M E M 0 R A N D U M
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SUBJECT: **A Synoptic Calibration of Electrical Potential Difference for Transport Measurements in Bear Cut**

Introduction

A calibration of electrical potential difference was undertaken in order to examine the relationship of the electrical potential to the actual transport in Bear Cut. This was accomplished by taking current measurements over a full tidal cycle, approximately 25 hours. The simple relationships of open channel flow were used in calculating the transport from the velocity data. In addition, tidal height data were also taken to establish the phase between tidal height and transport. The effective amplitude of velocity, computed transport, electrical potential, and tidal height were then obtained by computing the mean and the variance of the data. The calculated transport and the measured potential were then compared with the theoretical relation between transport and potential.

Geometry

The geometry of the calibration is outlined in Figure 1. Here, the bottom profile parallel to the Bear- Cut Bridge is shown as well as the location of the electrodes and the position of the Bear Cut Tower where data of tidal height, current speed and direction were obtained.

Instrumentation

A Savonious Rotor current meter was used to measure velocity. The current meter output was 10 pulses/rev. This signal was converted to a DC voltage via an Airpax Magmeter at the rate of 0.1 volts/(rev./sec.) An NLS 481-A digital voltmeter provided the read out. Velocities as small as 6.cm/sec. with accuracies of approximately +3% were obtained.

Unfortunately, the current meter direction readings were unreliable so it was assumed that the mean current direction was approximately normal to the plane of the bottom profile in Figure 1. This could produce as much as a 10 to 15 degree error in the mean current direction resulting in no more than a 5% error in transport.

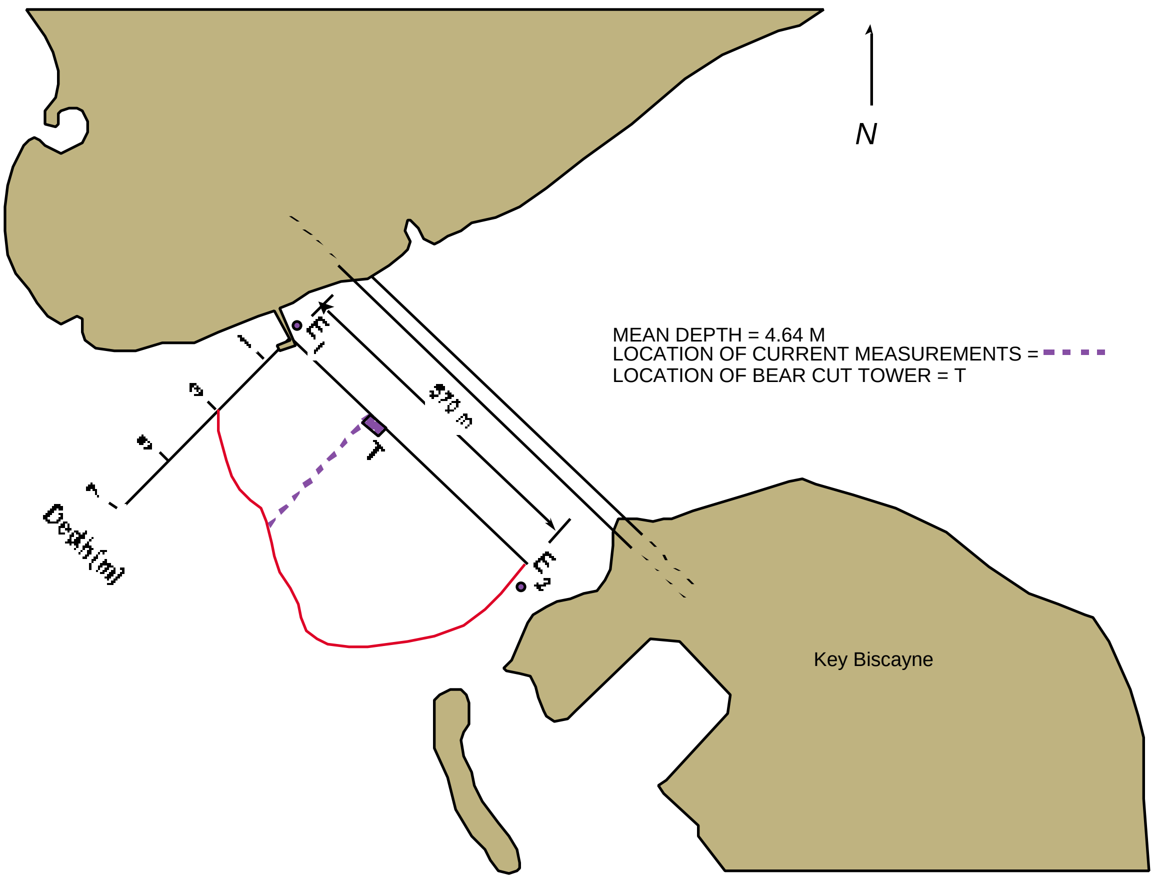

Figure 1. Geometry of calibration showing bottom profile, location of electrodes E_1 and E_2, and current measurements station T.

The Silver Chloride Electrodes, E_1 and E_2, were located on the bottom as shown in Figure 1. The raw signal was conditioned via a High Input Impedance Differential Amplifier end recorded continuously from August through October 1969.

Tidal height was measured with a meter stick wired to one of the tower pilings.

Procedure

Vertical velocity profiles and tidal height data were taken approximately every 40 min. over a 25 hr. period. Each vertical velocity distribution was obtained by taking readings at one foot intervals from the surface to the bottom. Typical velocity profiles are shown in Fig. 2. Each velocity profile was then integrated to obtain a mean velocity V_m.

Calculation of Transport from Mean Velocity

Transport was calculated from the mean velocity via the simple relationships of open channel flow.

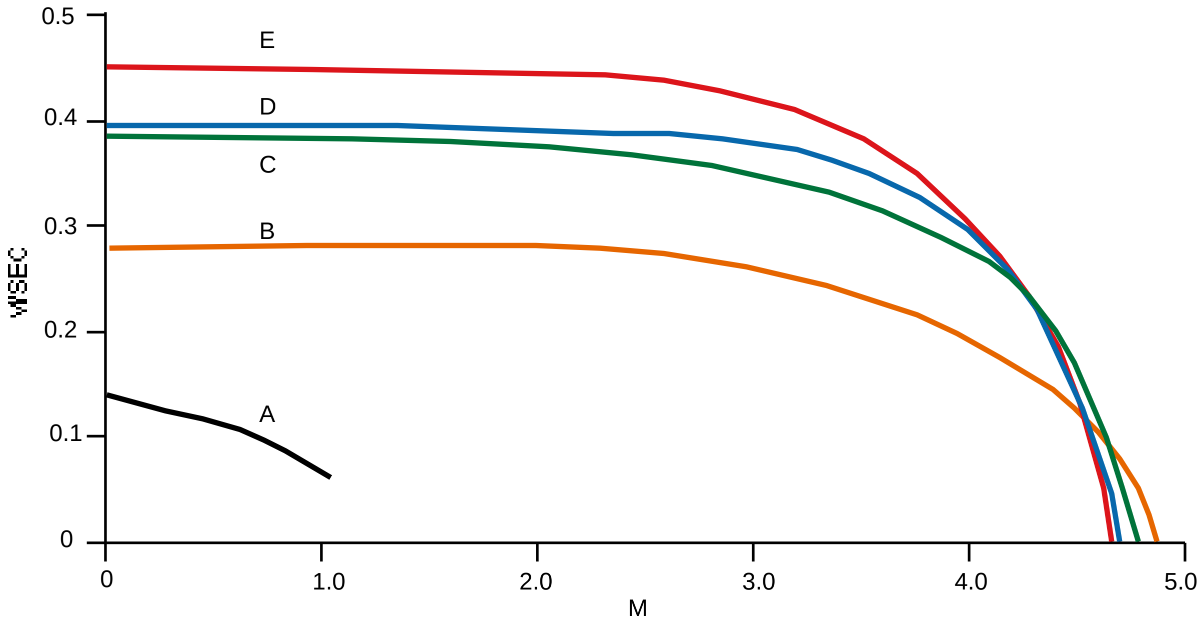

Figure 2. Typical vertical velocity profiles.

If the area of the channel is A and a vertical strip of area is $A_i = h_i\ y_i$ where h_i is the average depth of the strip and is a function of time, and y_i is the width, then the total transport through the channel is:

$$Q = KG$$

where $G = \sum y_i\ h_i^{5/3}$ and was determined from the geometry of the channel, Figure 1, and K is a constant determined from the velocity data, that is:

$$K = \frac{h}{V_m}$$

where h is the depth where the vertical velocity distribution was measured.

G is however, a function of time since:

$$h_i = H_i + h'$$

where H_i is the average depth of the strip and h' is the tidal height perturbation. G was linearized by the approximation:

$$G = A + h'B$$

where

$$A = \sum y_i\ h_i^{\ 5/3}$$

and

$$B = \frac{5}{3} \sum y_i\, h_i^{\;2/3}$$

Thus, for open channel flow, the total transport Q is a function of channel geometry, h' and V_m.

Calculation of Transport from Potential Measurements

If

$$\Delta\Phi = \Delta E\ (\delta)$$

where δ is the effect of bottom conductivity. The transport then is

$$Q = \frac{\overline{h}\ \Delta E}{H_z}$$

Where Q = transport, m^3/see; H_z = vertical component of the earth's magnetic field, 0.417 x 10^{-4} Webers/m^2; $\overline{h}$ average depth of profile, 4.64m; and ΔE is the corrected electrical potential difference, volts. In addition, the signal will be affected by a change in the mean depth by either a shift in the axis of the flow or the tidal height variations.

Results

Data of transport, mean velocity, electrical potential and tidal height are plotted vs time in Figure 3. These data represent a full tidal cycle 25.2 hours. For each curve, the mean and the variance were calculated so that a first order fourier series could be fitted. In general each parameter was represented by:

$$f(t) = a_0 + a_1 \cos \frac{2\pi}{12.6}(t + \theta) + b_1 \sin \frac{2\pi}{12.6} t$$

where a_0, a_1, b_1 and θ were determined from the data, and t is in hours.

The table below summarizes the results.

	a_0	a_1	b_1	θ
Q (m^3/sec)	0	0	10^3	0
V_m (m/sec)	0	0	0.39	0
$\Delta\Phi$ (mV)	-0.8	0	3.2	0
h (m)	0	-0.2	0	0.95

Comparison of Calculated Transport and Measured Potential

The potential corresponding to zero flow was determined from the mean velocity data. A line was drawn through the plot of potential to match the points corresponding to zero mean velocity. This then was the reference line used in calculating the mean and the variance of the

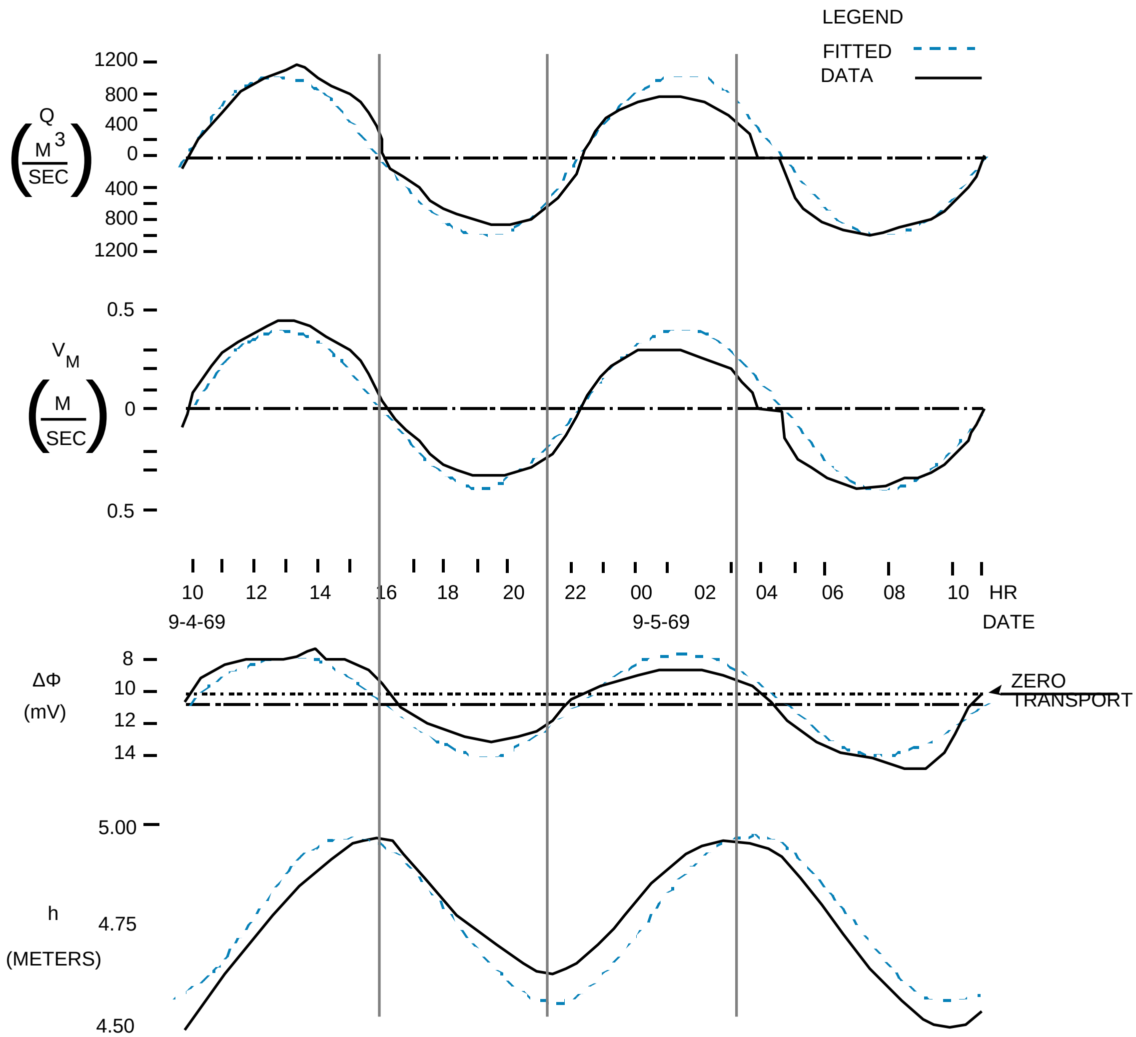

Figure 3. Data of transport, Q, mean velocity V_m, measured potential difference $\Delta\Phi$, and tidal height h vs time. Fitted curves are characterized by an average period of 12.6 hours.

potential. This zero transport line corresponded to approximately 10 mv of potential or about 17 mv/Km. This large potential gradient persisted for as long as the data of potential were taken, about 4 months and was quite puzzling since the electrodes in the laboratory had essentially the same potential.

Another important feature of the potential was that the mean was not zero while the mean of the velocity data was zero. The mean of the potential was a 0 = -0.8 mv or about 25% of the amplitude, b, = 3.2 mv. This could have been caused by a shift of the flow axis over varying depths as well as the variations in tidal height. Tidal height variations of ±0.2 m could only account for ±47 of the voltage. It is possible then that the balance of the voltage bias could be explained by a shift in the axis of the flow, that is, during a flood condition the mean depth h was greater than the mean depth during ebb flow. This is quite possible when you consider the asymmetry of the bottom contour in Figure 1.

According to the theory, the potential amplitude. of 3.2 mv is much too small to account for the transport amplitude of 10^3 m^3/sec. This suggests that a significant bottom conductivity was at work. This would severely moderate the expected potential for an insulated bottom. With an insulated bottom, a transport of 10^3 m^3/sec. and a mean depth of 4.64 m should produce a potential of ΔE = 9.0 mv. Thus the effect of bottom conductivity is determined and δ = 0.36.

Tidal Height

For the time period investigated, the tidal height variations at the measuring station were characterized by 4.75 ± 0.2 m as in Figure 3. The phase of tidal height with transport was, on the average for the 25.2 hours, 0.95 hours, that is, the high and low water levels preceded zero flow by 0.95 hours.

Conclusions

The calibration of electrical potential in Bear Cut showed that variations in tidal height, a shift in the flow axis over an asymmetric bottom contour, and the presence of a rather large potential gradient all contributed to a certain smudge factor resulting in a rather cloudy quantitative picture of transport.

Generally, for estuarine transport measurements, the method of electrical potential must be evaluated by a calibration for each particular application in order to obtain quantitative data. However, the technique does allow an investigator to obtain a long time series of potential that qualitatively raflects the variations in transport.

REFERENCE

Longuet - Higgins, M. S. 1949. The effects of tidal streams. Monthly Notices Royal Astronomical Society (Geophys. Suppl. 5), 8:285-307.