

HIGH VELOCITY BOTTOM BOUNDARY LAYER FLOW IN THE HEAD OF A SUBMARINE CANYON

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Continuous measurements of bottom boundary layer current velocity in the head of Salt River submarine canyon, St. Croix, U.S. Virgin Islands, were made during a six day period following the passage of hurricane Klaus. Axial and cross-canyon velocity measurements were made within 2m of the bottom at two stations inline with the canyon axis, in depths of 15m and 20m. On the third day of monitoring, an intense downcanyon "flow event" developed and persisted for approximately 30 hours. Average downcanyon current speeds during this event ranged from 0.45 to 0.80 m/s. High velocity "pulses" of downcanyon flow, ranging from 1.5 to 2.4 m/s, occurred at irregular intervals during the peak of this event. Each high velocity pulse had a duration of 5 to 7 minutes followed by an interval from 15 to 120 minutes. Downcanyon velocity during a high velocity "pulse" was extremely constant at the shallow (15m) station. Conversely, at the deeper (20m) station, downcanyon velocity was quite variable during a high velocity "pulse".

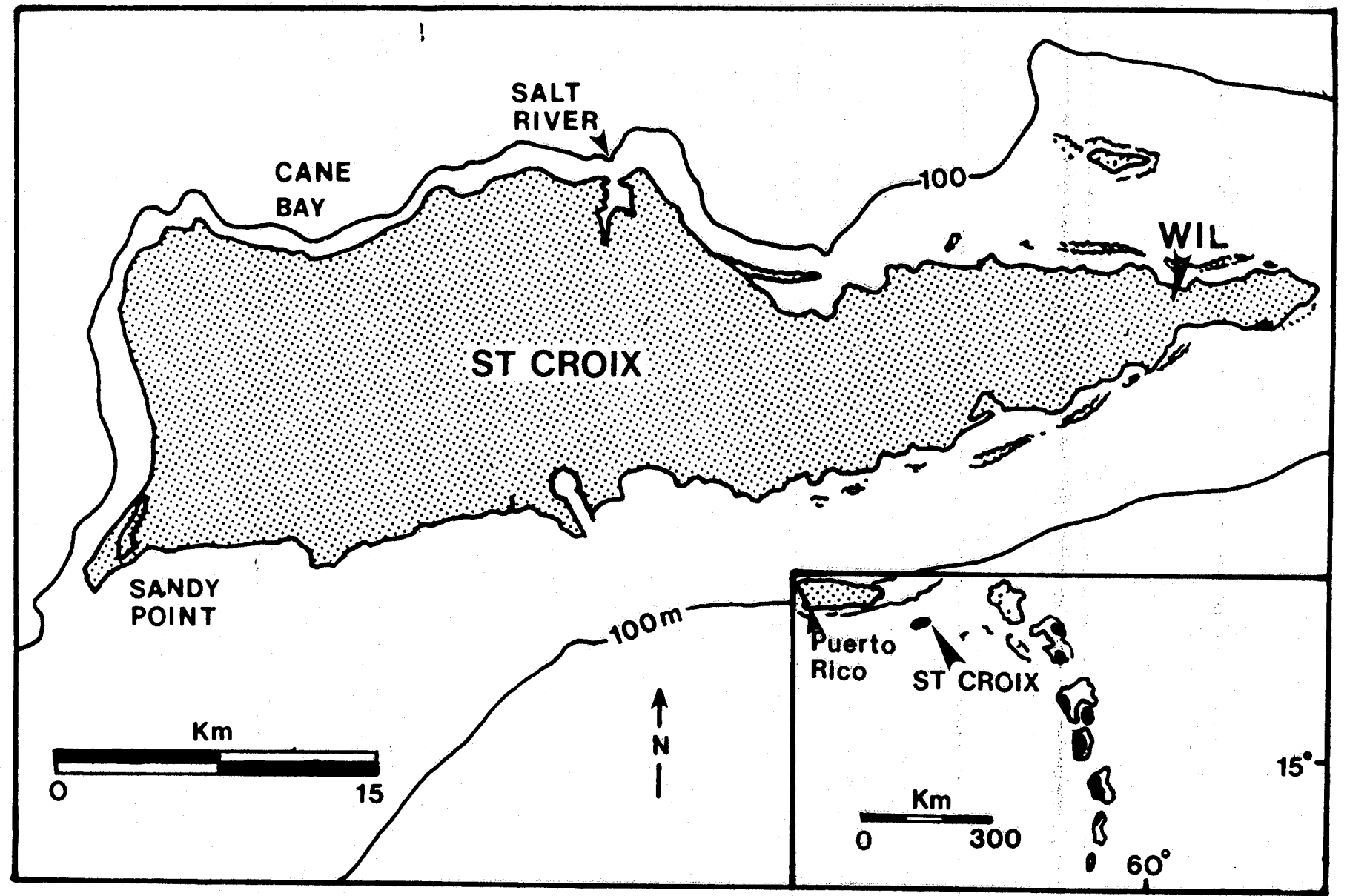


Figure 1. Location Map Salt River Canyon Experiment.

HYDROLAB EXPERIMENTAL DESIGN

An experiment, designed to study boundary layer shear-flow structure and sediment movement at the seafloor bed was conducted in the Salt River Canyon, St. Croix, U.S. Virgin Islands (Figure 1). This experiment utilized the HYDROLAB saturation diving facility located in the canyon head (NH-1, Figure 2). Water depths in the upper canyon head range from 15m to 30m and sediment size varies from 0.7 ϕ to 1.7 ϕ (Figure 3). Two Sea Data 635-12 puv meters were positioned inline along the canyon axis at C-0 (15m) and C-1 (20m), Figure 2. Temperature/pressure recording instruments were placed at the east and west walls of the canyon and at HYDROLAB. Wave, tide, uv current, and temperature measurements were recorded continuously during the six day experiment. An underwater photographic system consisting of a horizontal and vertical dye injection system, photographic grid, and movie camera (Figure 4) was used to record the simultaneous motion of sediment particles and injected dye at the seafloor bed. This photographic system was located 5m upcanyon and inline with puv meter C-0 (Figure 2). Photographic data on sediment/fluid motion in the seabed boundary layer was recorded in 2.5 to 3.0 hour segments during daylight periods.

--This experiment was conducted in November (1984) because meteorologic conditions are most favorable for producing high wave and current energy conditions in the canyon. High energy conditions were defined as those capable of initiating and sustaining sediment transport on the canyon floor. Meteorologic conditions which developed several days after the passage of hurricane Klaus produced a high long period swell which refracted across the island shelf and into the canyon head. This set of conditions produced an unusually high energy "hydrodynamic flow event" on the canyon floor. Sediment transport during most of this high energy event was too intense to be recorded with the photographic system. Therefore, the results presented in this paper focus on the bottom current flow measurements and the unique direct observations of associated sediment movement.

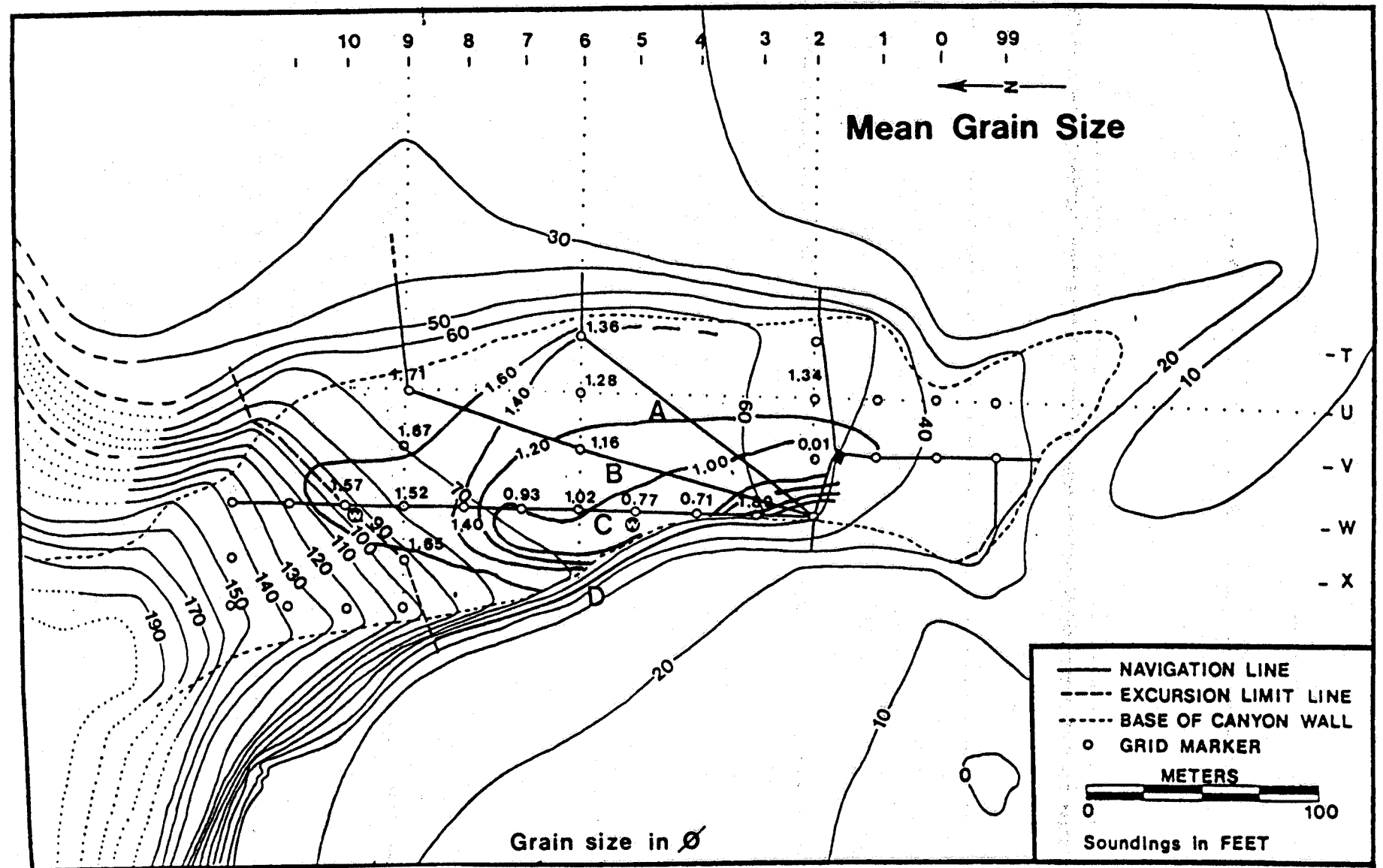


Figure 3. Bathymetry and Mean Grain-Size Distribution in Salt River Submarine Canyon.

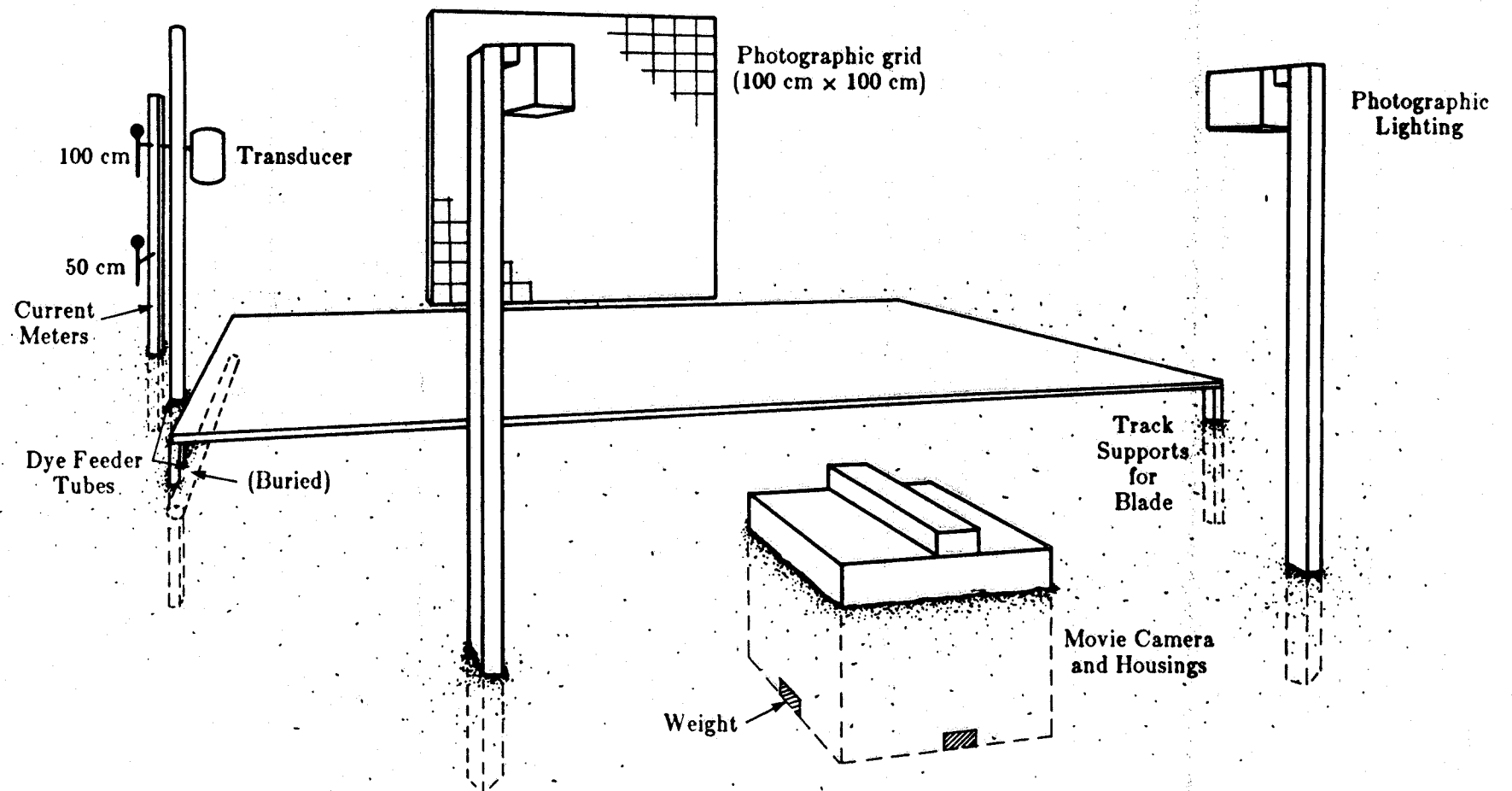


Figure 4. Underwater Photographic System.

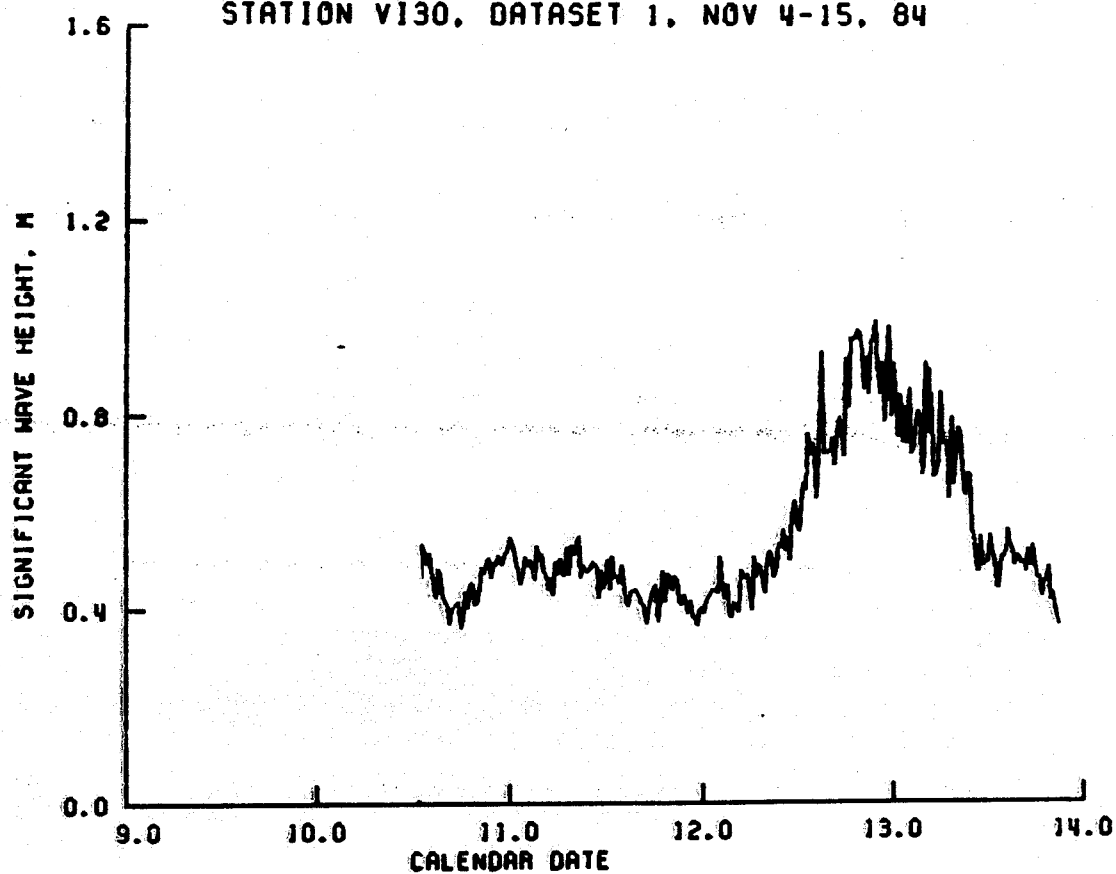
EXPERIMENTAL RESULTS

WAVES

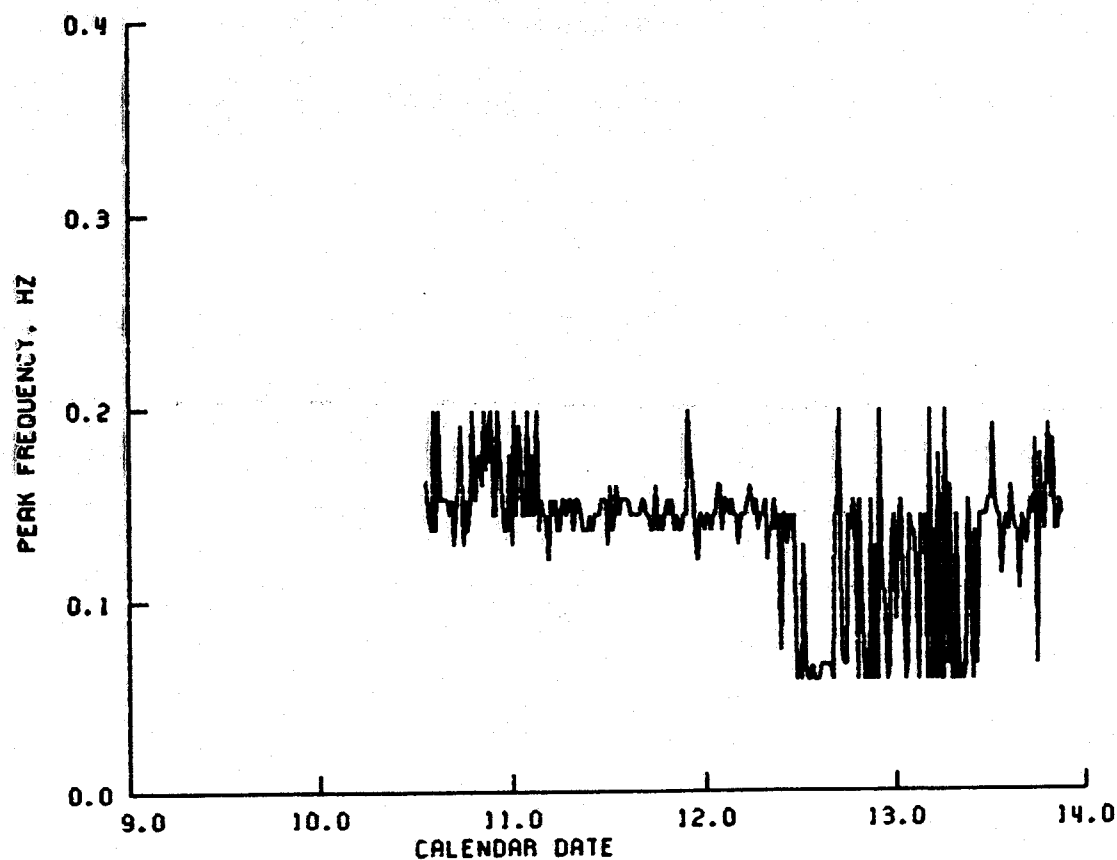
The time series of significant wave height and peak frequency for November 11, 12, and 13 are shown in Figure 5A and 5B respectively. The corresponding time series for direction and directional spread of the peak frequency waves, during this same time period, are shown in Figure 6A and 6B respectively. Common to all four of these time series is the onset of a distinct wave build-up beginning around 1200 hours on November 12. Increase in significant wave height is directly associated with a shift in peak frequency (towards longer periods) and direction (towards the north). During this wave growth period local wind waves (5 to 8 seconds) were augmented by a long period swell (15 to 17 seconds) arriving from a more northerly direction. Energy density in these two wave components was approximately equipartitioned throughout the "event" (Figure 7).

CURRENTS

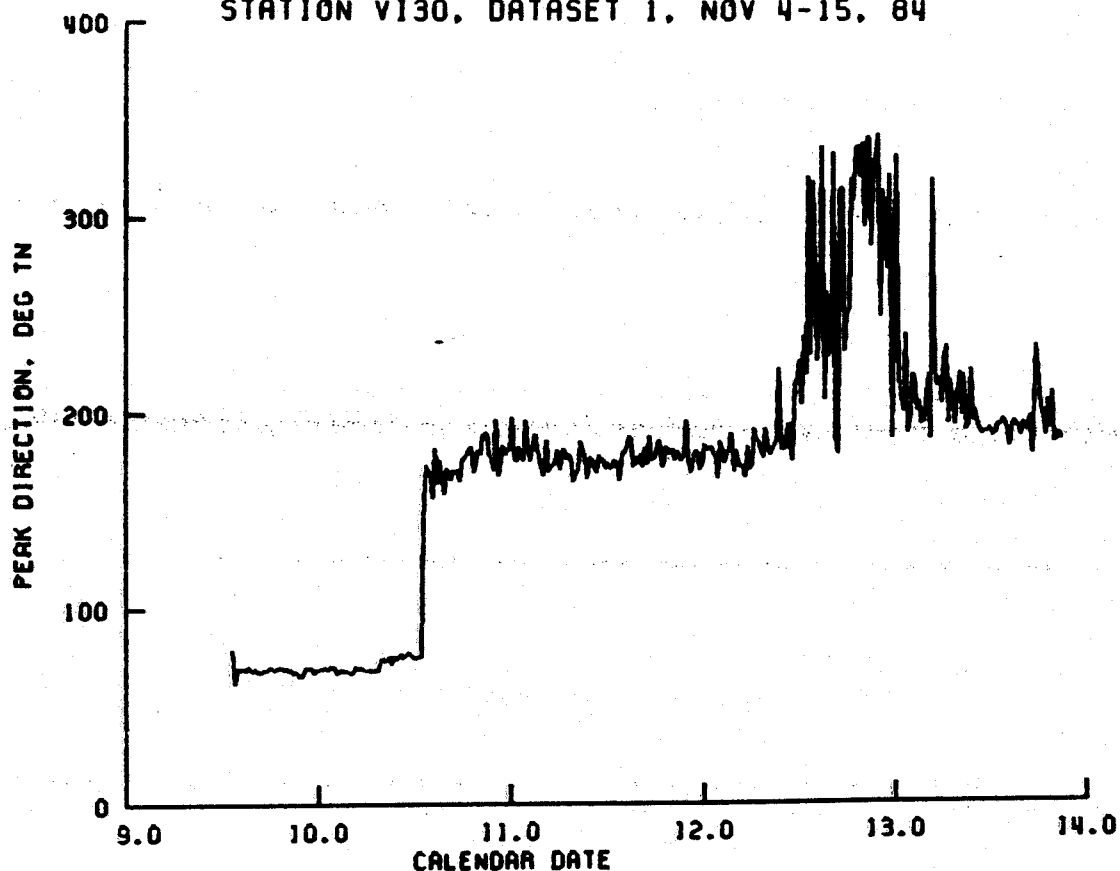
The time series of fourteen minute average current direction and speed for location C-0 (15m) and C-1 (20m) (see Figure 2) are shown in Figures 8A and 8B and 9A and 9B respectively. Meter VI 17 (Figure 8A and B) is approximately 1 meter from the bottom and meter VI 30 (Figure 9A and B) is approximately 2m from the bottom. Figure 9A and B shows average bottom current magnitude preceding the "high energy event" to range from 2 to 15 cm/s. Direction during this pre- "event" period had both up/down and cross canyon components of comparable magnitude. Around 1200 hours on day 12 (Figure 9A and B) currents on the canyon floor began a persistent downcanyon flow with rapidly increasing speeds. Within 4 hours, the average current speed increases to 45 to 80 cm/s at both the deep and shallow stations. These high



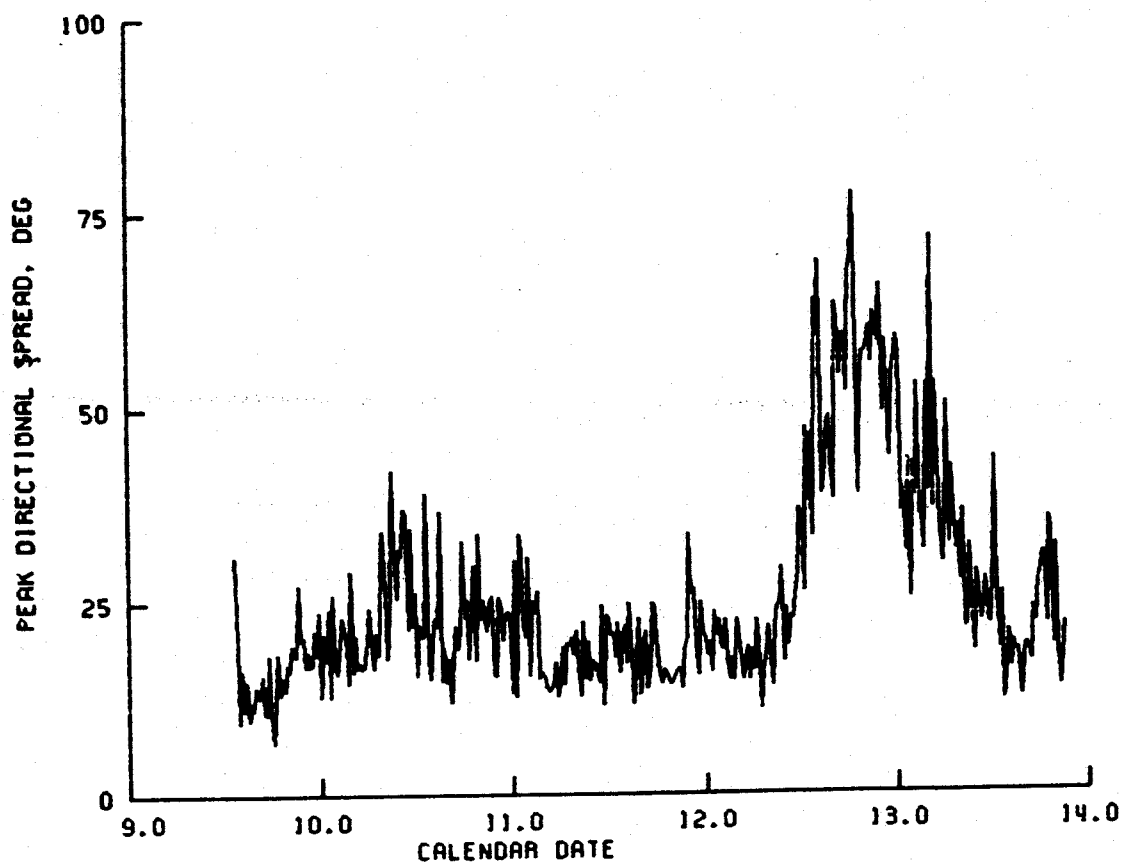
(A) TIME SERIES - 4-15 NOV 84



(B) TIME SERIES - 4-15 NOV 84



(A) TIME SERIES - 4-15 NOV 84



(B) TIME SERIES - 4-15 NOV 84

flow rates continued for approximately 30 hours and decreased rapidly as the surface swell diminished (see Figure 5A and B).

CURRENT "PULSES"

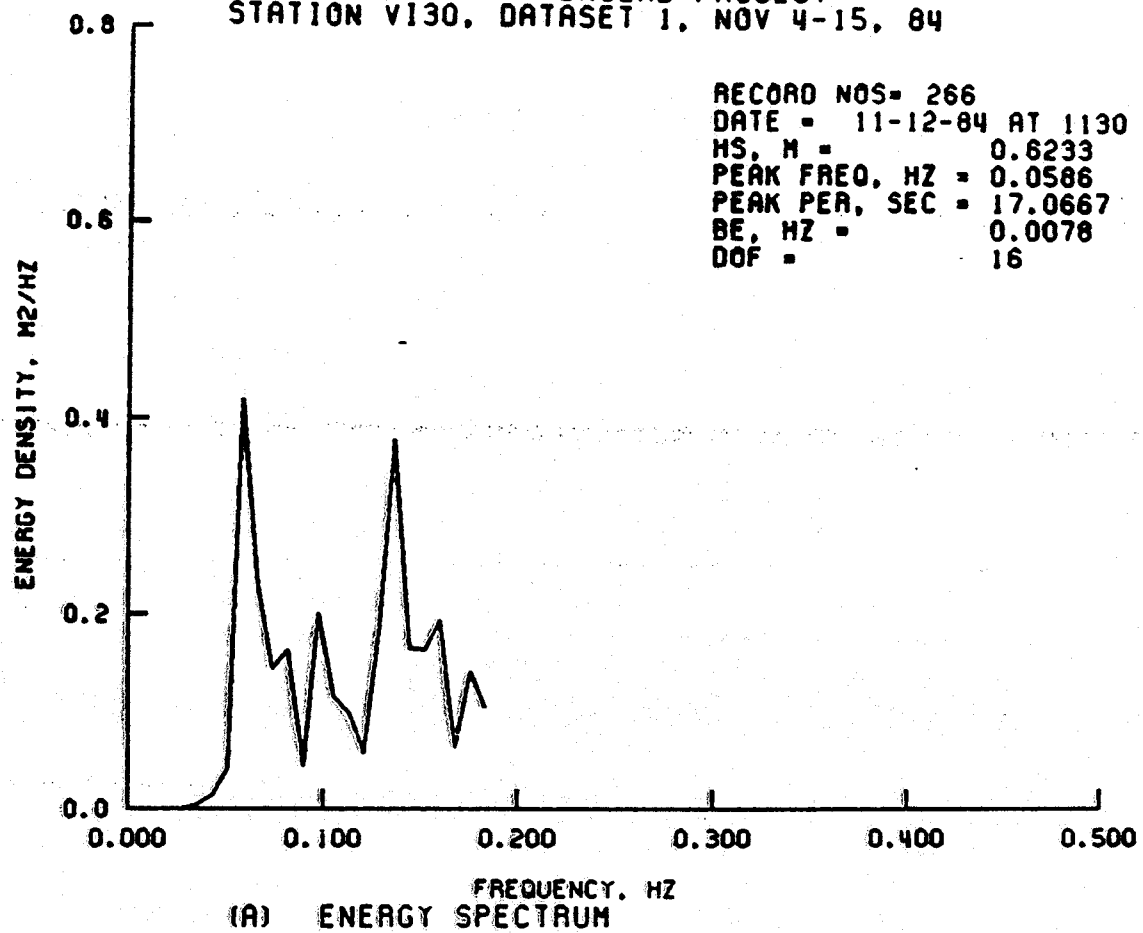
A major feature of the bottom current flow field was an irregular "pulse" of extremely high velocity flow. These "pulses" of downcanyon flow had durations from 5 to 7 minutes followed by an interval of average current velocity lasting from 15 to 120 minutes. Analysis failed to reveal any well defined periodicity in these "pulses". Average current speeds during "pulse" events ranged from 150 to 240 cm/s. The frequency of occurrence of these high velocity "pulses" was much greater at the upcanyon station, C-O than at the downcanyon station, C-1 (see Figures 8B and 9B). In addition to being more frequent, the velocities of a single "pulse" at the upcanyon station were extremely constant ($\pm 10\%$) compared to those at the downcanyon station ($\pm 25\%$).

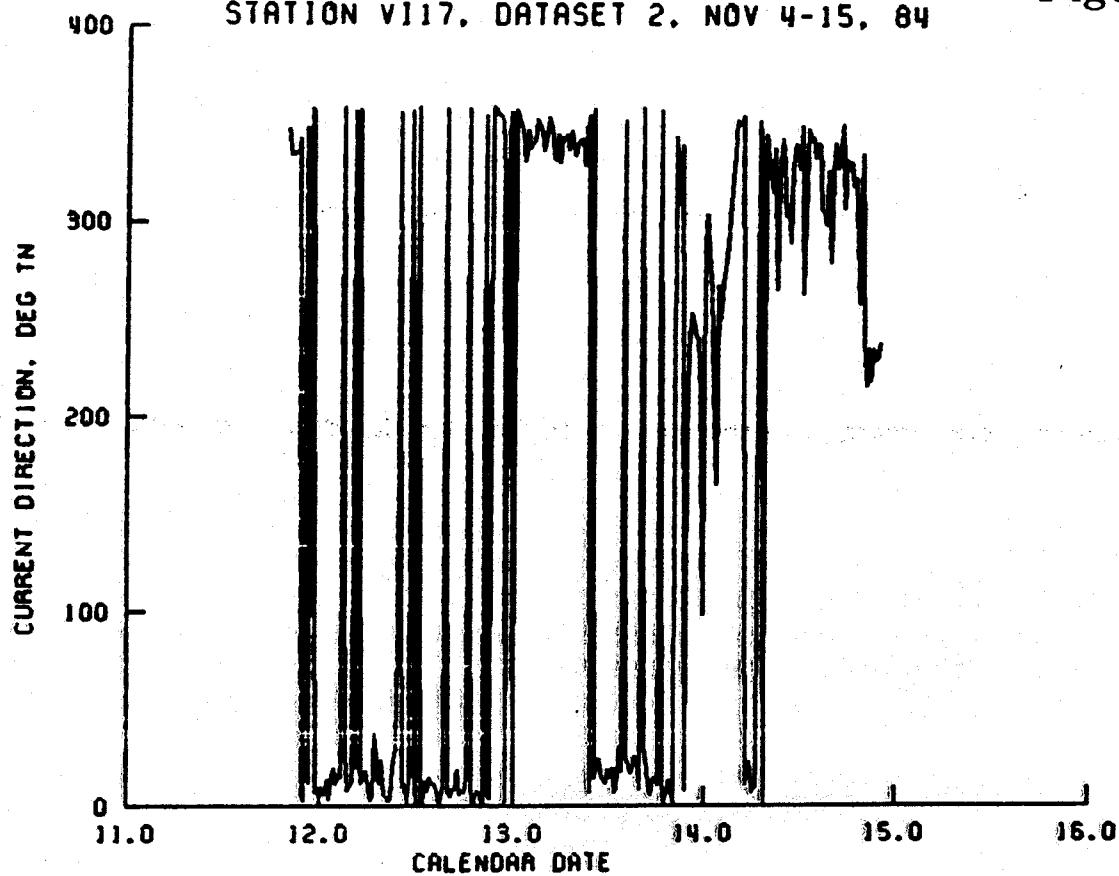
SEDIMENT TRANSPORT

Sediment transport was significant throughout this high velocity "event". Large "bar like" bed forms migrated downcanyon at rates estimated to be of the order of meters per hour. During a high velocity "pulse", sediment concentration was so great that sensible light levels were reduced to a point of producing near zero visibility. No quantitative measurements of sediment transport were determinable from the instrument system.

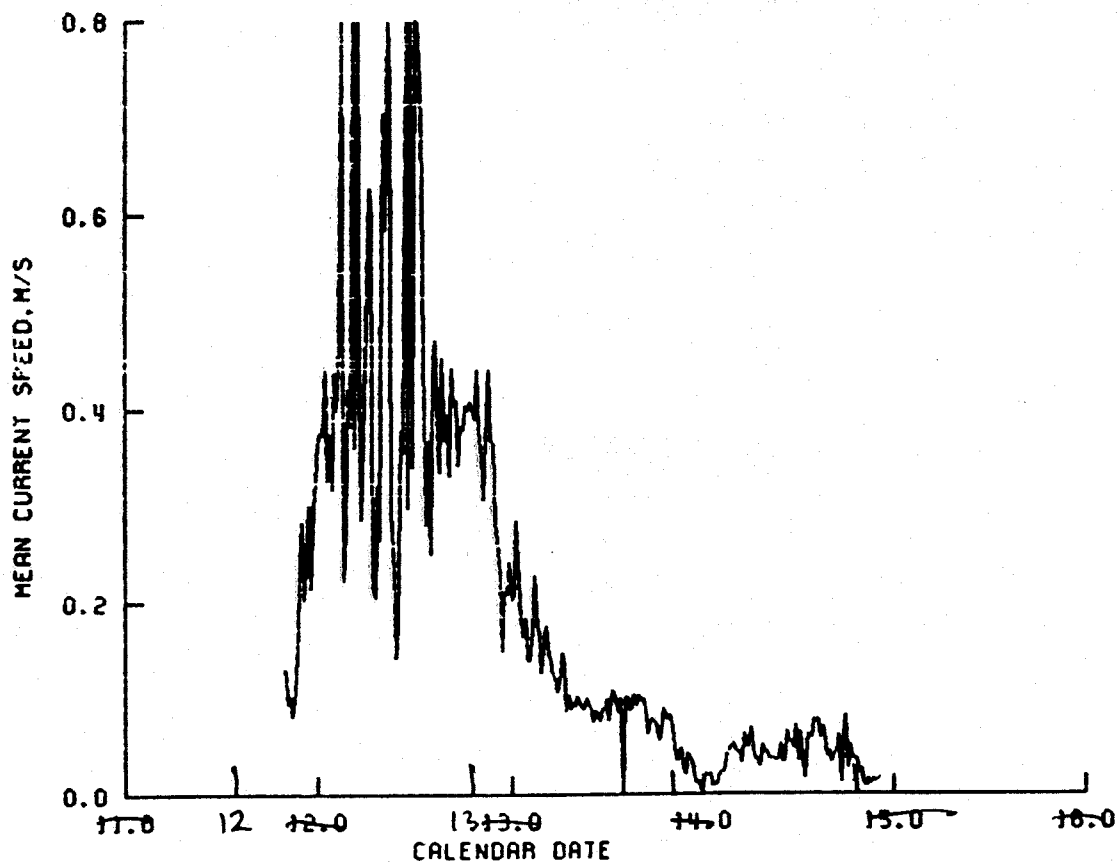
RESULTS FROM PROGRAM PUV
VIRGIN ISLANDS HYDROLAB PROJECT
STATION VI30, DATASET 1, NOV 4-15, 84

Figure 7.





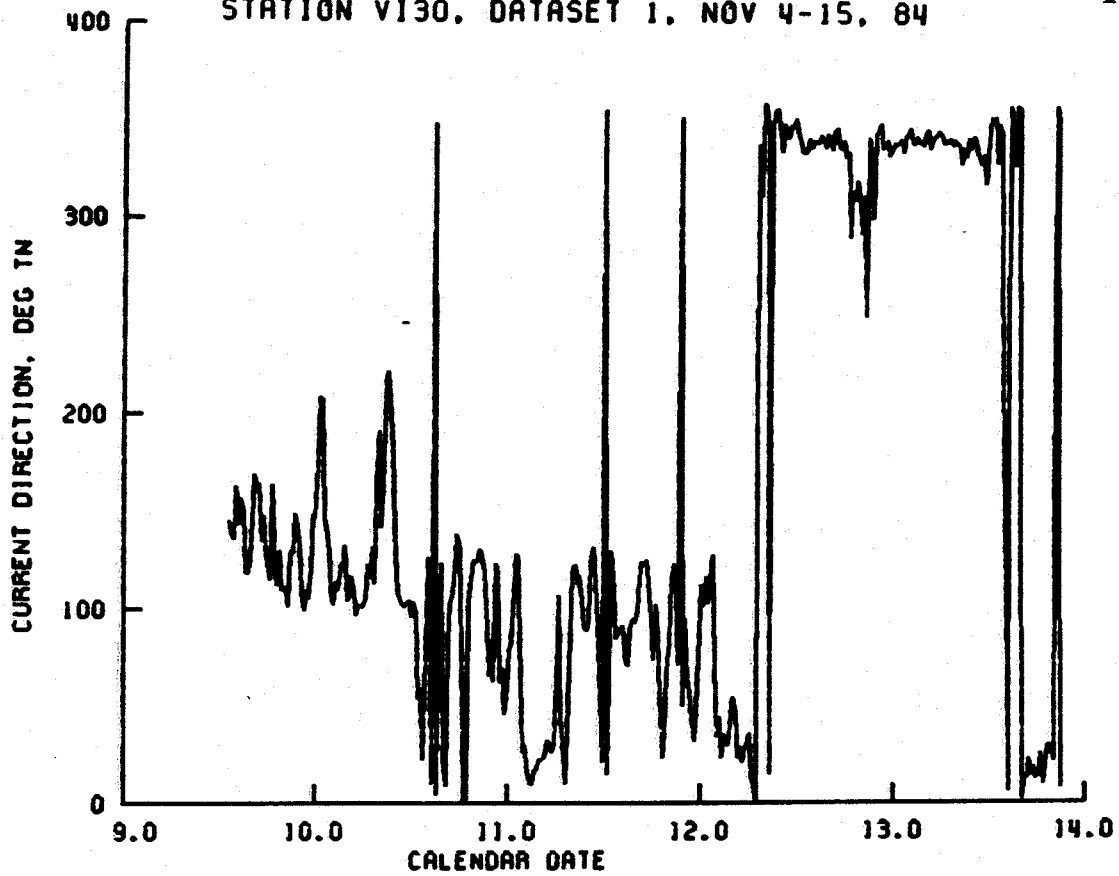
(A) TIME SERIES - 4-15 NOV 84



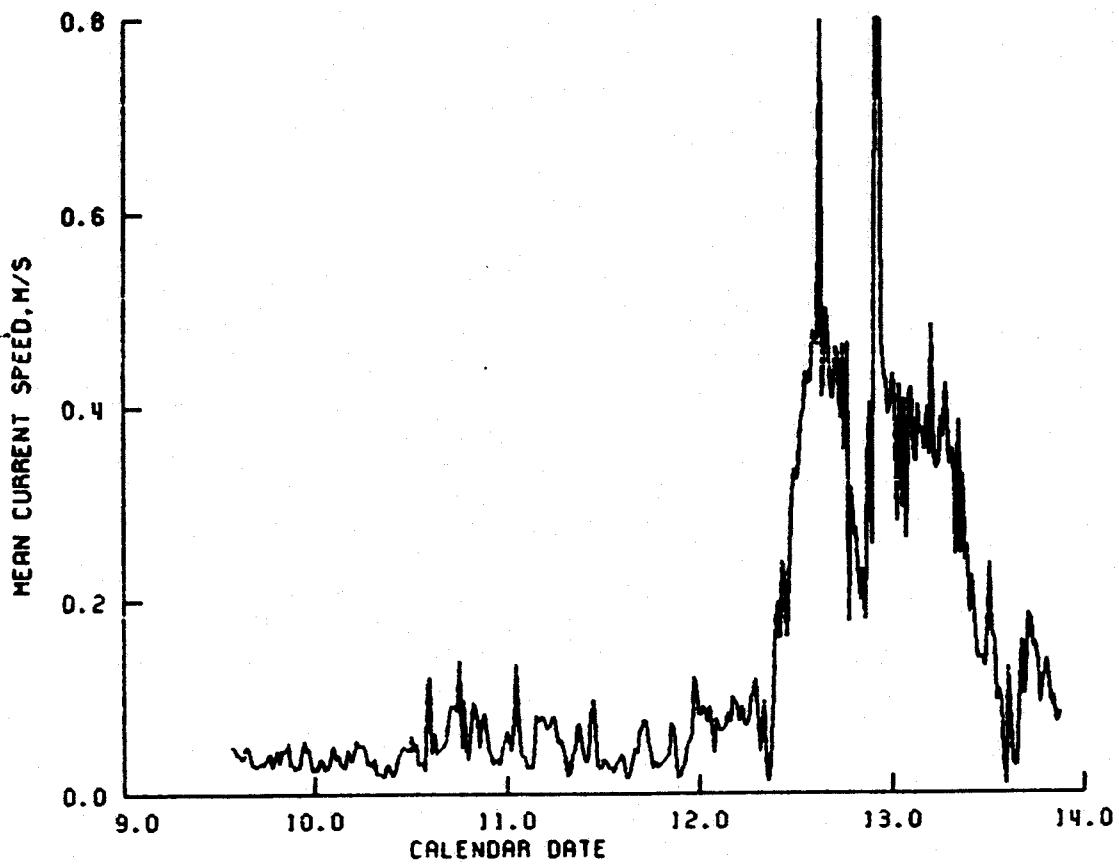
(B) TIME SERIES - 4-15 NOV 84

DISCUSSION

These data results provide insight into the magnitude and temporal variability of high velocity downcanyon flow events. While this type of event is widely evidenced by sediment discharge patterns in the heads of submarine canyons throughout the world, these measurements provide direct quantitative evidence of at least one type of such event. Since the primary purpose of the experiment was to study boundary layer sediment entrainment, these high velocity flow data have only recently been evaluated. Likewise, because of the restricted instrument placement there is a lack of good synoptic data for the entire upper canyon. It is anticipated that additional analysis and some recently acquired support data will provide greater insight into the physical forcing mechanisms responsible for these flows.



(A) TIME SERIES - 4-15 NOV 84



(B) TIME SERIES - 4-15 NOV 84