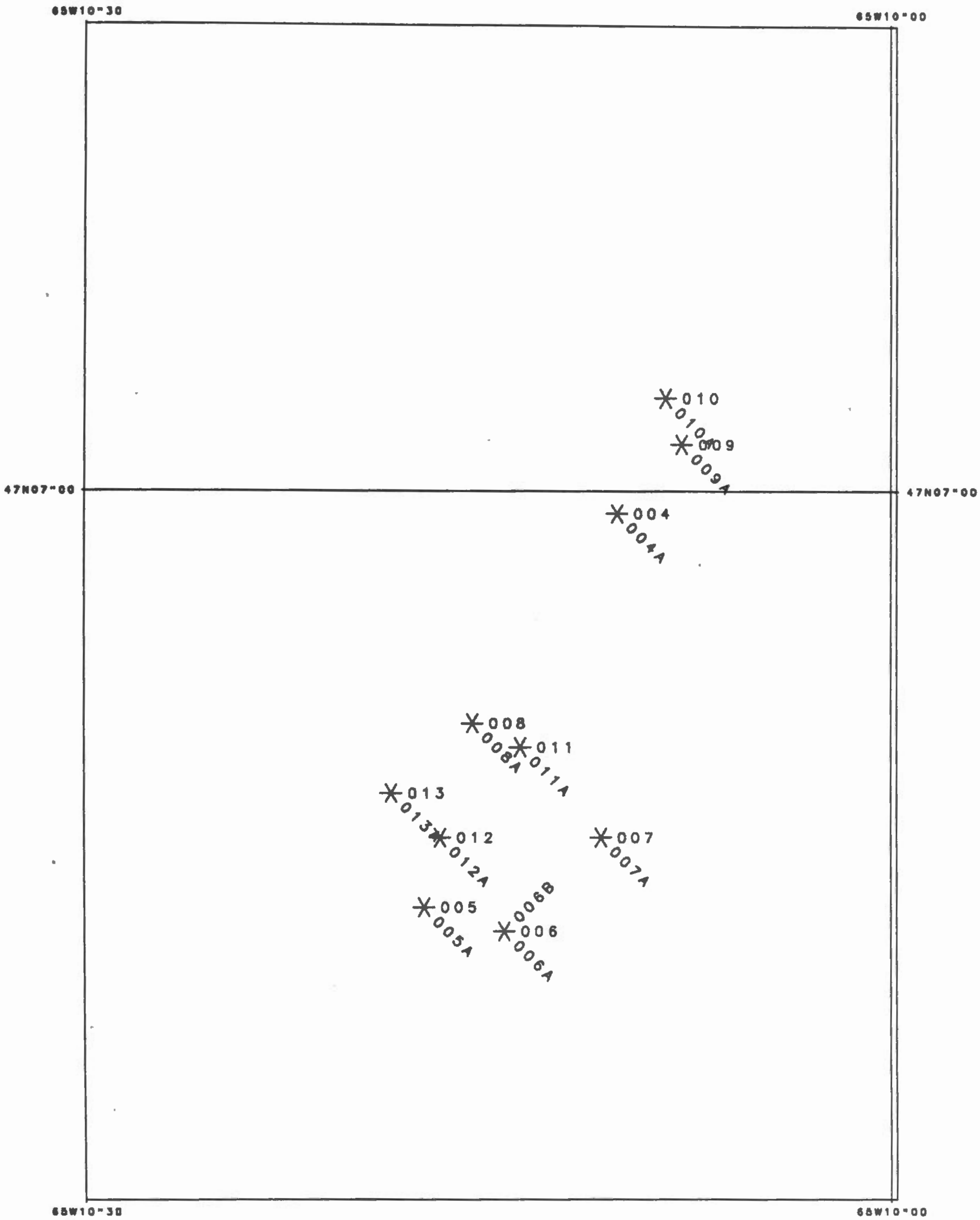
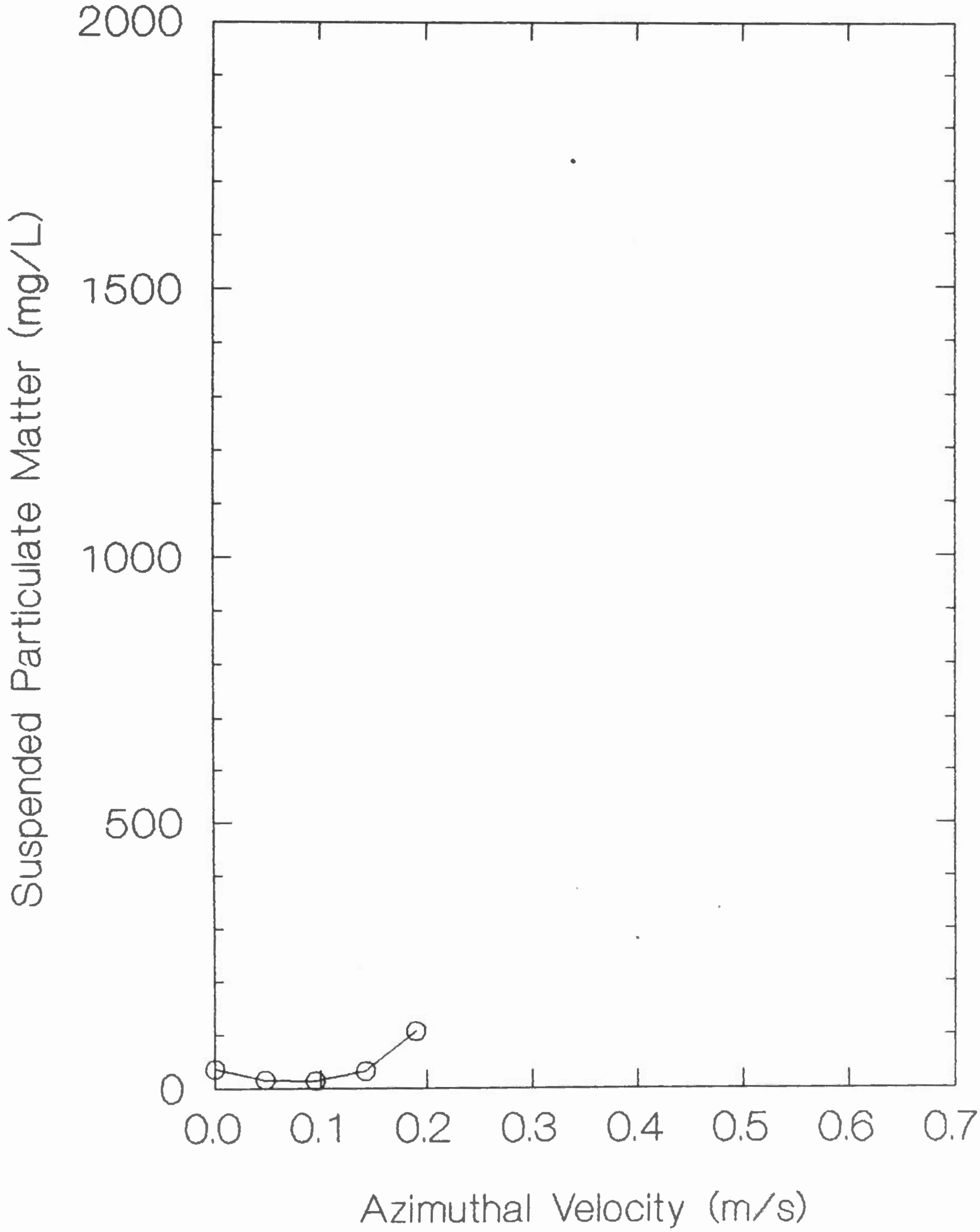

65W10"30
65W10"00
47N07"00
47N07"00
010
010A
009
009A
004
004A
008
008A
011
011A
013
013A
012
012A
007
007A
005
005A
006B
006
006A
65W10"30
65W10"00

FIGURE 8.3.2B

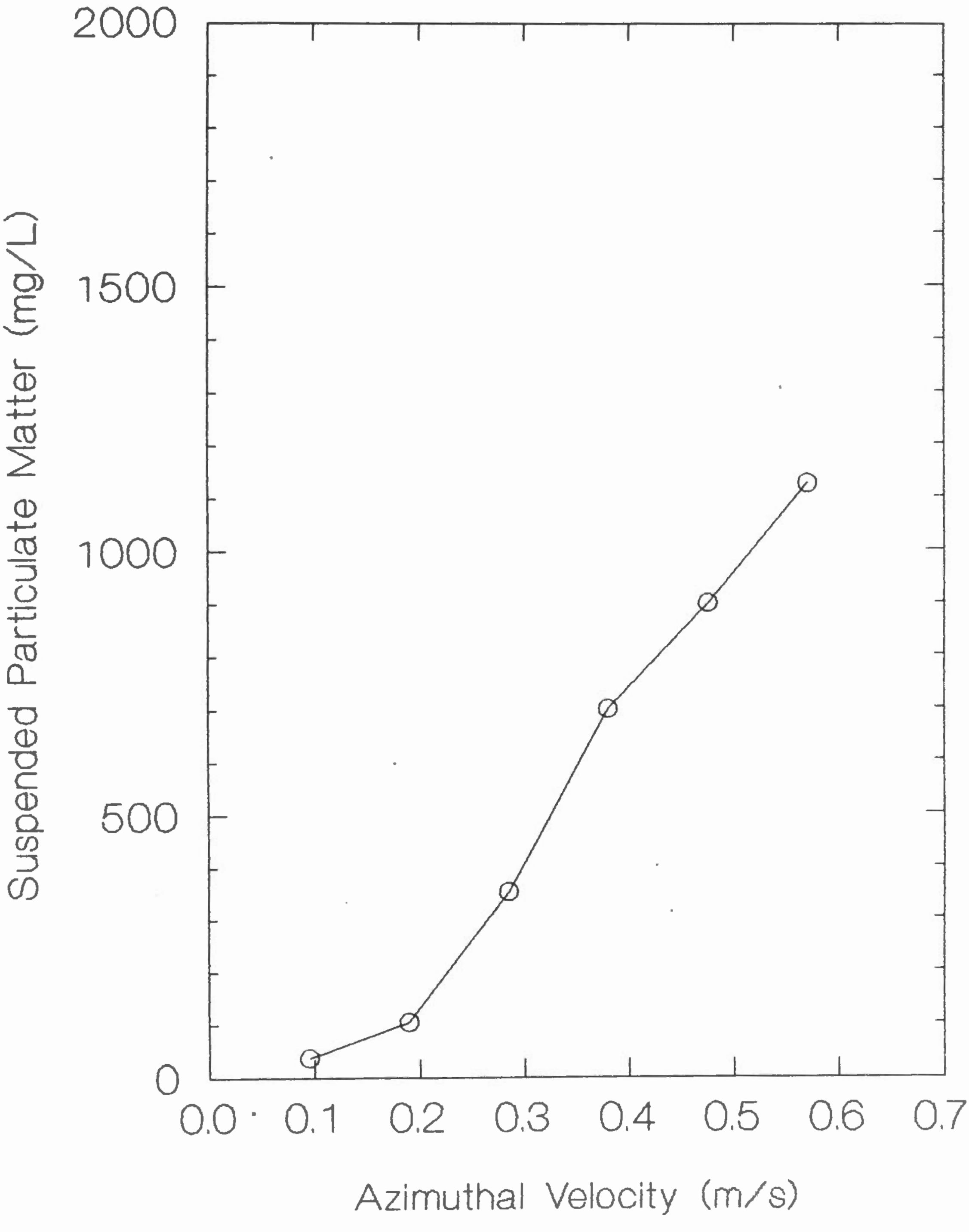
APPENDIX 1. Time-series plots of measured suspended sediment concentration (SSC) plotted against azimuthal current velocity for each Sea Carousel station.

APPENDIX 2. The calibration of the upper Optical Backscatter sensor (OBS) against suspended sediment concentration (SSC) for each Sea Carousel station.

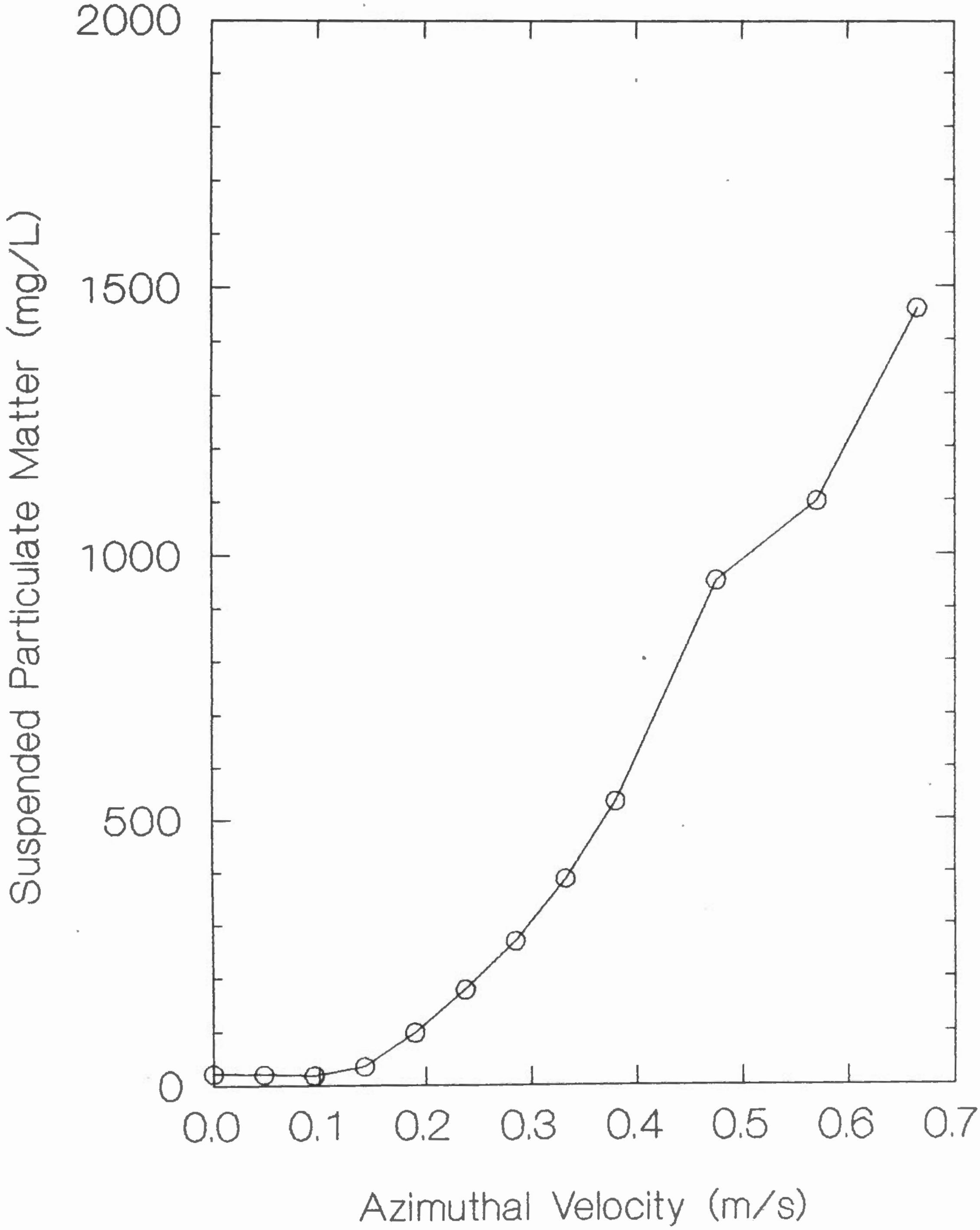
Suspended Solids by Velocity, Station MIR1



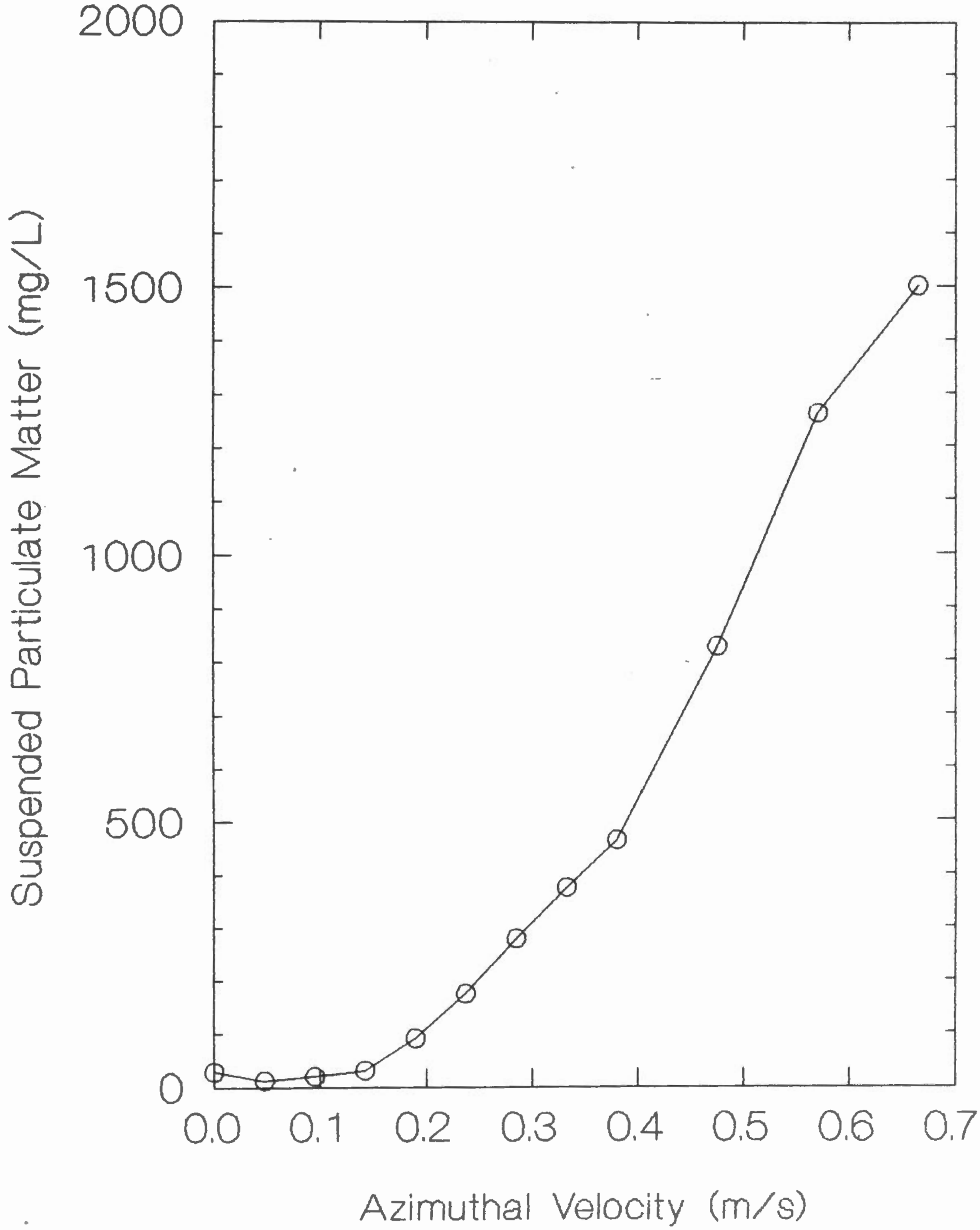
Suspended Solids by Velocity, Station MIR1,



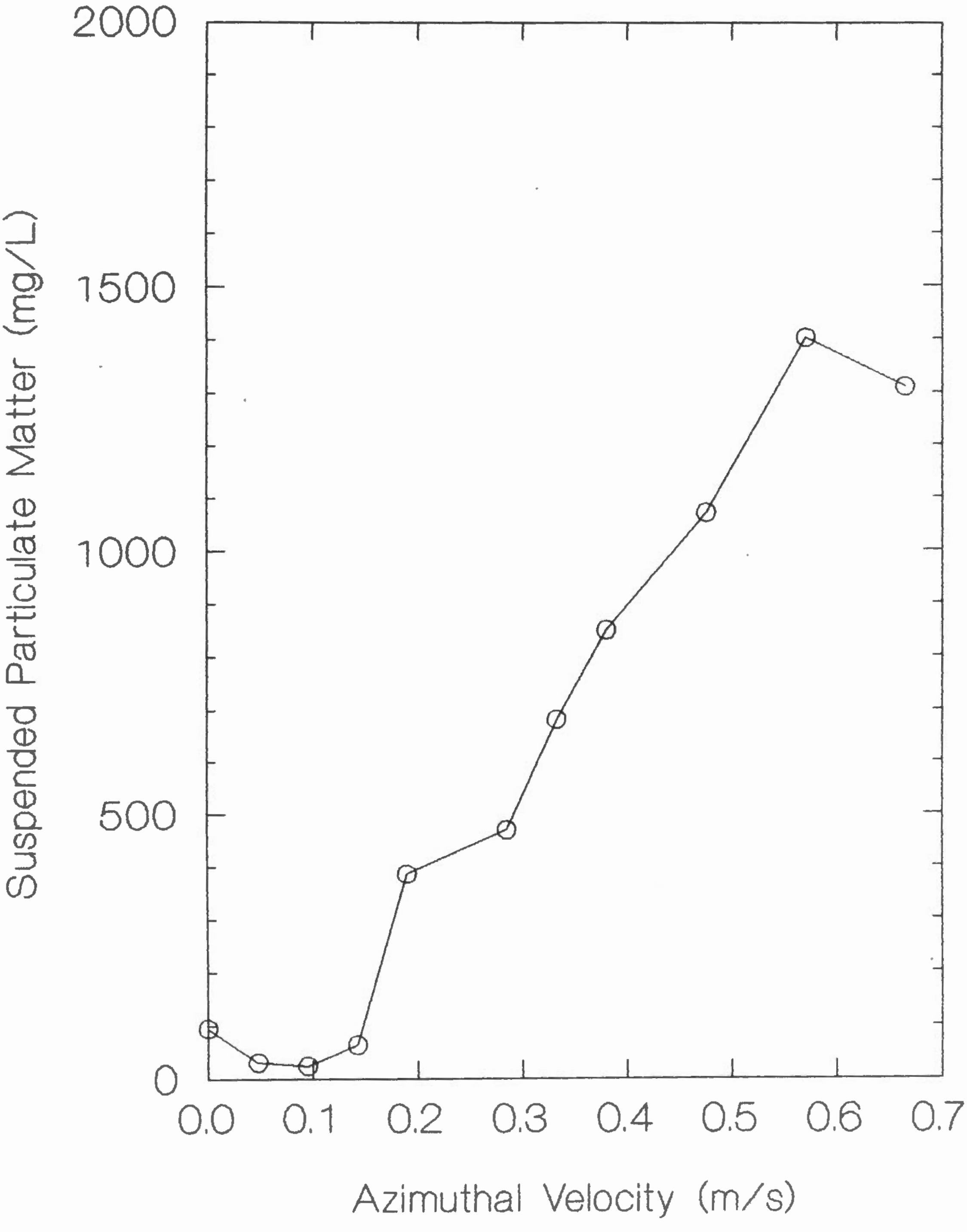
Suspended Solids by Velocity, Station MIR2



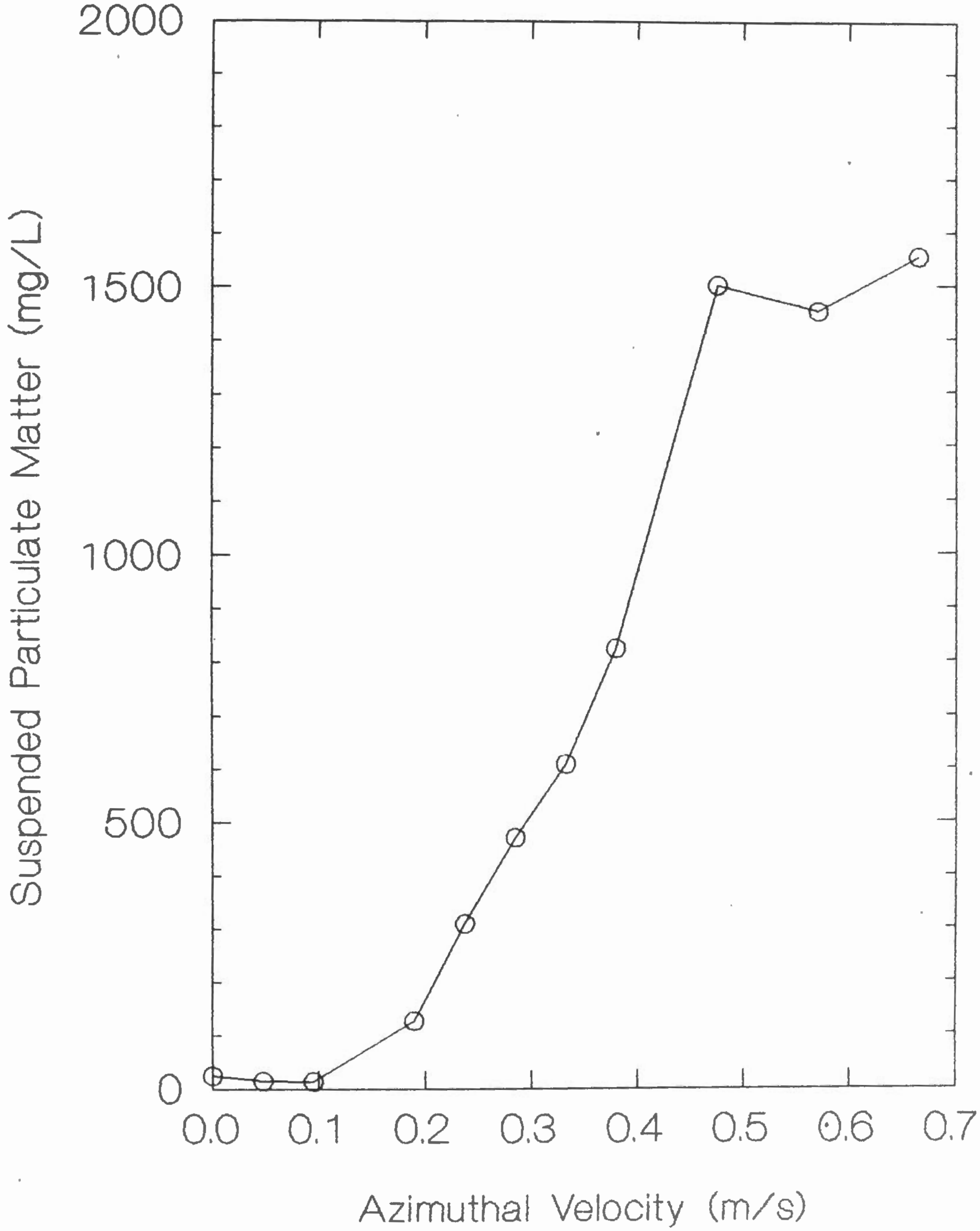
Suspended Solids by Velocity, Station MIR3



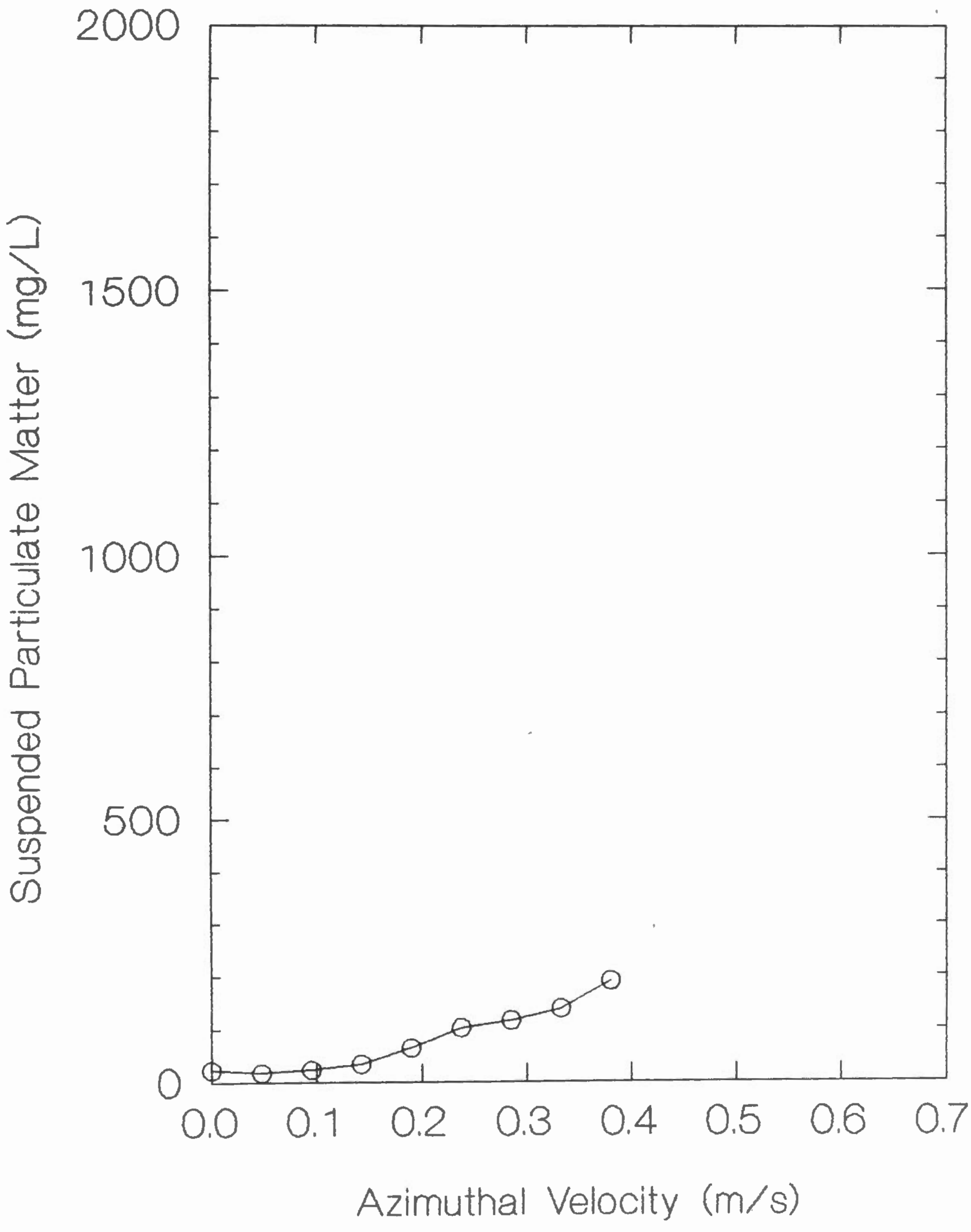
Suspended Solids by Velocity, Station MIR4



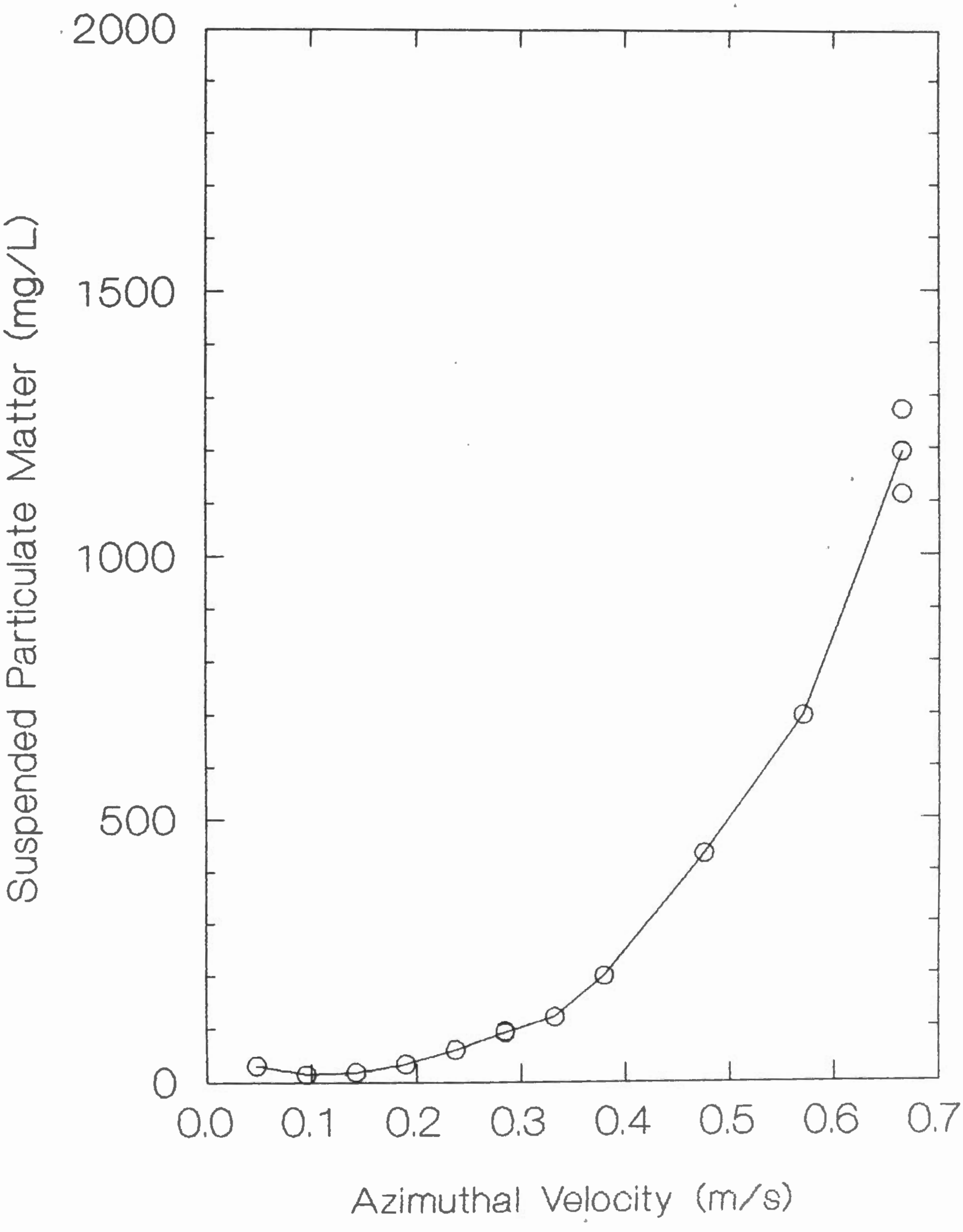
Suspended Solids by Velocity, Station MIR5



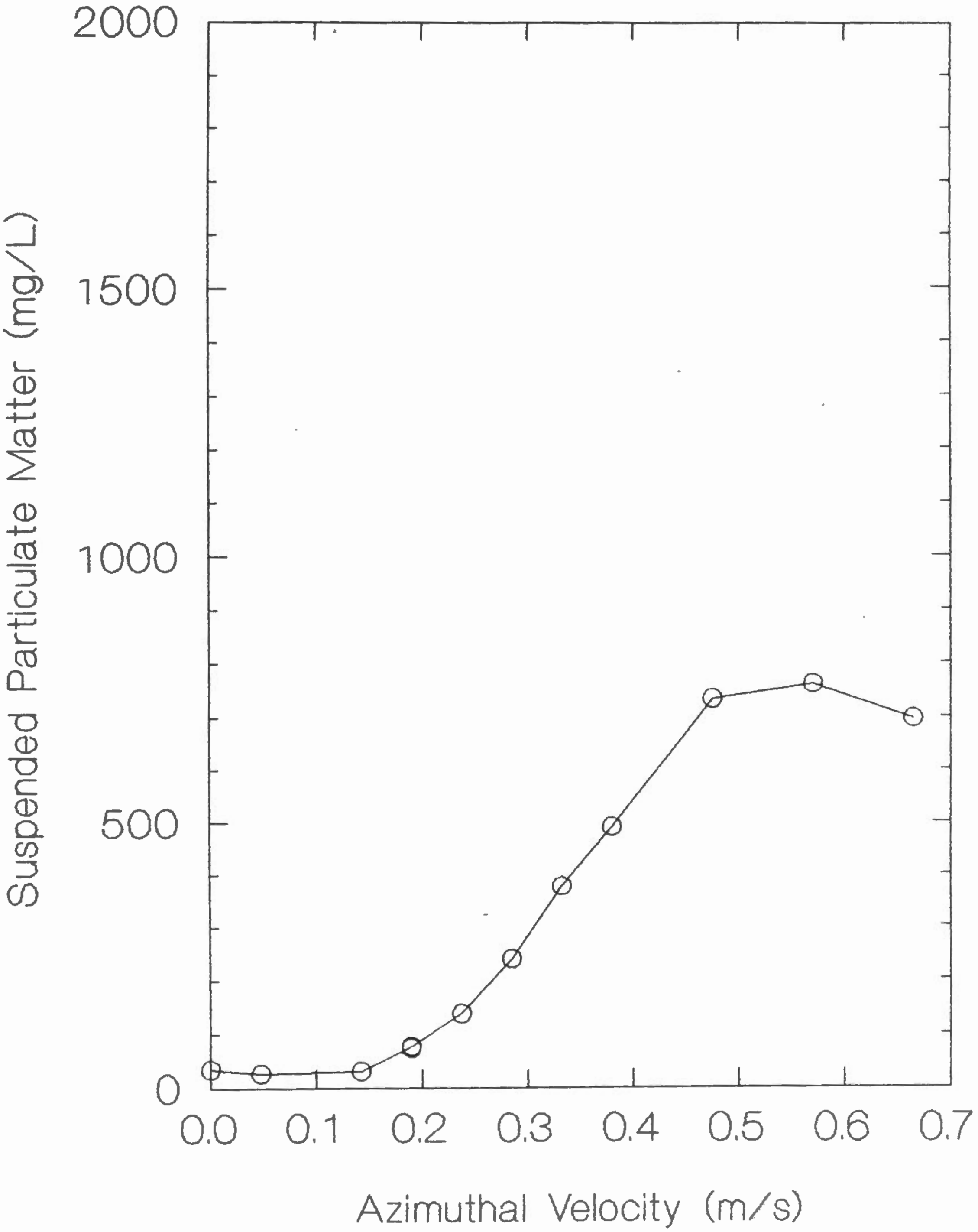
Suspended Solids by Velocity, Station MIRE



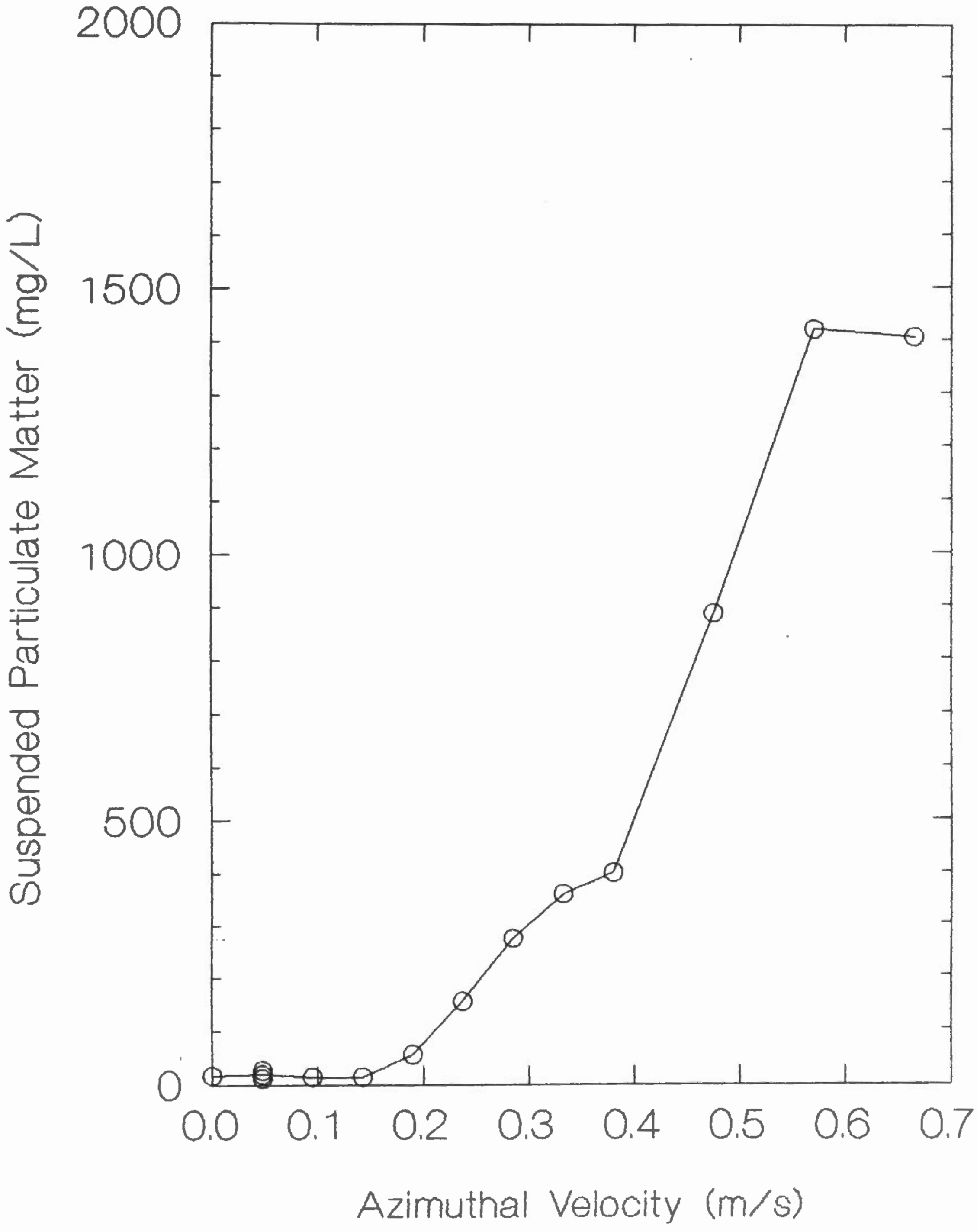
Suspended Solids by Velocity, Station MIR7,



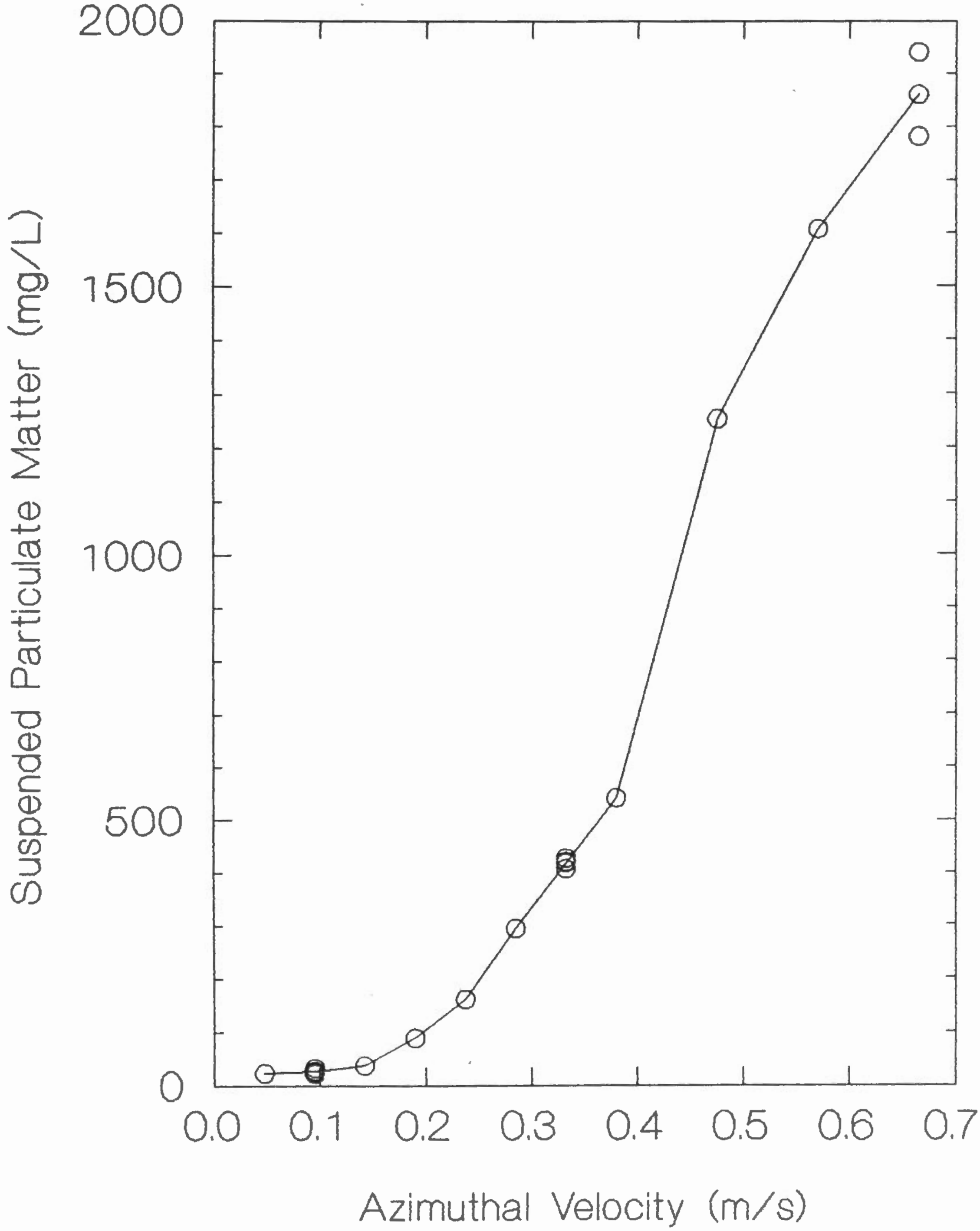
Suspended Solids by Velocity, Station MIRE



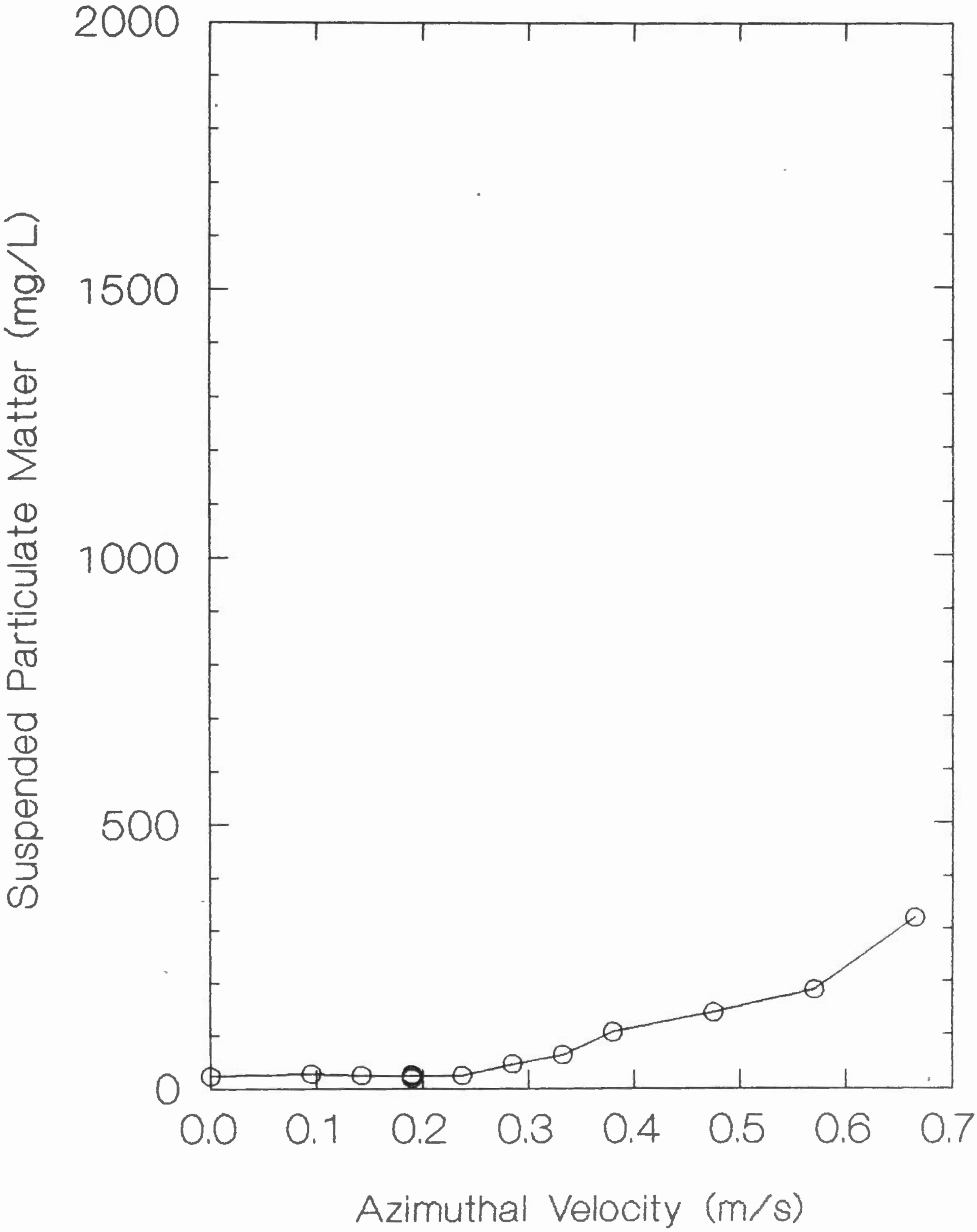
Suspended Solids by Velocity, Station MIR9



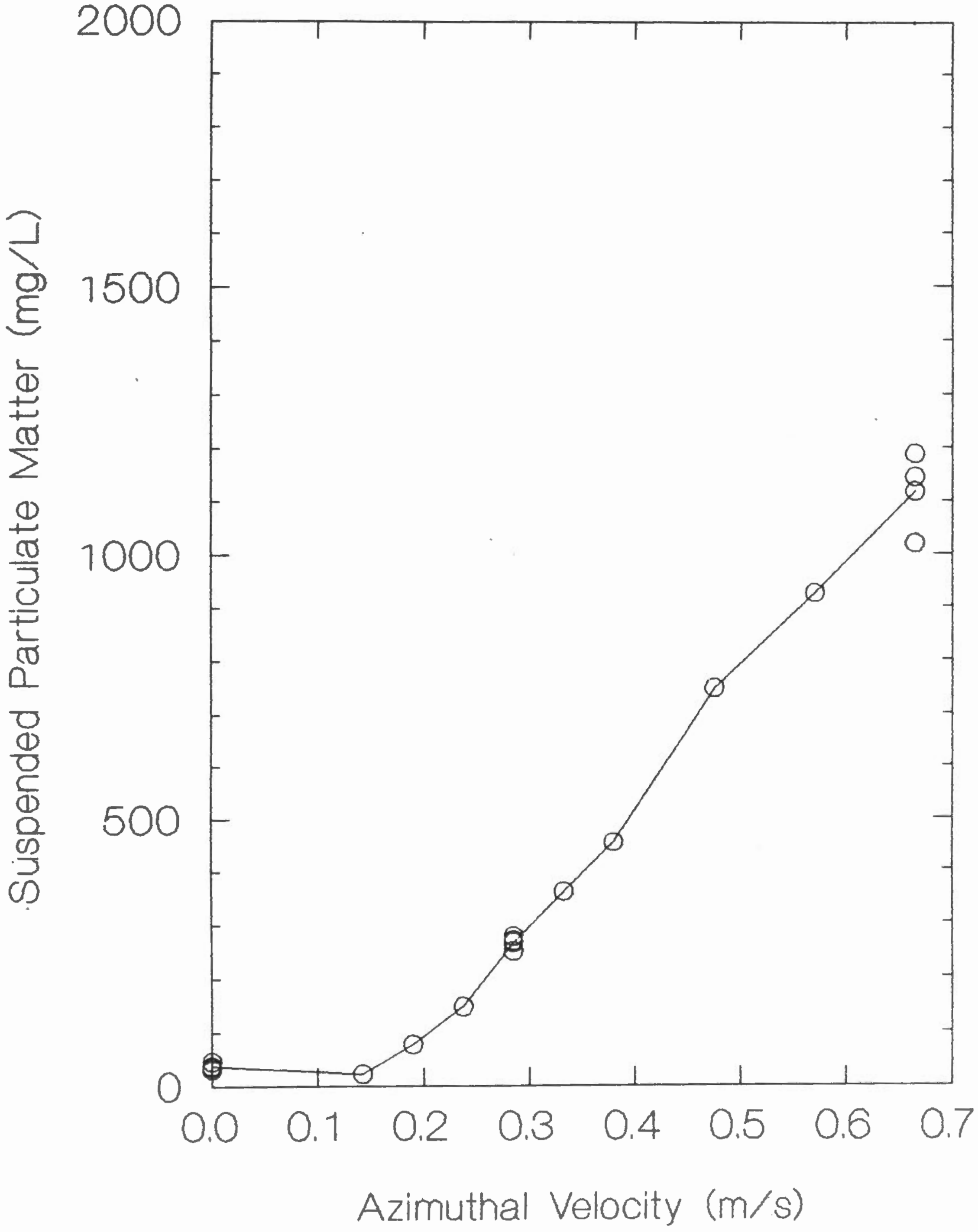
Suspended Solids by Velocity, Station MIR1(



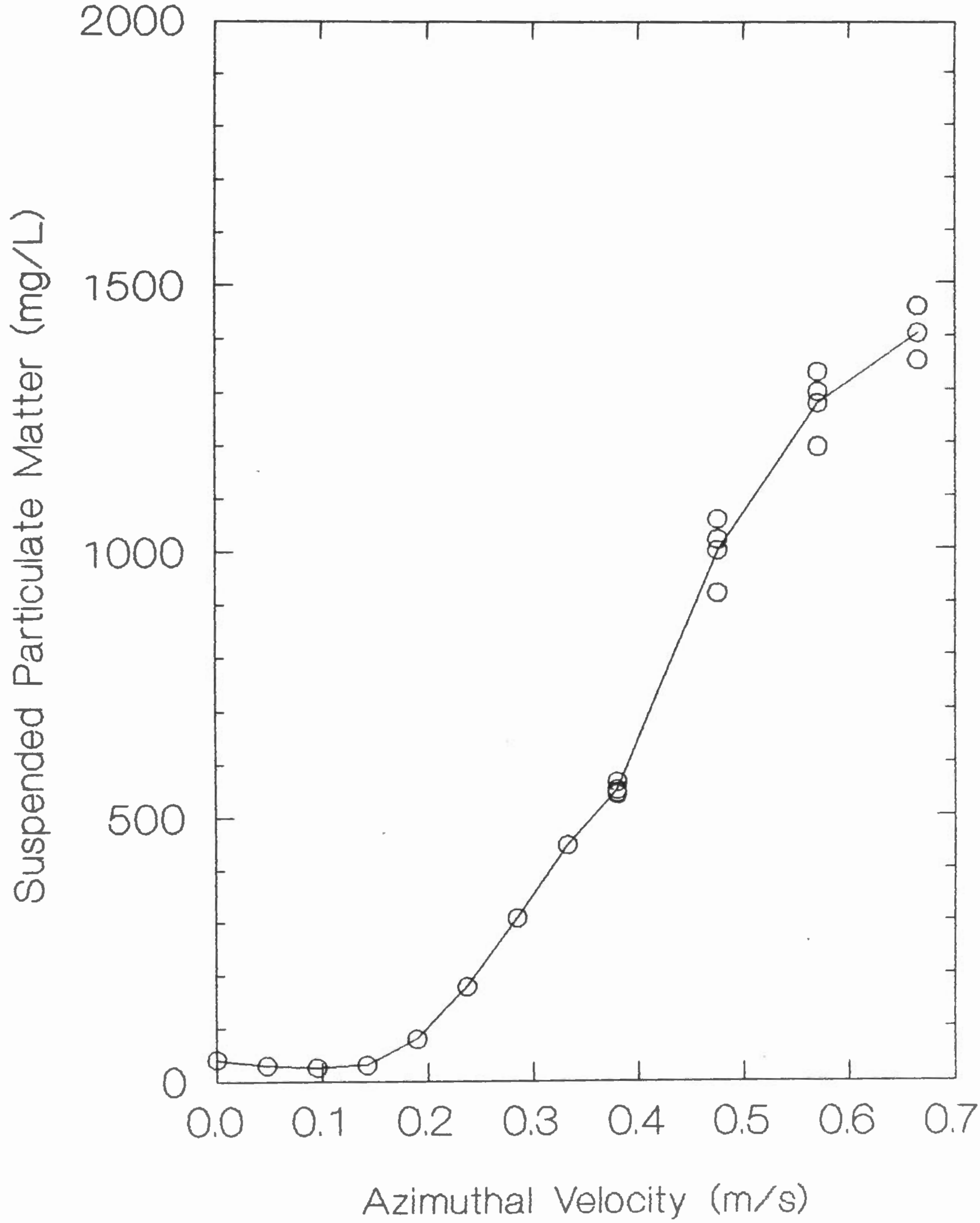
Suspended Solids by Velocity, Station MIR1



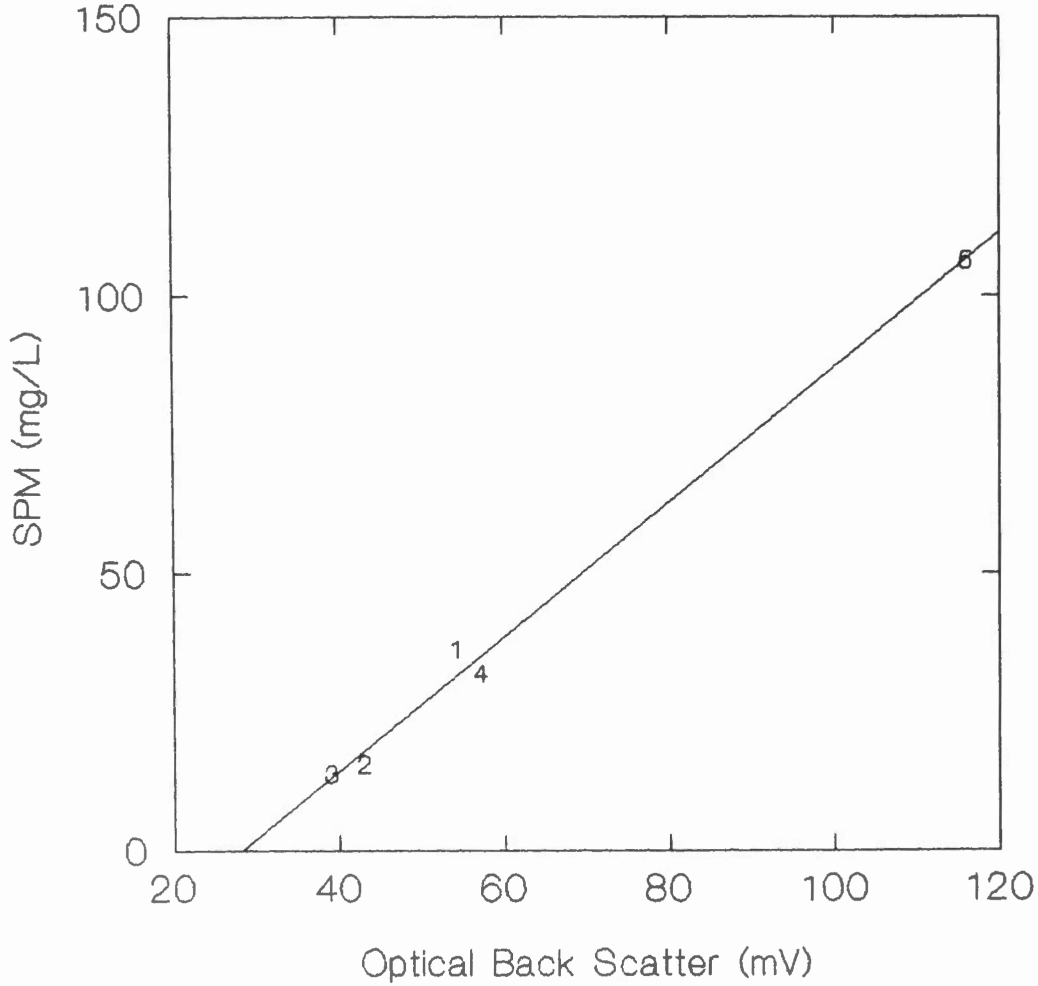
Suspended Solids by Velocity, Station MIR1:



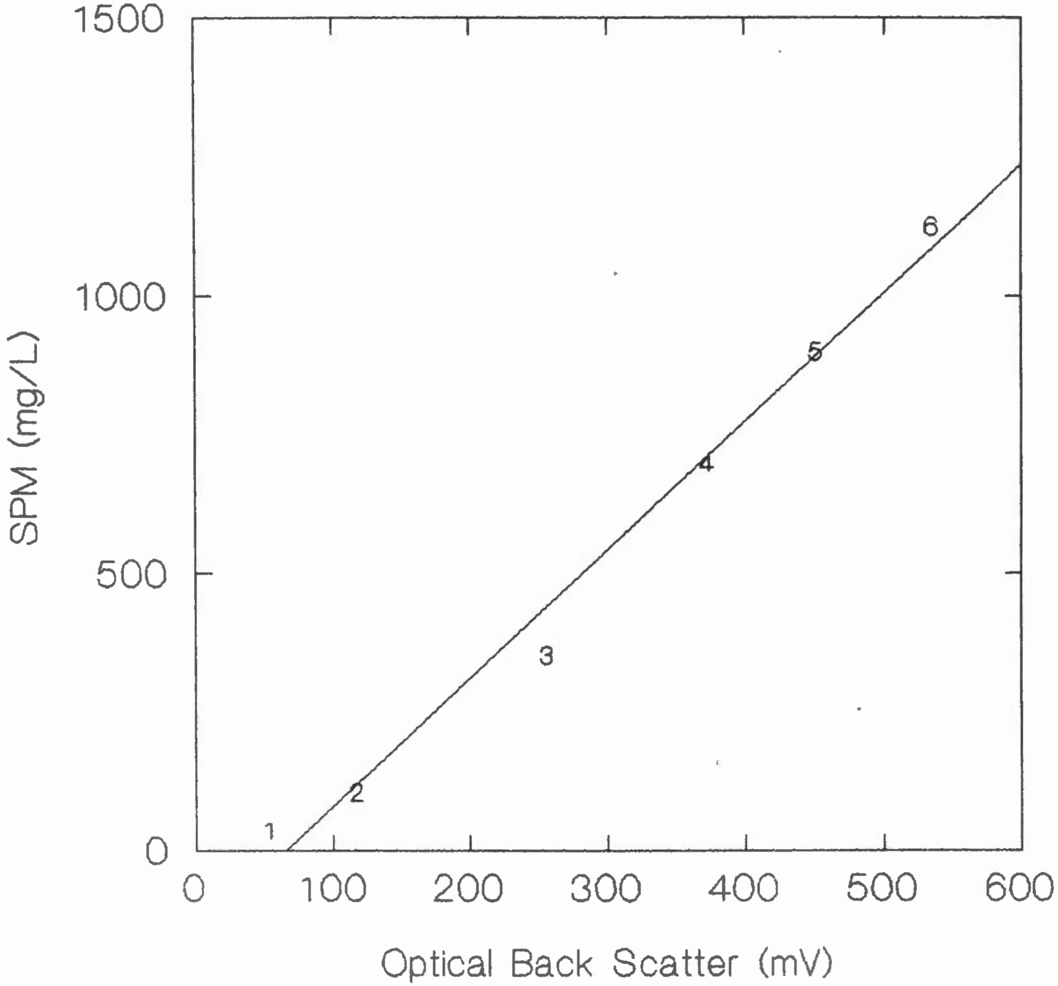
Suspended Solids by Velocity, Station MIR1



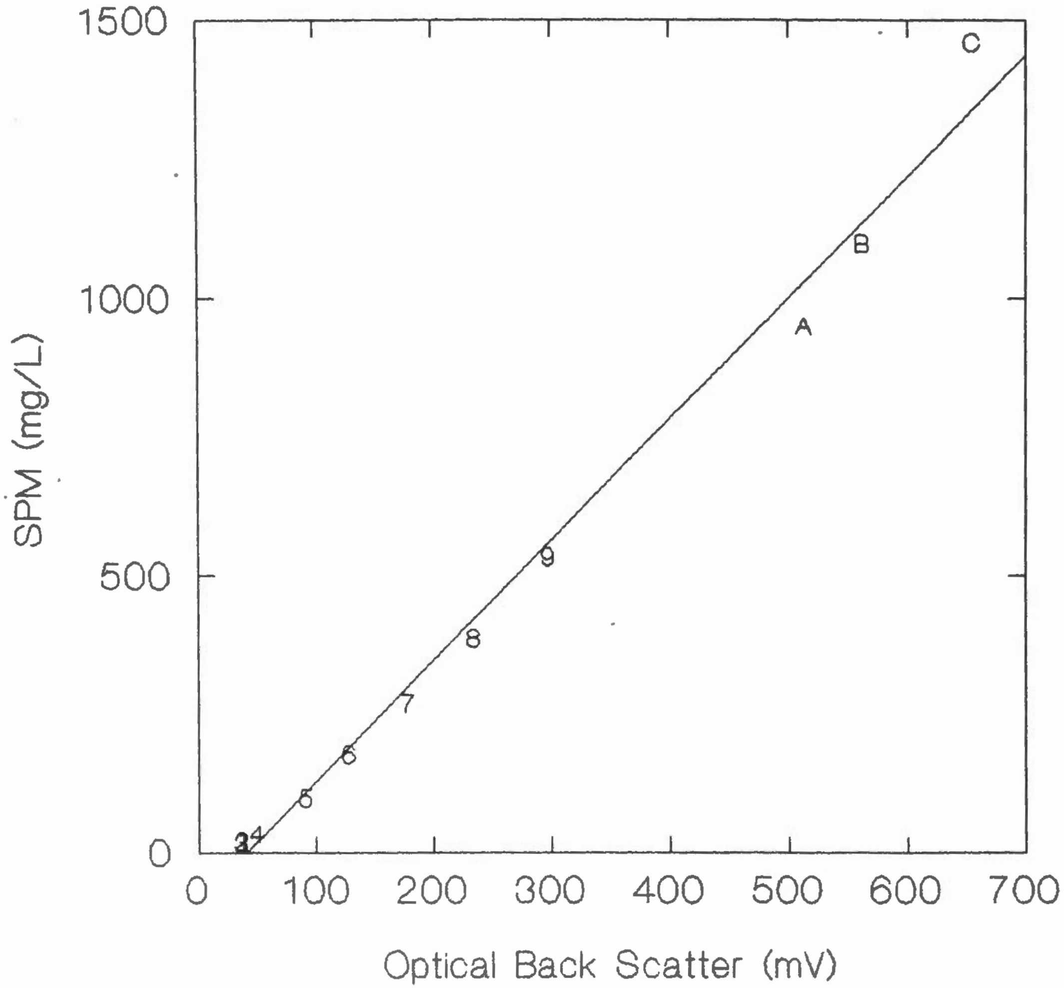
94-350 Sea Carousel calibration curve for station MIR1



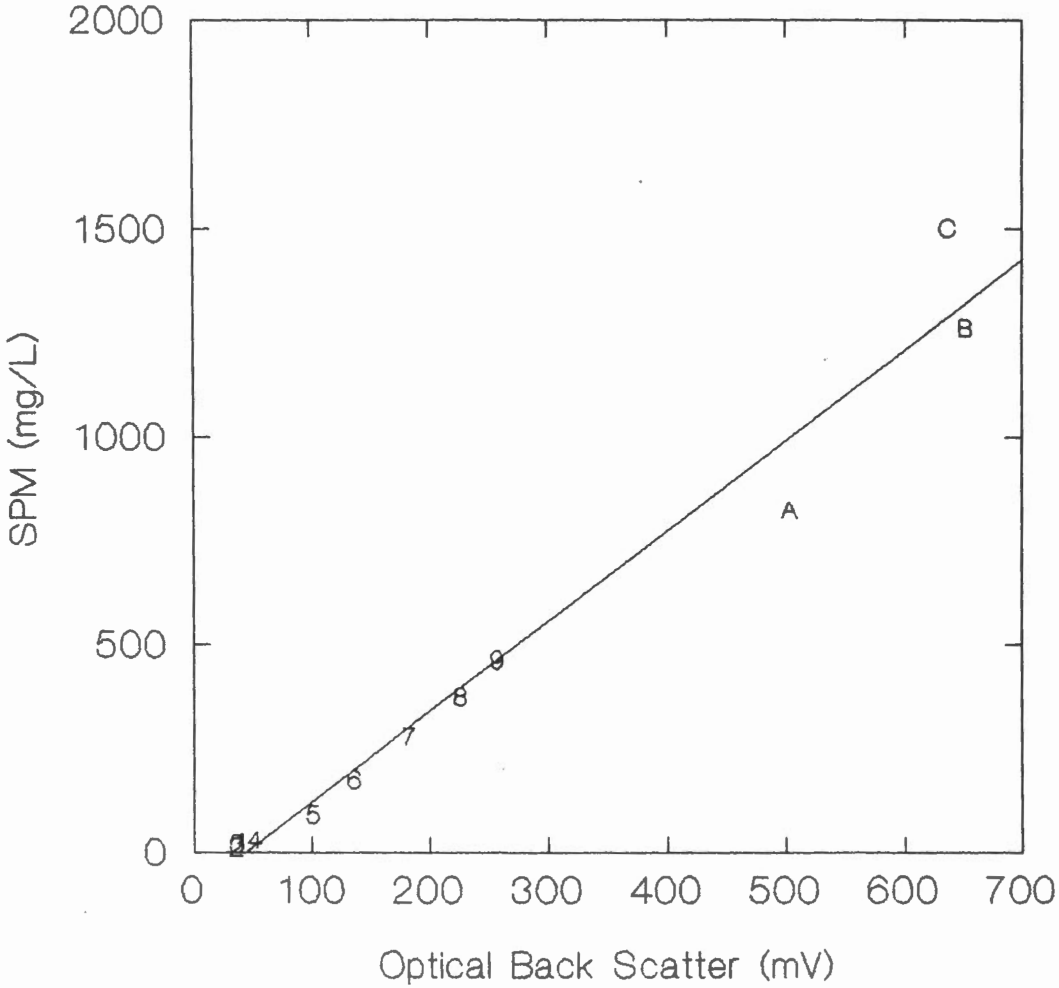
94-350 Sea Carousel calibration curve for station MIR1A



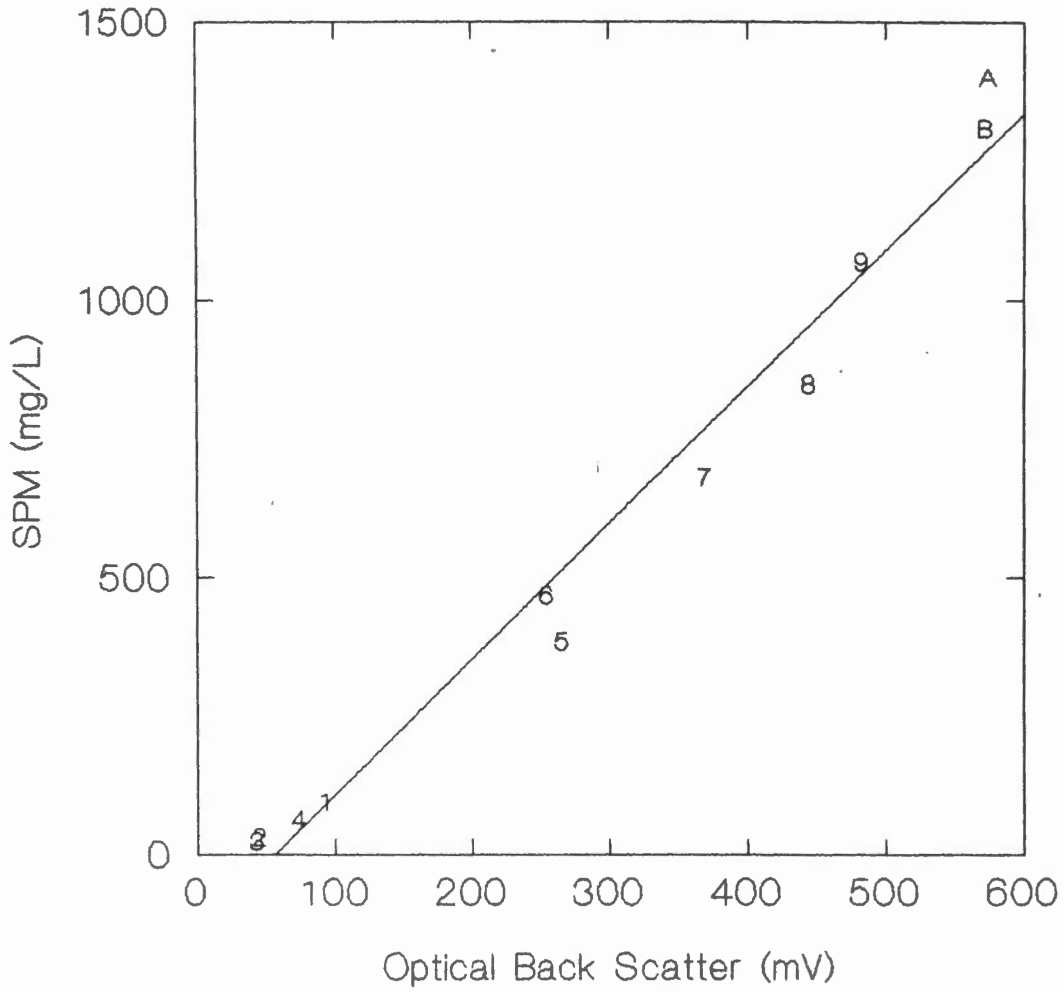
94-350 Sea Carousel calibration curve for station MIR2



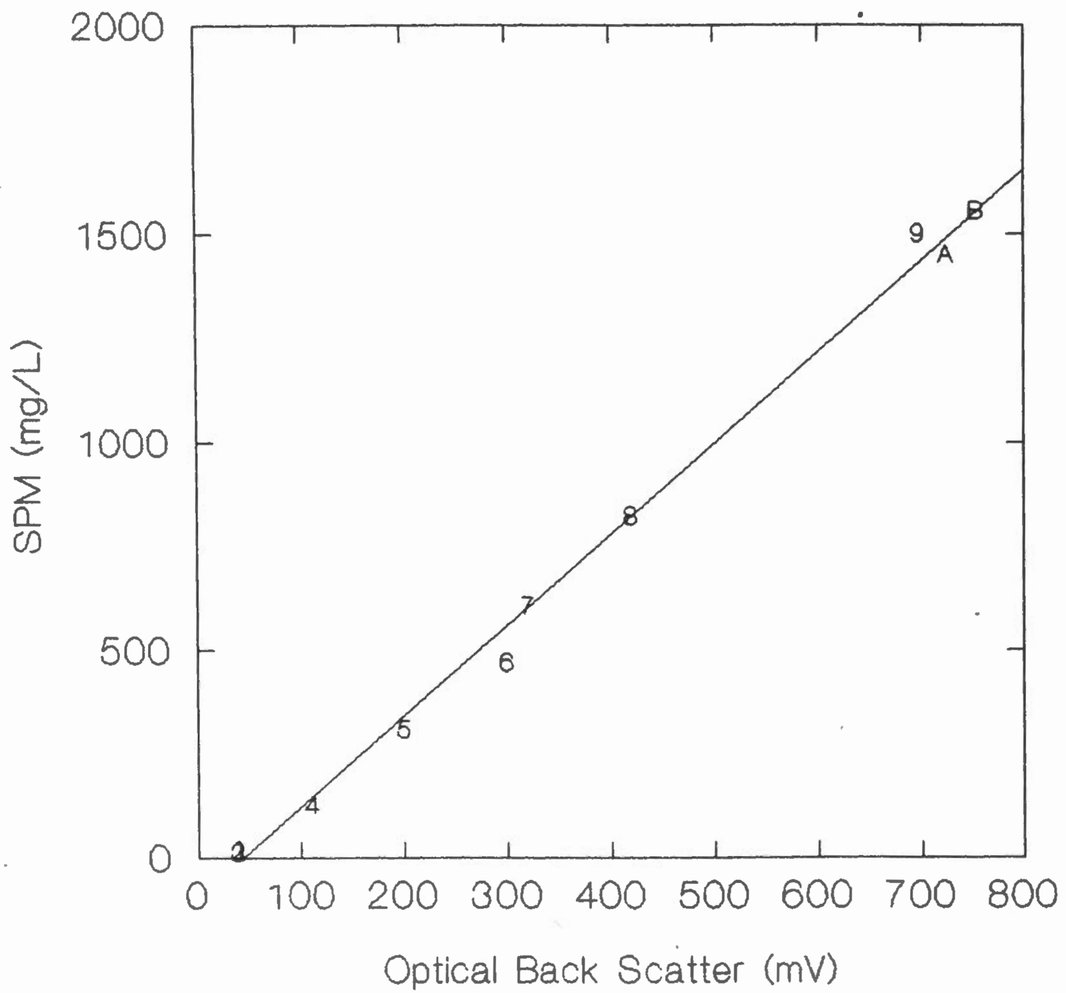
94-350 Sea Carousel calibration curve for station MIR3



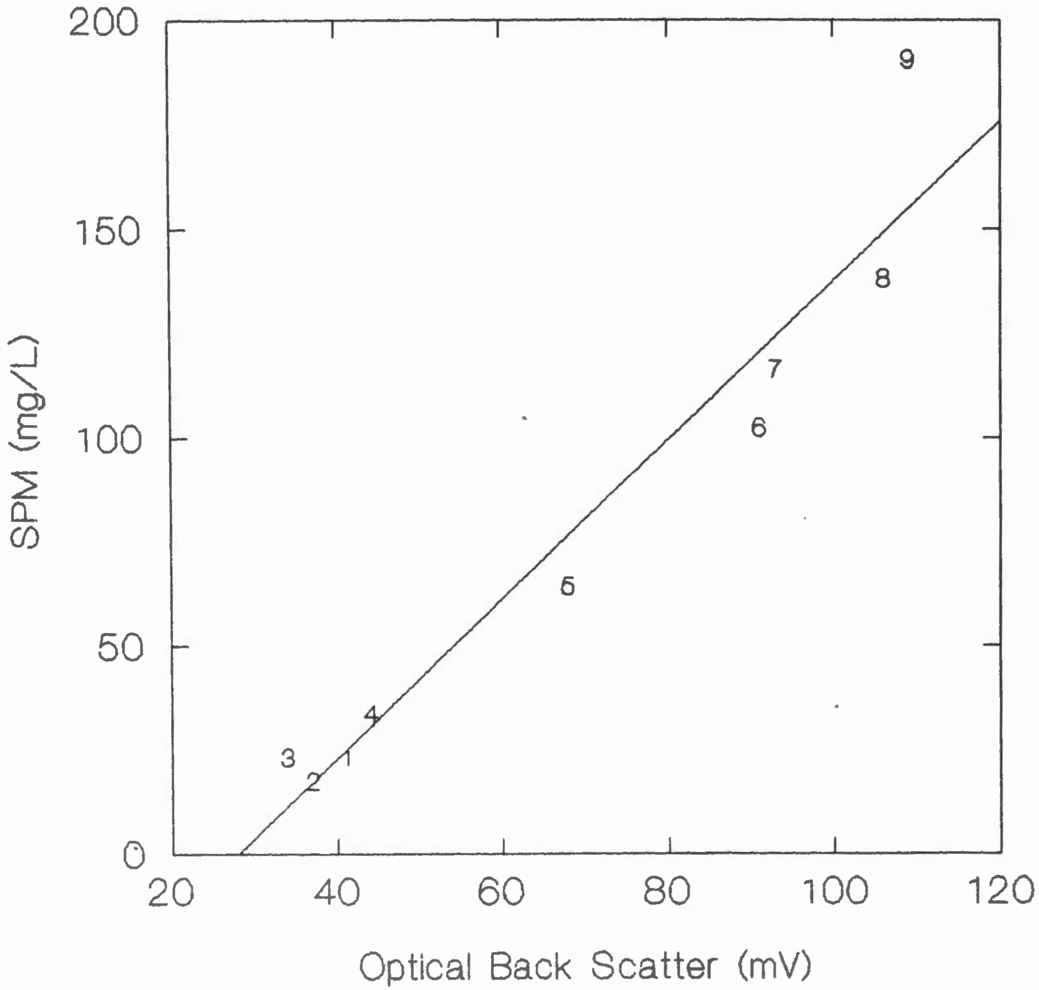
94-350 Sea Carousel calibration curve for station MIR4



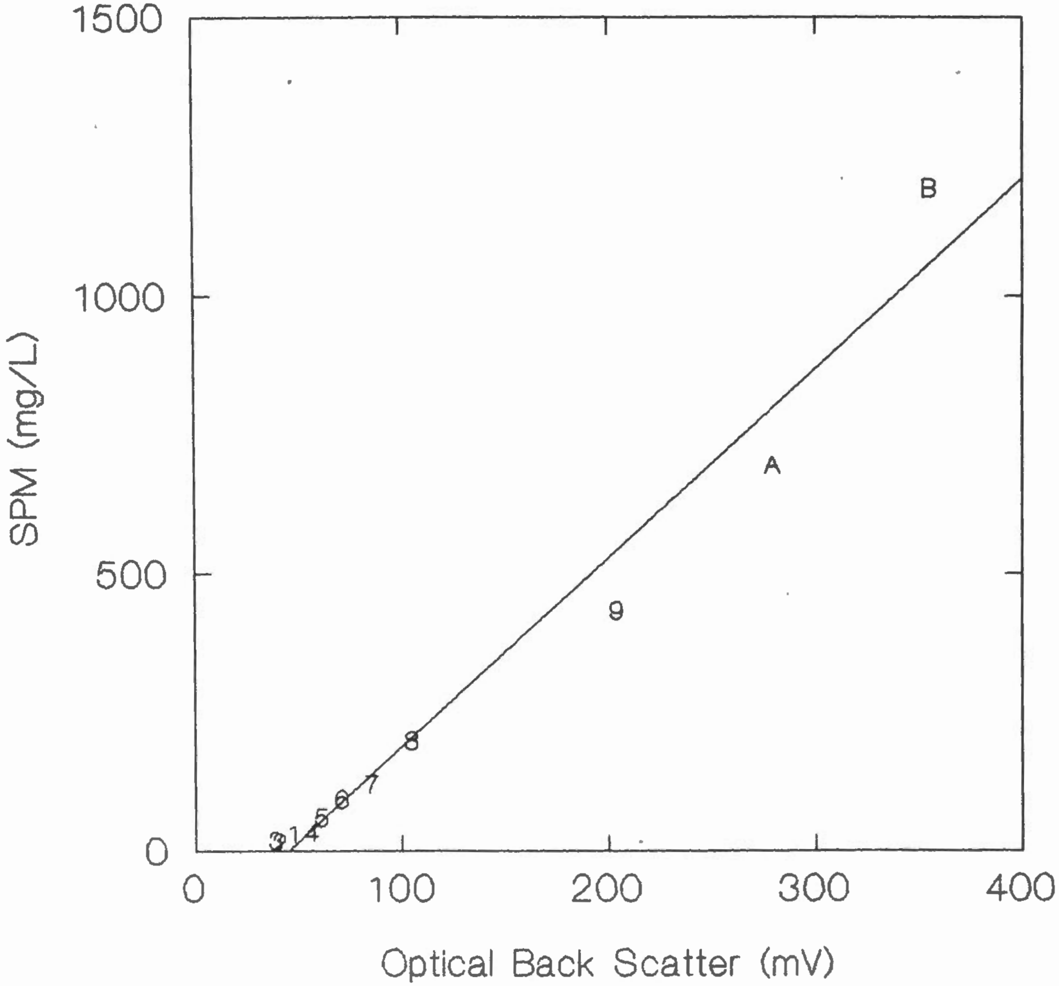
94-350 Sea Carousel calibration curve for station MIR5



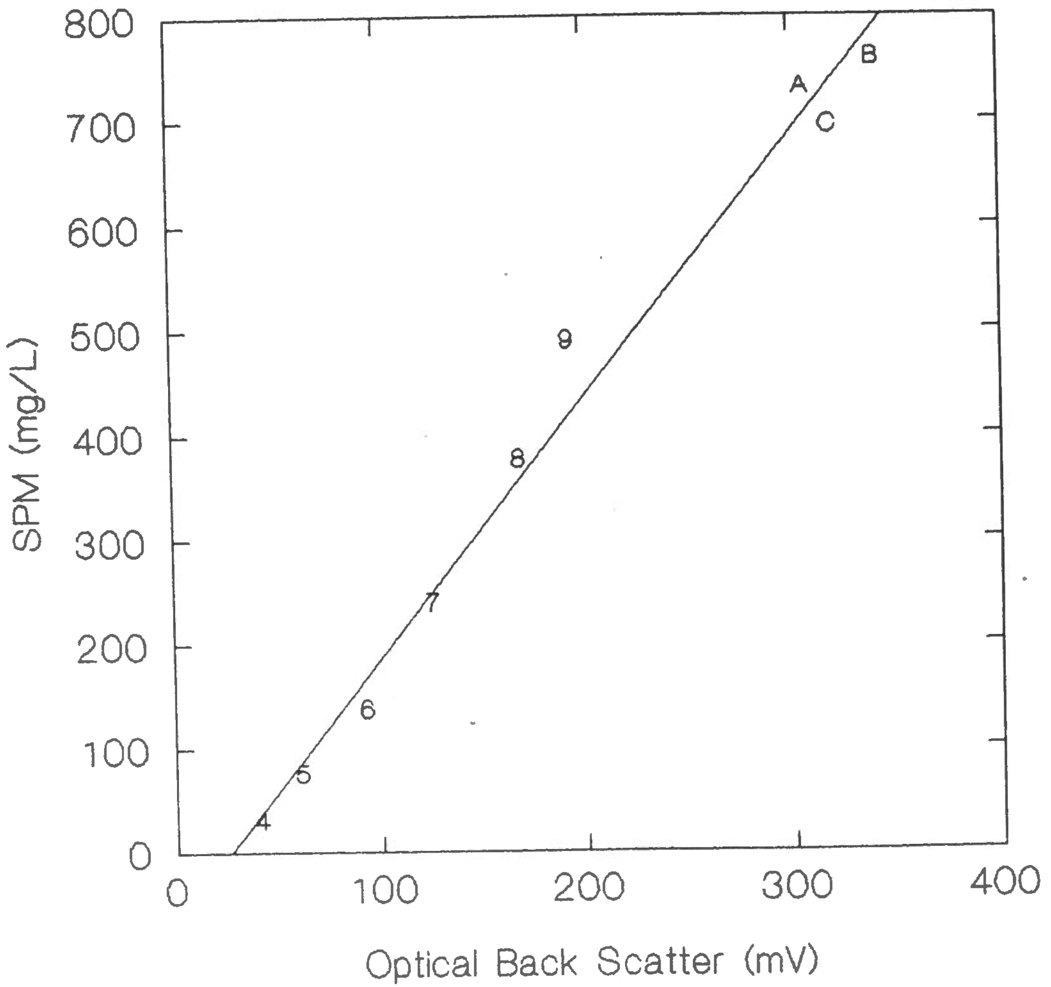
94-350 Sea Carousel calibration curve for station MIR6



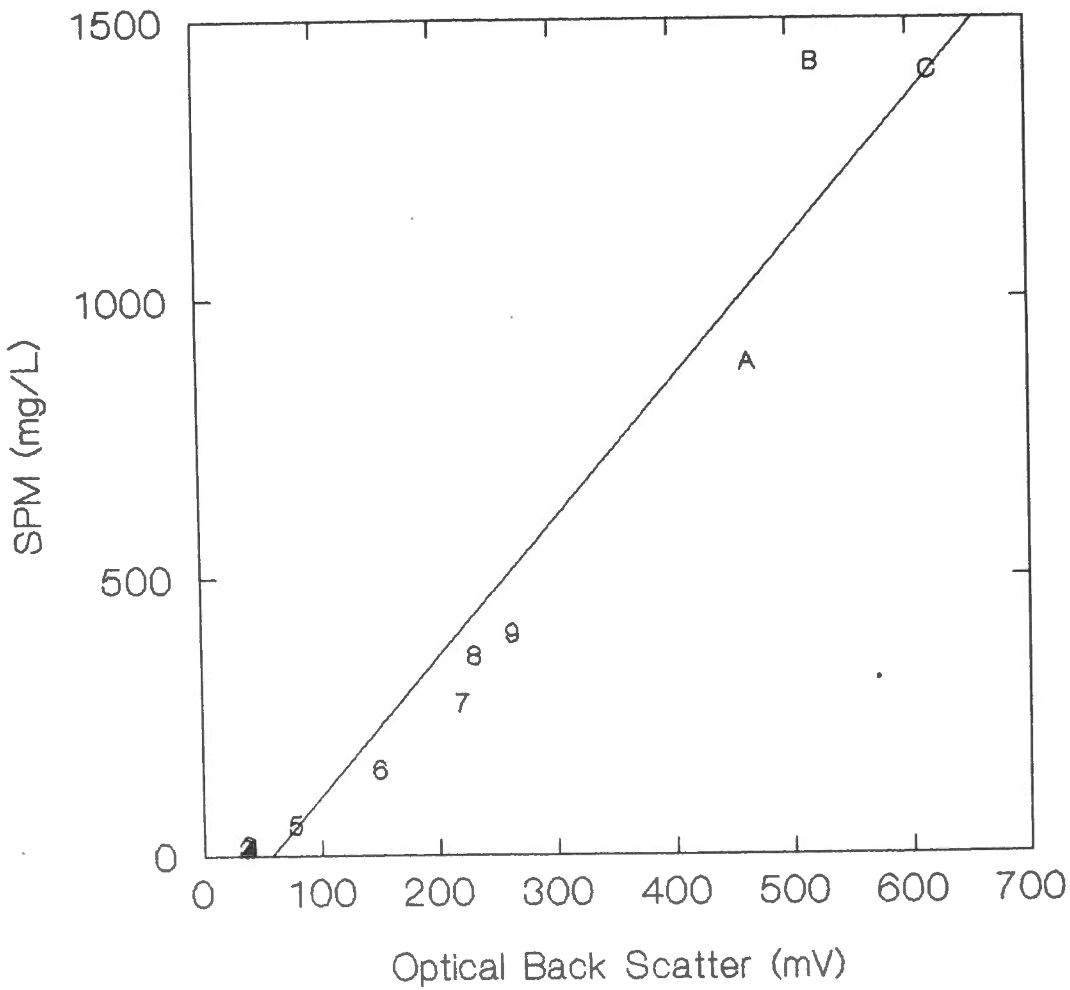
94-350 Sea Carousel calibration curve for station MIR7A



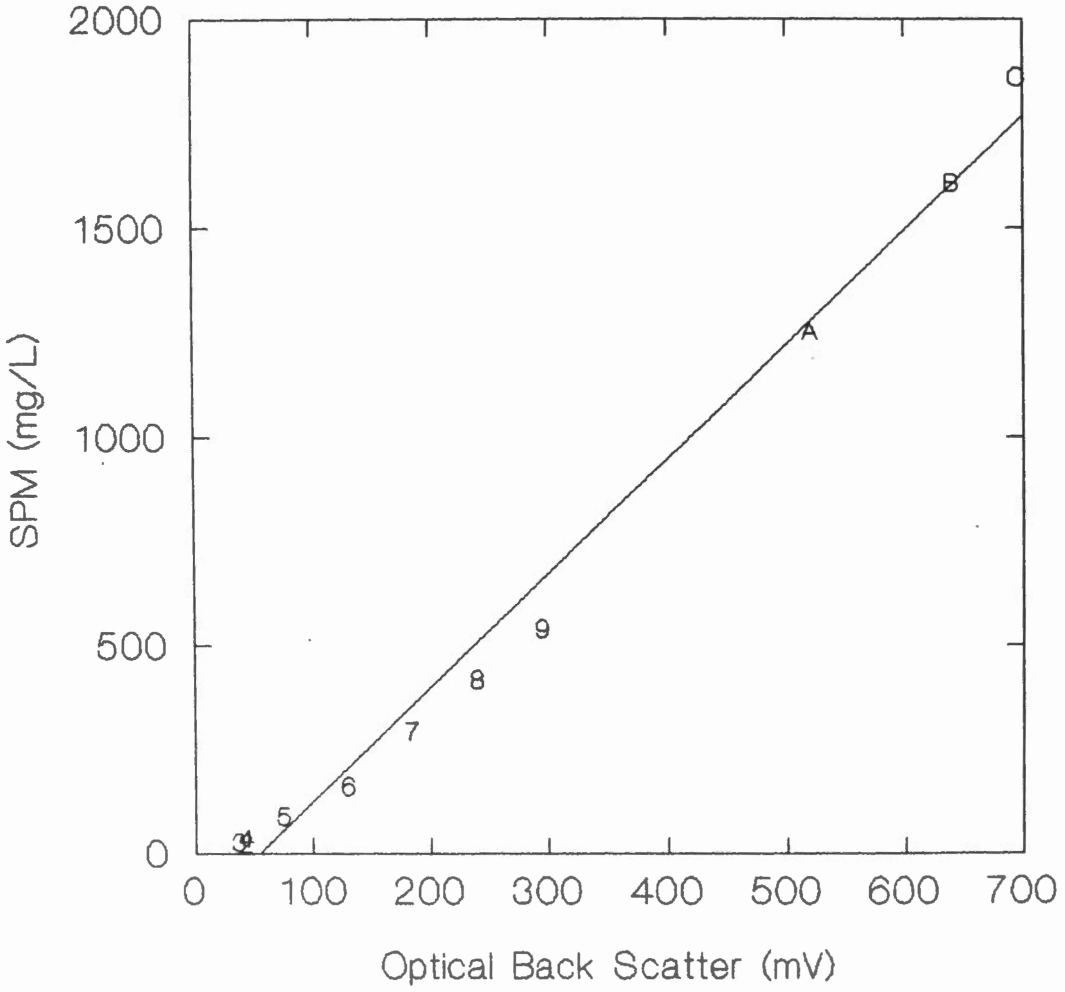
94-350 Sea Carousel calibration curve for station MIR8



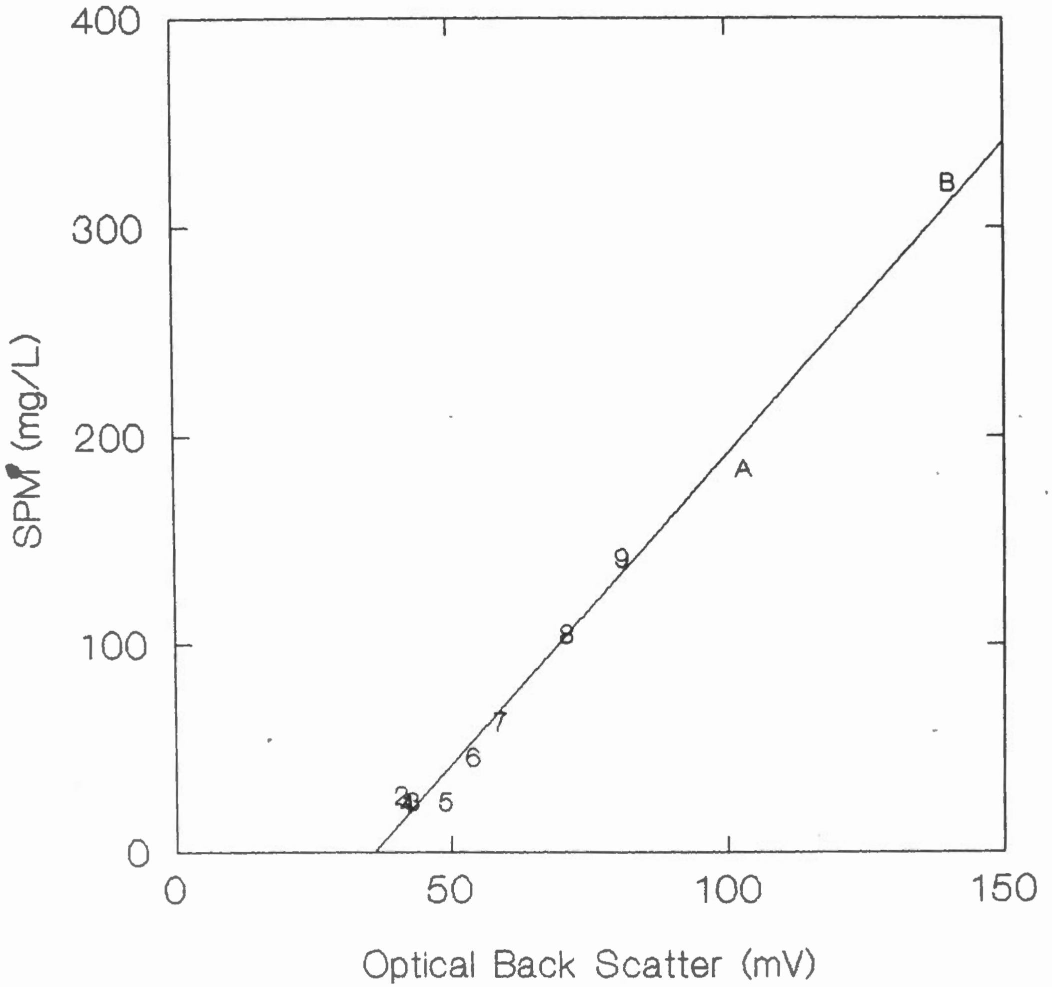
94-350 Sea Carousel calibration curve for station MIR9



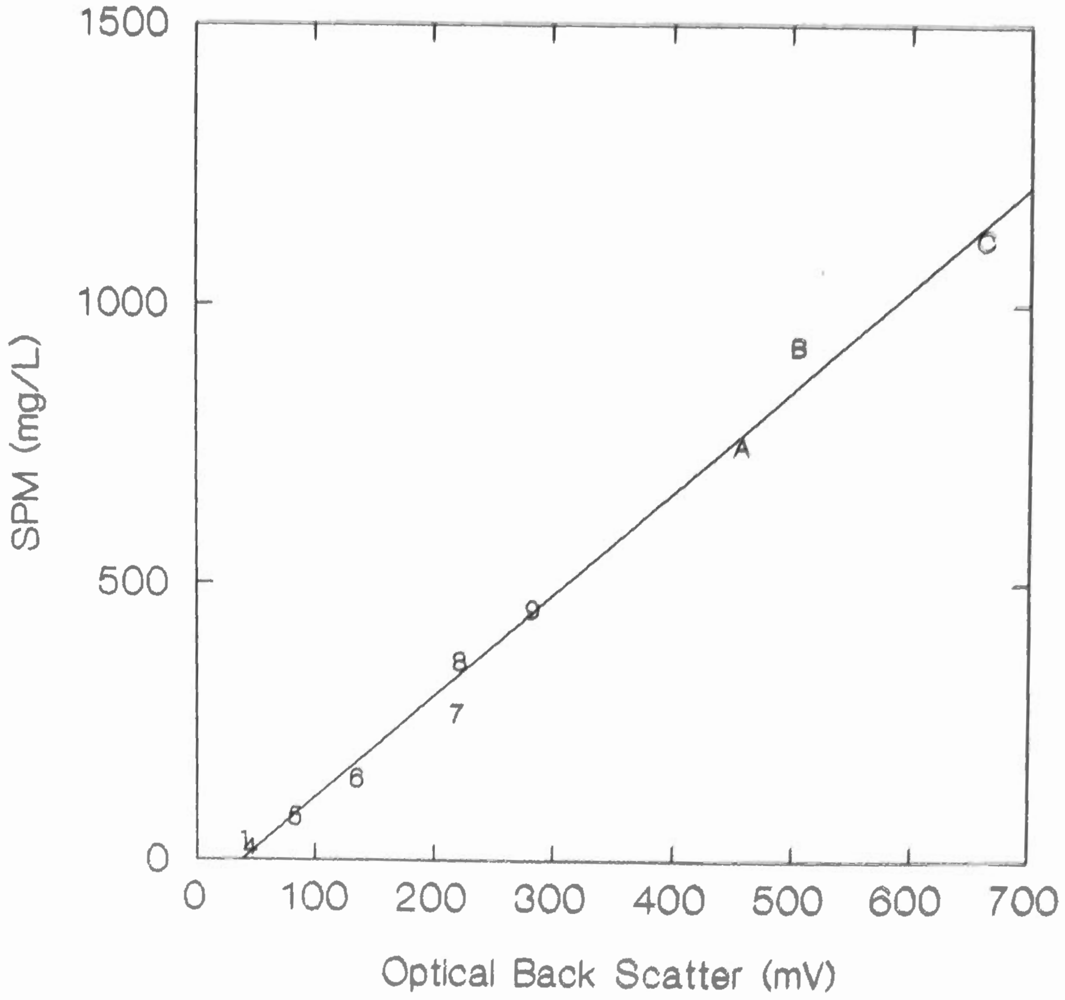
94-350 Sea Carousel calibration curve for station MIR10



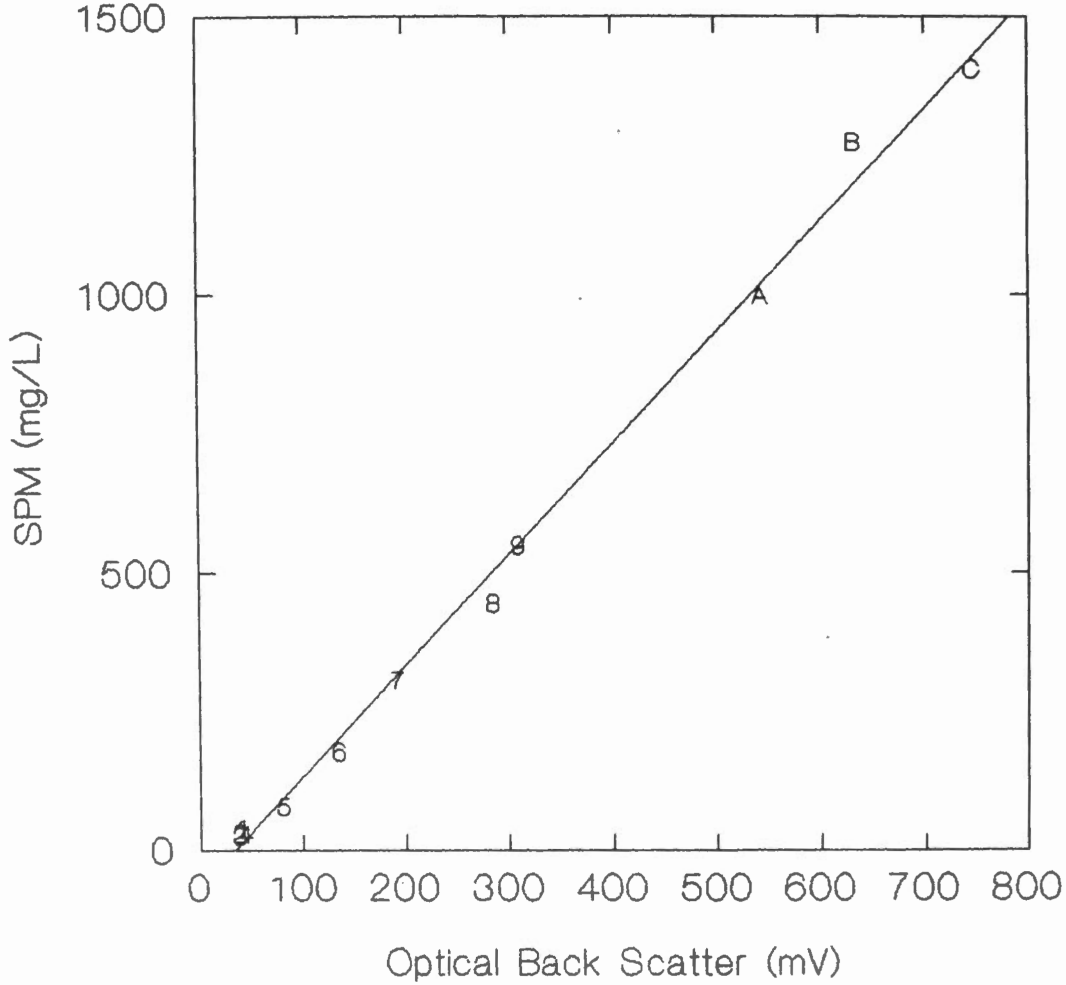
94-350 Sea Carousel calibration curve for station MIR11

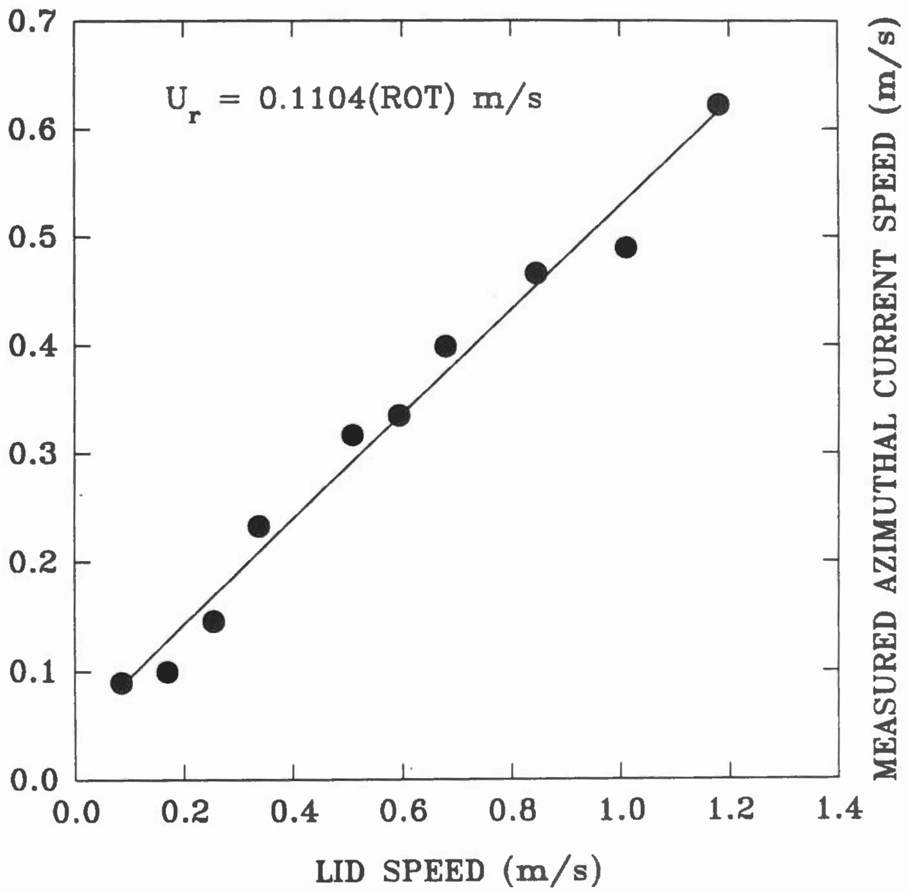


94-350 Sea Carousel calibration curve for station MIR12

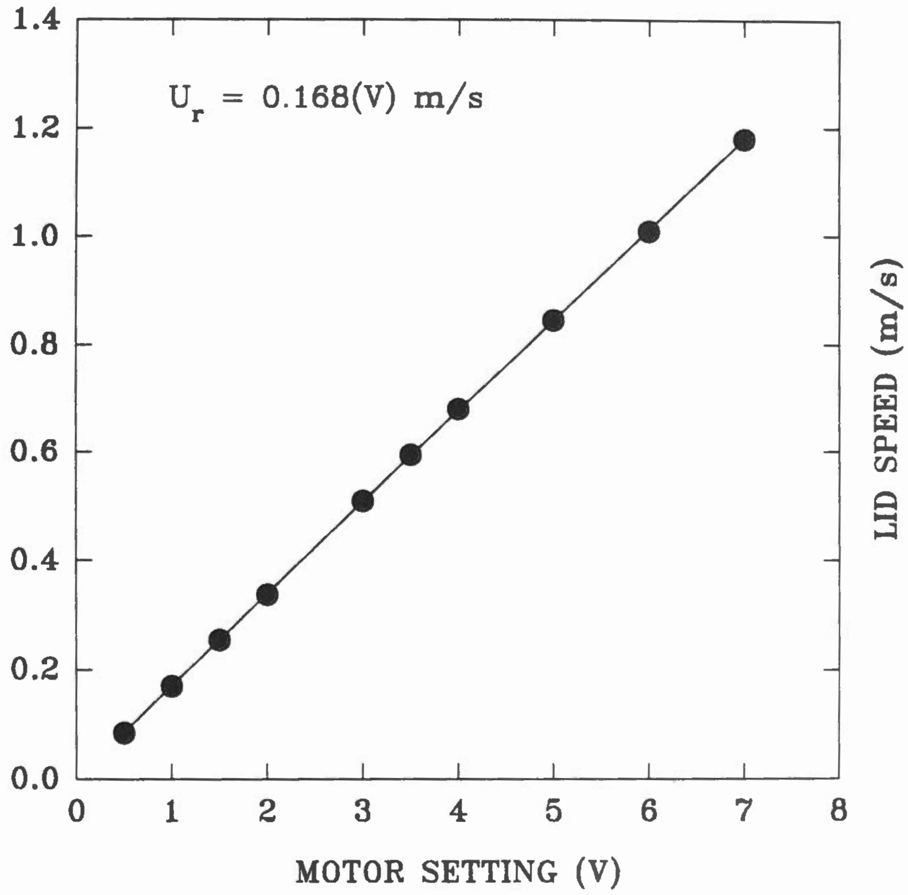


94-350 Sea Carousel calibration curve for station MIR13

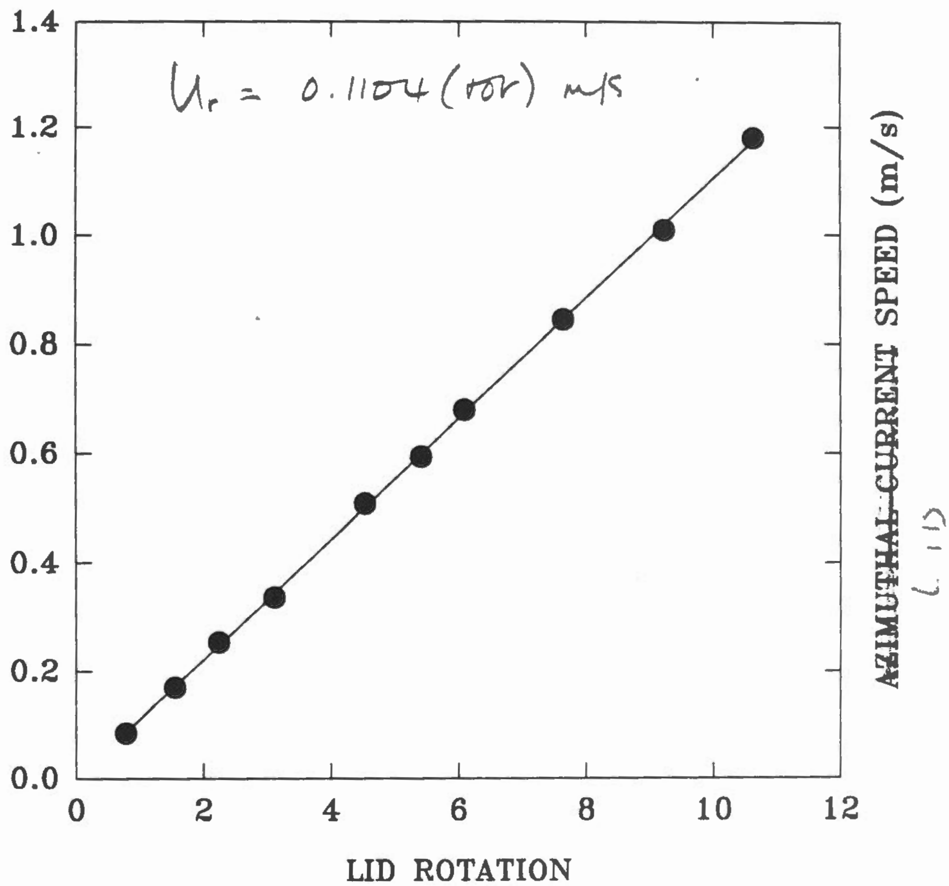




U_r = 0.1104(ROT) m/s
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
LID SPEED (m/s)
MEASURED AZIMUTHAL CURRENT SPEED (m/s)



$U_r = 0.168(V)$ m/s
LID SPEED (m/s)
MOTOR SETTING (V)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
1
2
3
4
5
6
7
8



Miramichi Bay Station 13.
Rot rom *.dat .

U_r = 0.1104 (rot)