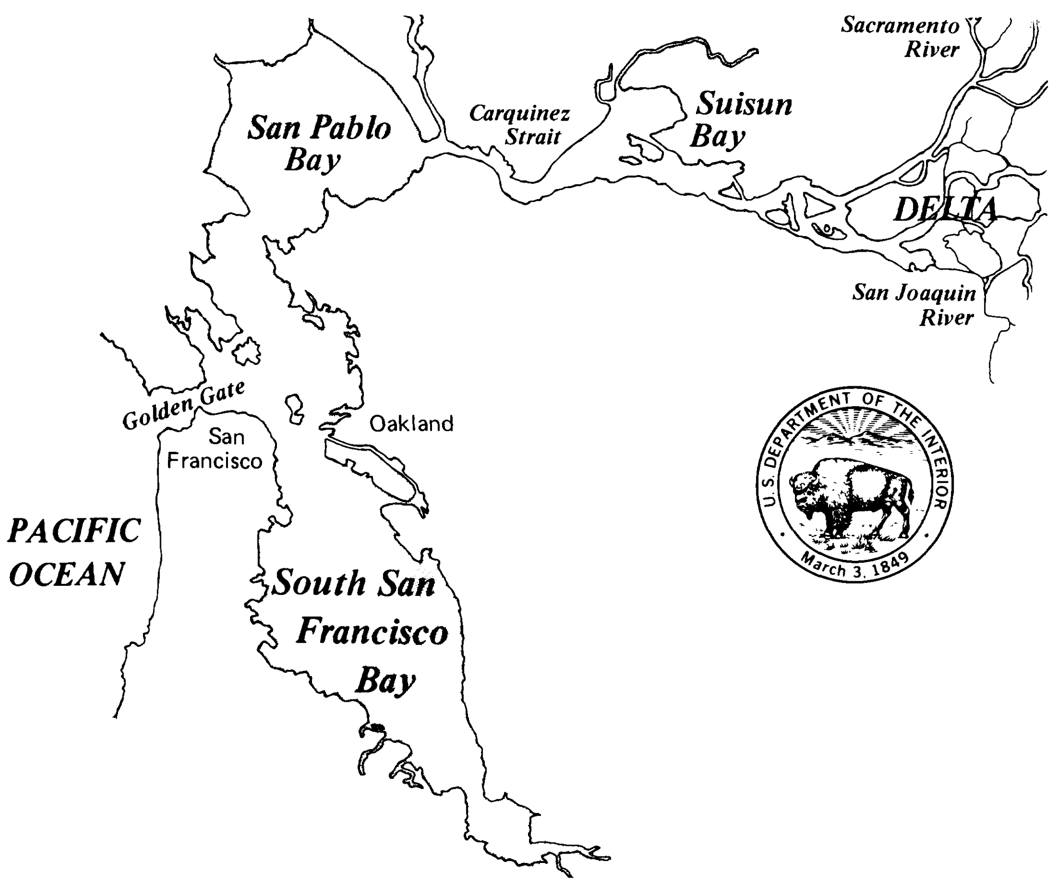
TIDES, AND TIDAL AND RESIDUAL CURRENTS IN SUISUN AND SAN PABLO BAYS, CALIFORNIA,

RESULTS OF MEASUREMENTS, 1986

U. S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 88-4027



Prepared in cooperation with the
CALIFORNIA STATE WATER RESOURCES CONTROL BOARD
and the
CALIFORNIA DEPARTMENT OF WATER RESOURCES

TIDES, AND TIDAL AND RESIDUAL CURRENTS IN SUISUN AND SAN PABLO BAYS, CALIFORNIA--RESULTS OF MEASUREMENTS, 1986

By Jeffrey W. Gartner and Brian T. Yost

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 88-4027

Prepared in cooperation with the
CALIFORNIA STATE WATER RESOURCES CONTROL BOARD and the
CALIFORNIA DEPARTMENT OF WATER RESOURCES

Menlo Park, California
1988

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

Regional Hydrologist
Water Resources Division
U.S. Geological Survey
345 Middlefield Road, MS 470
Menlo Park, CA 94025

Copies of this report can be purchased from:

Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Bldg 810, Box 25425
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

Conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in)
centimeter per second (cm/s)	0.3937	inch per second (in/s)
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)
cubic meters per second (m^3/s)	35.31	cubic feet per second (f^3/s)
square kilometers (km^2)	0.3861	square miles (mi^2)
cubic kilometers per year (km^3/yr)	0.2399	cubic miles per year (mi^3/yr)

Temperature in degrees Celsius (^{o}C) can be converted to degrees Fahrenheit (^{o}F) as follows:

$$^{o}F = 1.8 \times {}^{o}C + 32$$

Tides, and Tidal and Residual Currents in Suisun and San Pablo Bays, California, Results of Measurements, 1986

by

Jeffrey W. Gartner and Brian T. Yost

ABSTRACT

Current-meter data collected at 11 stations and water-level data collected at one station in Suisun and San Pablo Bays, California in 1986 are compiled in this report. Current-meter measurements include current speed and direction, and water temperature and salinity (computed from temperature and conductivity). For each of the 19 current-meter records, data are presented in two forms. These are: (1) results of harmonic analysis; and (2) plots of tidal current speed and direction versus time and plots of temperature and salinity versus time. Spatial distribution of the properties of tidal currents are given in graphic form. In addition, Eulerian residual currents have been compiled by using a vector-averaging technique. Water-level data are presented in the form of a time-series plot and the results of harmonic analysis.

Results of harmonic analysis indicate that other than at shoal stations, the tidal currents generally are bi-directional and the principal direction depends on basin bathymetry. Current speed indicates a spring/neap variation of about a factor of three and the calculated form number indicates that the tidal current is mixed but closer to semidiurnal than to diurnal. At those stations where multiple meters were deployed in the verti-

cal, the root mean square (RMS) velocity values decrease from top to bottom as expected. In general, tidal currents in shoal regions of Grizzly Bay are not bi-directional. During a period of high river inflow, several velocity records indicate flows with riverine characteristics. Eulerian residual flows at deep water stations indicate down-estuary flows during periods of high inflows, and multiple-meter stations display evidence of gravitational circulation. The magnitude of residual flows at shoal stations generally are low and values calculated from measurements at these stations probably are not meaningful.

Analysis of water-level data indicates a phase shift of about 80 to 100 degrees when compared with current data (currents lead tide) indicative of the standing-wave characteristic of tidal propagation in Grizzly Bay. Tidal-form number in Grizzly Bay is typical of values throughout Suisun Bay and indicates a mixed, mainly semidiurnal tide.

INTRODUCTION

The San Francisco Bay estuary and Delta has been the focus of extensive interdisciplinary studies undertaken to better understand the physical, chemical, and biological processes that affect this complex estuarine system (fig. 1). Broad goals of these studies are to understand the processes by which water, solutes, sediments, and organisms interact; to quantify effects of river inflow, winds, and tides; and to develop and verify various conceptual and numerical models of these relations (Cheng and Conomos, 1980). As an aid to accomplishing these goals, it is recognized that the description of hydrodynamic processes is important to the understanding of transport processes, circulation, and mixing, and as an aid to implementing hydrodynamic models

A study to examine tides and tidal currents of San Francisco Bay was undertaken by the U.S. Geological Survey in cooperation with the California Department of Water Resources and the State Water Resources Control Board. This study was part of ongoing research being conducted by the Interagency Ecological Studies Group whose other members include California Department of Fish and Game, U.S. Bureau of Reclamation, and the U.S. Fish and Wildlife Service.

In-situ recording current-meter and tide (water-level) stations have been established throughout the bay system. The current meters record current speed and direction, and water temperature and conductivity at 2-minute intervals for deployment

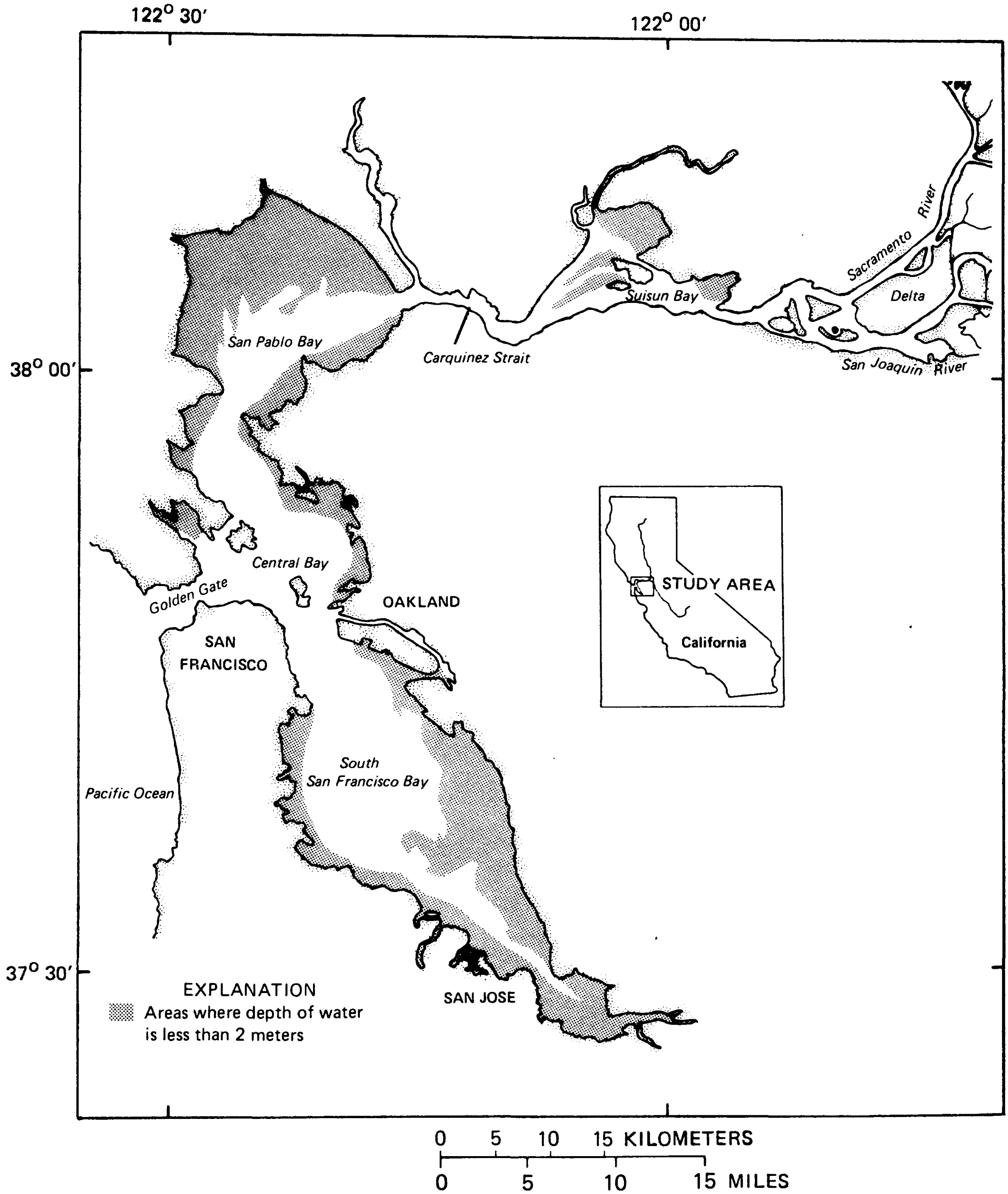


Figure 1. San Francisco Bay estuarine system.

periods of as much as 30 to 40 days. Previous reports document current-meter and water-level data collected from 1978 through 1985 (Gartner and Cheng, 1982; Cheng and Gartner, 1984; Gartner and Walters, 1986; and Gartner, 1986).

Purpose and Scope

The purpose of this report is to present in a useful form, all current-meter and water-level data collected in 1986. Data are displayed graphically in the form of time-series plots and the spatial distribution of major properties of tidal currents are shown. Tidal elevation and velocity data have been harmonically analyzed to determine the amplitude and phase of the primary tidal constituents (harmonic constants). The harmonic constants are used to qualitatively define the tide and may be used for tide and tidal current predictions. Eulerian residual currents have been determined by vector averaging the velocity-time series. All data collected during this period were in Suisun and San Pablo Bays. A brief summary of the data-collection program and data processing procedures is given below. More complete descriptions of equipment and deployment, recovery, maintenance, and data processing procedures are given by Cheng and Gartner (1980, 1984).

Acknowledgments

The authors gratefully acknowledge the assistance of the Tiburon Center for Environmental Studies who provided some of the field data documented in this report.

DATA-COLLECTION PROGRAM

Suisun and San Pablo Bays

All current-meter and water-level data collected in 1986 were from stations in Suisun and San Pablo Bays (fig. 1). Suisun Bay has a surface area of approximately 94 km^2 and a mean depth of 4.3 m. [All depths are referenced to mean lower low water (MLLW).] The embayment is characterized by deep channels (9-14 m) surrounding numerous shoal regions and islands. There are two subembayments (Grizzly and Honker Bays) with mean depths less than 2 m. (fig. 2). San Pablo Bay has a surface area of 271 km^2 and a mean depth of 2.7 m. There is a deep shipping channel to the southeast part of the embayment and a shoal region in the northwest. Fifty-seven percent of San Pablo Bay is less than 2 m deep.

Water properties vary seasonally and are controlled in part by freshwater inflows into Suisun Bay from the Sacramento and San Joaquin Rivers. Inflow values during summer months are typically 300 to 400 m^3/s, whereas winter flows may reach 8,000 to 12,000 m^3/s. Increased winter flows may cause Suisun Bay to become riverine with seaward river inflows dominating over tidal oscillations. Typical salinity values for Suisun Bay are 1 to 3 $^o/oo$ near the confluence of the Sacramento and San Joaquin Rivers, and 10 to 20 $^o/oo$ at the west end near Carquinez Strait. Typical salinity values for San Pablo Bay are 20 to 28$^o/oo$ and during wet winters vertical stratification may exceed 10 $^o/oo$.

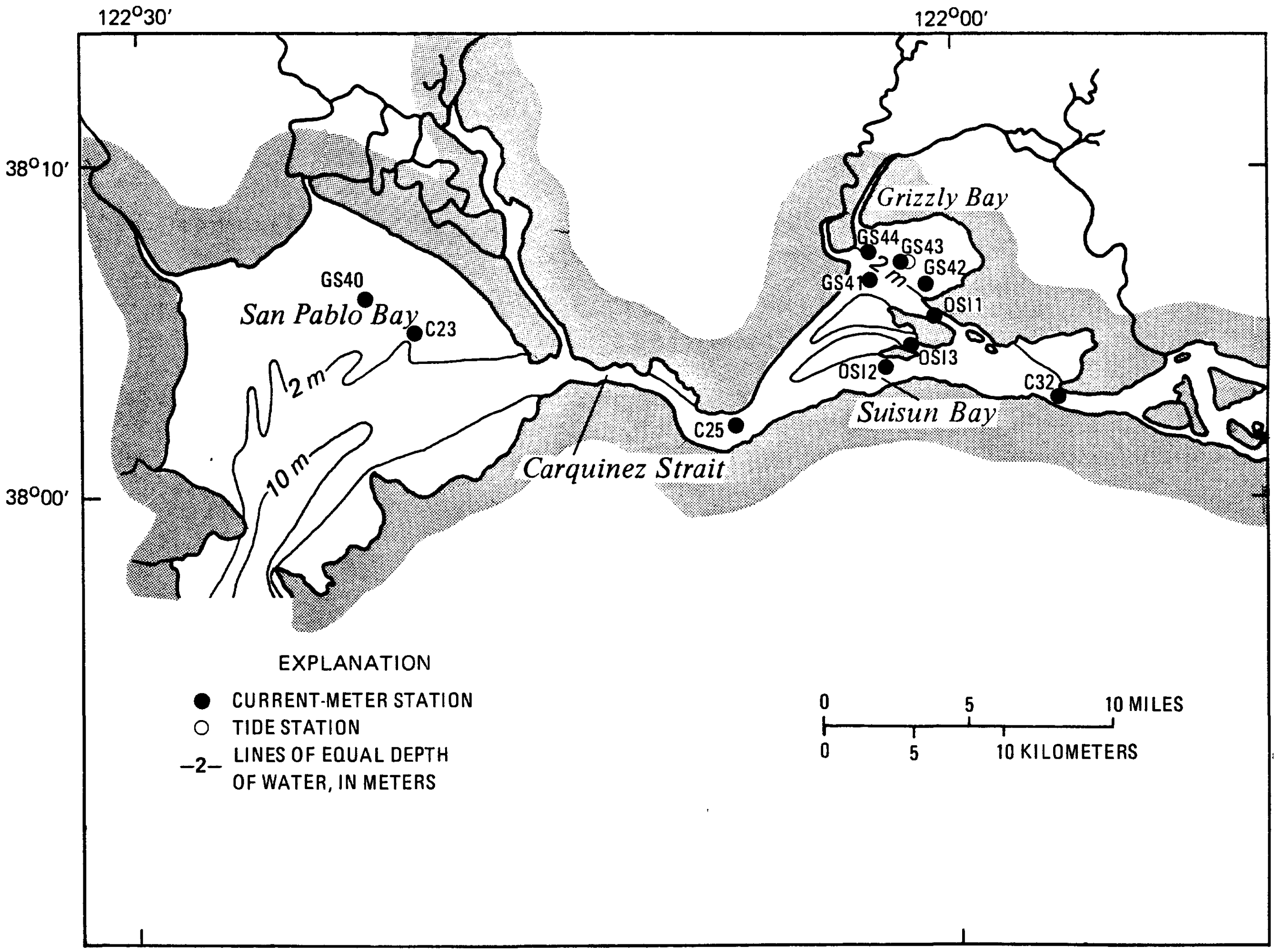


Figure 2. Suisun and San Pablo Bay region and the location of current-meter moorings and water-level recorder.

Meteorological conditions for Suisun Bay are characterized by prevailing westerly or southwesterly winds in the late spring, summer, and early fall and by more intermittent northerly winds in winter. Winds in San Pablo Bay are generally southwesterly in the spring, summer, and fall, and more north or northeasterly in the winter (Gartner and Cheng, 1983). Winter winds are more variable, whereas summer winds, driven by heating of inland air masses, generally are stronger.

Measurements of Tides and Tidal Currents

Tides and tidal currents in San Francisco Bay consist of the sum of numerous partial tidal constituents. Of these, half a dozen semidiurnal and diurnal partial tides and one overtide are the most important. Because the frequencies of partial tides are different, resulting tides (and tidal currents) in San Francisco Bay vary constantly as the partial tides move in phase (reinforcing each other) and out of phase (canceling each other) in a fortnightly cycle. The net effect of these phase differences gives rise to spring and neap variations of tides and tidal currents. One of the principal objectives of the present data-collection program is to measure the tides and tidal currents and define the partial tides from these data. Clearly, the longer the time-series of field data, the better each frequency can be separated and the more accurately each partial tide can be computed. Therefore, only self-contained recording current meters and tide recorders that are capable of recording data for a minimum of 15 days were used.

Equipment

Current meters used in the study are Endeco-174[1] digital recording current meters. The Endeco-174 is an axial-flow, ducted-impeller current meter that stores data on a magnetic tape cartridge or in CMOS memory (Cheng and Wang, 1985). As much as 40 days of data can be stored when the data-recording interval is selected to be 2 minutes. Accuracy specifications for Endeco-174 current meters provided by the manufacturer (Endeco Inc., Marion, Mass.) (Endeco 1978) are: speed, ±3.0 percent of full scale (223 cm/s) above the threshold (2.6 cm/s); direction, ±7.2°; temperature, ±0.2 °C; and conductivity, ±0.55 mS/cm (millisiemens per centimeter).

Current speed is determined by measuring the displacement of an encoder-disc driven by an impeller through a magnetic coupler and a 500:1 reduction gear. Current direction (current meter heading) is determined from the output of a damped magnetic compass. Temperature is determined by a thermistor and conductivity by an induction type electrodeless-conductivity probe. Current speed is the average speed over the sampling interval while current direction and water temperature and conductivity are instantaneous values at the time of sampling.

---

[1]Use of trade name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey

Water-level data were recorded by using an Endeco-1032 tide recorder. The recorder uses a semiconductor strain-gage pressure sensor and a 60-second digital integration of pressure to determine a average of pressure for each sample. This method filters out pressure variations caused by wave motion. Data are recorded on eight-track tape or stored in CMOS memory in a manner similar to that used in the Endeco-174 current meter. Pressure variations caused by daily atmospheric pressure changes were accounted for during data translation.

Water-Level and Current-Meter Stations

Six current-meter stations were established in Suisun Bay and two in San Pablo Bay by the Geological Survey during two time periods in 1986. Three additional stations were established in Suisun Bay during the second period by Ocean Surveys Inc. for Tiburon Center for Environmental Studies. A water-level recorder was used at one station during each time period. A total of 18 current-meter records and 1 water-level record are presented in this report; equipment were redeployed at the same location and multiple current meters were deployed at the Ocean Surveys Inc. stations. The minimum length current-meter deployment was 26 days (meter hit, dragged, and removed early); the maximum deployment was 55 days (equipment not recovered on first attempt). Useable data generally were limited to about 42 days for data collected by the Geological Survey and about 30 days for data collected by Ocean Surveys Inc. Figure 2 shows the approximate location of the current-meter and water-level stations. The latitude and longitude and the water depth for each station are compiled in table 1. The positions of current-meter stations were determined by Loran C fixes ($\pm$30 m). Also included in table 1 are the depths at which the current meters were deployed, and the deployment and recovery dates for all equipment used. All reference times have been converted to Pacific Standard Time. Figure 3 is a chronological bargraph that indicates the period of time during which current-meter data were collected during 1986. The open bars on the bargraph indicate current-meter stations where multiple current meters were used for the indicated period of time. Table 1, figure 2, and figure 3 define the complete spatial and temporal distributions of the field data.

Table 1.--Current-meter and tide stations in Suisun and San Pablo Bays, California in 1986. Datum level for depths is mean lower low water (MLLW).

Station number	Latitude (North)	Longitude (West)	Deployment date	Recovery date	Water depth (meters)	Meter Depth below MLLW (meters)
C23	38°04'35"	122°20'47"	3/14/86	4/23/86	2.2	1.0
C23	38°04'41"	122°20'48"	9/24/86	11/5/86	2.1	0.9
C25	38°02'10"	122° 7'55"	3/14/86	5/2/86	17.0	9.1
C32	38°02'55"	121°55'25"	3/13/86	4/7/86	11.3	5.2
GS40	38°05'29"	122°22'34"	9/24/86	11/4/86	1.6	0.4
GS41	38°06'33"	122° 2'55"	3/13/86	5/2/86	4.0	1.2
GS41	38°06'28"	122° 2'46"	9/23/86	11/4/86	2.5	0.3
GS42	38°06'13"	122° 0'45"	3/13/86	5/1/86	2.1	0.9
GS42	38°06' 6"	122° 0'56'	9/23/86	11/4/86	2.0	0.5
GS43	38°07'17"	122° 1'35"	3/13/86	5/1/86	2.1	0.9
GS44	38°07'13"	122° 2'46"	3/13/86	5/1/86	2.1	0.9
GS44	38°07'13"	122° 3' 4"	9/23/86	11/4/86	2.2	1.0
OSI1	38°05'27"	122° 0'27"	9/28/86	10/29/86	9.2	4.2
OSI1	38°05'27"	122° 0'27"	9/28/86	10/29/86	9.2	7.2
OSI2	38°03'54"	122° 2'33"	9/28/86	10/29/86	8.2	1.5
OSI2	38°03'54"	122° 2'33"	9/28/86	10/29/86	8.2	3.2
OSI3	38°04'28"	122° 1'30"	9/28/86	10/31/86	9.8	1.5
OSI3	38°04'28"	122° 1'30"	9/28/86	10/31/86	9.8	4.8
OSI3	38°04'28"	122° 1'30"	9/28/86	10/31/86	9.8	7.8
TG43	38° 7'17"	122° 1'35"	3/13/86	4/25/86	1.9	1.4

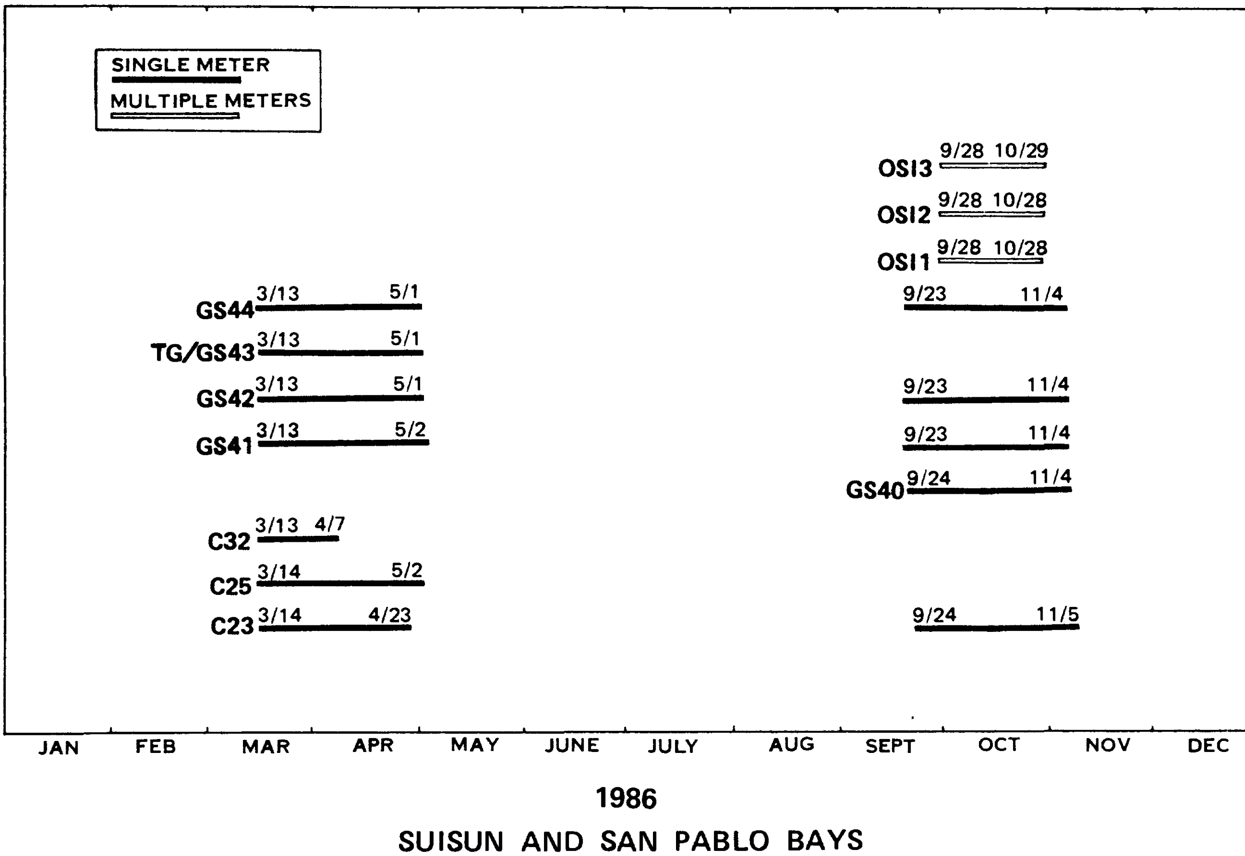


Figure 3. Bar graph of periods when current-meter arrays and tide gage were deployed in Suisun and San Pablo Bays in 1986.

DATA-PROCESSING PROCEDURES

Data Translation

Raw data from the tide gage and current meters were translated into computer-readable code by using special tape readers (Cheng and Gartner, 1979; Cheng and Wang, 1985). The 2-minute interval data were examined for possible record gaps, and individual sensor calibration constants were applied to convert the data to engineering units. Salinity was not directly measured; it was computed from water temperature and conductivity values based upon the modified Cox relation (D. Pritchard, unpublished notes, 1978). Computer programs used in the processing of these data have been described in Cheng and Gartner (1980, 1984).

Post Processing

Fifteen-minute interval current-meter data collected by Ocean Systems Inc. were supplied in engineering units. These data were reformatted to be compatible with post-processing programs in use by the Geological Survey.

Current speeds and directions were vector-averaged to produce a time series of 30-minute averaged data for time-series plots. Similar time series of 30-minute averaged temperature and salinity data were also computed and plotted. Original speed and direction data were also vector averaged to a 30-minute interval time series as part of the harmonic analysis technique.

Time-Series Plot

A time-series plot of current-meter data is one of the most useful ways for clearly displaying temporal variations in the data. Time-series plots of all data records are given in the Appendix. The tidal-current velocity is plotted in the form of speed and direction (relative to true north) versus time. In general, current speed and direction data were not edited. Portions of the data may be invalid because of marine fouling, malfunction of instrument, or for other unknown reasons. Where questionable or unreliable data are apparent on the time-series plots in the Appendix, those sections are noted. Only valid data (our own best judgement) were used in the harmonic analyses. Whereas the time-series plots cover the entire deployment, in the case of harmonic analysis the start time and the length of the record analyzed are noted on the harmonic analysis summary sheets.

A time-series plot of water temperature and salinity versus time is also given for each data file. Accuracy of conductivity (from which salinity is calculated) data may be affected by several factors including marine growth on the external sensor and battery voltage (a function of the deployment duration and water temperature). Bottle samples for salinity analysis were collected during equipment recovery or deployment cruises for later comparison to recorded values. Spurious temperature and conductivity readings in the records were corrected or deleted when identified.

Harmonic Analysis

The method of harmonic analysis for tide and tidal current data is well documented by Schureman (1940) and Cheng and Gartner (1984). In all cases the data sets are truncated to an even number of M_2 cycles. The M_2 cycle (12.42 hours) is used for this purpose because it is by far the most dominant tidal constituent (partial tide) in San Francisco Bay. The method of referring to partial tidal constituents is to use a letter which stands for the origin of the constituent, and a lower case number which refers to the number of cycles per day. The origins, cycles per day, and angular frequencies of the tidal constituents included in the analysis are given in table 2.

In the case of water-level data, major harmonic constituents (O_1, K_1, N_2, M_2, S_2, MK_3, and M_4) were solved by least-squares technique and secondary constituents (Q_1, P_1, J_1, ν_2, L_2, K_2, μ_2, M_1, and T_2) were computed by inference based on equilibrium theory. In the case of the current (velocity) data, six harmonic constituents (O_1, K_1, N_2, M_2, S_2, M_4) were computed for east-west and north-south tidal velocity components. Harmonic constants derived from the two velocity component series were then combined to define a tidal current ellipse for the partial tide. Results of harmonic analysis are included in the Appendix and may be used for prediction of tides and tidal currents at the same location (Cheng and Gartner, 1984). Included with the results of harmonic analysis of velocity data are some general properties of tidal currents computed by the harmonic analysis program such as the RMS current speed, spring current maxima, neap tidal current

Table 2.--Principal astronomical partial tidal constituents

Symbol	Period (solar hours)	Angular frequency (degrees per hour)	Origin and name
		DIURNAL SPECIES	
K_1	23.93	15.0411	Luni-solar
O_1	25.82	13.9430	Principal lunar
P_1	24.07	14.9589	Principal solar
Q_1	26.87	13.3987	Larger lunar elliptic
J_1	23.10	15.5854	Small lunar elliptic
M_1	24.83	14.4967	Smaller lunar elliptic
		SEMIDIURNAL SPECIES	
M_2	12.42	28.9841	Principal lunar
S_2	12.00	30.0000	Principal solar
N_2	12.66	28.4397	Larger lunar elliptic
K_2	11.97	30.0821	Luni-solar
ν_2	12.63	28.5126	Larger lunar evectional
L_2	12.19	29.6285	Smaller lunar elliptic
T_2	12.02	29.9589	Larger solar elliptic
μ_2	12.87	27.9682	Variational
		TERDIURNAL SPECIES	
MK_3	8.18	44.0252	M_2-K_1 interaction
		QUARTER DIURNAL SPECIES	
M_4	6.21	57.9682	Lunar quarter diurnal

minima, principal tidal current direction, tidal current form number, and Eulerian residual current (time averaged velocity) (Cheng and Gartner, 1984). Depending upon the usable length of the record, the time average velocities are computed for every 12 M_2 tidal cycles, and an even number less than 12 M_2 cycles for the remaining available data in the record. The time average for the entire record length (maximum even M_2 cycles) is also given.

TIDE IN SUISUN BAY

Only one of the two water-level records collected in Suisun Bay during 1986 contained useable data. That record was at station GS43 in Grizzly Bay. Results of harmonic analysis and the time-series plot of that record are shown in the appendix. A tidal form number, F has been defined as the ratio of the sum of the amplitudes of the diurnal tidal constituents over the sum of the amplitudes of the semidiurnal tidal constituents. The ratio $F=(O_1+K_1)/(M_2+S_2)$ may be used to define the tide type. Form numbers less than 0.25 indicate a semidiurnal tide while form numbers greater than 3.0 indicate a diurnal tide. Form numbers between 0.25 and 3.0 indicate a mixed tide. Analyses of results shows that the tide is mixed, mainly semidiurnal (F=0.77) and is typical of the tide in Suisun Bay. The M_2 constituent amplitude is damped relative to the tide at the Golden Gate whereas the other constituents are somewhat amplified. That is atypical of the tidal characteristics in Suisun Bay and may be a function of the analysis of a rather short record (42 days) during a period of unusually high Delta inflow. Constituent phase angles are typical and reflect the 2- to 3-hour delay in arrival of the tide at that location relative to the Golden Gate.

Comparison of the phase angles of the tide relative to the tidal currents is an indication of the characteristics of tidal propagation. A phase difference of 0^{o} between tides and currents is indicative of tidal propagation as a progressive wave whereas a difference of 90^{o} (tidal currents leading tidal elevation) is indicative of tidal propagation as a standing wave. The difference between the tide and tidal current phase for the M_2 (primary) constituent is about 70^{o} and the average of the K_1, O_1, N_2, and S_2 constituents is about 80^{o}. The tide propagates like a standing wave in the area of station GS43.

TIDAL CURRENTS IN SUISUN AND SAN PABLO BAYS

Velocity records from the deep stations (C32, C25, OSI1, OSI2, and OSI3) in Suisun Bay indicate that, in general, the tidal currents are strongly bi-directional and that the current directions parallel the channel at those stations. The tidal ellipses for the partial tides are highly eccentric; ratios of major to minor axes exceed 30:1 in most cases. Tidal ellipses computed from analysis of data from the top and middle meters at stations OSI2 and OSI3 were somewhat less eccentric. Multiple meter stations have typical velocity profiles with RMS speed values decreasing with depth, and there is little variation in principal direction among records at the same station. There is more than a 3:1 factor in the variation in current speed between maximum spring and minimum neap tides. Records from station C32 and station C25 (spring deployment) include periods of highly riverine characteristics during a period of high river inflow (greater than 5,900m^3/s based on a 10-day average of Delta outflow provided by the California Department of Water Resources). Delta outflow is an estimate of inflow to Suisun Bay. Specifically, from the beginning of the deployment through Julian day 80 to 81, river inflow dominated over tidal flow and flood tides were minimal or nonexistent.

Those records from stations in shallow regions of Grizzly Bay show quite different characteristics. Records from both the spring and fall deployments are clearly less bi-directional than are records from channel stations. The partial tidal ellipses are less eccentric; ratios of the major axes to minor axes are generally less than 5:1 and in many cases 1:1 ratios indicate nearly circular tidal ellipses. As expected, speeds are lower in the shallow regions than in the channels. The calculated principal directions are east-northeast and result from the propagation of the flood tide into Grizzly Bay from the northeasterly trending channel on the west side of Suisun Bay. The record from the spring deployment at station GS41, the deepest-water deployment of the four stations in Grizzly Bay, also shows the period of riverine-like flow seen at the deep-water stations. No direction information is available at station GS44 because of an electronic failure in the current meter.

Records from both the spring and fall deployments at station GS40 in San Pablo Bay indicate that wind affected the velocity record. Neither record appears usable for harmonic analysis, and even a qualitative evaluation of current speed or direction is impossible from data at this very shallow station. It appears likely that, in addition to being affected by wind waves, the current meter was above the water surface during numerous periods of the deployment. Under these circumstances the temperature and salinity records are also suspect. Results of harmonic analysis (both deployments) and time-series plots from the spring deployment are not presented. The speed and direction plots from the fall deployment are included in the appendix only for reference. An expanded plot of one week of data from station GS40 is shown in figure 4 and the unusual character of the velocity record is clearly apparent. Full speed scale for the current meter is 223 cm/s; impeller revolutions caused by higher speeds will be

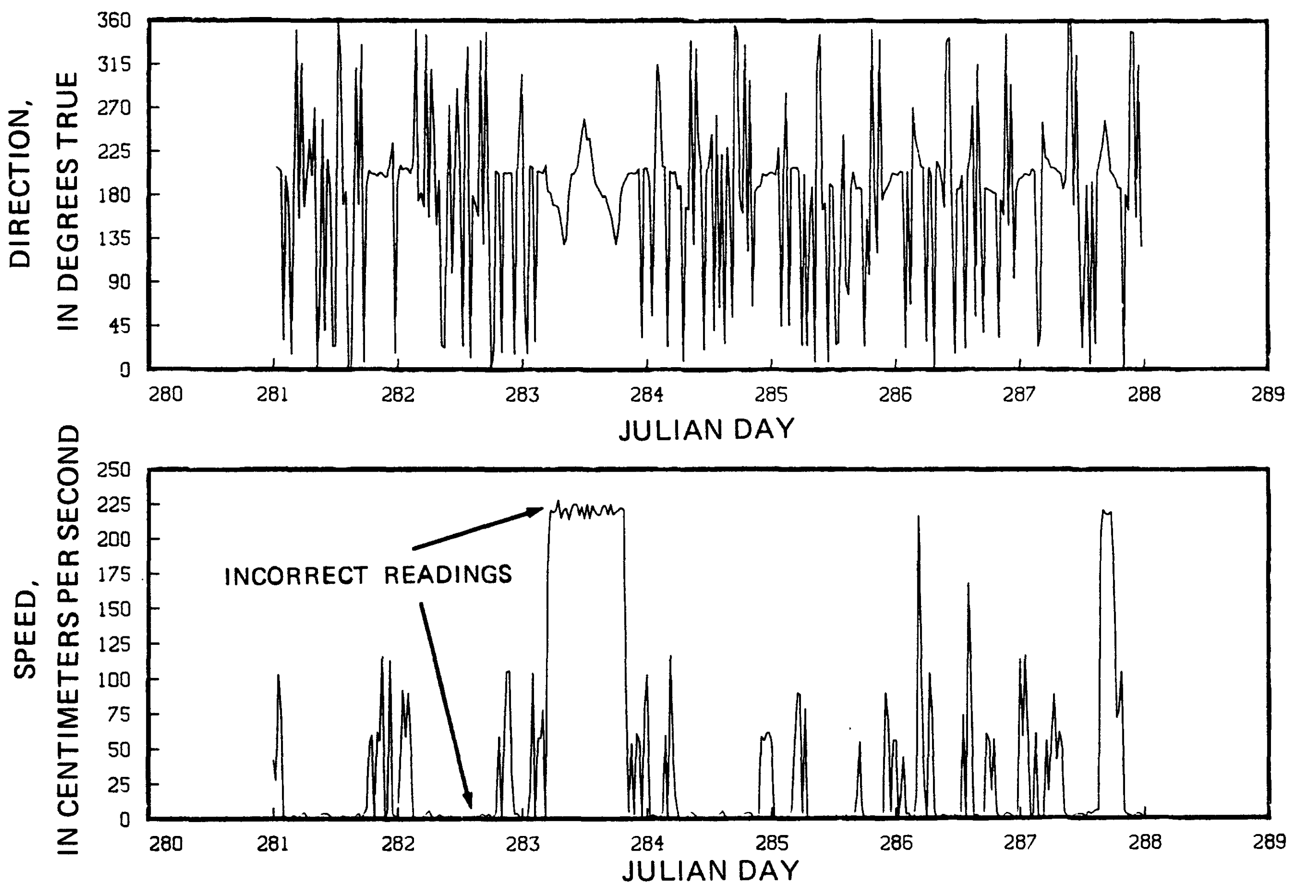


Figure 4. Expanded time-series plot of current velocity showing sections of incorrect readings.

incorrectly interpreted to mean lower speeds. This would occur if a current meter (on fixed platform and exposed above the water surface) were exposed to wind of greater speed than the maximum for the speed scale in use (223 cm/s). This appear to have occured at station GS40. On the other hand, station C23 was deployed nearby in deeper water and shows the typical spring/neap variation in speed and current direction parallel to bathymetry lines. Water temperature at stations GS41 and GS44 appears unusually low during the early part of the fall deployment (prior to Julian day 282). No explanation is presented and temperature data from these records should be used with caution.

The spatial distribution of descriptive tidal current properties is plotted in figure 5 in which the M_2, RMS, and the estimated spring and neap tidal current vectors are plotted in the principal tidal current direction at each station.

A tidal current form number, F' is defined as the ratio of the sum of the semimajor axes of diurnal tidal species to the sum of the semimajor axes of semidiurnal species. As in the case of the tidal form number, the ratio $F'=(O_1+K_1)/(M_2+S_2)$ may be used to define the tidal current type. The range of form numbers for all velocity records is 0.23 to 0.46; the tidal currents in Suisun and San Pablo Bays are mixed semidiurnal and diurnal types; for the most part, the tidal current type is closer to semidiurnal than diurnal.

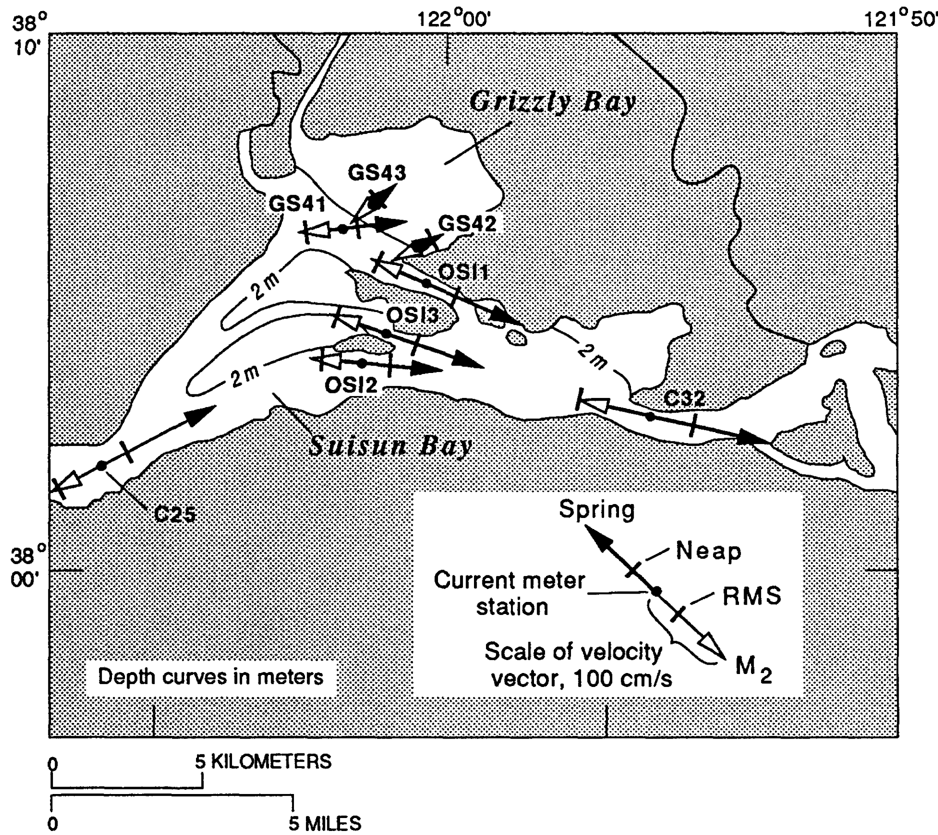


Figure 5. Spatial distribution of tidal current properties in Suisun and San Pablo Bays.

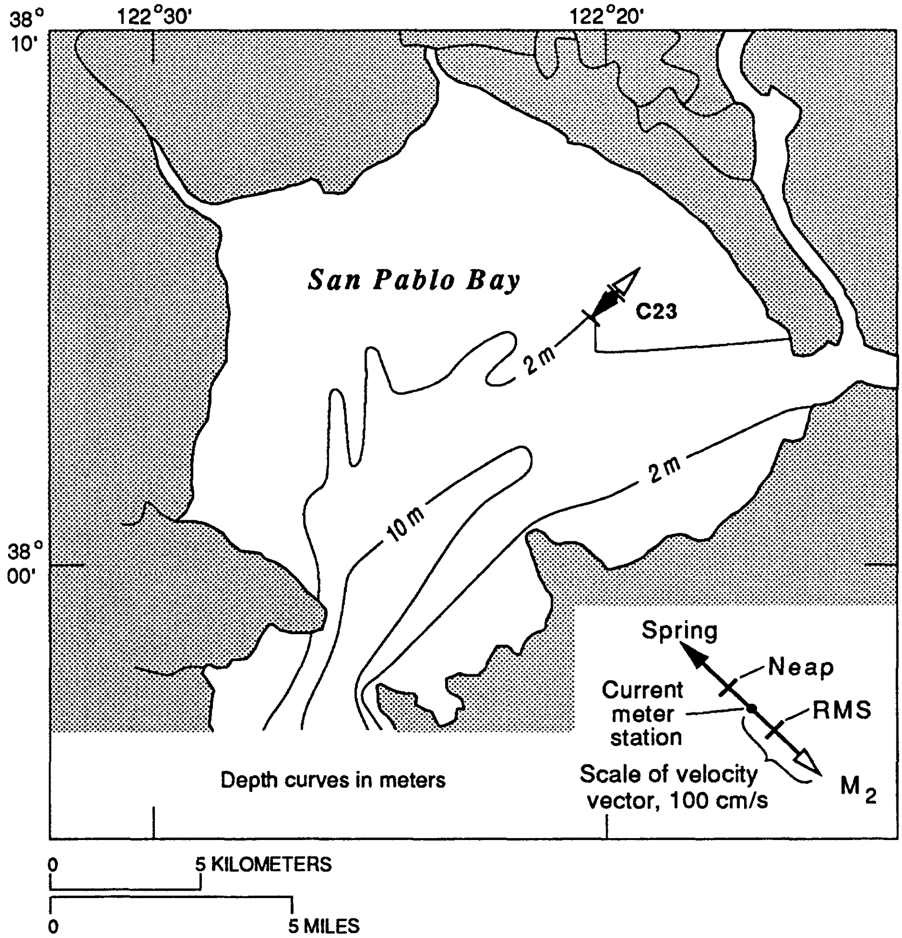


Figure 5. Continued.

EULERIAN RESIDUAL CURRENTS IN SUISUN AND SAN PABLO BAYS

The Eulerian residual current is defined here to be the vectorial average of the current-meter data made over several (an even number of) M_2 tidal cycles. This serves to average out the tidal signal; what remains is an estimate of the Eulerian residual. The Eulerian residual current is generally a factor of ten smaller than the tidal current. As the speed accuracy of the current meter is stated to be about ± 7 cm/s and the current-meter record represents speed only at a single point in the water column (and the water depth varies over a tidal cycle), one must be careful in drawing conclusions from the Eulerian residual currents calculated in this way. The computed Eulerian residual currents are given in the summary for each current-meter data file in the format of north/south (north = +) and east/west (east = +) components. Figure 6 shows the vectors representing the calculated Eulerian residual currents at each available station. At multiple meter stations only the middle record is displayed. The factors that affect the Eulerian residual currents are rather complex. Basin bathymetry, Delta outflow, spatial distribution of tidal currents (tidal current shear), long term temporal variations of tidal currents (spring and neap variations), and wind forcing at the water surface are all important factors which may have effects on the magnitude and spatial distribution of the Eulerian residual currents (see Walters, 1982; Walters and Gartner, 1985; and Cheng and Gartner, 1985). Since the Delta outflow is one of the variables which affect the Eulerian resi-

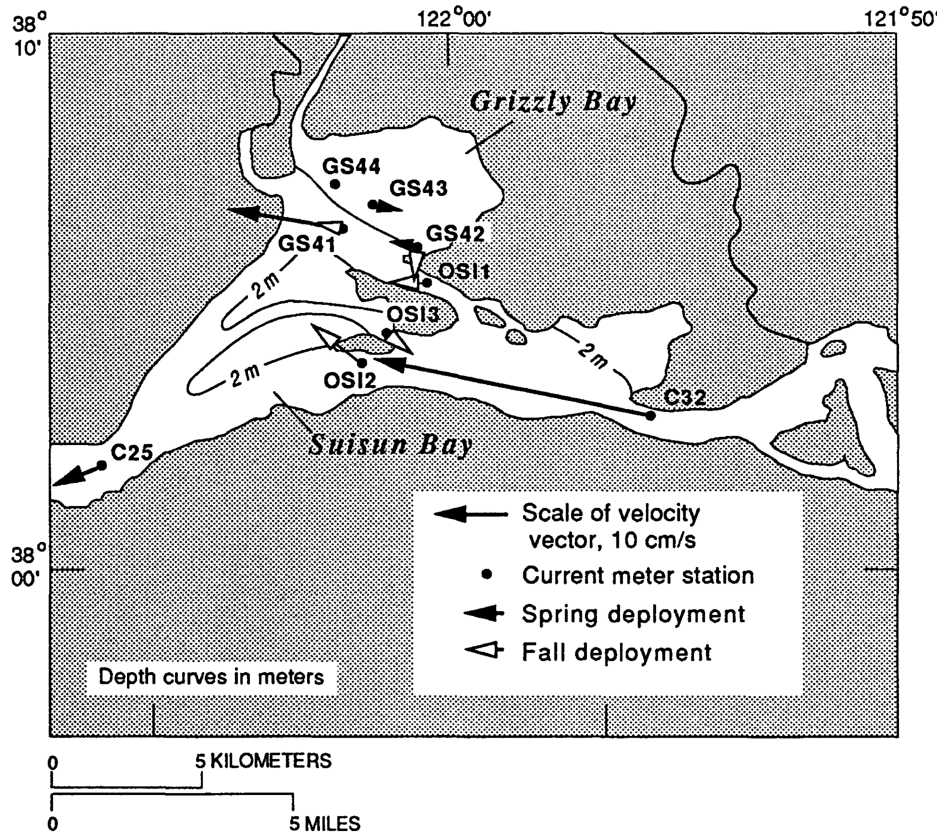


Figure 6. Eulerian residual currents in Suisun and San Pablo Bays.

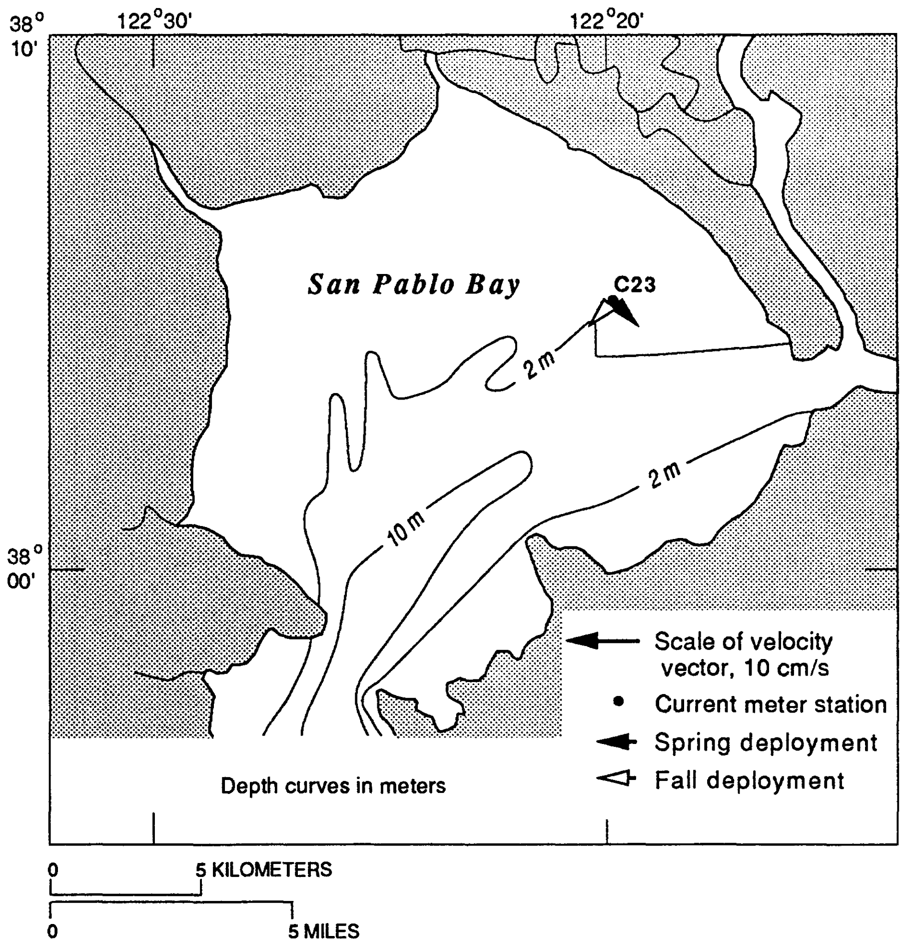


Figure 6. Continued.

dual current, the averaged values of the Delta outflow (preliminary) during the current-meter deployments have been computed and are given in the summary sheets.

Those Eulerian residual current vectors that were calculated at deep stations (including GS41) during the spring deployment (figure 6) clearly indicate the down estuary residual flow driven by the high Delta inflows. Data are not available from these stations for the fall deployment but examination of records from these stations from other years (Cheng and Gartner, 1984) does not show significant down estuary residual flows during sustained periods of low Delta inflow (less than about $200 m^3/s$). Where more than one record is available in the vertical, Eulerian residuals indicate the presence of gravitational circulation evidenced by a general shift from down estuary to up estuary residual flow as one moves from top to bottom in the water column. This is clearly shown at all three Ocean Surveys stations in spite of the generally low values of the residual flows. Residual values at the shoal stations (both spring and fall deployments) are generally less than 1-2 cm/s and are probably not of sufficient magnitude to be meaningful.

SUMMARY

Analyses of hydrodynamic field data collected in Suisun and San Pablo Bays demonstrate the presence of a mixed, mainly-semidiurnal tide. Comparison of the results of harmonic analyses of water-level and velocity data indicates that the tide propagates mainly like a standing wave in Grizzly Bay. Velocity data indicate that the tidal currents are generally bi-directional except at shoal stations where the tidal ellipses have a more circular character. Current principal directions are aligned with basin bathymetry, and where multiple meters were used in the vertical, the RMS speed values decrease from top to bottom. Current magnitudes vary over a spring-neap cycle by about a factor of three.

Records from several current meters include periods when flows were riverine in character. High river inflows overwhelmed the normal flood and ebb current directions and residual flows generally were down estuary at deep-water stations. Otherwise, multiple meter stations exhibit evidence of gravitational circulation. Residual currents in the shallows generally were small enough that calculated values are probably insignificant.

REFERENCES

Cheng, R. T., and Conomos, T. J., 1980, Studies of San Francisco Bay by the U.S. Geological Survey: Institute of Environmental Science, Philadelphia, Penn., May 12-14, 1980, Proceedings, p 299-303.

Cheng, R. T., and Gartner, J. W., 1979, A microcomputer based system for current meter data acquisition: Institute of Electrical and Electronics Engineers, Oceans '79, San Diego, Calif., September 17-19, 1979, Proceedings, p. 288-291.

-----1980, Working notes on current meter deployment, recovery, maintenance, and data processing for San Francisco Bay: U.S. Geological Survey Open-File Report 80-1297, 68 p.

-----1984, Tides, tidal and residual currents in San Francisco Bay, California - Results of measurements, Part 1, Description of data: U.S. Geological Survey Water-Resources Investigations Report 84-4339, 72 p.

-----1985, Harmonic analysis of tides and tidal currents in South San Francisco Bay, California: Estuarine Coastal and Shelf Science, 21, p. 57-74.

Cheng, R.T., and Wang, L. ,1985, Solid state recording current meter conversion: Institute of Electrical and Electronics Engineers, Oceans '85, San Diego, Calif., November 12-14, 1985, Proceedings, p 752-754.

Endeco Inc., 1978, Endeco type 174 digital magnetic tape recording tethered current meter; Service manual: Marion, Mass, 16 p.

Gartner, J. W., 1986, Tidal and residual currents near the confluence of the Sacramento and San Joaquin Rivers, results of measurements, 1984-85: U.S. Geological Survey Water-Resources Investigations Report 86-4025, 42 p.

Gartner, J. W., and Cheng, R. T., 1982, Observations from moored current meters in San Francisco Bay, 1978: U.S. Geological Survey Open-File Report 82-153, 91 p.

-----1983, Observations from remote weather stations in San Francisco Bay, California, 1979-1981: U.S. Geological Survey Open-File Report 83-269, 120 p.

Gartner, J. W., and Oltmann, R. N., 1985, Comparison of recording current meters used for measuring velocities in shallow waters of San Francisco Bay, California: Institute of Electrical and Electronics Engineers, Oceans '85, San Diego, Calif., November 12-14, 1985, Proceedings, p 752-754.

Gartner, J. W., and Walters, R. A., 1986, Tidal and residual currents in South San Francisco Bay, California, results of measurements in 1981-1983: U.S. Geological Survey Water-Resources Investigations Report 86-4024, 148 p.

Schureman, Paul, 1940, Manual of harmonic analysis and prediction of tides (reprinted with corrections, 1976): U.S. Coast and Geodetic Survey, Special Publication no. 98, 317 p.

Walters, R. A., 1982, Low-frequency variations in sea level and currents in South San Francisco Bay: Journal of Physical Oceanography, 12, p 658-668.

Walters, R. A. and Gartner, J. W., 1985, Subtidal sea level variations in the northern reach of San Francisco Bay: Estuarine Coastal and Shelf Science, 21, p. 17-32.

page 35 follows

APPENDIX

The current-meter data are presented chronologically and station-by-station in Appendix A. For each file, the measured data and the results of analyses are presented in two forms: (1) results from the harmonic analyses; and (2) time series plots of tidal-current velocity (speed and direction) versus time, and salinity and temperature versus time. These results are given in the order of station numbers as listed in table 1.

The following abbreviations are used in the appendix:

MLLW	Mean lower low water (a tidal reference datum).
PST	Pacific standard time.
CM/S	Centimeters per second
DEG T	Degrees true (angular measurement from true north).
RMS	Root mean square.
CMS	Cubic meters per second; m^3/s is used in the text.

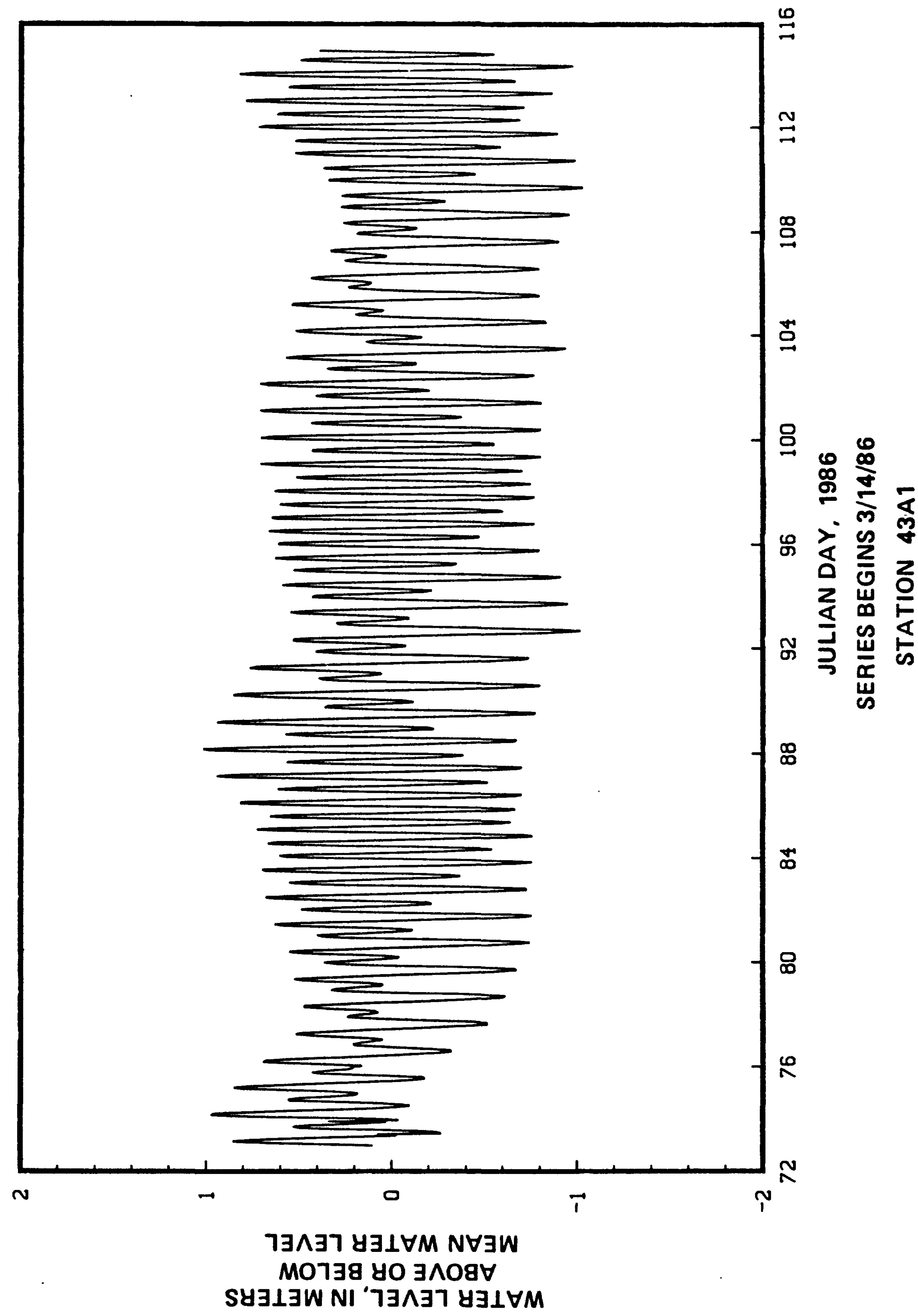
STATION NUMBER= TG43A1
TIME IN THE ORIGINAL DATA IS PST
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=14 HOUR= 0
TIME MERIDIAN= 120 W
STATION POSITION= 38- 7-17N 122- 1-35W
APPROXIMATE RECORD LENGTH IS 43 DAYS
THERE ARE 1044 DATA POINTS

TIME SERIES MEAN= 228.243

RESULTS OF LEAST SQUARES AFTER TIDAL INFERENCE

NAME	CYCLES/DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
Q1	0.89324	3.50866	110.09	124.93
O1	0.92954	18.08587	123.99	134.48
M1	0.96645	1.28410	138.01	144.07
P1	0.99726	10.93538	149.93	152.28
K1	1.00274	33.03742	152.03	153.73
J1	1.03903	1.42878	165.94	163.28
MU2	1.86455	1.26174	36.18	56.49
N2	1.89598	20.36377	354.56	11.09
NU2	1.90084	3.95057	1.88	17.83
M2	1.93227	52.57232	49.20	61.38
L2	1.96856	1.47202	103.85	111.67
T2	1.99726	0.83745	61.70	66.09
S2	2.00000	14.19407	62.23	66.28
K2	2.00548	3.86079	63.28	66.68
M4	3.86455	3.50016	17.53	41.89
MK3	2.93501	2.38220	92.54	106.42

STANDARD DEVIATION, U SERIES (CM/S)= 15.91


WATER LEVEL, IN METERS
ABOVE OR BELOW
MEAN WATER LEVEL
2
1
0
-1
-2
72
76
80
84
88
92
96
100
104
108
112
116
JULIAN DAY, 1986
SERIES BEGINS 3/14/86
STATION 43A1

STATION NUMBER= C23
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=14 HOUR=1211
TIME MERIDIAN= 120 W
STATION POSITION= 38- 4-35N 122-20-47W
METER DEPTH= 1.0M BELOW MLLW WATER DEPTH= 2.2M
RECORD LENGTH IS 76 M2 CYCLES: 1886 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.11357	7.41	18.21
K1	1.00274	5.06848	20.17	22.19
N2	1.89598	3.45391	280.52	297.69
M2	1.93227	20.38882	295.90	308.72
S2	2.00000	6.67664	292.77	297.47
M4	3.86455	1.96780	98.90	124.54

RESULTS FOR V (+NORTH) SERIES

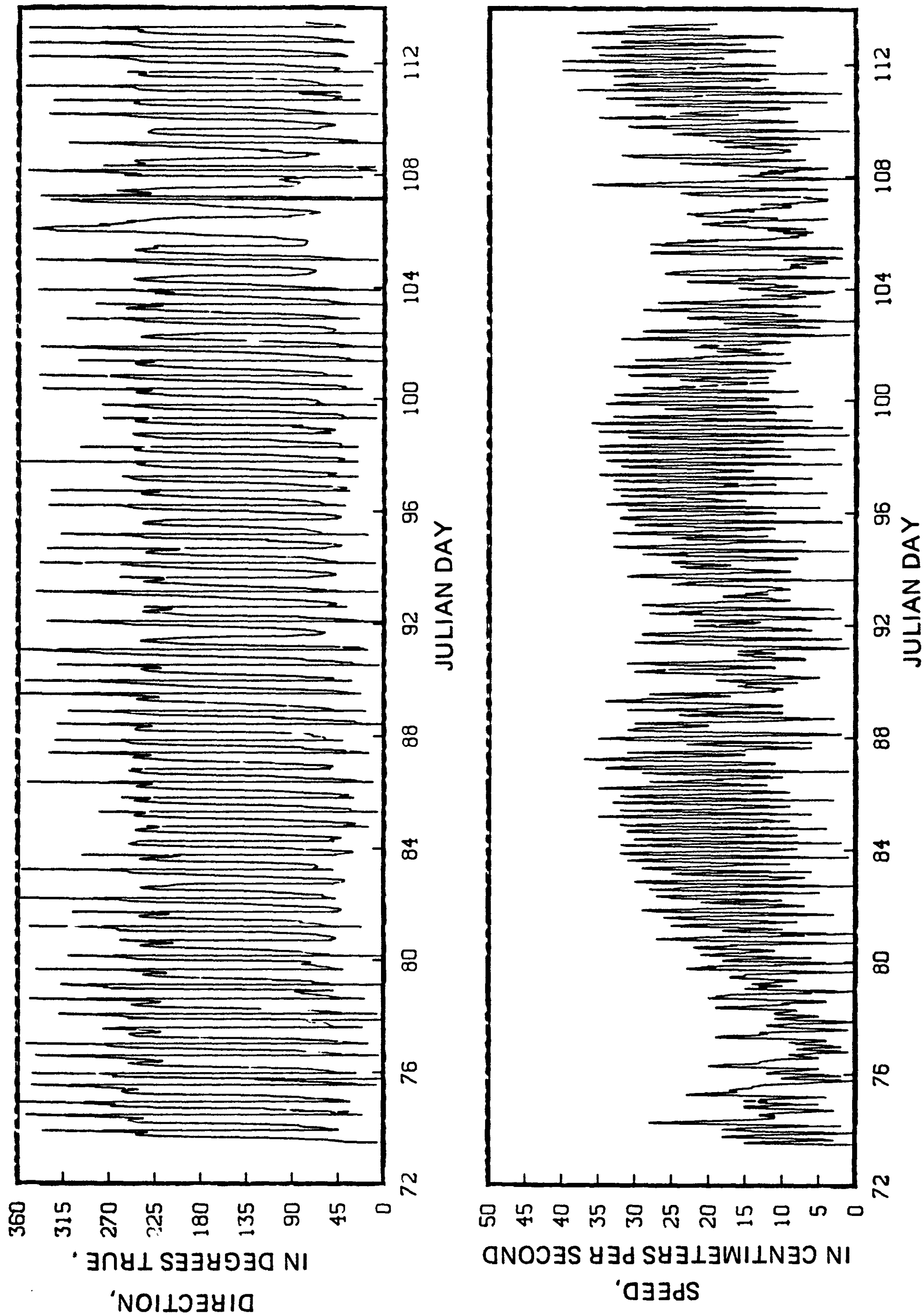
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.57941	20.25	31.06
K1	1.00274	2.41990	42.08	44.10
N2	1.89598	2.87628	242.37	259.55
M2	1.93227	14.33372	265.21	278.03
S2	2.00000	4.87481	268.31	273.00
M4	3.86455	2.31369	139.83	165.47

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	3.31	0.37	39.2	25.9	15.0	COUNTER-CLOCKWISE
K1	5.56	0.82	65.5	26.0	260.1	COUNTER-CLOCKWISE
N2	4.26	1.44	51.6	282.7	119.3	CLOCKWISE
M2	24.15	6.18	56.3	299.0	273.6	CLOCKWISE
S2	8.10	1.66	54.7	289.2	3.3	CLOCKWISE
M4	2.85	1.05	38.9	149.0	187.3	COUNTER-CLOCKWISE

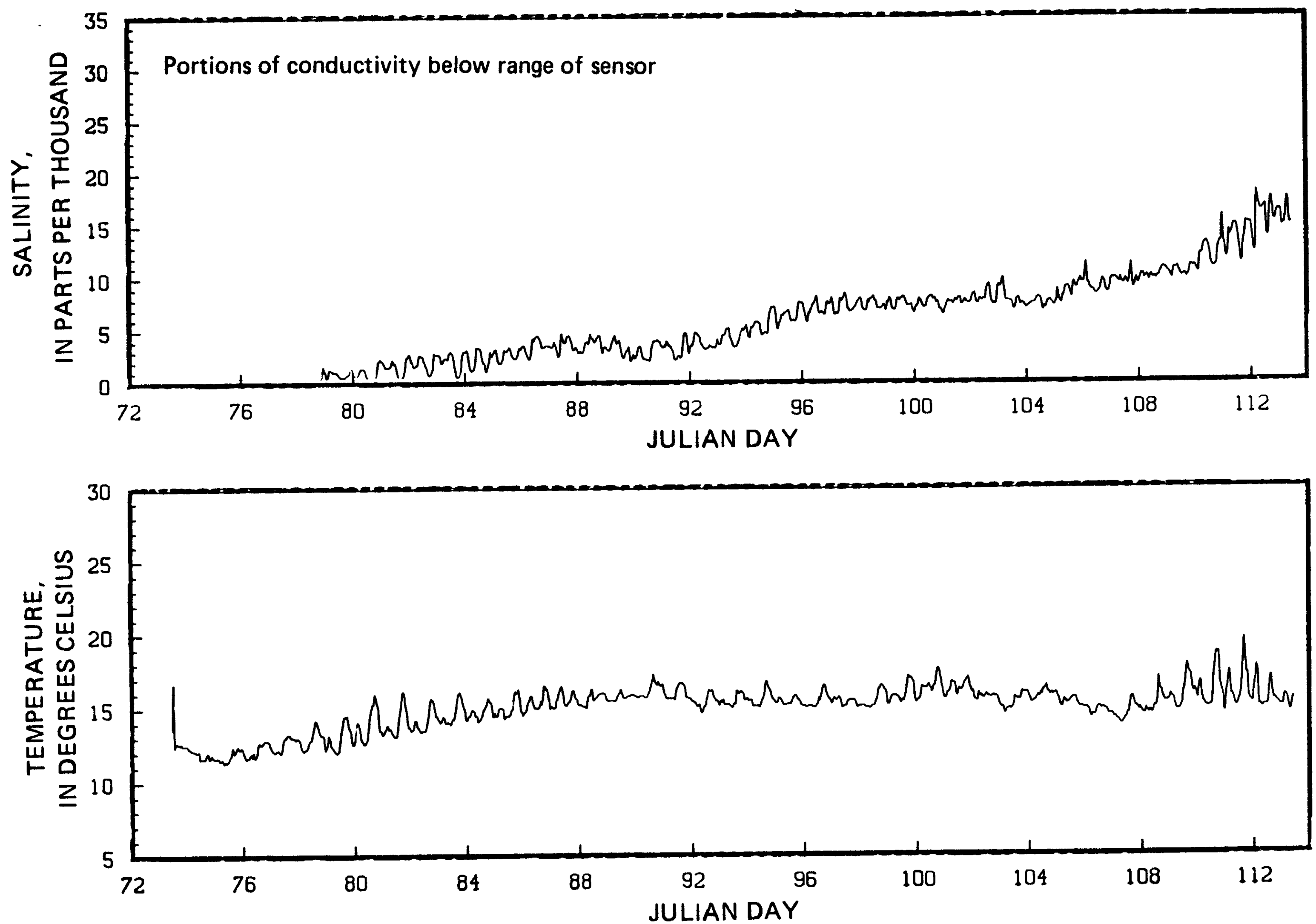
ROOT-MEAN-SQUARES SPEED, (CM/S)= 19.56
STANDARD DEVIATION, U SERIES (CM/S)= 5.88
STANDARD DEVIATION, V SERIES (CM/S)= 4.07
TIDAL-FORM NUMBER= 0.28
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 41.11
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 13.81
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 55.88

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-1.6	0.0	6096
2	12	1.9	0.2	3544
3	12	-0.6	-0.2	2612
4	12	2.5	-0.8	1992
5	12	2.0	-0.8	1441
6	12	1.7	-1.3	1154
7	4	1.0	1.1	936
ALL	76	1.0	-0.4	



CURRENT-METER OBSERVATIONS (30 MINUTE AVERAGES)
USGS STATION C23 38- 4-35N 122-20-47W
METER 1.0 METERS BELOW MLLW. WATER DEPTH 2.2 METERS



CURRENT-METER OBSERVATIONS (30 MINUTE AVERAGES)
USGS STATION C23 38- 4-35N 122-20-47W
METER 1.0 METERS BELOW MLLW. WATER DEPTH 2.2 METERS

STATION NUMBER= C25
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=14 HOUR=1025
TIME MERIDIAN= 120 W
STATION POSITION= 38- 2-10N 122- 7-55W
METER DEPTH= 9.1M BELOW MLLW WATER DEPTH= 17.1M
RECORD LENGTH IS 94 M2 CYCLES: 2334 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	12.69122	62.99	73.57
K1	1.00274	22.14469	80.25	82.05
N2	1.89598	14.33069	333.51	350.25
M2	1.93227	63.94219	352.25	4.64
S2	2.00000	20.67163	351.32	355.58
M4	3.86455	2.42286	12.04	36.82

RESULTS FOR V (+NORTH) SERIES

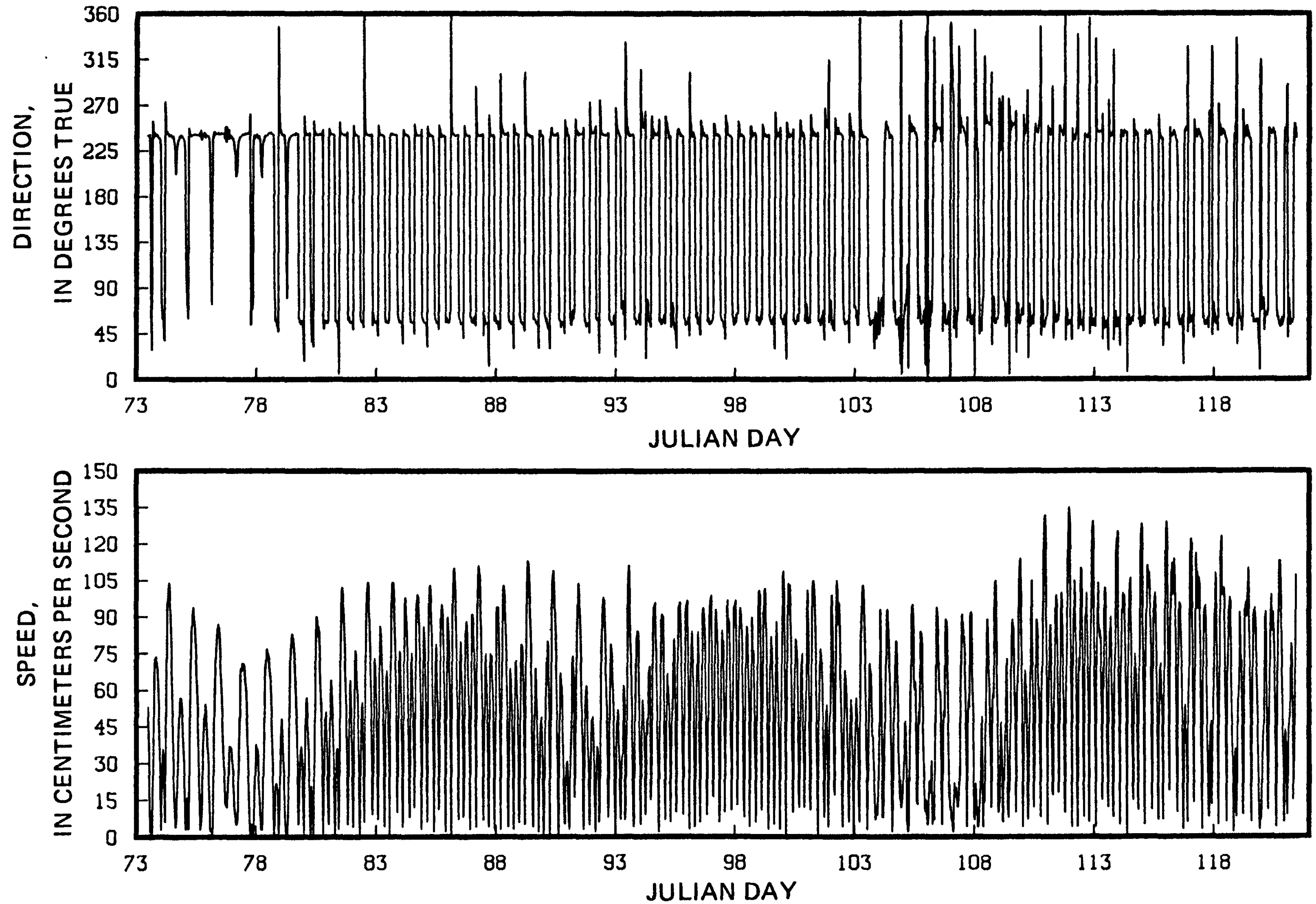
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	6.68565	61.07	71.66
K1	1.00274	12.50432	79.16	80.97
N2	1.89598	9.69021	333.59	350.34
M2	1.93227	35.66741	356.20	8.59
S2	2.00000	12.47076	352.99	357.26
M4	3.86455	2.85165	13.08	37.86

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	14.34	0.20	62.2	73.2	349.0	CLOCKWISE
K1	25.43	0.21	60.6	81.8	232.1	CLOCKWISE
N2	17.30	0.01	55.9	350.3	66.4	COUNTER-CLOCKWISE
M2	73.19	2.15	60.9	5.6	219.7	COUNTER-CLOCKWISE
S2	24.14	0.31	58.9	356.0	307.5	COUNTER-CLOCKWISE
M4	3.74	0.03	40.4	37.4	79.5	COUNTER-CLOCKWISE

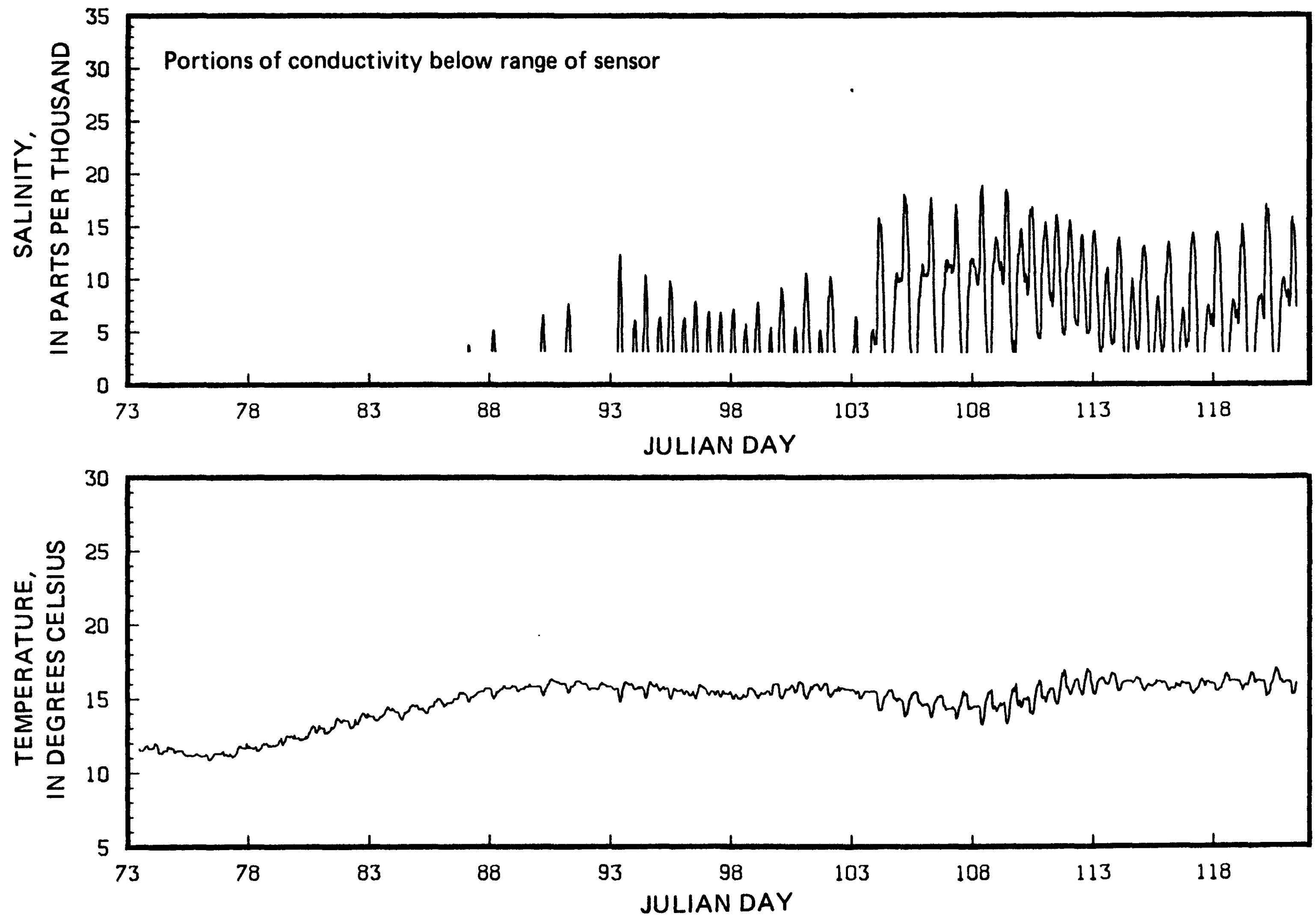
ROOT-MEAN-SQUARES SPEED, (CM/S)= 62.49
STANDARD DEVIATION, U SERIES (CM/S)= 17.36
STANDARD DEVIATION, V SERIES (CM/S)= 11.39
TIDAL-FORM NUMBER= 0.41
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 137.10
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 37.96
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 60.61

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-31.5	-17.9	6096
2	12	-18.9	-8.8	3544
3	12	-9.4	-2.8	2612
4	12	-5.9	-0.6	1992
5	12	-3.7	-0.1	1441
6	12	2.1	4.4	1154
7	12	3.5	6.0	853
8	10	6.0	6.6	589
ALL	94	-7.5	-1.8	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION C25 38- 2-10N 122- 7-55W
METER 9.1 METERS BELOW MLLW. WATER DEPTH 17.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION C25 38- 2-10N 122- 7-55W
METER 9.1 METERS BELOW MLLW. WATER DEPTH 17.1 METERS

STATION NUMBER= C32
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=13 HOUR=1105
TIME MERIDIAN= 120 W
STATION POSITION= 38- 2-55N 121-55-25W
METER DEPTH= 5.2M BELOW MLLW WATER DEPTH= 11.3M
RECORD LENGTH IS 46 M2 CYCLES: 1142 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	10.69197	83.38	93.76
K1	1.00274	19.74331	108.61	110.21
N2	1.89598	18.25291	12.02	28.35
M2	1.93227	64.35512	32.82	44.79
S2	2.00000	23.74826	38.90	42.75
M4	3.86455	6.22798	60.98	84.93

RESULTS FOR V (+NORTH) SERIES

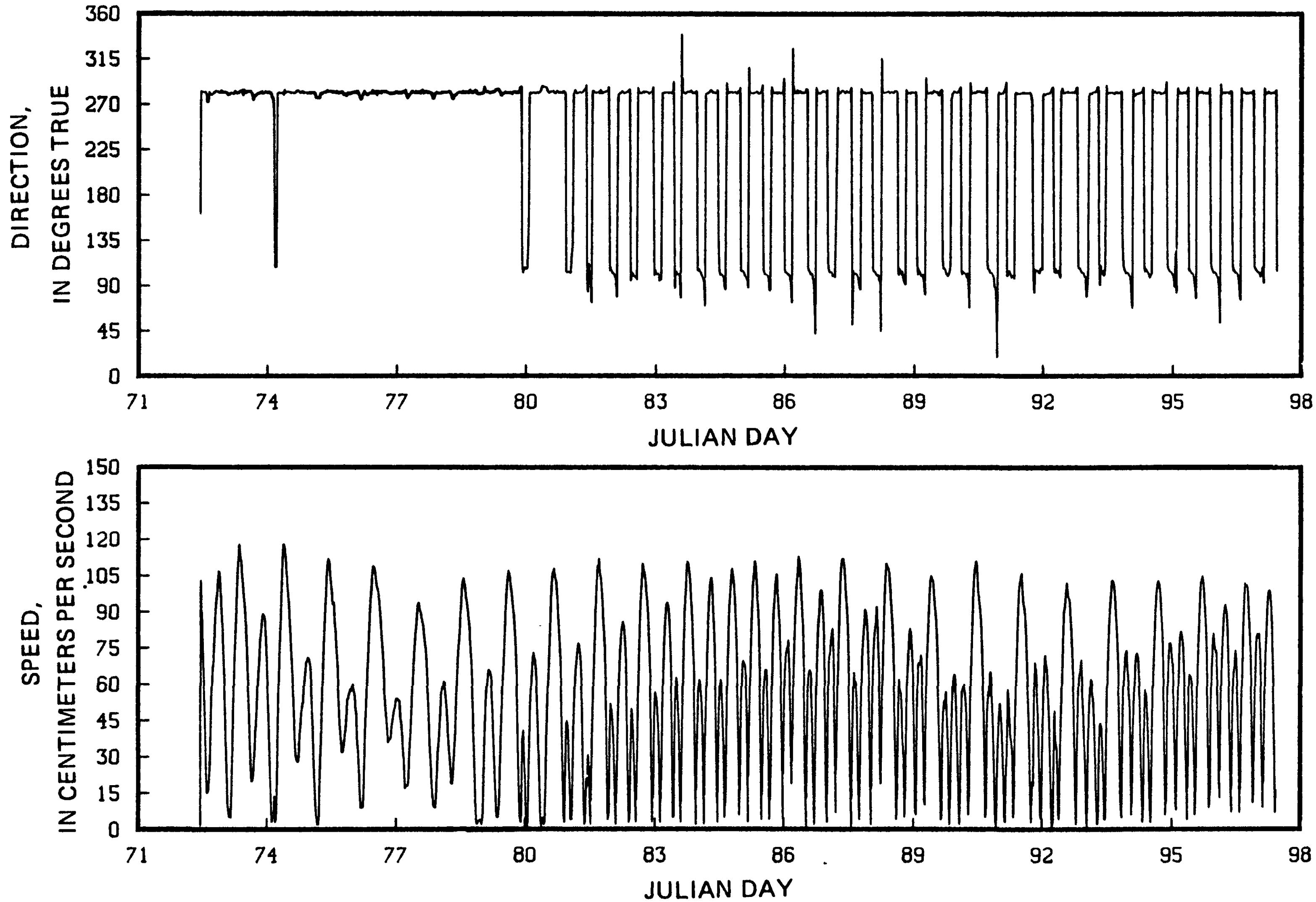
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.35541	264.22	274.60
K1	1.00274	4.32240	285.39	286.98
N2	1.89598	3.67059	182.16	198.49
M2	1.93227	13.97873	210.85	222.82
S2	2.00000	4.97728	213.98	217.83
M4	3.86455	1.56431	230.16	254.11

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	10.95	0.03	102.4	93.8	25.6	CLOCKWISE
K1	20.21	0.24	102.3	110.1	243.1	COUNTER-CLOCKWISE
N2	18.61	0.62	101.2	28.0	126.6	COUNTER-CLOCKWISE
M2	65.85	0.47	102.2	44.7	267.3	COUNTER-CLOCKWISE
S2	24.26	0.42	101.8	42.5	331.5	COUNTER-CLOCKWISE
M4	6.42	0.29	103.9	84.3	174.6	COUNTER-CLOCKWISE

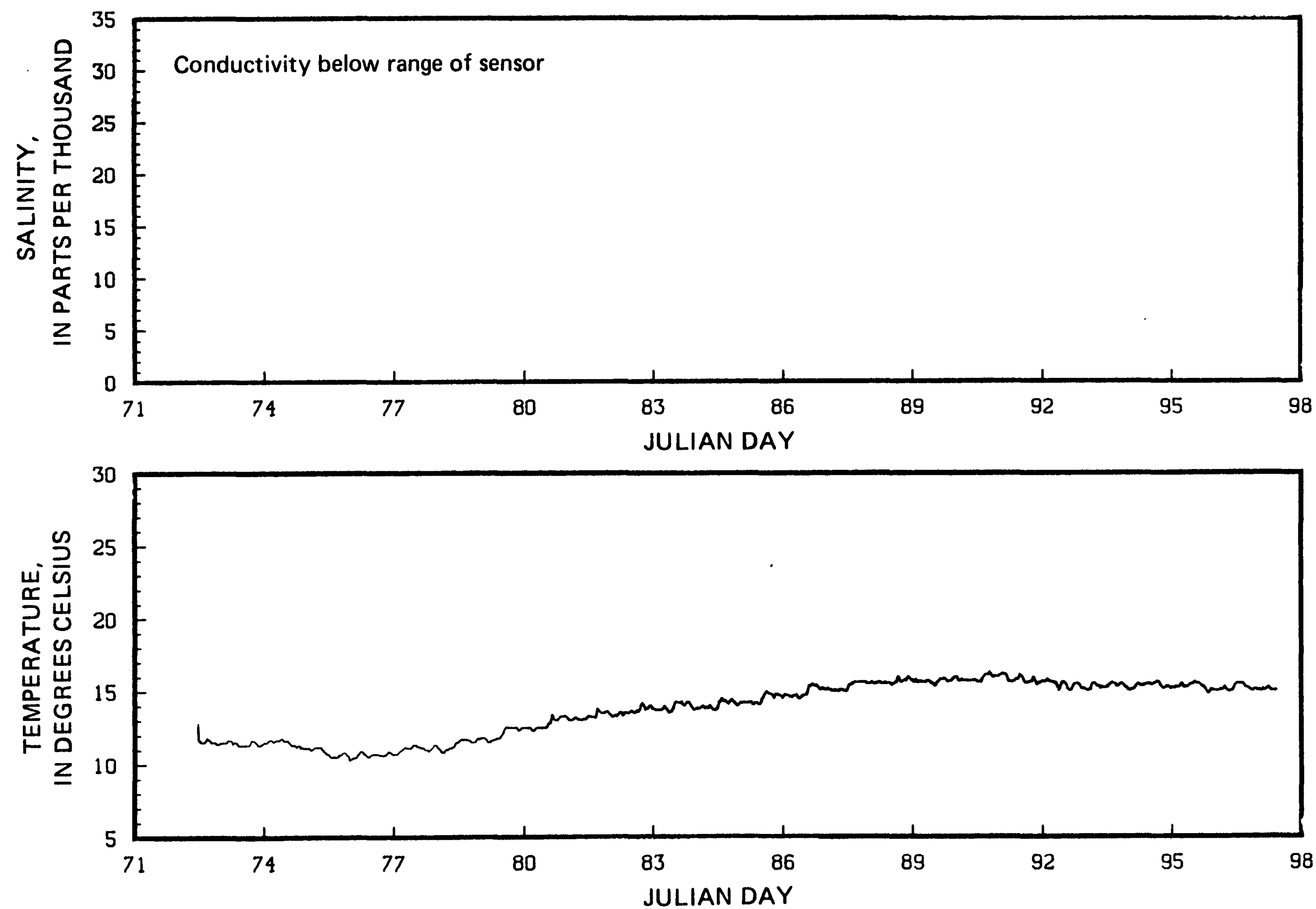
ROOT-MEAN-SQUARES SPEED, (CM/S)= 65.45
STANDARD DEVIATION, U SERIES (CM/S)= 19.23
STANDARD DEVIATION, V SERIES (CM/S)= 4.52
TIDAL-FORM NUMBER= 0.35
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 121.27
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 32.33
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 102.19

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-57.7	12.2	6384
2	12	-37.9	8.3	3937
3	12	-21.9	5.2	2496
4	10	-19.6	4.0	1948
ALL	46	-34.9	7.6	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION C32 38- 2-55N 121-55-25W
METER 5.2 METERS BELOW MLLW. WATER DEPTH 11.3 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION C32 38- 2-55N 121-55-25W

METER 5.2 METERS BELOW MLLW. WATER DEPTH 11.3 METERS

STATION NUMBER= GS41
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=13 HOUR=1841
TIME MERIDIAN= 120 W
STATION POSITION= 38- 6-33N 122- 2-55W
METER DEPTH= 1.2M BELOW MLLW WATER DEPTH= 4.0M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	9.07269	78.85	89.35
K1	1.00274	13.11964	96.32	98.04
N2	1.89598	7.15739	359.18	15.76
M2	1.93227	35.95720	15.45	27.67
S2	2.00000	11.80399	17.52	21.62
M4	3.86455	1.72750	306.54	330.99

RESULTS FOR V (+NORTH) SERIES

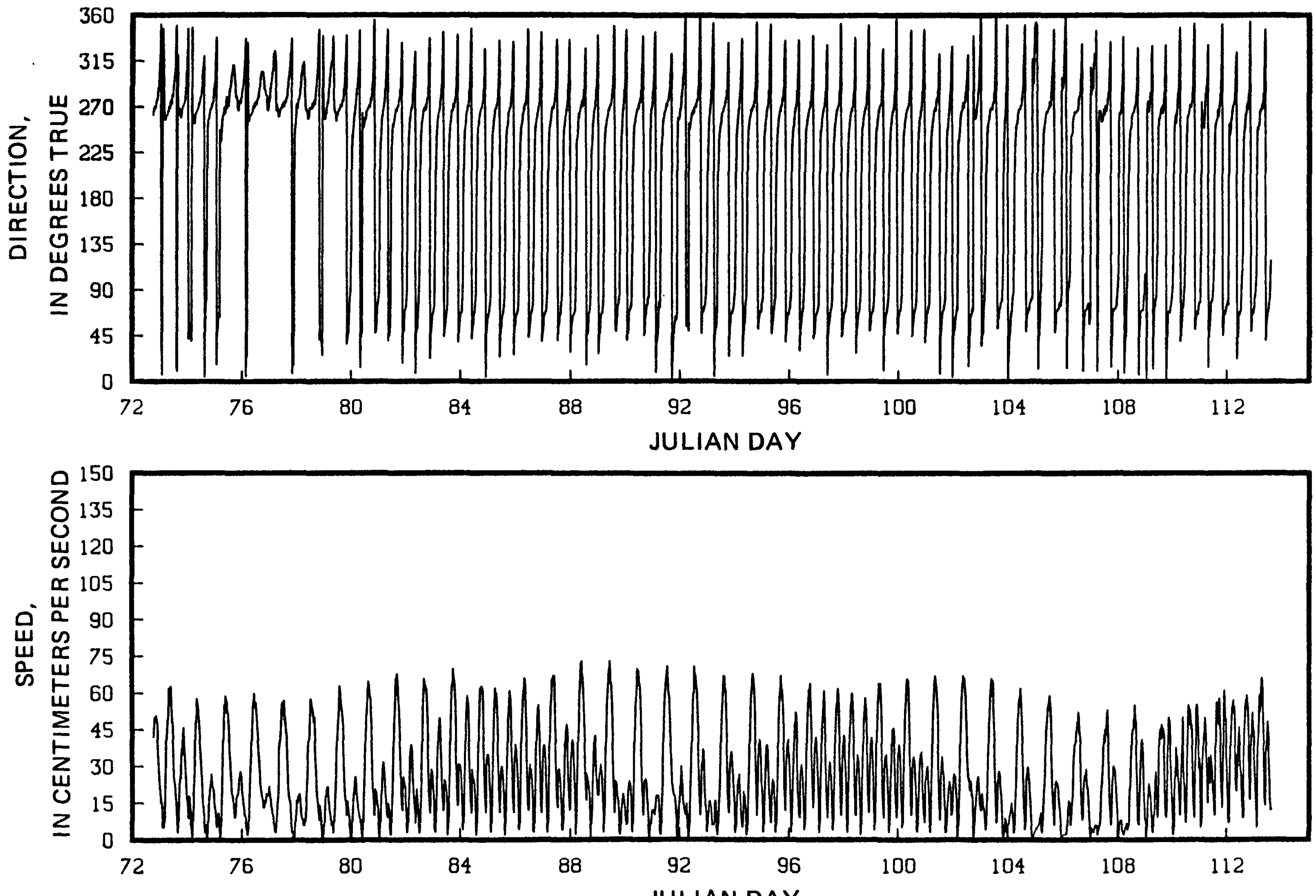
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.72669	2.14	12.64
K1	1.00274	2.43125	45.10	46.82
N2	1.89598	2.40222	305.74	322.32
M2	1.93227	9.95182	320.08	332.30
S2	2.00000	3.72445	334.07	338.17
M4	3.86455	0.69252	37.14	61.59

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	9.08	1.68	87.4	88.9	128.2	CLOCKWISE
K1	13.21	1.88	83.2	97.1	353.8	CLOCKWISE
N2	7.31	1.89	77.9	12.6	335.9	CLOCKWISE
M2	36.42	8.08	80.6	25.6	120.6	CLOCKWISE
S2	12.12	2.49	76.5	18.8	192.3	CLOCKWISE
M4	1.73	0.69	90.3	330.9	241.2	COUNTER-CLOCKWISE

ROOT-MEAN-SQUARES SPEED, (CM/S)=	33.22
STANDARD DEVIATION, U SERIES (CM/S)=	7.77
STANDARD DEVIATION, V SERIES (CM/S)=	2.64
TIDAL-FORM NUMBER=	0.46
SPRING TIDAL CURRENT MAXIMUM (CM/S)=	70.84
NEAP TIDAL CURRENT MAXIMUM (CM/S)=	20.17
PRINCIPAL CURRENT DIRECTION (DEG. T.)=	81.26

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

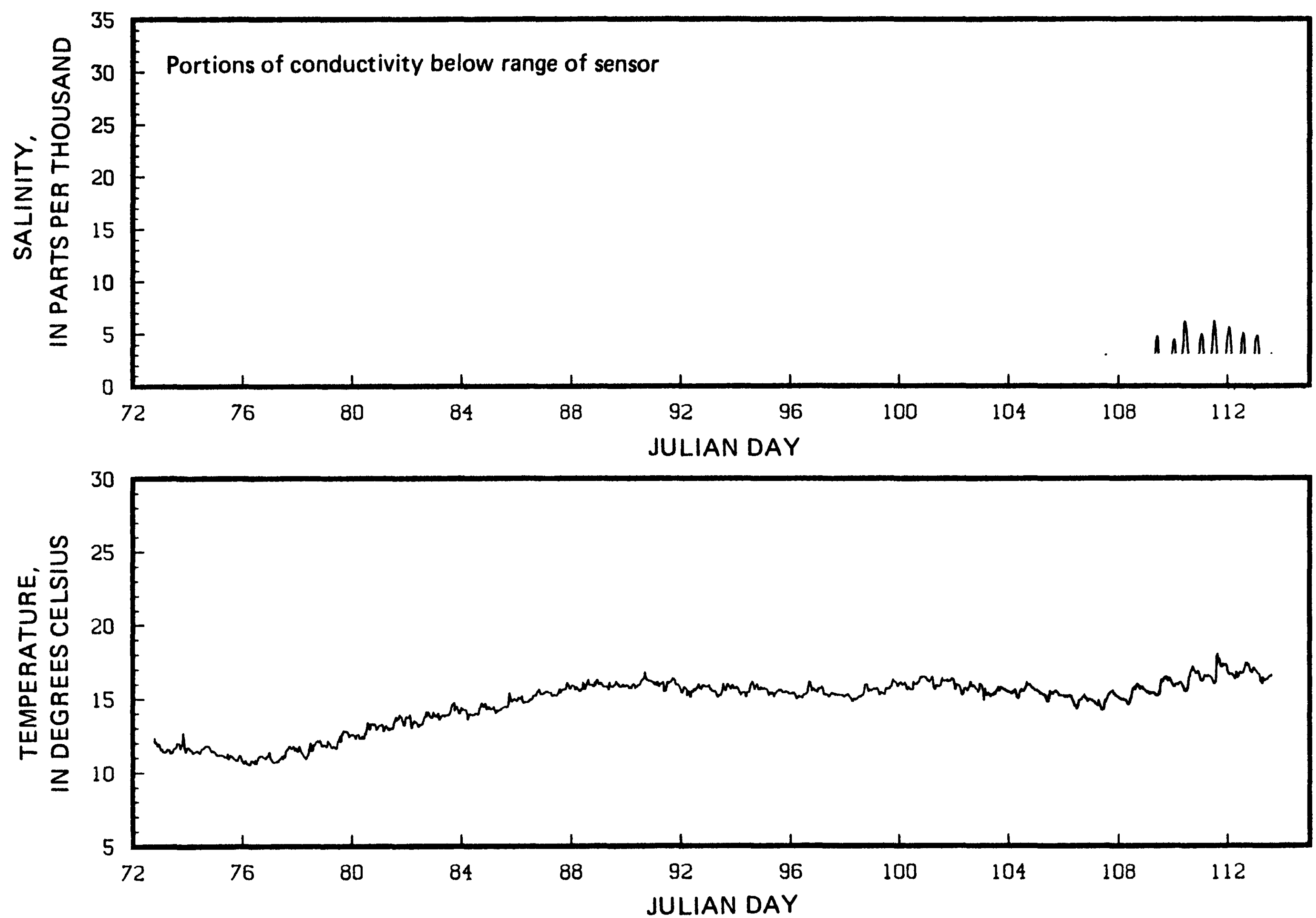
INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-23.2	3.0	6384
2	12	-17.1	2.7	3937
3	12	-13.4	3.4	2496
4	12	-13.0	3.5	1888
5	12	-11.8	3.2	1441
6	12	-7.0	2.1	1154
7	6	-5.0	4.3	936
ALL	78	-13.5	3.1	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION GS41 38- 6-33N 122- 2-55W

METER 1.2 METERS BELOW MLLW. WATER DEPTH 4.0 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS41 38- 6-33N 122- 2-55W
METER 1.2 METERS BELOW MLLW. WATER DEPTH 4.0 METERS

STATION NUMBER= GS42
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=13 HOUR=1475
TIME MERIDIAN= 120 W
STATION POSITION= 38- 6-13N 122- 0-45W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	0.94401	8.33	18.80
K1	1.00274	1.96077	73.93	75.62
N2	1.89598	1.43877	293.46	309.97
M2	1.93227	7.57585	303.39	315.55
S2	2.00000	2.80111	307.76	311.79
M4	3.86455	0.68431	198.81	223.12

RESULTS FOR V (+NORTH) SERIES

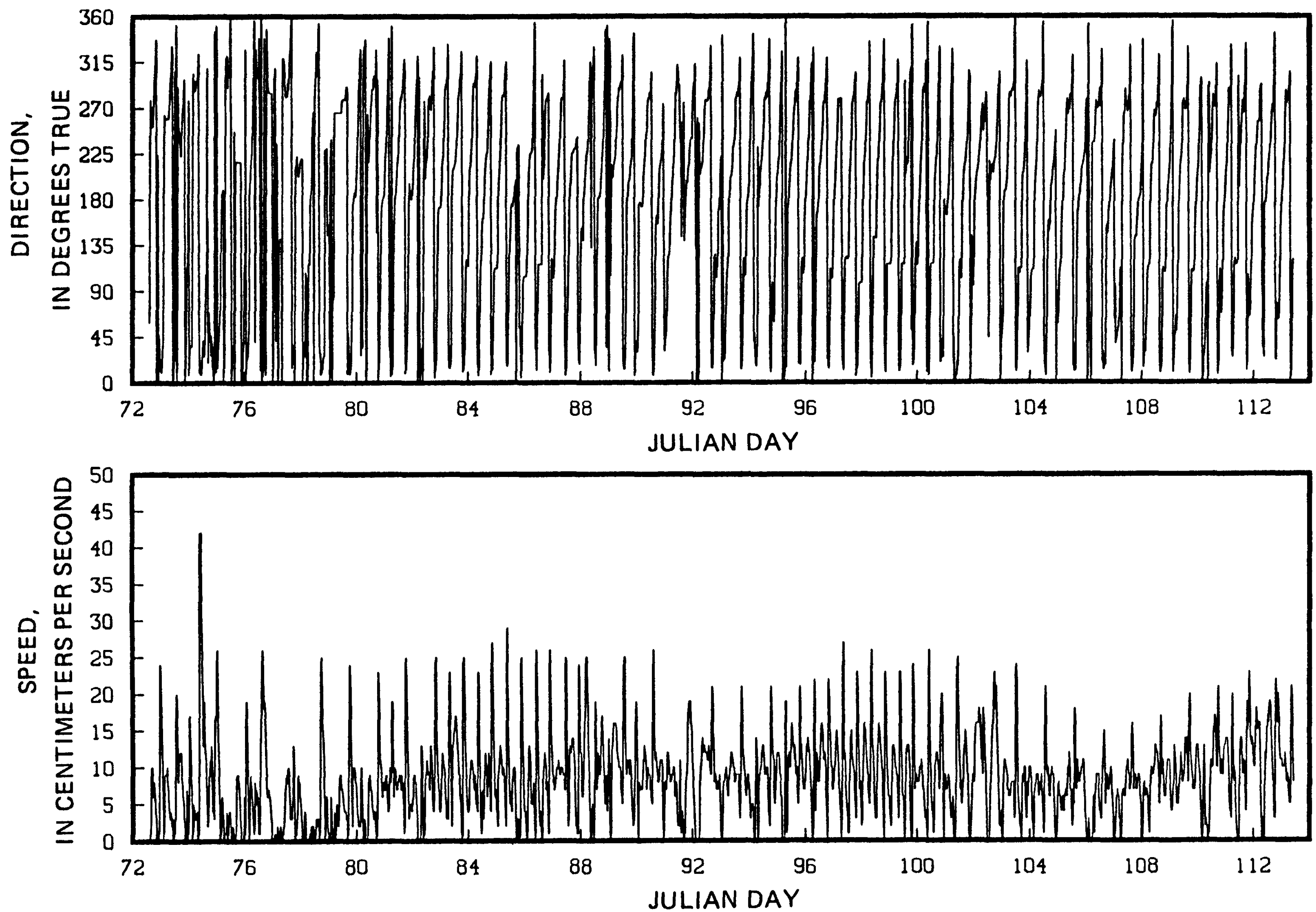
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.00099	285.65	296.12
K1	1.00274	1.46047	306.75	308.43
N2	1.89598	1.36116	214.10	230.61
M2	1.93227	8.06370	243.97	256.12
S2	2.00000	2.29553	255.11	259.14
M4	3.86455	1.58126	194.52	218.82

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	1.04	0.90	32.6	325.2	77.2	CLOCKWISE
K1	2.22	1.03	121.8	91.7	298.8	CLOCKWISE
N2	1.53	1.26	53.4	278.5	231.8	CLOCKWISE
M2	9.62	5.47	41.5	282.8	14.5	CLOCKWISE
S2	3.27	1.57	54.1	292.7	82.5	CLOCKWISE
M4	1.72	0.05	23.4	219.5	29.1	CLOCKWISE

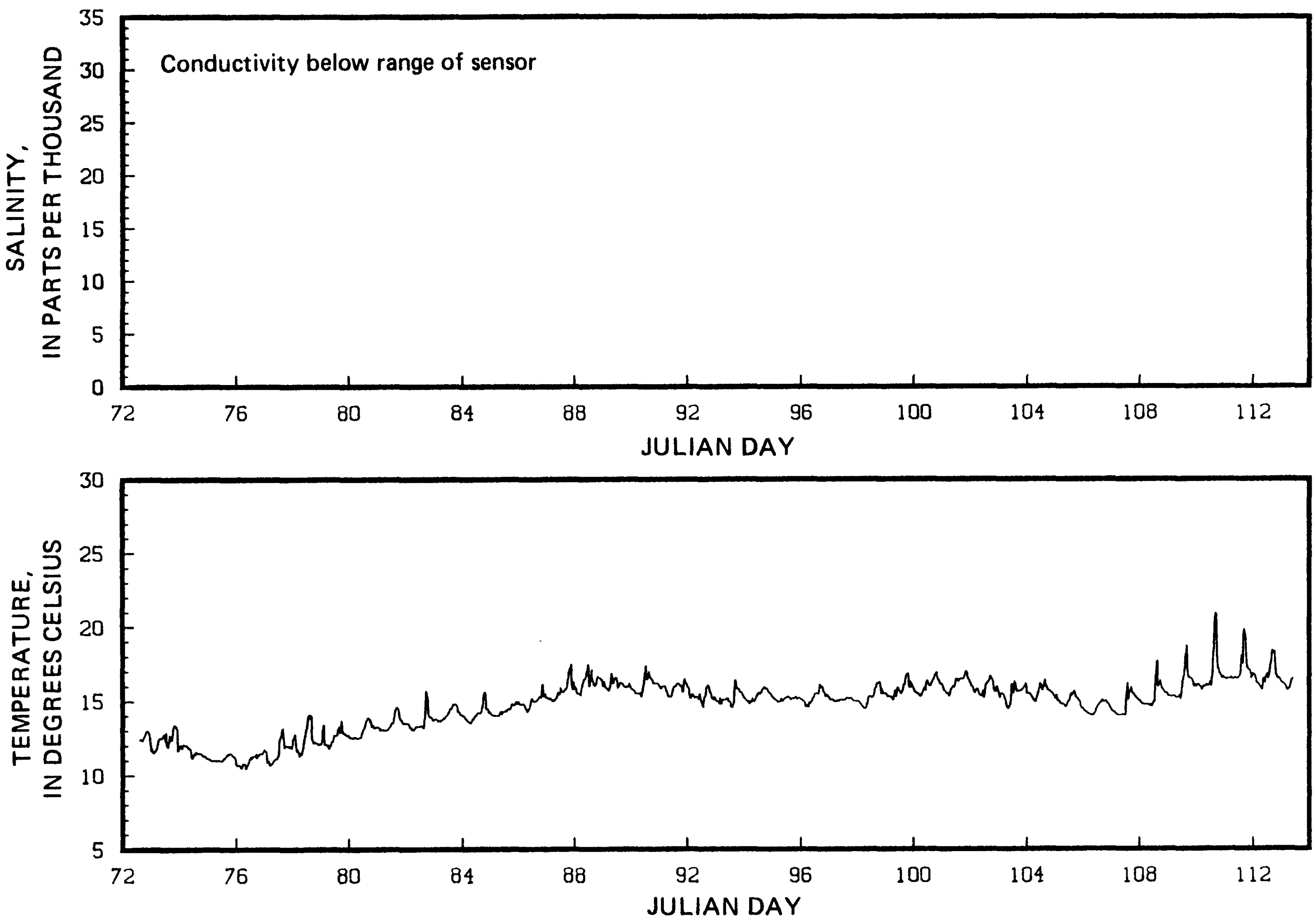
ROOT-MEAN-SQUARES SPEED, (CM/S)=	10.69
STANDARD DEVIATION, U SERIES (CM/S)=	3.74
STANDARD DEVIATION, V SERIES (CM/S)=	5.78
TIDAL-FORM NUMBER=	0.25
SPRING TIDAL CURRENT MAXIMUM (CM/S)=	16.14
NEAP TIDAL CURRENT MAXIMUM (CM/S)=	5.17
PRINCIPAL CURRENT DIRECTION (DEG. T.)=	54.53

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-0.5	3.4	6384
2	12	-1.4	0.8	3937
3	12	-1.2	-1.3	2496
4	12	-2.2	-1.3	1888
5	12	-1.6	-1.1	1441
6	12	-1.0	-0.6	1154
7	6	-1.5	-1.6	936
ALL	78	-1.3	-0.1	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS42 38- 6-13N 122- 0-45W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS42 38- 6-13N 122- 0-45W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= GS43
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=13 HOUR=1575
TIME MERIDIAN= 120 W
STATION POSITION= 38- 7-17N 122- 1-35W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.24739	27.91	38.39
K1	1.00274	1.60929	49.27	50.97
N2	1.89598	0.87812	306.16	322.70
M2	1.93227	6.26046	333.35	345.53
S2	2.00000	1.90495	333.14	337.19
M4	3.86455	1.04185	243.94	268.30

RESULTS FOR V (+NORTH) SERIES

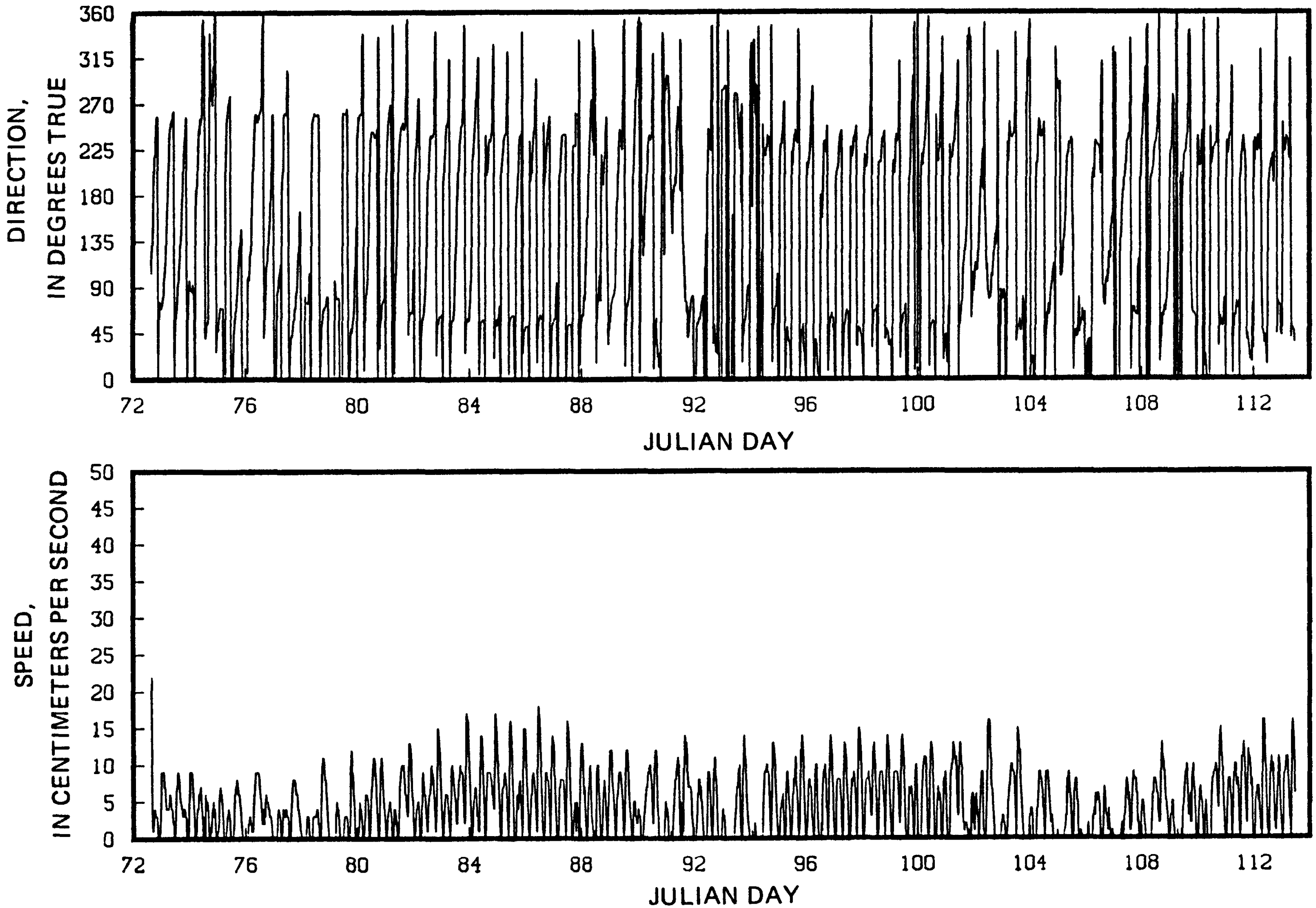
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	0.83214	10.75	21.24
K1	1.00274	1.04601	52.02	53.72
N2	1.89598	0.93446	301.24	317.78
M2	1.93227	4.34386	311.85	324.03
S2	2.00000	1.96154	314.94	318.99
M4	3.86455	0.44266	244.92	269.28

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	1.49	0.21	56.8	33.2	91.1	CLOCKWISE
K1	1.92	0.04	57.0	51.8	313.8	COUNTER-CLOCKWISE
N2	1.28	0.05	43.2	320.1	260.3	CLOCKWISE
M2	7.50	1.33	55.9	338.7	43.5	CLOCKWISE
S2	2.70	0.43	44.1	327.8	112.5	CLOCKWISE
M4	1.13	0.01	67.0	268.4	87.0	COUNTER-CLOCKWISE

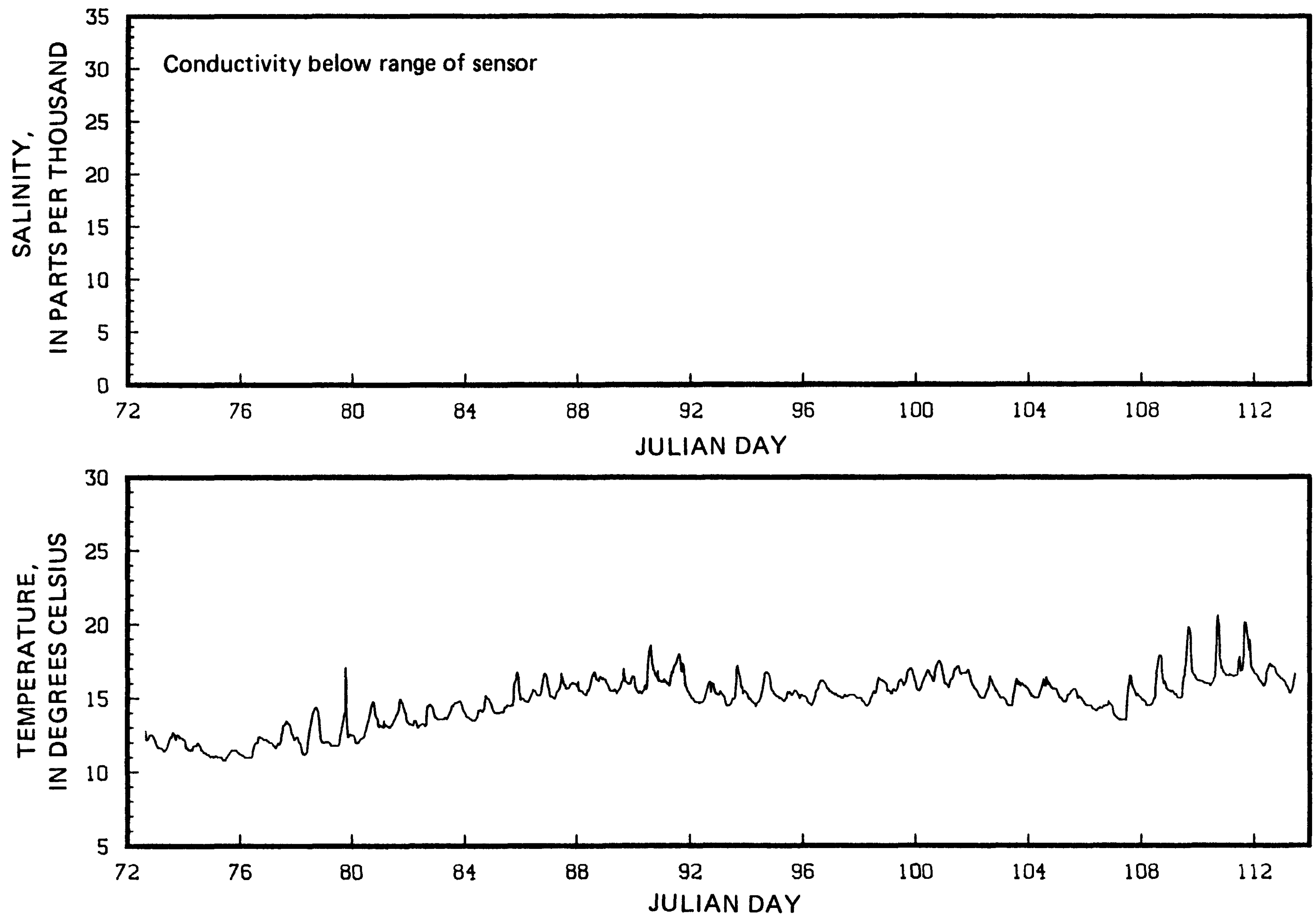
ROOT-MEAN-SQUARES SPEED, (CM/S)= 6.54
STANDARD DEVIATION, U SERIES (CM/S)= 2.47
STANDARD DEVIATION, V SERIES (CM/S)= 1.87
TIDAL-FORM NUMBER= 0.33
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 13.61
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 4.37
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 53.83

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	0.9	-0.2	6384
2	12	0.5	0.3	3937
3	12	0.7	0.2	2496
4	12	0.4	0.2	1888
5	12	0.5	-0.2	1441
6	12	0.1	-0.3	1154
7	6	0.2	0.0	936
ALL	78	0.5	0.0	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS43 38- 7-17N 122- 1-35W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS43 38- 7-17N 122- 1-35W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= GS44
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 3 DAY=13 HOUR=1681
TIME MERIDIAN= 120 W
STATION POSITION= 38- 7-13N 122- 2-46W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.0000			
M4	3.86455			

RESULTS FOR V (+NORTH) SERIES

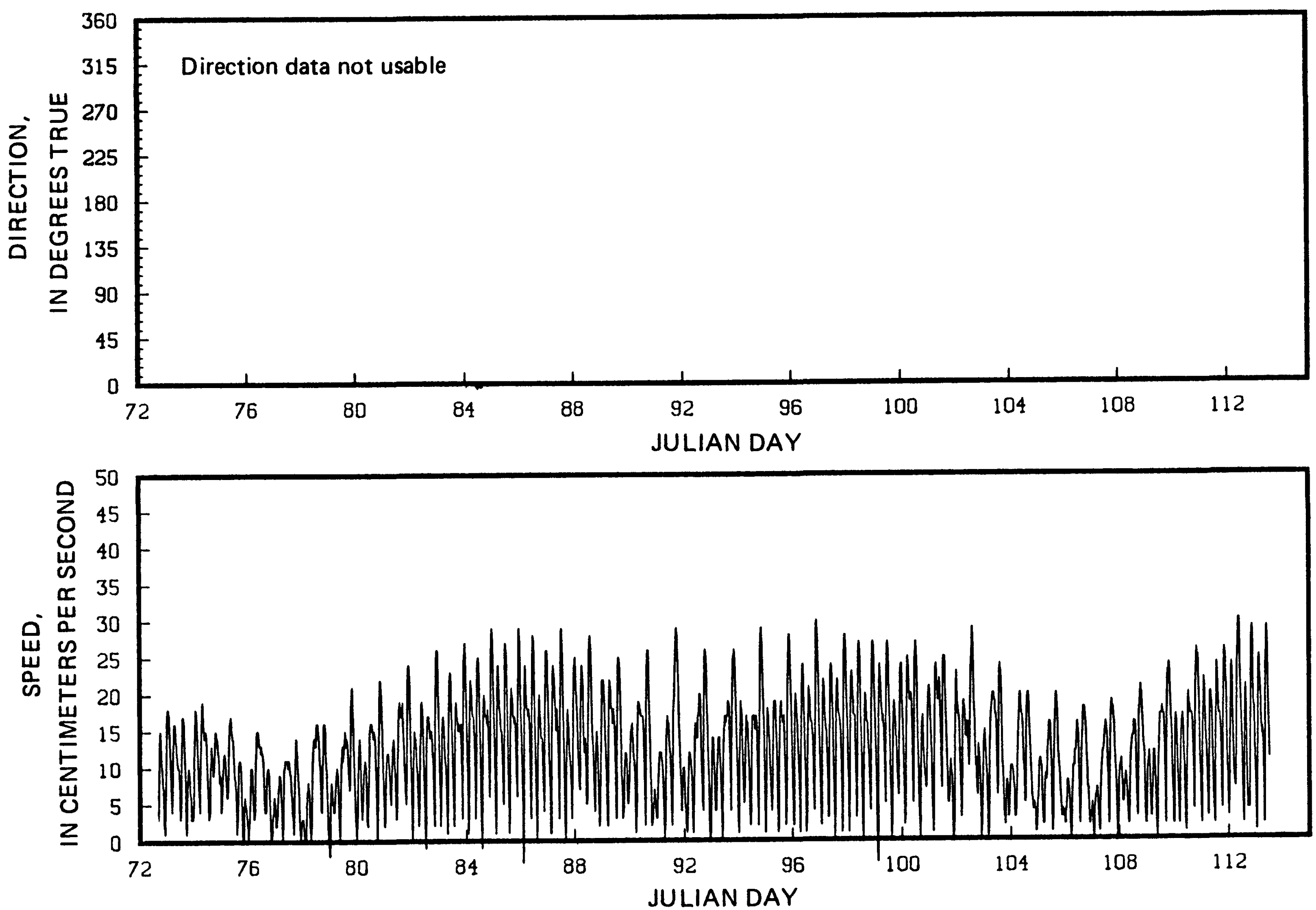
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.00000			
M4	3.86455			

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1					105.9	
K1					329.8	
N2					290.4	
M2					74.2	
S2					144.3	
M4					148.5	

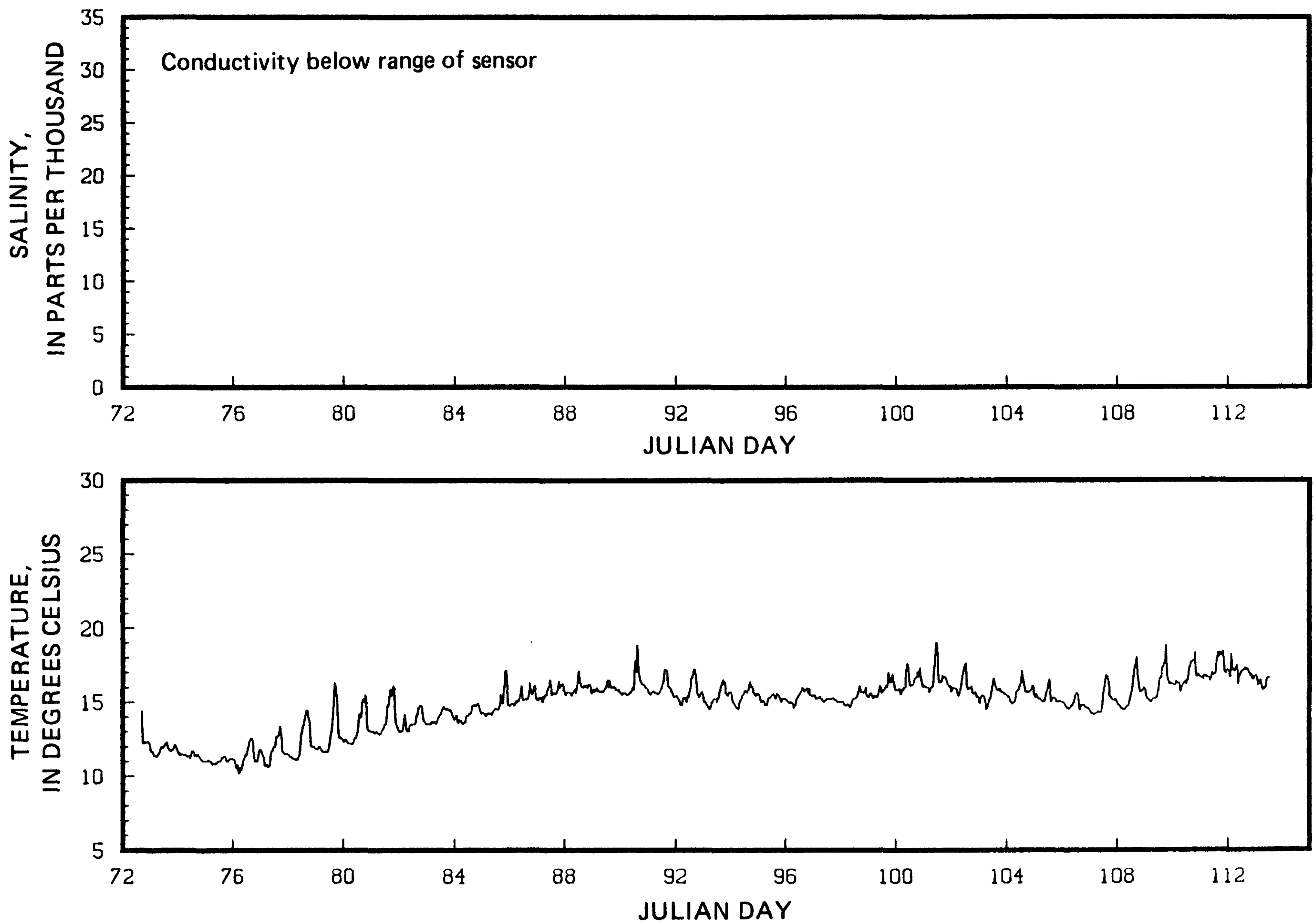
ROOT-MEAN-SQUARES SPEED, (CM/S)= 14.06
STANDARD DEVIATION, U SERIES (CM/S)=
STANDARD DEVIATION, V SERIES (CM/S)=
TIDAL-FORM NUMBER=
SPRING TIDAL CURRENT MAXIMUM (CM/S)=
NEAP TIDAL CURRENT MAXIMUM (CM/S)=
PRINCIPAL CURRENT DIRECTION (DEG. T.)=

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12			
2	12			
3	12			
4	12			
5	12			
6	12			
7	6			
ALL	78			



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS44 38- 7-13N 122- 2-46W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS44 38- 7-13N 122- 2-46W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= C23
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=24 HOUR=1210
TIME MERIDIAN= 120 W
STATION POSITION= 38- 4-41N 122-20-48W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.83064	44.54	55.35
K1	1.00274	4.57263	50.23	52.25
N2	1.89598	2.50305	301.54	318.71
M2	1.93227	14.94647	311.24	324.06
S2	2.00000	3.44943	308.09	312.78
M4	3.86455	1.34444	142.13	167.77

RESULTS FOR V (+NORTH) SERIES

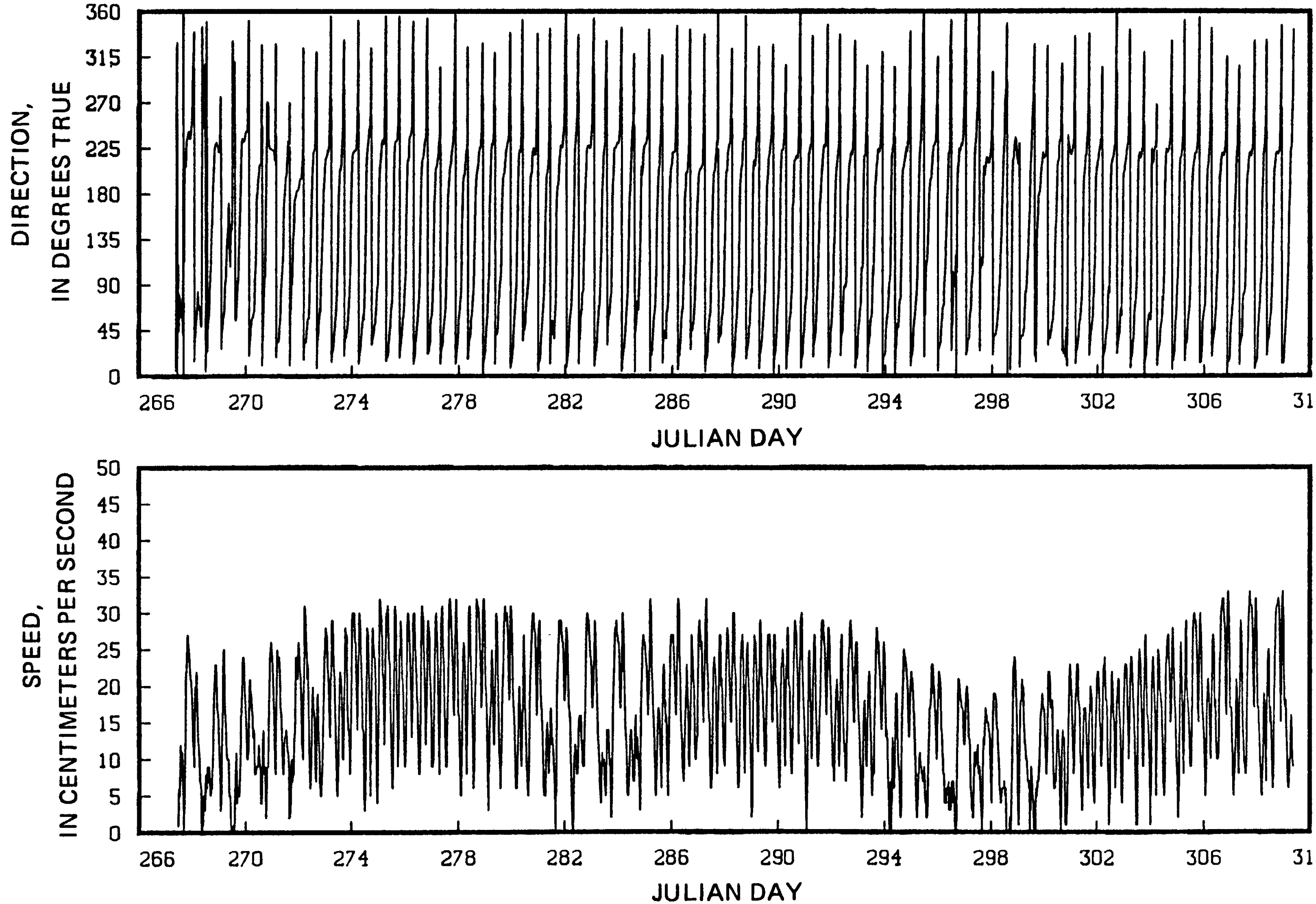
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	3.33073	8.43	19.23
K1	1.00274	4.61286	16.49	18.51
N2	1.89598	3.09553	264.14	281.32
M2	1.93227	17.42644	275.98	288.80
S2	2.00000	5.14209	270.45	275.14
M4	3.86455	3.16045	121.28	146.92

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	4.16	1.33	39.3	33.9	133.7	CLOCKWISE
K1	6.22	1.88	44.7	35.2	91.1	CLOCKWISE
N2	3.78	1.24	37.5	295.5	54.3	CLOCKWISE
M2	21.91	6.86	39.7	303.4	223.3	CLOCKWISE
S2	5.91	1.83	31.3	285.8	3.0	CLOCKWISE
M4	3.41	0.44	22.1	150.0	86.7	CLOCKWISE

ROOT-MEAN-SQUARES SPEED, (CM/S)= 18.60
STANDARD DEVIATION, U SERIES (CM/S)= 3.89
STANDARD DEVIATION, V SERIES (CM/S)= 4.09
TIDAL-FORM NUMBER= 0.37
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 38.20
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 13.94
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 39.14

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

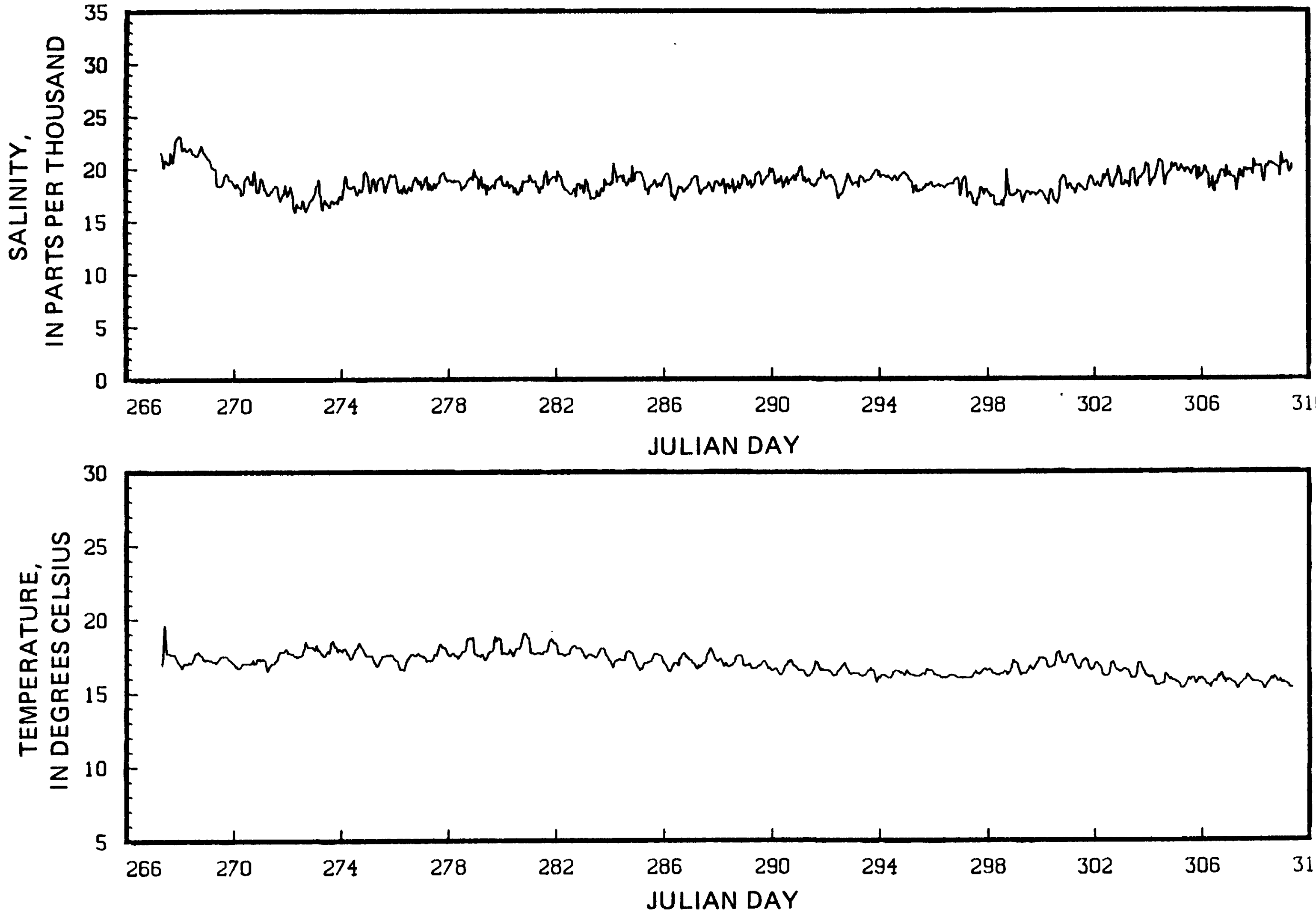
INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	0.1	-2.4	
2	12	-0.2	-0.1	
3	12	-1.0	-0.4	
4	12	0.3	-0.1	
5	12	0.0	-0.6	
6	12	-0.2	-0.5	
7	6	-0.3	-0.6	
ALL	78	-0.2	-0.7	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION C23 38- 4-41N 122-20-48W

METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION C23 38- 4-41N 122-20-48W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= GS40
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=24 HOUR=1310
TIME MERIDIAN= 120 W
STATION POSITION= 38- 5-29N 122-22-34W
METER DEPTH= 0.3M BELOW MLLW WATER DEPTH= 1.5M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.00000			
M4	3.86455			

RESULTS FOR V (+NORTH) SERIES

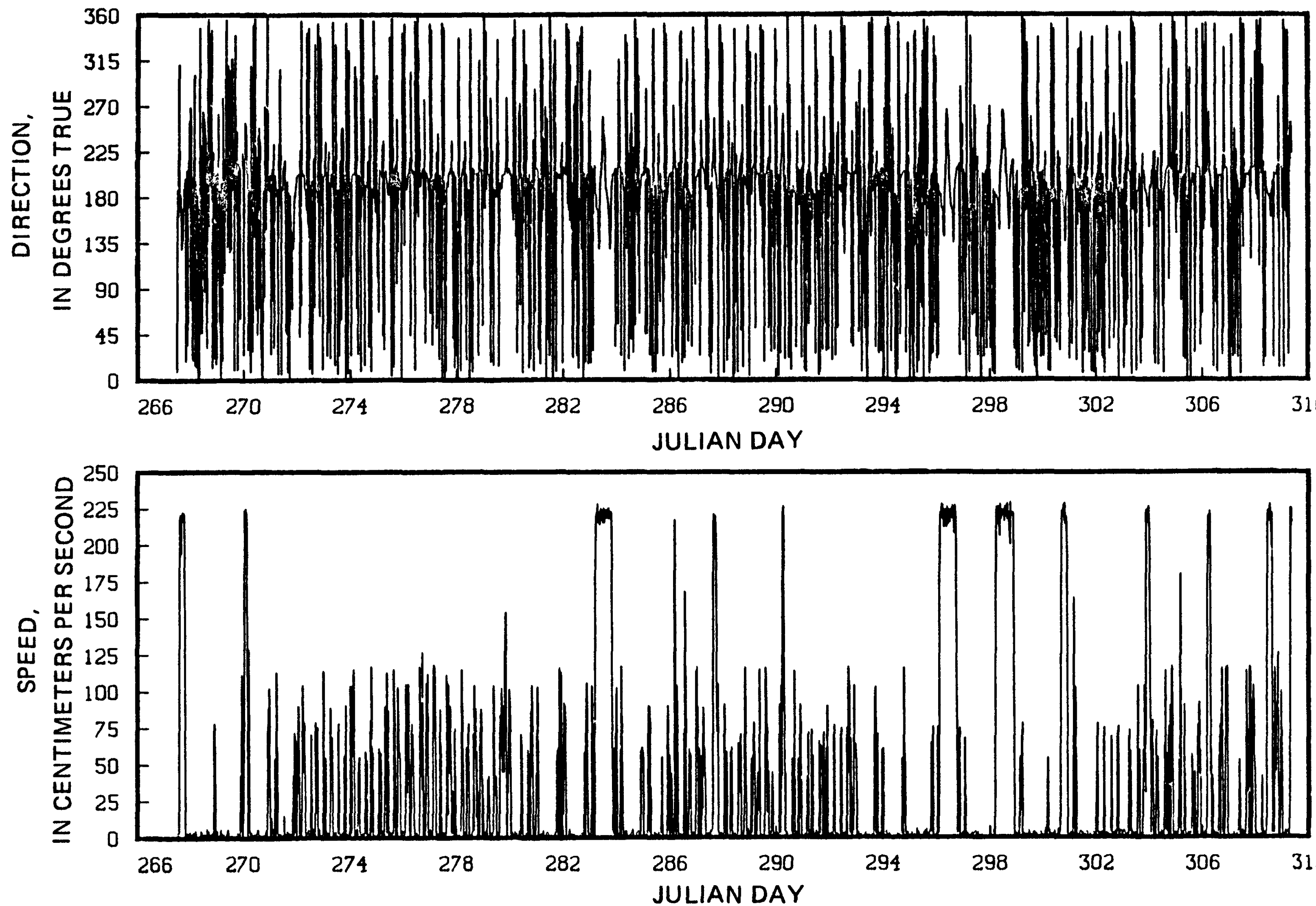
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.00000			
M4	3.86455			

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1					147.6	
K1					106.1	
N2					82.8	
M2					252.3	
S2					33.0	
M4					144.6	

ROOT-MEAN-SQUARES SPEED, (CM/S)=
STANDARD DEVIATION, U SERIES (CM/S)=
STANDARD DEVIATION, V SERIES (CM/S)=
TIDAL-FORM NUMBER=
SPRING TIDAL CURRENT MAXIMUM (CM/S)=
NEAP TIDAL CURRENT MAXIMUM (CM/S)=
PRINCIPAL CURRENT DIRECTION (DEG. T.)=

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

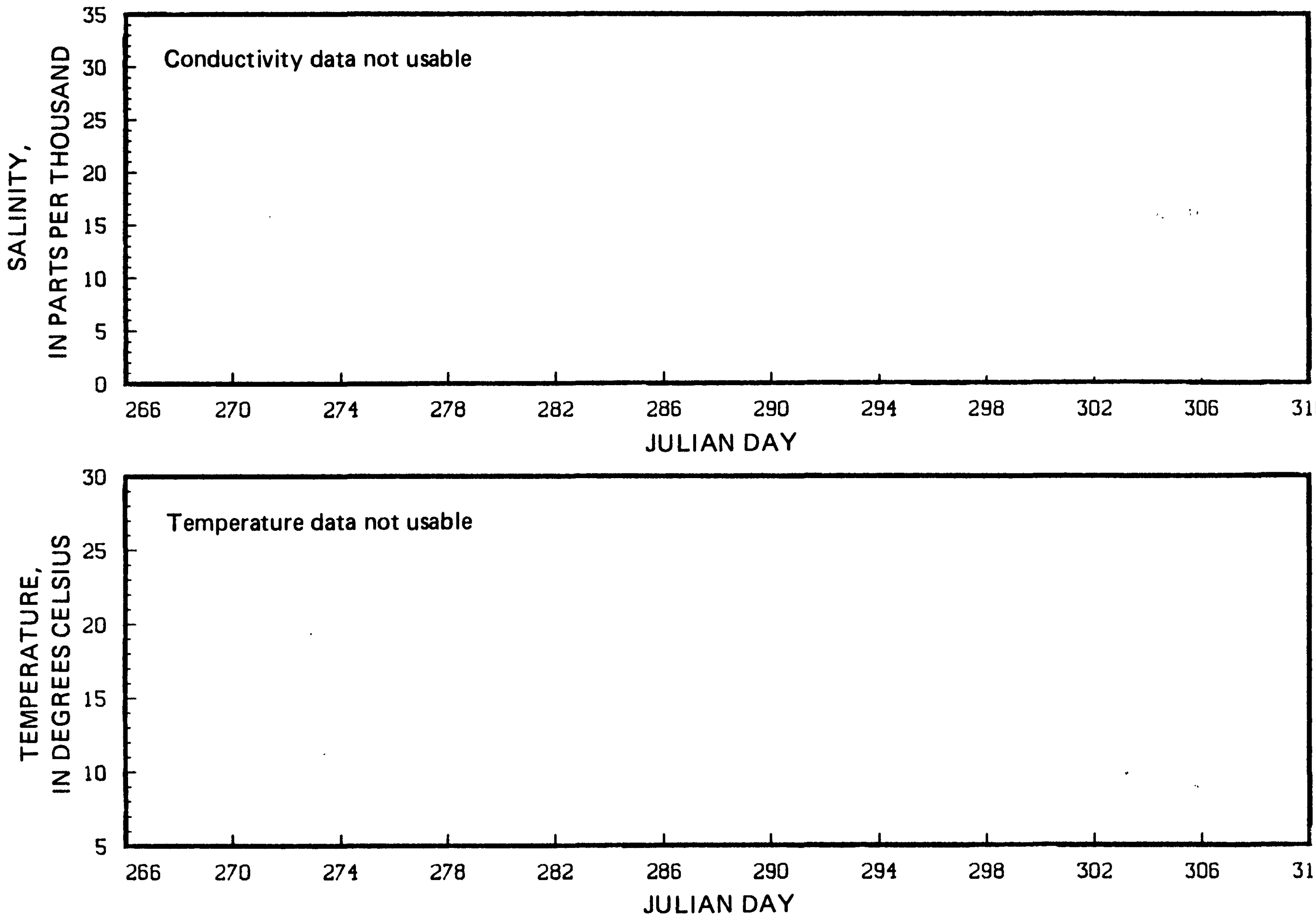
INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12			
2	12			
3	12			
4	12			
5	12			
6	12			
7	6			
ALL	78			



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION gs40 38- 5-29N 122-22-34W

METER .3 METERS BELOW MLLW. WATER DEPTH 1.5 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION gs40 38- 5-29N 122-22-34W
METER .3 METERS BELOW MLLW. WATER DEPTH 1.5 METERS

STATION NUMBER= GS41
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=23 HOUR=1403
TIME MERIDIAN= 120 W
STATION POSITION= 38- 6-28N 122- 2-46W
METER DEPTH= 1.2M BELOW MLLW WATER DEPTH= 2.4M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	0.86412	31.13	41.63
K1	1.00274	1.88971	169.18	170.90
N2	1.89598	1.47273	38.27	54.84
M2	1.93227	7.36255	64.49	76.71
S2	2.00000	2.75053	112.91	117.00
M4	3.86455	0.30699	169.18	193.62

RESULTS FOR V (+NORTH) SERIES

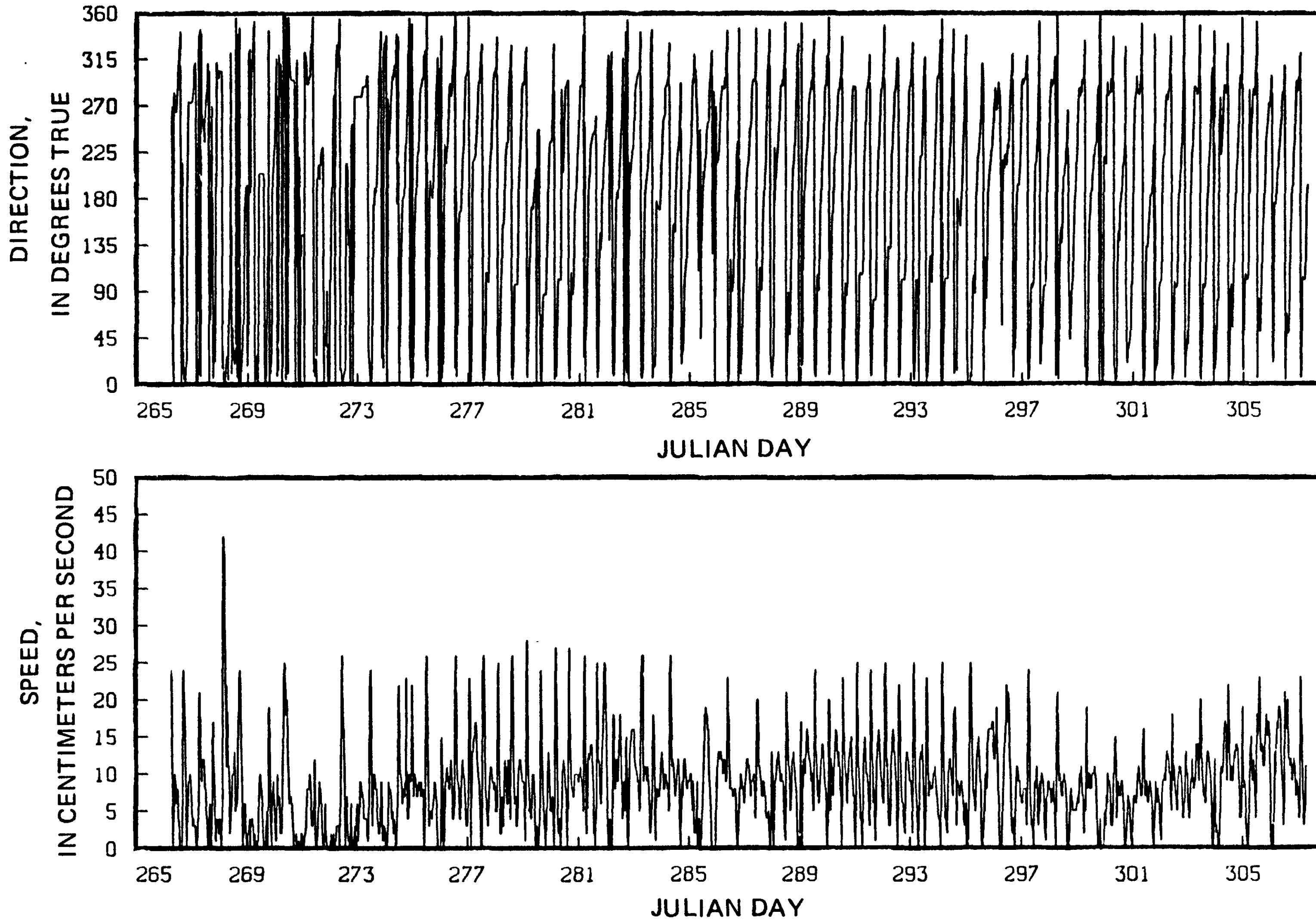
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.18278	305.91	316.41
K1	1.00274	1.50980	40.52	42.24
N2	1.89598	1.32750	321.96	338.54
M2	1.93227	8.04050	2.42	14.63
S2	2.00000	2.31964	58.53	62.63
M4	3.86455	1.94002	86.56	111.00

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	1.19	0.86	7.3	321.7	185.9	CLOCKWISE
K1	2.20	1.01	125.0	188.9	119.1	CLOCKWISE
N2	1.57	1.21	56.9	28.2	146.7	CLOCKWISE
M2	9.36	5.59	39.7	41.0	303.6	CLOCKWISE
S2	3.22	1.61	53.2	96.4	60.9	CLOCKWISE
M4	1.94	0.30	1.2	111.2	247.3	CLOCKWISE

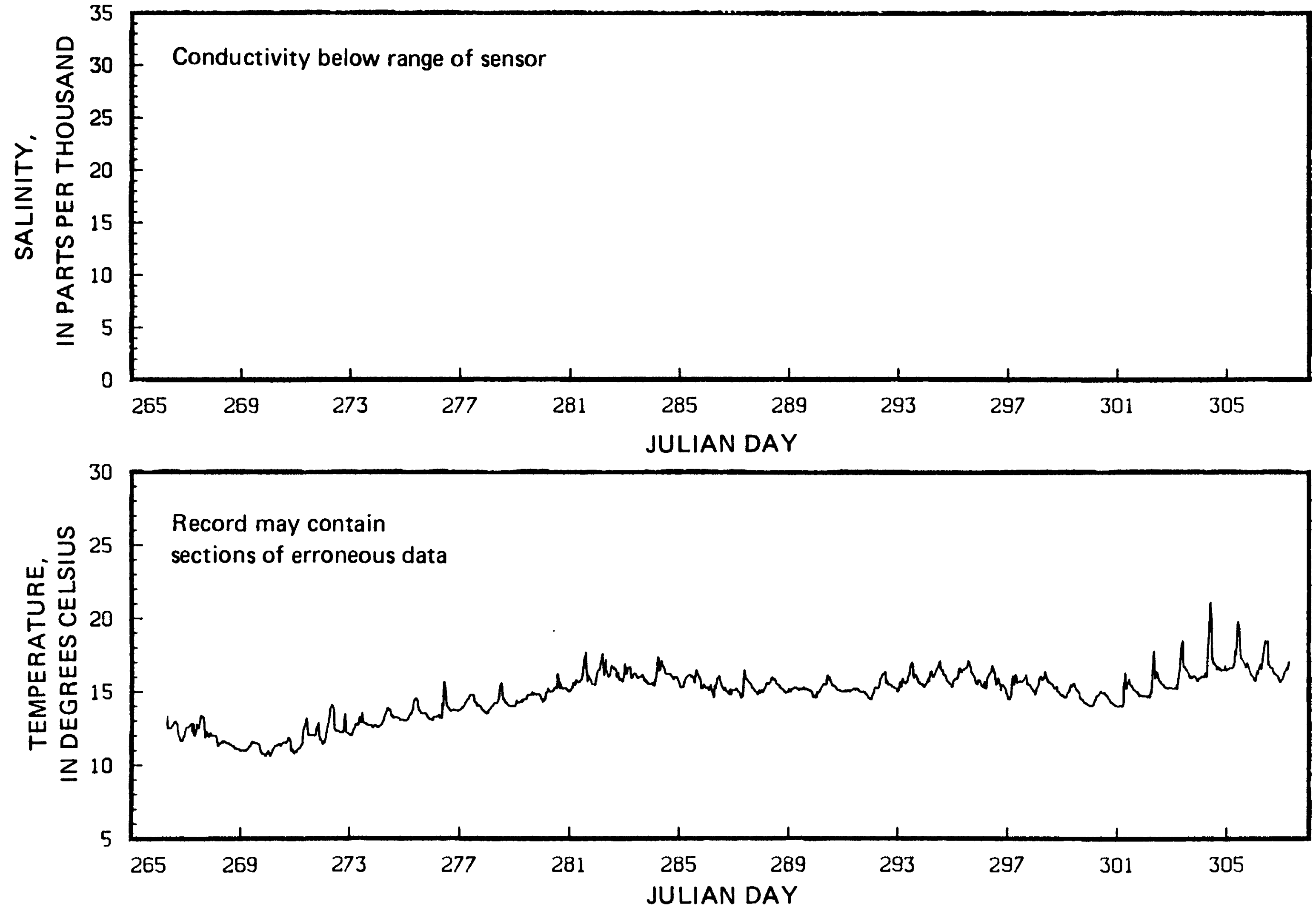
ROOT-MEAN-SQUARES SPEED, (CM/S)=	10.75
STANDARD DEVIATION, U SERIES (CM/S)=	3.75
STANDARD DEVIATION, V SERIES (CM/S)=	5.78
TIDAL-FORM NUMBER=	0.27
SPRING TIDAL CURRENT MAXIMUM (CM/S)=	15.96
NEAP TIDAL CURRENT MAXIMUM (CM/S)=	5.14
PRINCIPAL CURRENT DIRECTION (DEG. T.)=	51.73

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-0.8	3.9	491
2	12	-2.3	1.5	425
3	12	-1.8	-0.2	408
4	12	-2.6	-0.1	370
5	12	-2.2	0.2	266
6	12	-1.2	0.2	245
7	6	-2.2	0.1	259
ALL	78	-1.8	0.9	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS41 38- 6-28N 122- 2-46W
METER 1.2 METERS BELOW MLLW. WATER DEPTH 2.4 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS41 38- 6-28N 122- 2-46W
METER 1.2 METERS BELOW MLLW. WATER DEPTH 2.4 METERS

STATION NUMBER= GS42
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=23 HOUR=1203
TIME MERIDIAN= 120 W
STATION POSITION= 38- 6- 6N 122- 0-56W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 76 M2 CYCLES: 1886 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.80243	48.86	59.33
K1	1.00274	4.17983	69.12	70.80
N2	1.89598	1.71448	332.57	349.08
M2	1.93227	14.15096	341.83	353.98
S2	2.00000	4.48592	330.59	334.62
M4	3.86455	1.03364	161.05	185.37

RESULTS FOR V (+NORTH) SERIES

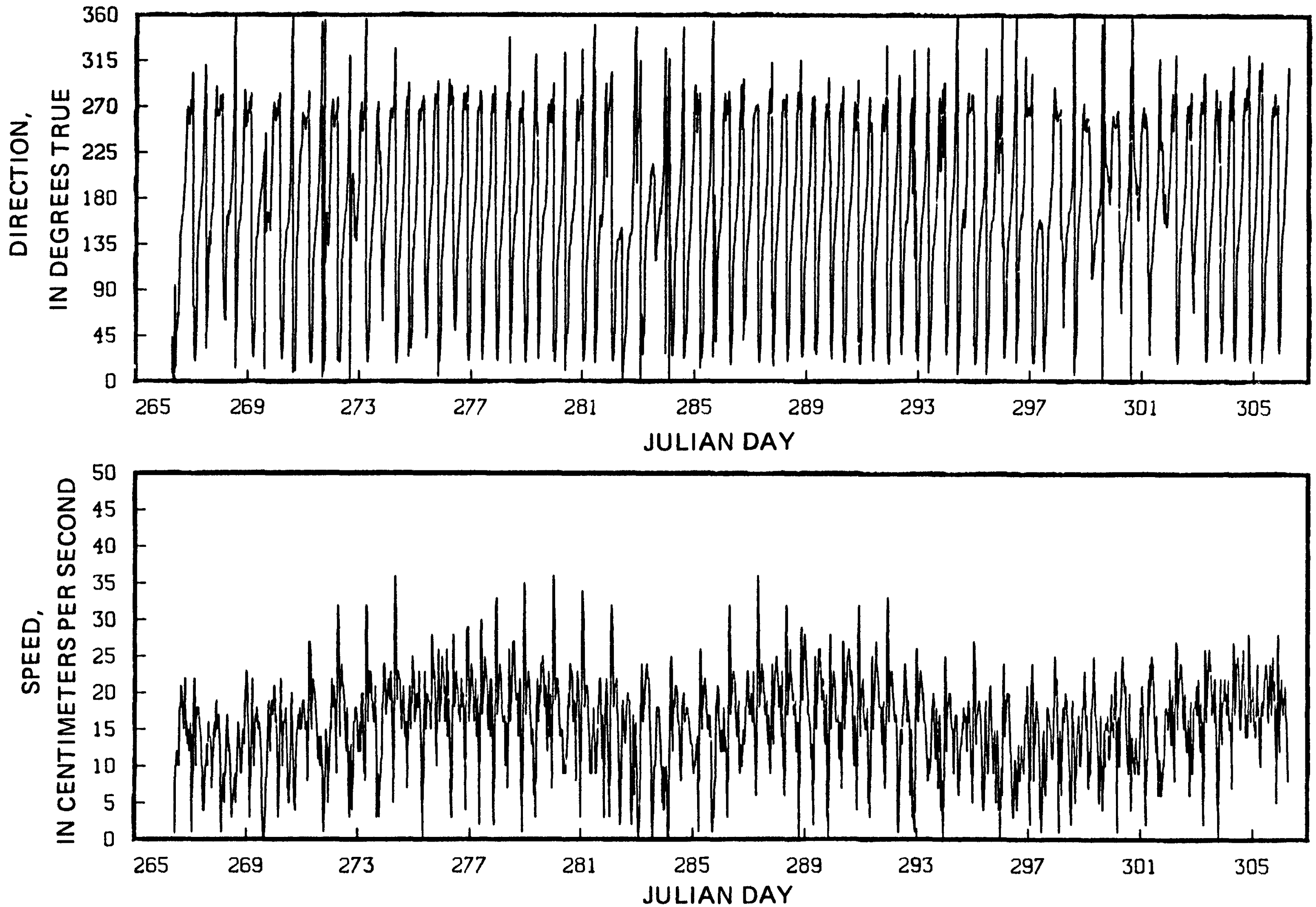
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.20936	317.59	328.06
K1	1.00274	2.36293	324.28	325.97
N2	1.89598	2.51191	227.62	244.13
M2	1.93227	12.97328	250.91	263.07
S2	2.00000	3.72356	253.67	257.70
M4	3.86455	4.24377	251.10	275.42

NAME	MAJOR CM/S	MINOR CM/S	DIR DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	2.80	1.21	90.7	59.6	158.1	CLOCKWISE
K1	4.24	2.25	101.5	77.0	89.0	CLOCKWISE
N2	2.58	1.61	163.3	53.5	89.8	CLOCKWISE
M2	14.16	12.96	95.2	358.8	245.7	CLOCKWISE
S2	4.68	3.48	64.8	315.4	0.9	CLOCKWISE
M4	4.24	1.03	180.0	95.4	131.4	COUNTER-CLOCKWISE

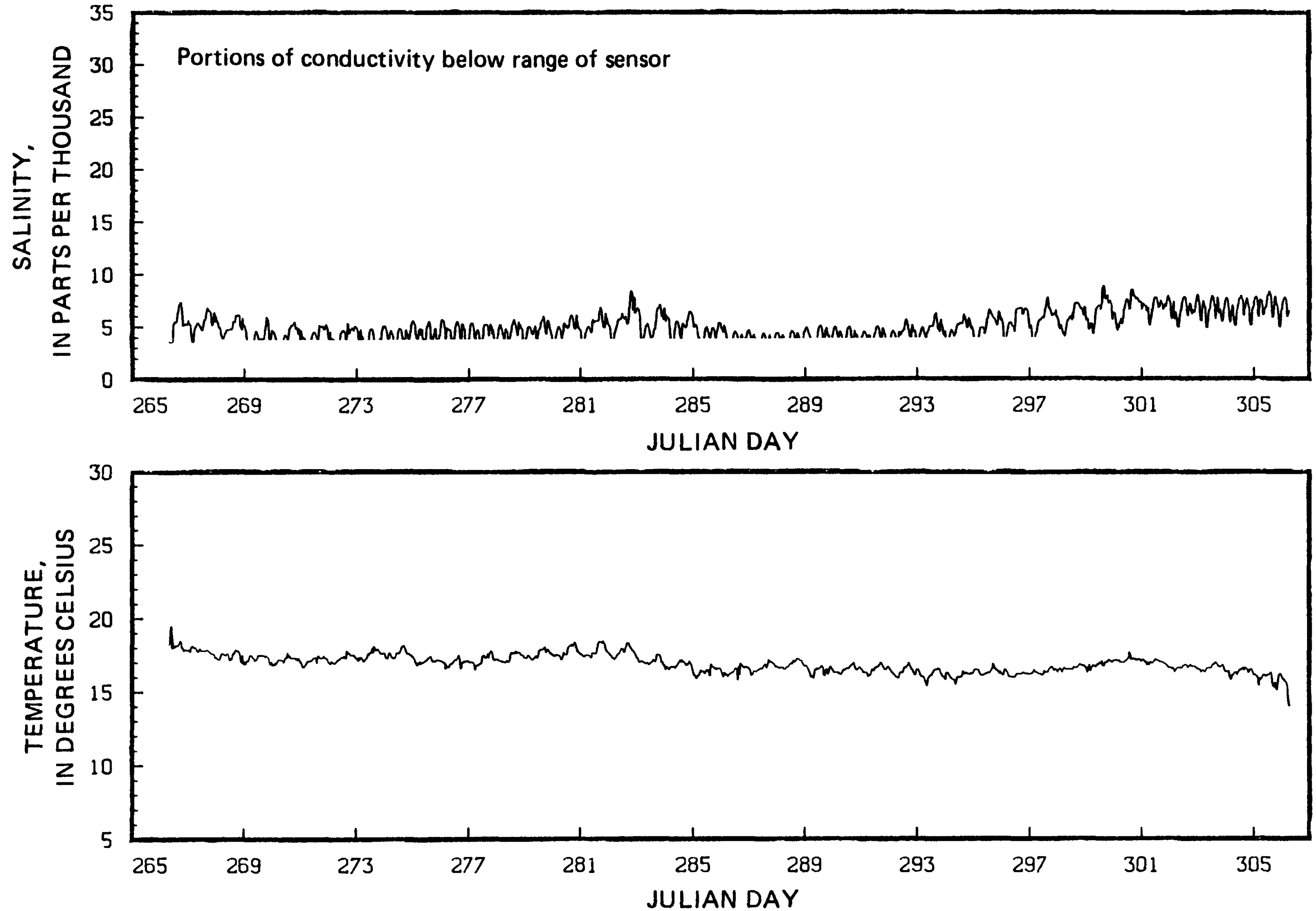
ROOT-MEAN-SQUARES SPEED, (CM/S)= 17.52
STANDARD DEVIATION, U SERIES (CM/S)= 4.34
STANDARD DEVIATION, V SERIES (CM/S)= 7.76
TIDAL-FORM NUMBER= 0.37
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 25.88
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 8.04
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 90.26

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-1.4	-3.6	491
2	12	-0.8	-4.6	425
3	12	2.3	-3.5	404
4	12	0.1	-4.3	370
5	12	1.2	-3.7	266
6	12	-1.6	-6.5	245
7	4	-1.3	-3.1	261
ALL	76	-0.1	-4.3	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS42 38- 6- 6N 122- 0-56W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS42 38- 6- 6N 122- 0-56W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= GS44
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=23 HOUR=1403
TIME MERIDIAN= 120 W
STATION POSITION= 38- 7-13N 122- 3- 4W
METER DEPTH= 0.9M BELOW MLLW WATER DEPTH= 2.1M
RECORD LENGTH IS 78 M2 CYCLES: 1936 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.00000			
M4	3.86455			

RESULTS FOR V (+NORTH) SERIES

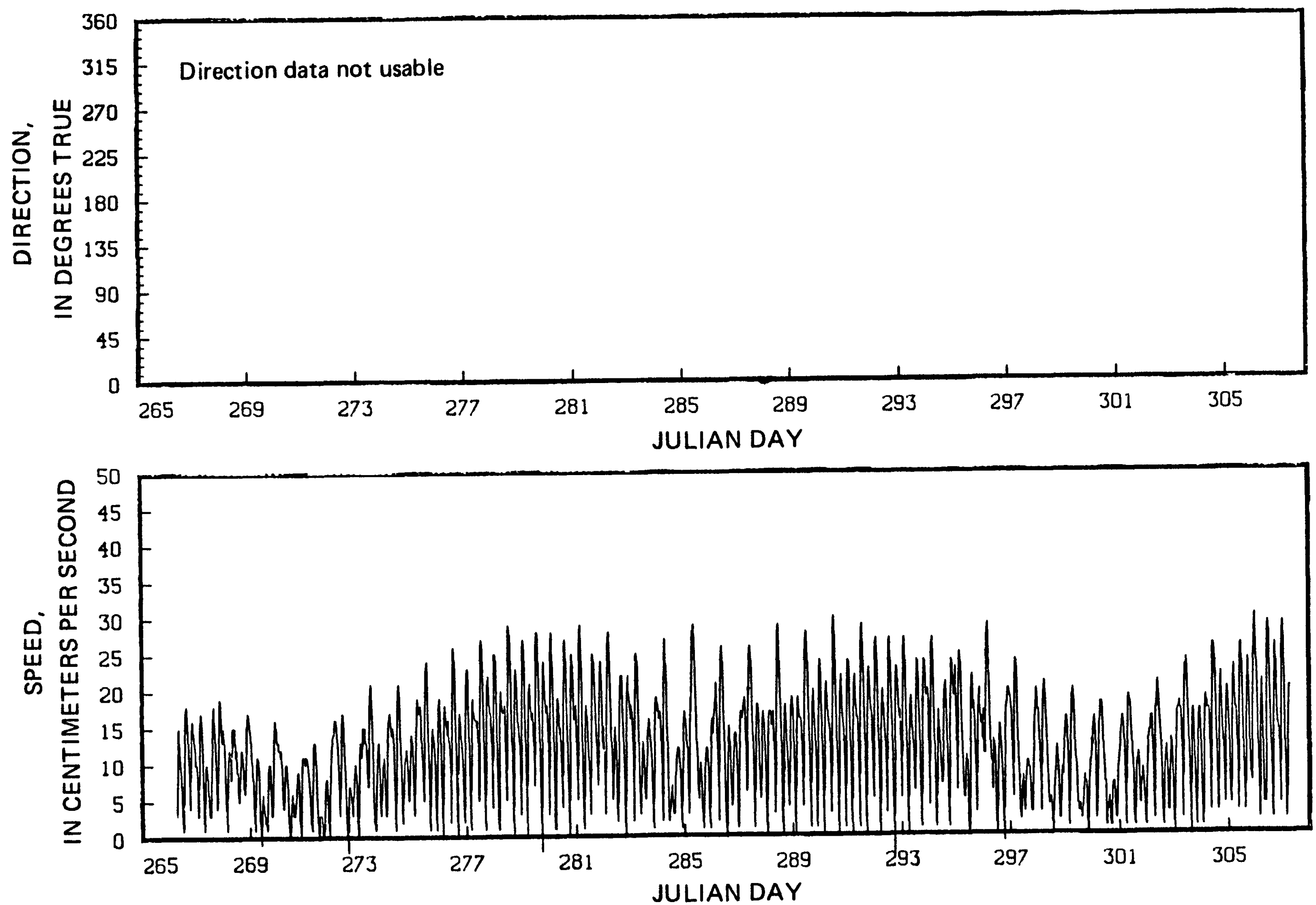
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954			
K1	1.00274			
N2	1.89598			
M2	1.93227			
S2	2.00000			
M4	3.86455			

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1					185.9	
K1					119.1	
N2					146.7	
M2					303.6	
S2					60.9	
M4					247.3	

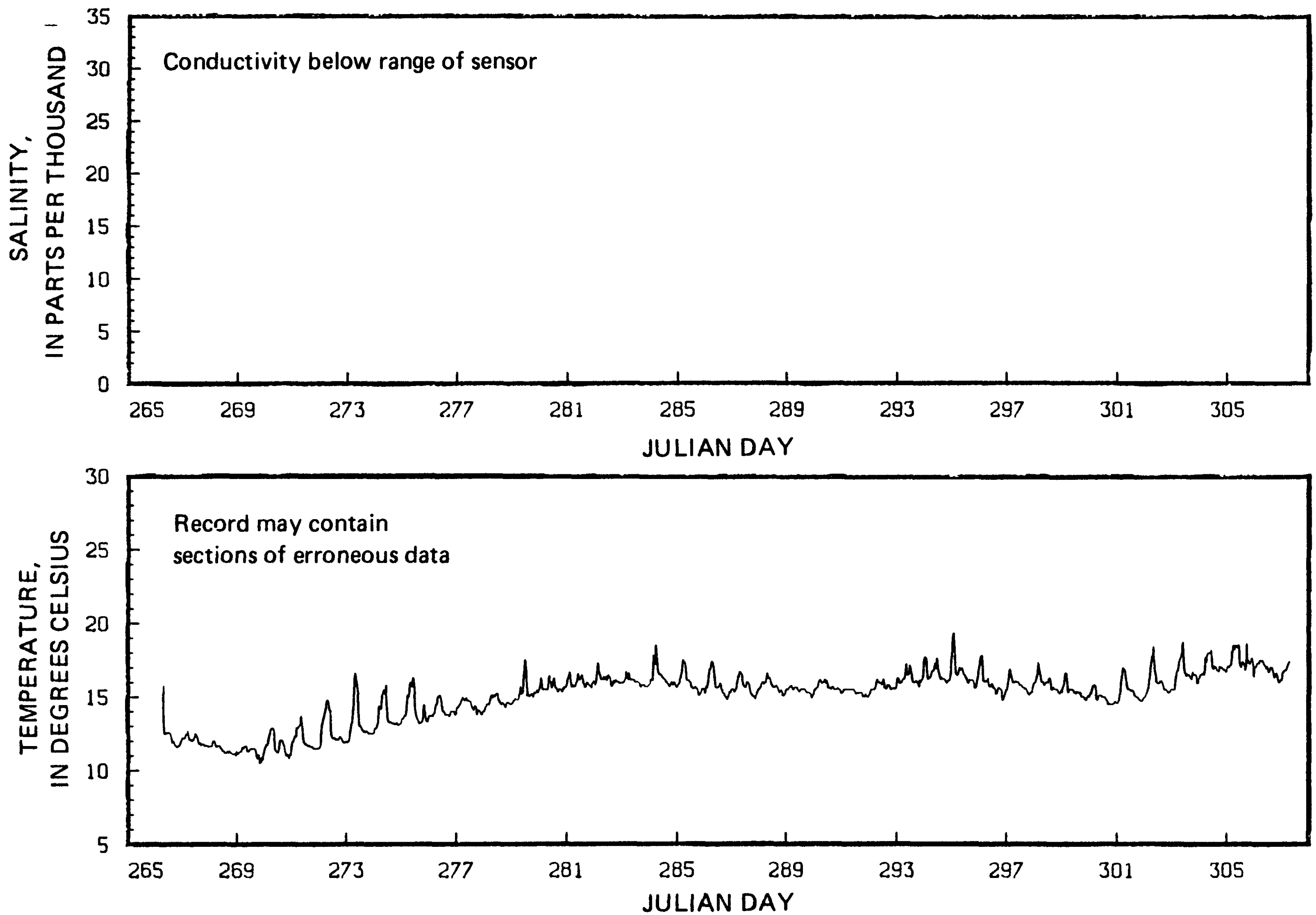
ROOT-MEAN-SQUARES SPEED, (CM/S)= 14.11
STANDARD DEVIATION, U SERIES (CM/S)=
STANDARD DEVIATION, V SERIES (CM/S)=
TIDAL-FORM NUMBER=
SPRING TIDAL CURRENT MAXIMUM (CM/S)=
NEAP TIDAL CURRENT MAXIMUM (CM/S)=
PRINCIPAL CURRENT DIRECTION (DEG. T.)=

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	2.5	8.2	
2	12	3.7	12.0	
3	12	4.1	13.3	
4	12	4.0	13.1	
5	12	4.1	13.5	
6	12	2.9	9.5	
7	6	4.3	14.2	
ALL	78	3.6	11.8	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS44 38- 7-13N 122- 3- 4W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION GS44 38- 7-13N 122- 3- 4W
METER .9 METERS BELOW MLLW. WATER DEPTH 2.1 METERS

STATION NUMBER= OSI1
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1791
TIME MERIDIAN= 120 W
STATION POSITION= 38- 5-27N 122- 0-27W
METER DEPTH= 4.2M BELOW MLLW WATER DEPTH= 9.2M
RECORD LENGTH IS 58 M2 CYCLES: 1441 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	11.82219	87.24	97.71
K1	1.00274	16.05396	99.89	101.57
N2	1.89598	8.02044	15.96	32.46
M2	1.93227	50.70986	31.95	44.09
S2	2.00000	14.75830	20.49	24.51
M4	3.86455	2.69369	52.91	77.19

RESULTS FOR V (+NORTH) SERIES

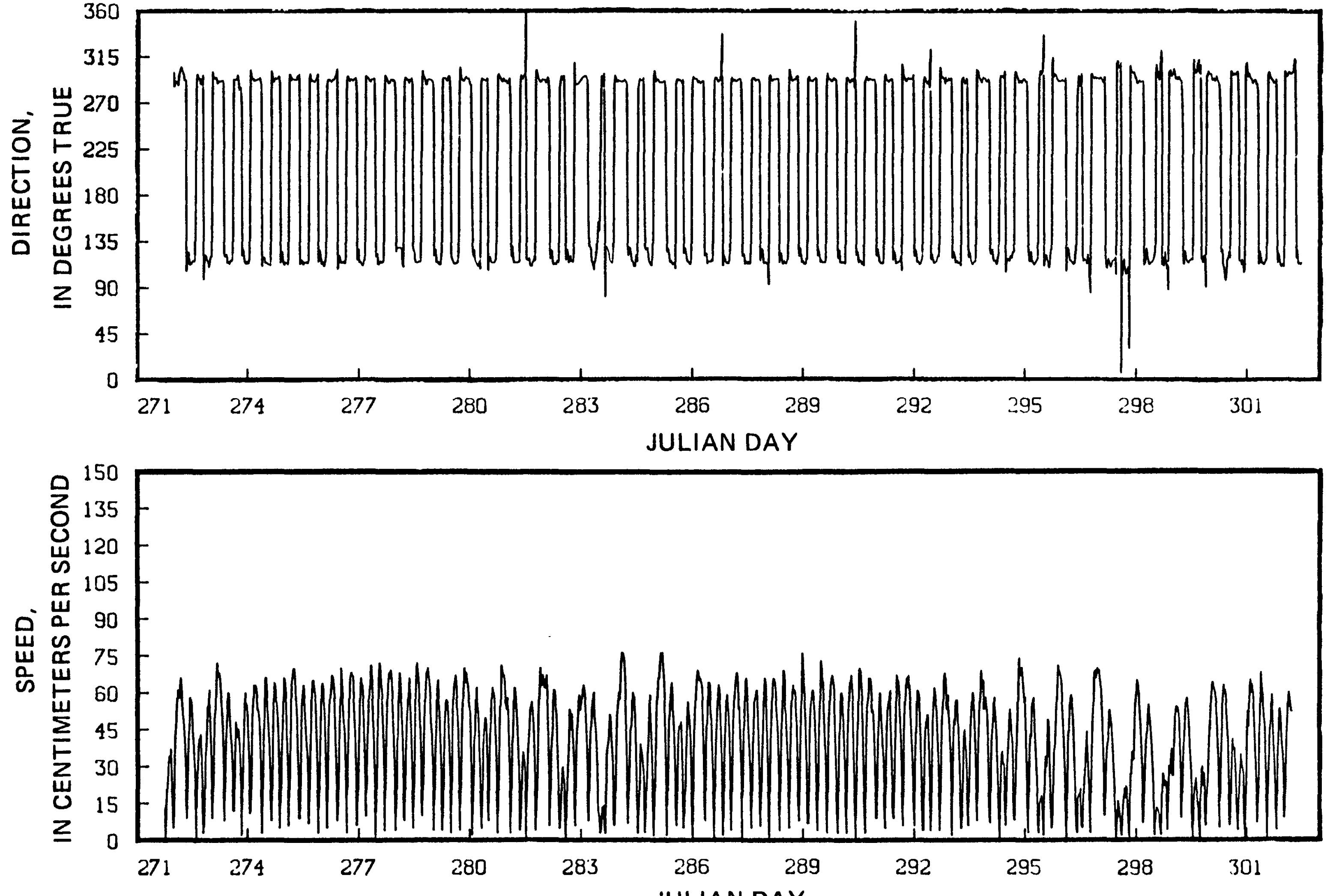
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	5.16690	262.57	273.03
K1	1.00274	6.81637	276.20	277.88
N2	1.89598	3.44202	194.24	210.73
M2	1.93227	22.77608	209.20	221.34
S2	2.00000	6.47002	199.72	203.73
M4	3.86455	2.29057	204.49	228.77

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	12.90	0.39	113.6	97.0	113.2	COUNTER-CLOCKWISE
K1	17.44	0.40	113.0	101.0	182.4	COUNTER-CLOCKWISE
N2	8.73	0.10	113.2	32.2	69.8	COUNTER-CLOCKWISE
M2	55.58	1.00	114.2	43.6	294.2	COUNTER-CLOCKWISE
S2	16.11	0.08	113.7	24.4	177.3	COUNTER-CLOCKWISE
M4	3.43	0.86	129.8	65.5	228.4	COUNTER-CLOCKWISE

ROOT-MEAN-SQUARES SPEED, (CM/S)= 44.82
STANDARD DEVIATION, U SERIES (CM/S)= 9.40
STANDARD DEVIATION, V SERIES (CM/S)= 4.97
TIDAL-FORM NUMBER= 0.42
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 102.03
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 34.93
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 113.81

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

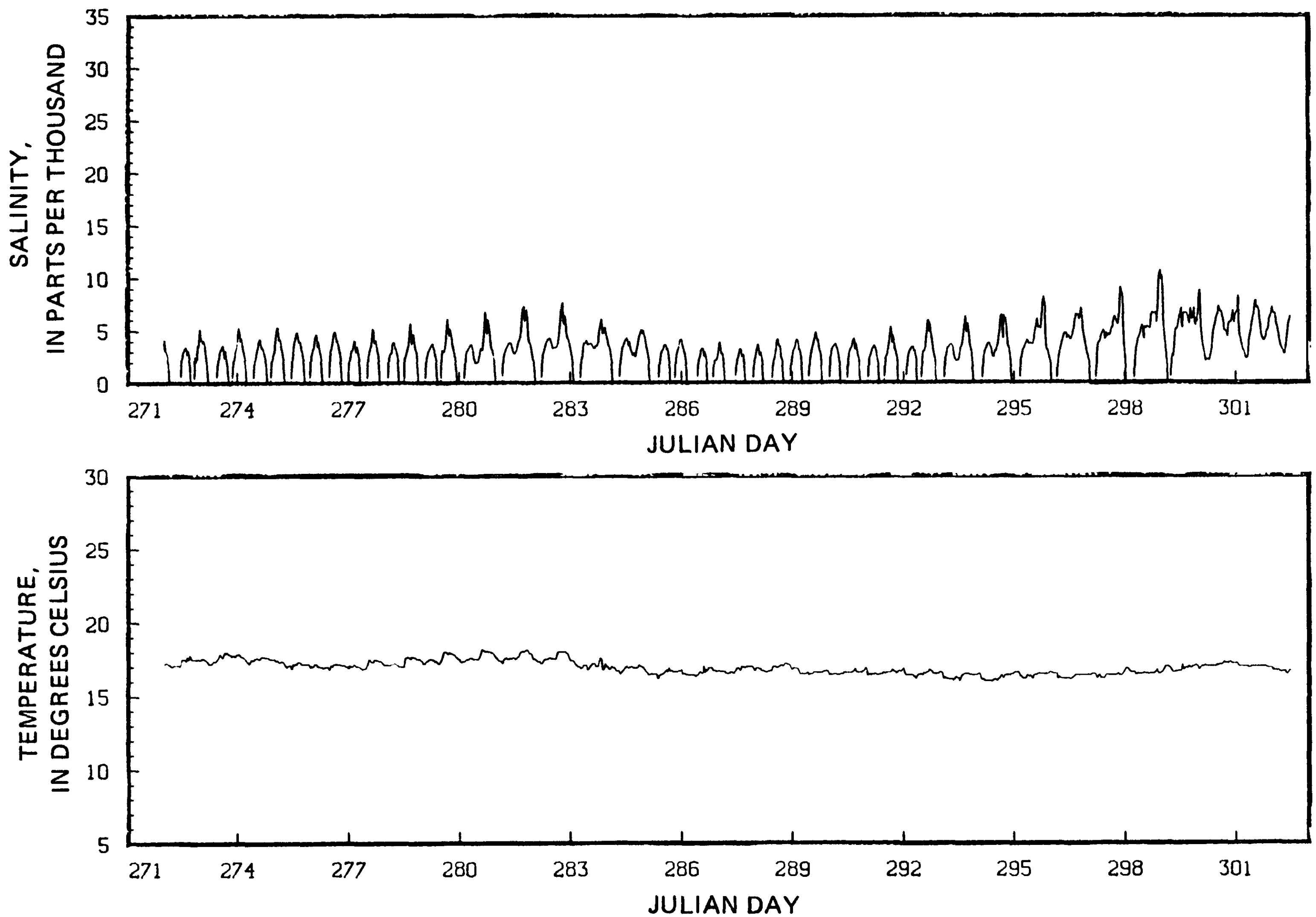
INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-5.4	1.3	442
2	12	-2.9	-0.8	404
3	12	-4.7	0.1	386
4	12	-2.4	-0.6	283
5	10	-4.5	2.0	232
ALL	58	-4.0	0.3	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION OSI1 38- 5-27N 122- 0-27W

METER 4.2 METERS BELOW MLLW. WATER DEPTH 9.2 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION OSI1 38- 5-27N 122- 0-27W

METER 4.2 METERS BELOW MLLW. WATER DEPTH 9.2 METERS

STATION NUMBER= OSI1
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1675
TIME MERIDIAN= 120 W
STATION POSITION= 38- 5-27N 122- 0-27W
METER DEPTH= 7.2M BELOW MLLW WATER DEPTH= 9.2M
RECORD LENGTH IS 58 M2 CYCLES: 1441 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	10.90765	96.05	106.51
K1	1.00274	14.26447	105.94	107.62
N2	1.89598	9.57340	12.32	28.82
M2	1.93227	45.76051	32.12	44.26
S2	2.00000	13.34130	23.29	27.31
M4	3.86455	2.75521	351.34	15.62

RESULTS FOR V (+NORTH) SERIES

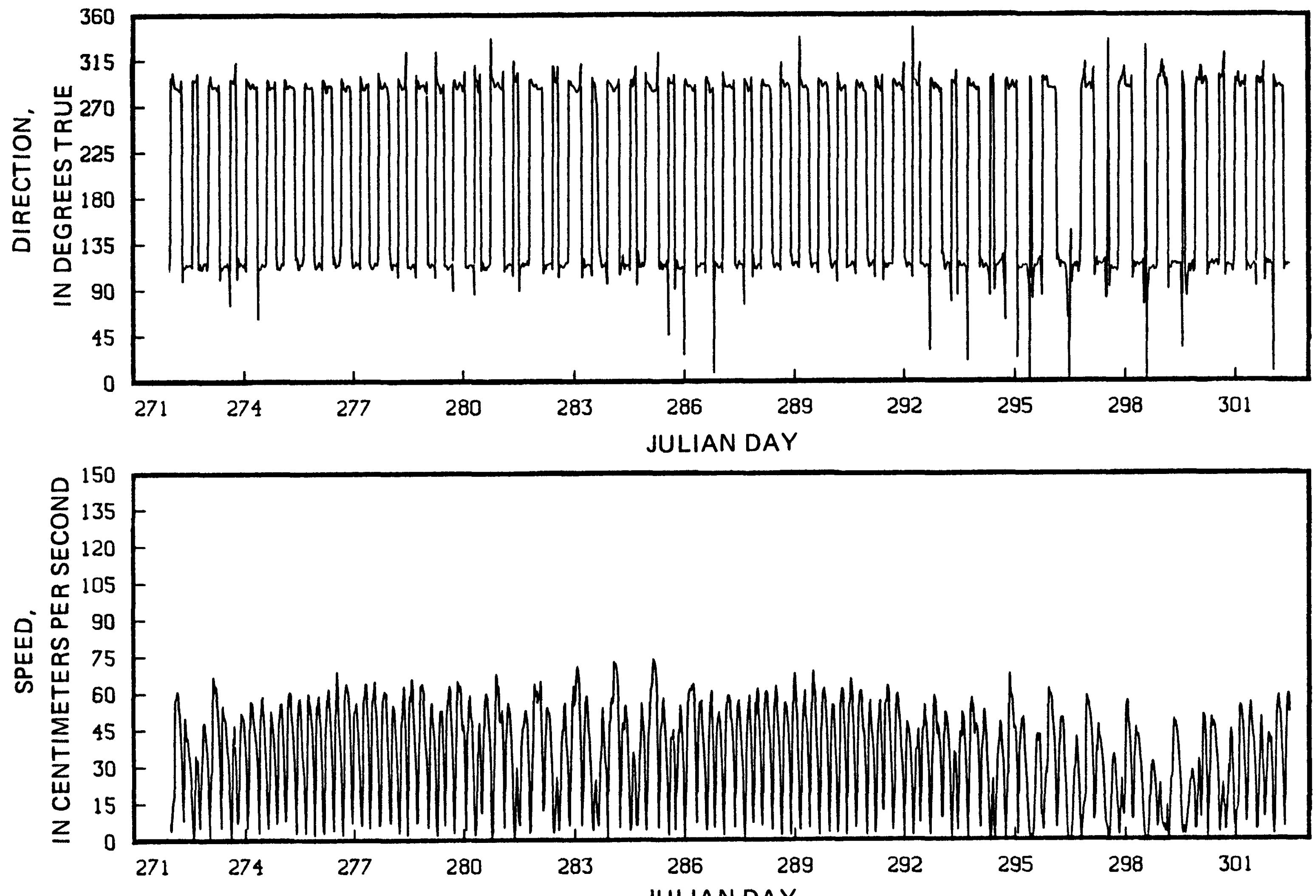
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	3.96960	271.31	281.77
K1	1.00274	5.48749	281.85	283.53
N2	1.89598	3.39291	188.85	205.35
M2	1.93227	18.51794	209.81	221.95
S2	2.00000	5.39555	202.28	206.29
M4	3.86455	1.05271	208.27	232.56

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	11.60	0.31	109.9	106.0	97.0	COUNTER-CLOCKWISE
K1	15.28	0.37	111.0	107.1	164.9	COUNTER-CLOCKWISE
N2	10.16	0.19	109.5	28.4	36.8	COUNTER-CLOCKWISE
M2	49.36	0.69	112.0	43.9	260.6	COUNTER-CLOCKWISE
S2	14.39	0.09	112.0	27.2	142.5	COUNTER-CLOCKWISE
M4	2.89	0.60	107.8	19.5	161.2	CLOCKWISE

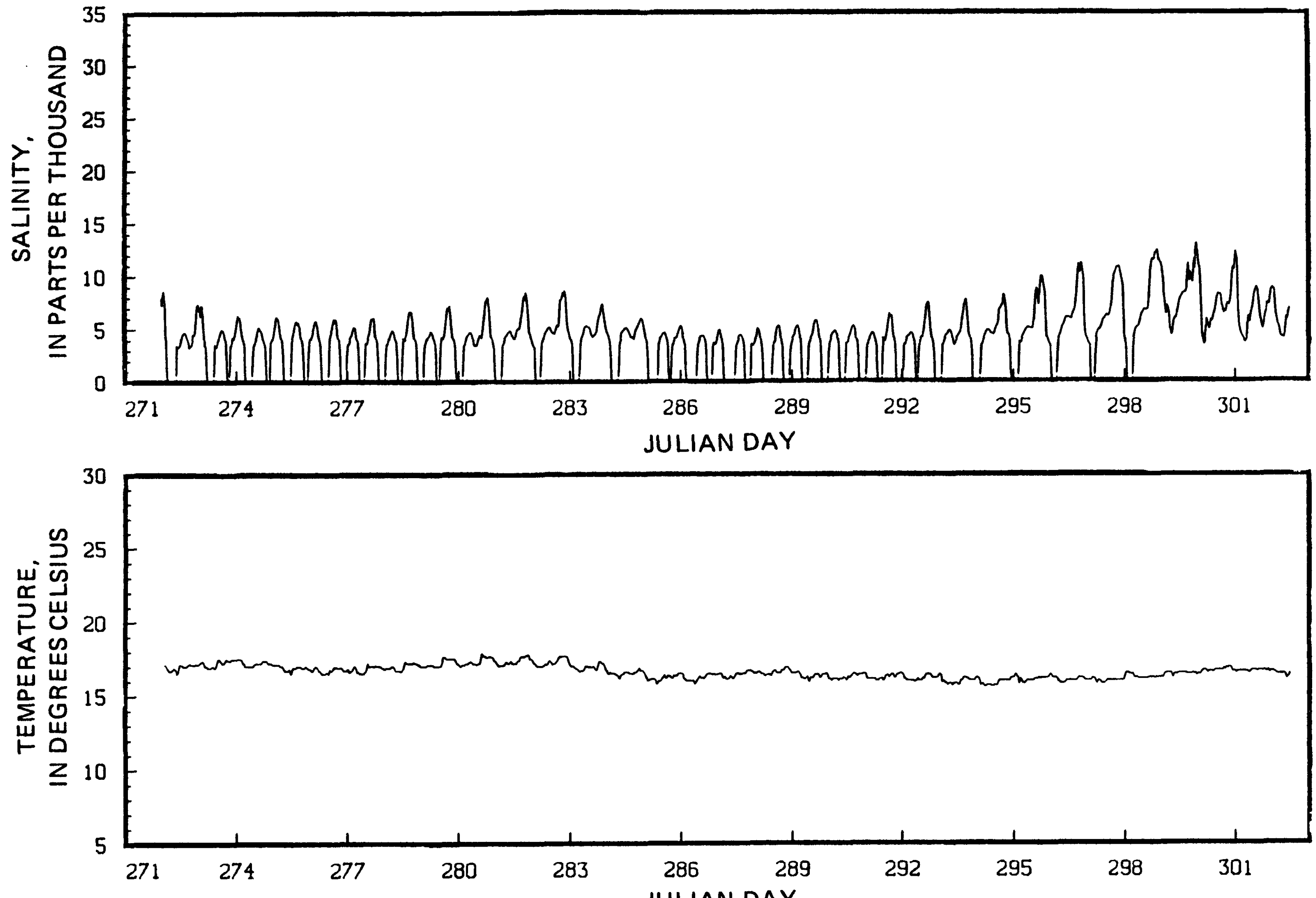
ROOT-MEAN-SQUARES SPEED, (CM/S)= 39.95
STANDARD DEVIATION, U SERIES (CM/S)= 9.30
STANDARD DEVIATION, V SERIES (CM/S)= 4.02
TIDAL-FORM NUMBER= 0.42
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 90.63
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 31.29
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 111.58

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-1.6	-0.7	442
2	12	0.1	-1.3	404
3	12	-2.3	-0.7	386
4	12	1.2	-1.6	283
5	10	5.4	-2.1	232
ALL	58	0.4	-1.3	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI1 38- 5-27N 122- 0-27W
METER 7.2 METERS BELOW MLLW. WATER DEPTH 9.2 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI1 38- 5-27N 122- 0-27W
METER 7.2 METERS BELOW MLLW. WATER DEPTH 9.2 METERS

STATION NUMBER= OSI2
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1658
TIME MERIDIAN= 120 W
STATION POSITION= 38- 3-54N 122- 2-33W
METER DEPTH= 1.5M BELOW MLLW WATER DEPTH= 8.2M
RECORD LENGTH IS 58 M2 CYCLES: 1441 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	11.10098	48.95	59.42
K1	1.00274	15.55999	83.85	85.53
N2	1.89598	9.96612	340.69	357.18
M2	1.93227	61.90365	11.32	23.46
S2	2.00000	19.62485	352.00	356.01
M4	3.86455	5.31312	17.07	41.35

RESULTS FOR V (+NORTH) SERIES

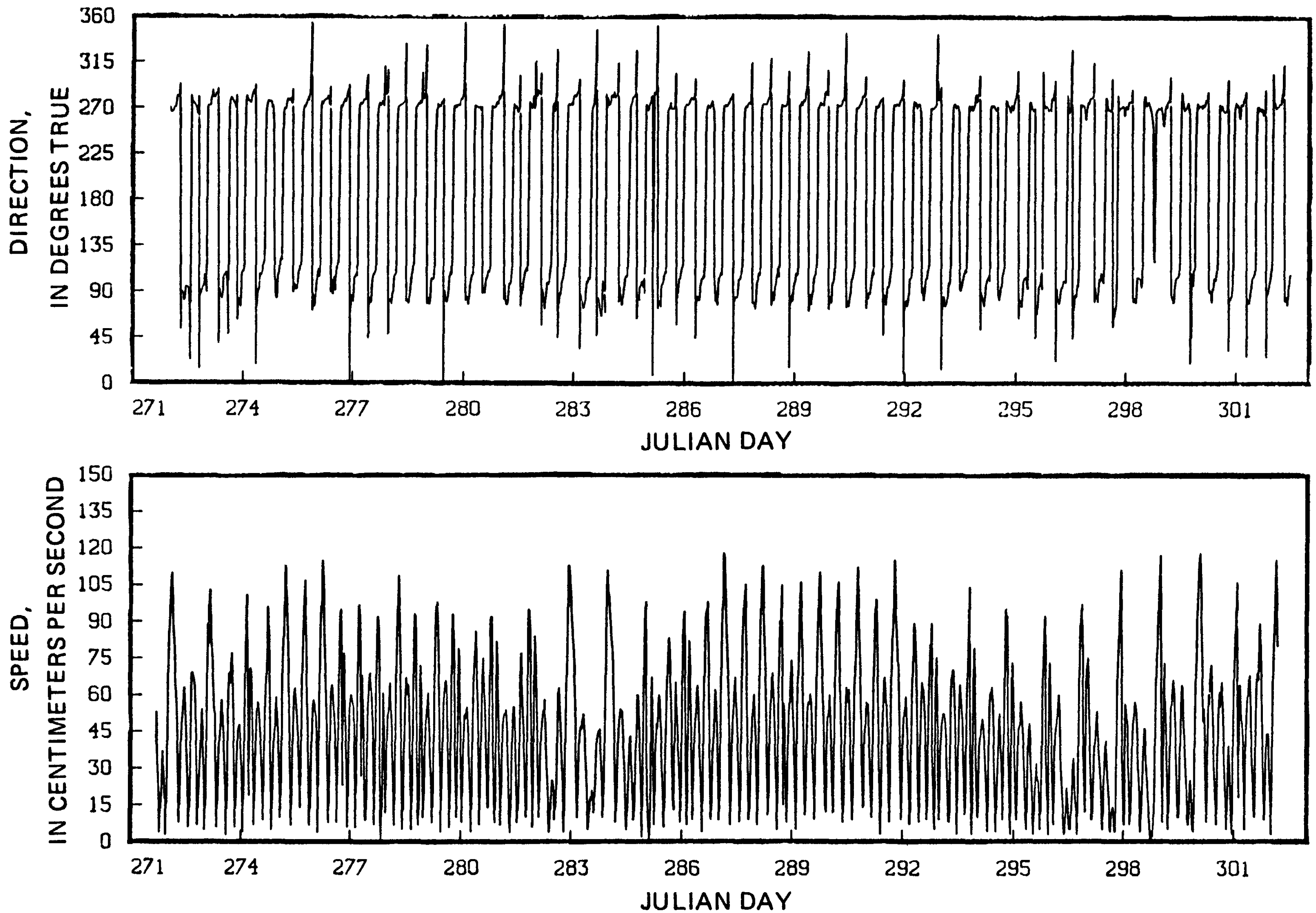
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.13420	314.10	324.56
K1	1.00274	2.81074	309.25	310.93
N2	1.89598	1.80030	220.74	237.24
M2	1.93227	6.39518	245.40	257.55
S2	2.00000	2.12074	210.21	214.23
M4	3.86455	1.19701	304.58	328.86

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	11.10	1.13	90.5	59.5	94.7	CLOCKWISE
K1	15.69	1.98	97.3	86.5	162.4	CLOCKWISE
N2	10.01	1.55	95.3	358.0	32.0	CLOCKWISE
M2	62.02	5.17	93.5	23.8	255.6	CLOCKWISE
S2	19.70	1.31	94.9	356.3	137.4	CLOCKWISE
M4	5.33	1.14	85.9	40.5	151.3	CLOCKWISE

ROOT-MEAN-SQUARES SPEED, (CM/S)= 53.38
STANDARD DEVIATION, U SERIES (CM/S)= 20.50
STANDARD DEVIATION, V SERIES (CM/S)= 5.42
TIDAL-FORM NUMBER= 0.33
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 108.50
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 37.74
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 93.99

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

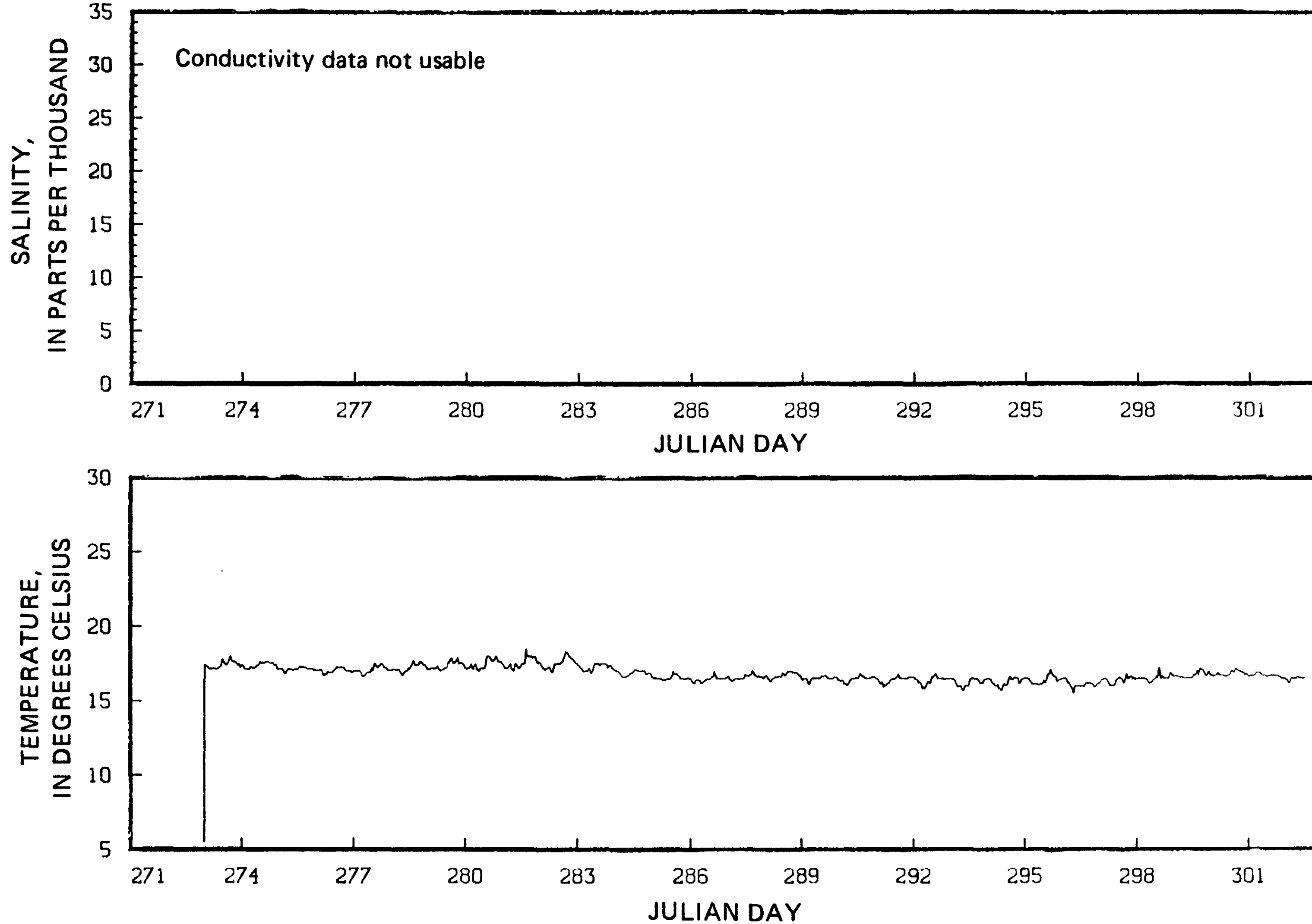
INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-14.5	1.2	442
2	12	-8.0	2.3	404
3	12	-11.8	2.0	386
4	12	-9.0	1.5	283
5	10	-16.0	0.3	232
ALL	58	-11.7	1.5	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION OSI2 38- 3-54N 122- 2-33W

METER 1.5 METERS BELOW MLLW. WATER DEPTH 8.2 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION OSI2 38- 3-54N 122- 2-33W

METER 1.5 METERS BELOW MLLW. WATER DEPTH 8.2 METERS

STATION NUMBER= OSI2
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1633
TIME MERIDIAN= 120 W
STATION POSITION= 38- 3-54N 122- 2-33W
METER DEPTH= 3.2M BELOW MLLW WATER DEPTH= 8.2M
RECORD LENGTH IS 58 M2 CYCLES: 1441 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	10.45395	76.39	86.85
K1	1.00274	14.51028	91.76	93.44
N2	1.89598	8.04570	358.45	14.94
M2	1.93227	50.64403	11.50	23.64
S2	2.00000	15.49122	355.35	359.37
M4	3.86455	3.28274	326.04	350.32

RESULTS FOR V (+NORTH) SERIES

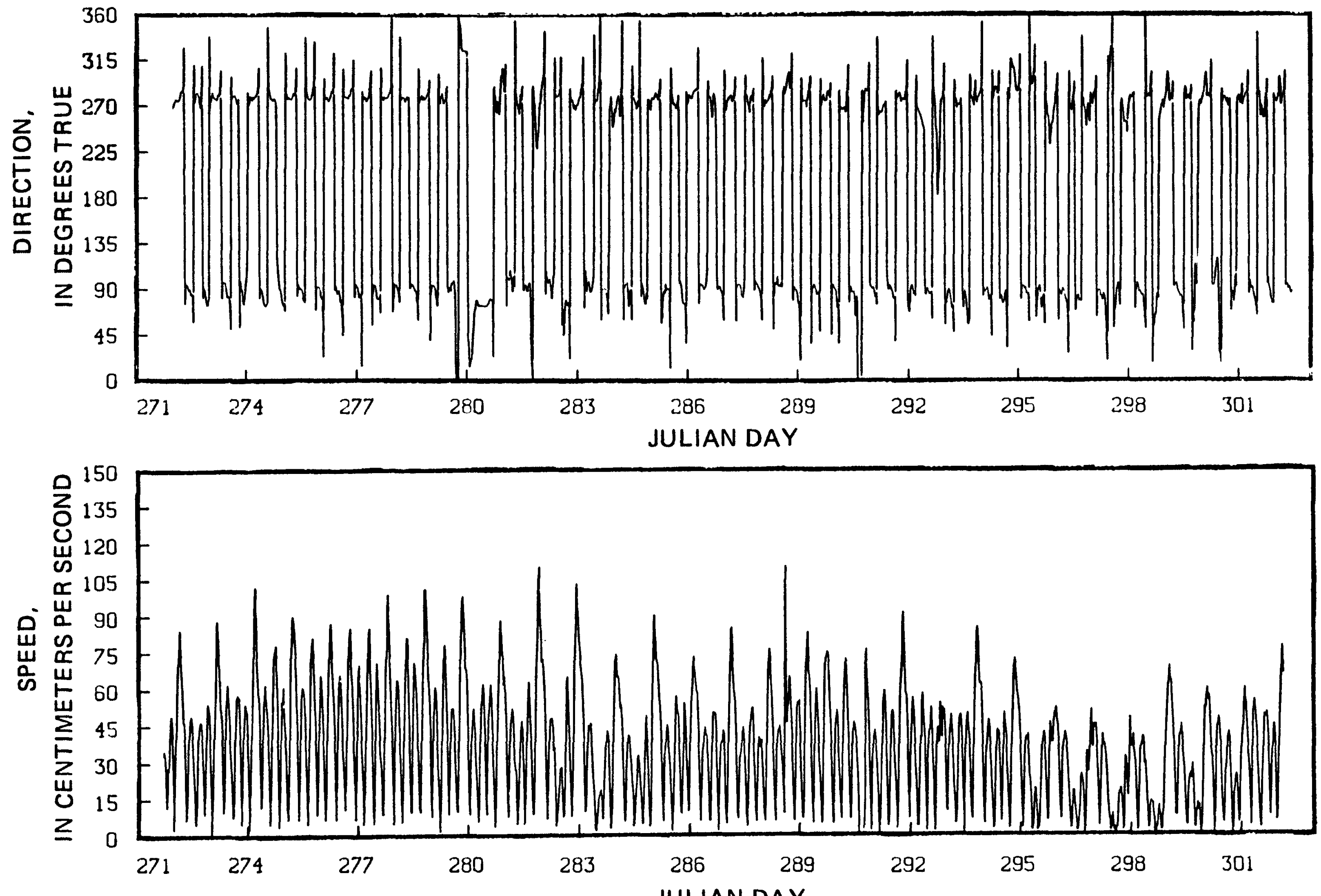
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	1.23163	299.75	310.22
K1	1.00274	1.52009	249.23	250.91
N2	1.89598	1.70714	222.52	239.01
M2	1.93227	2.62394	208.68	220.83
S2	2.00000	1.47822	133.89	137.91
M4	3.86455	1.31795	123.76	148.05

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	10.49	0.84	94.9	87.2	91.2	CLOCKWISE
K1	14.58	0.58	95.5	93.2	158.6	COUNTER-CLOCKWISE
N2	8.14	1.17	98.9	16.2	24.9	CLOCKWISE
M2	50.71	0.77	92.8	23.7	248.4	CLOCKWISE
S2	15.53	0.98	94.1	359.1	129.9	COUNTER-CLOCKWISE
M4	3.51	0.47	110.8	347.4	136.8	COUNTER-CLOCKWISE

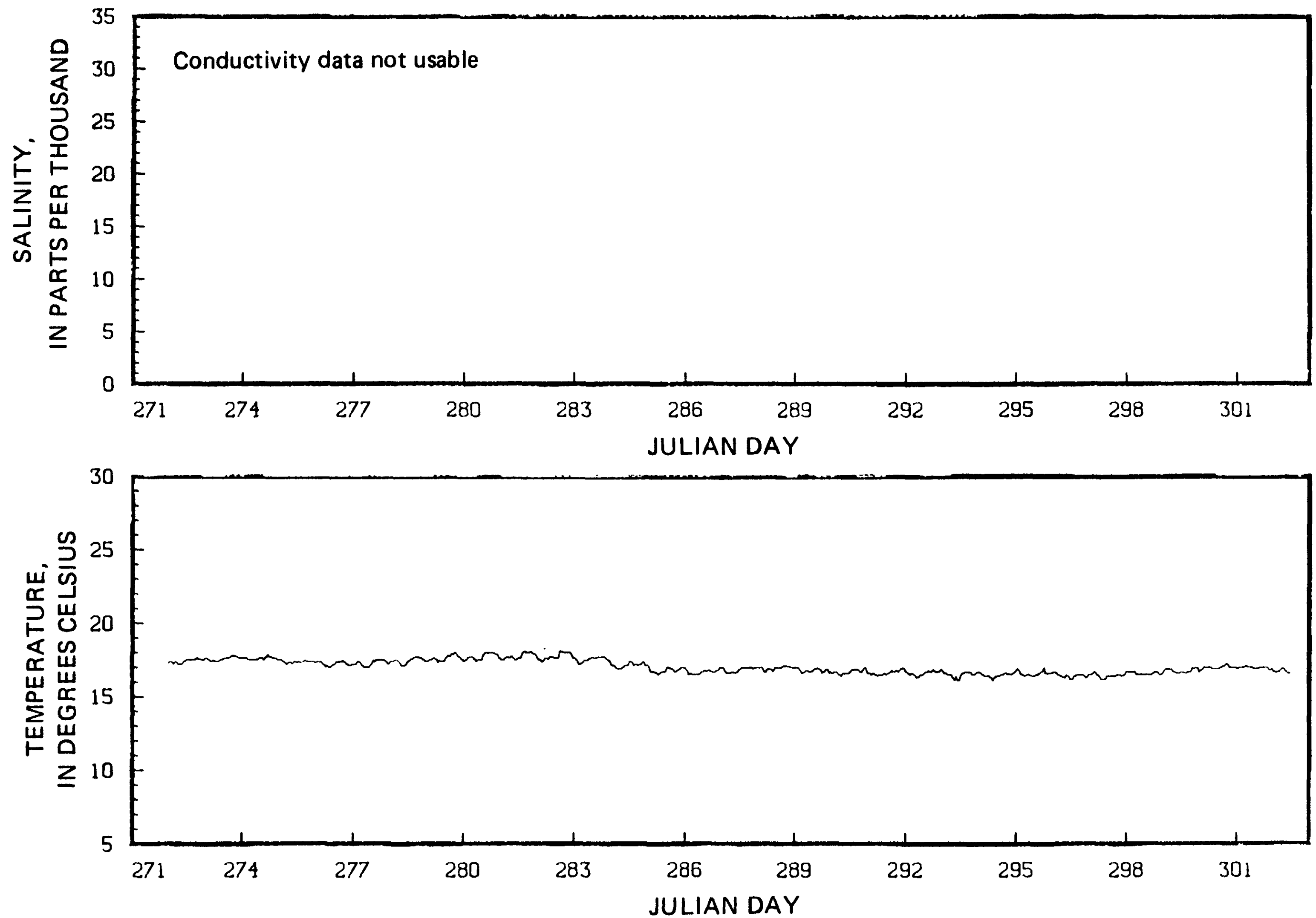
ROOT-MEAN-SQUARES SPEED, (CM/S)= 43.35
STANDARD DEVIATION, U SERIES (CM/S)= 13.13
STANDARD DEVIATION, V SERIES (CM/S)= 9.94
TIDAL-FORM NUMBER= 0.38
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 91.31
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 31.09
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 93.72

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-10.2	5.3	442
2	12	-4.8	6.3	404
3	12	-9.9	3.7	386
4	12	-4.6	2.9	283
5	10	-6.3	2.3	232
ALL	58	-7.2	4.2	



CURRENT-METER OBSERVATIONS (3C-MINUTE AVERAGES)
USGS STATION OSI2 38- 3-54N 122- 2-33W
METER 3.2 METERS BELOW MLLW. WATER DEPTH 8.2 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI2 38- 3-54N 122- 2-33W
METER 3.2 METERS BELOW MLLW. WATER DEPTH 8.2 METERS

STATION NUMBER= OSI3
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1646
TIME MERIDIAN= 120 W
STATION POSITION= 38- 4-28N 122- 1-30W
METER DEPTH= 1.5M BELOW MLLW WATER DEPTH= 9.8M
RECORD LENGTH IS 60 M2 CYCLES: 1491 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	13.25403	67.85	78.31
K1	1.00274	18.18530	80.38	82.06
N2	1.89598	8.06622	347.93	4.43
M2	1.93227	61.21024	3.98	16.12
S2	2.00000	16.96541	354.26	358.27
M4	3.86455	1.55797	318.44	342.73

RESULTS FOR V (+NORTH) SERIES

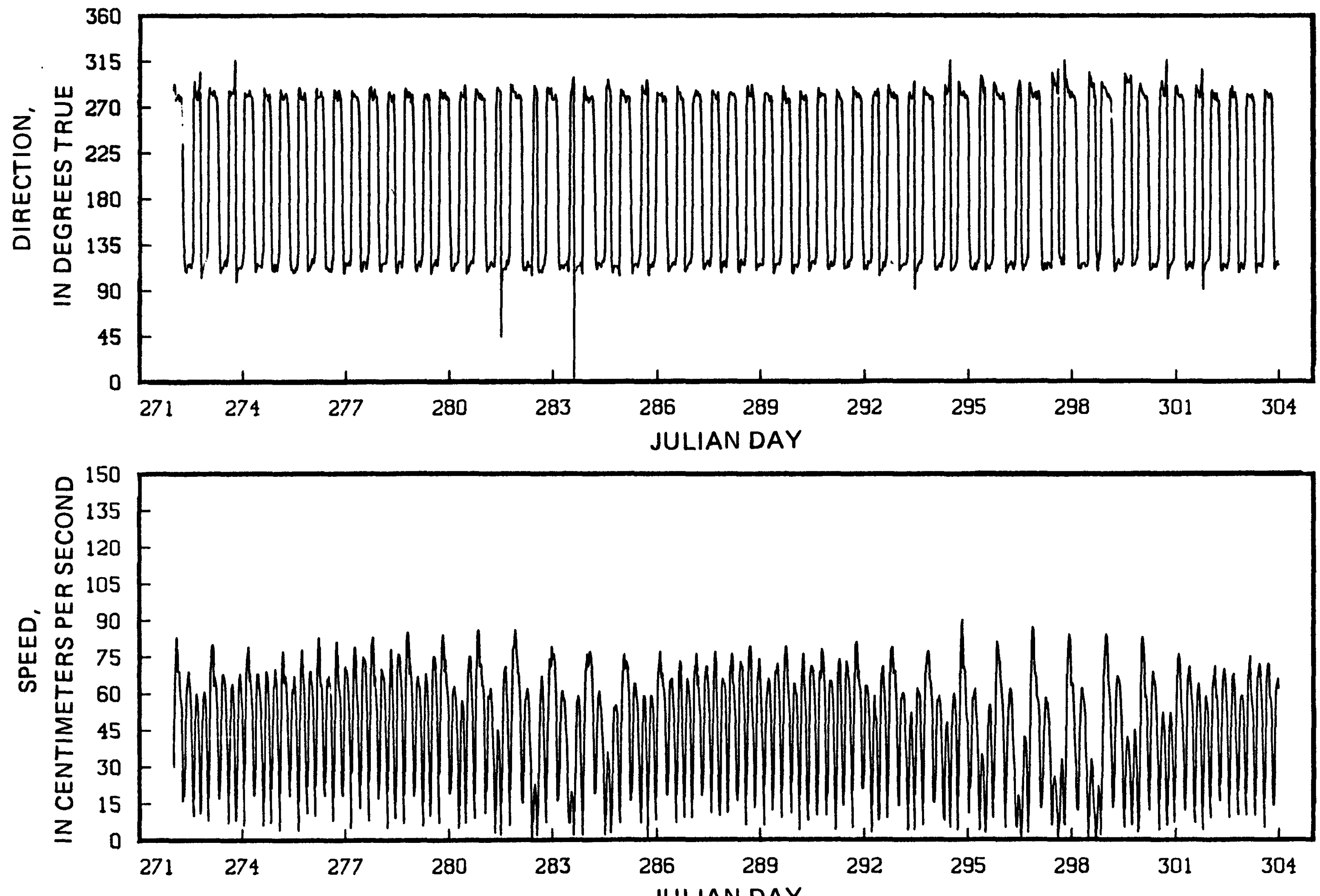
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	2.95661	223.93	234.39
K1	1.00274	5.08685	242.88	244.56
N2	1.89598	2.42420	161.37	177.86
M2	1.93227	19.25632	181.73	193.88
S2	2.00000	5.21067	169.50	173.51
M4	3.86455	1.34050	221.99	246.27

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	13.53	1.17	101.6	77.3	93.0	COUNTER-CLOCKWISE
K1	18.83	1.48	105.0	80.9	160.6	COUNTER-CLOCKWISE
N2	8.42	0.27	106.6	3.9	28.6	COUNTER-CLOCKWISE
M2	64.16	0.72	107.5	15.9	252.2	COUNTER-CLOCKWISE
S2	17.74	0.41	107.0	357.9	133.8	COUNTER-CLOCKWISE
M4	1.58	1.31	108.3	358.1	144.3	CLOCKWISE

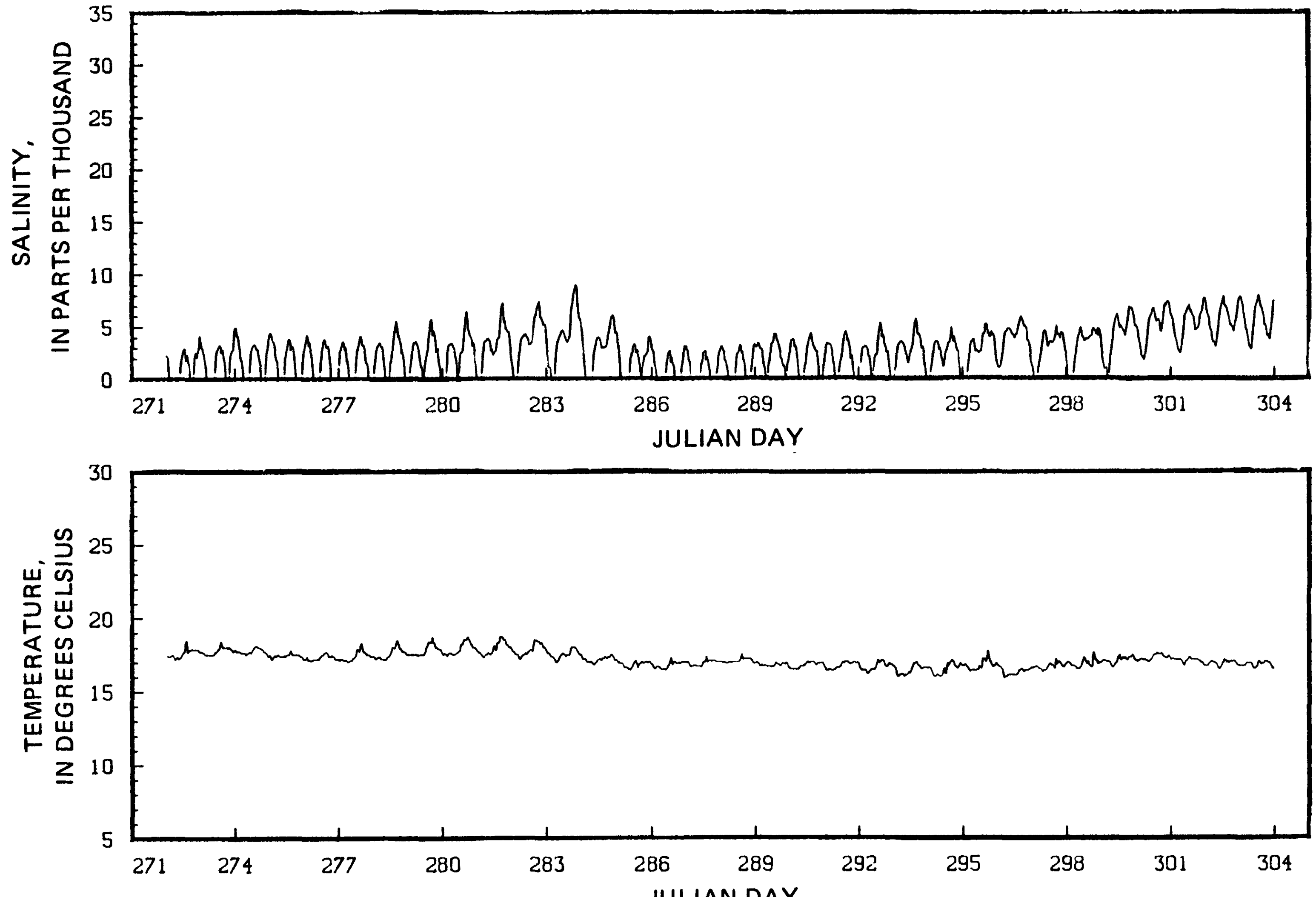
ROOT-MEAN-SQUARES SPEED, (CM/S)= 51.01
STANDARD DEVIATION, U SERIES (CM/S)= 10.90
STANDARD DEVIATION, V SERIES (CM/S)= 5.85
TIDAL-FORM NUMBER= 0.40
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 114.26
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 41.12
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 106.30

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	-5.3	-4.7	442
2	12	-2.4	-5.4	404
3	12	-3.7	-5.6	386
4	12	-2.3	-4.9	283
5	12	-5.7	-2.8	239
ALL	60	-3.9	-4.7	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI3 38- 4-28N 122- 1-30W
METER 1.5 METERS BELOW MLLW. WATER DEPTH 9.8 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI3 38- 4-28N 122- 1-30W
METER 1.5 METERS BELOW MLLW. WATER DEPTH 9.8 METERS

STATION NUMBER= OSI3
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1523
TIME MERIDIAN= 120 W
STATION POSITION= 38- 4-28N 122- 1-30W
METER DEPTH= 4.8M BELOW MLLW WATER DEPTH= 9.8M
RECORD LENGTH IS 60 M2 CYCLES: 1491 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	11.38229	71.44	81.90
K1	1.00274	15.91321	87.82	89.50
N2	1.89598	6.69513	355.68	12.17
M2	1.93227	54.73605	10.75	22.89
S2	2.00000	14.83246	2.06	6.08
M4	3.86455	2.20029	333.37	357.66

RESULTS FOR V (+NORTH) SERIES

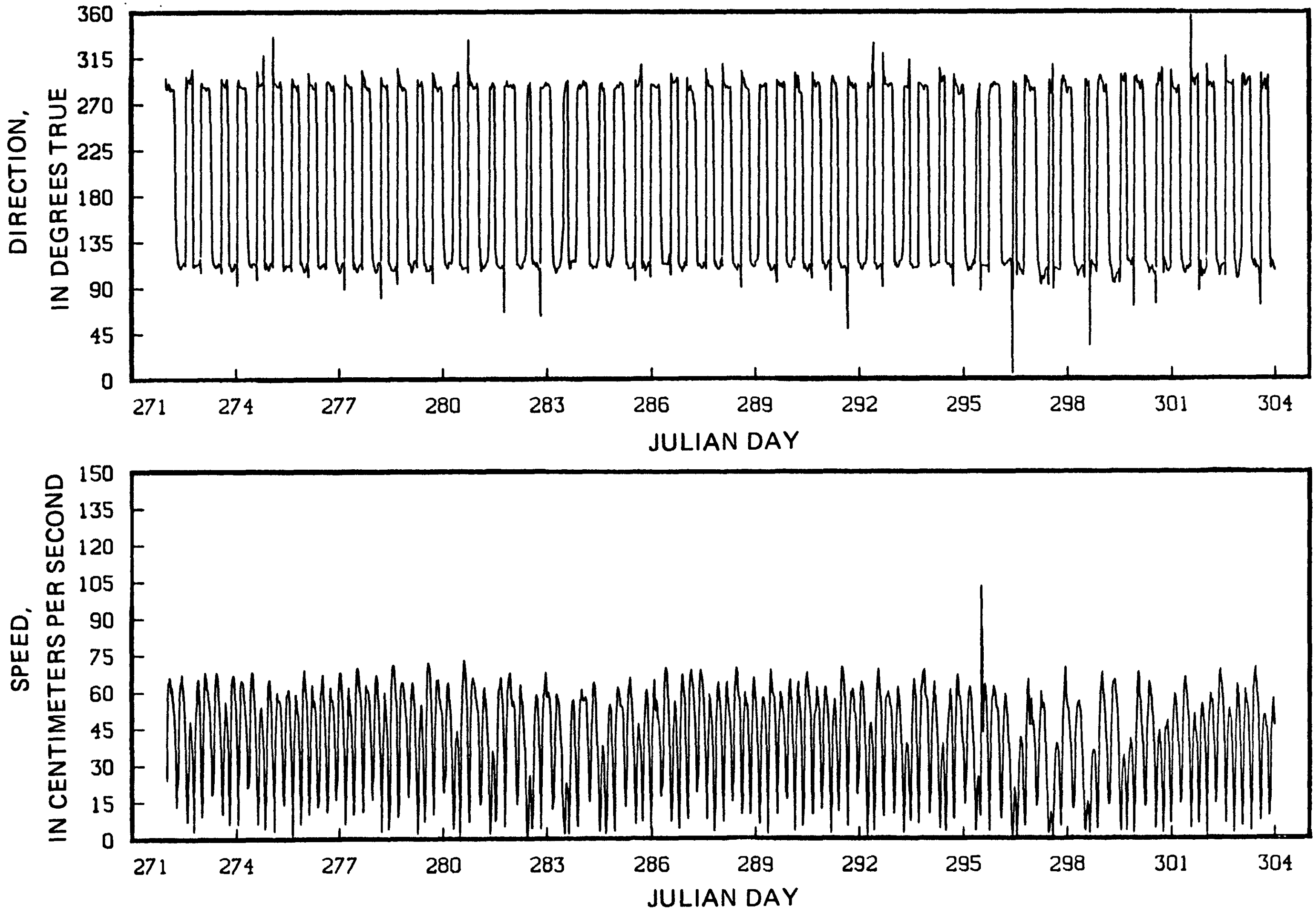
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	3.36605	243.79	254.26
K1	1.00274	4.84037	253.55	255.22
N2	1.89598	2.64365	173.15	189.64
M2	1.93227	18.44467	185.79	197.93
S2	2.00000	5.23013	176.97	180.99
M4	3.86455	0.76772	75.69	99.97

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	11.86	0.43	106.4	81.3	75.8	COUNTER-CLOCKWISE
K1	16.59	1.14	106.5	88.3	142.1	COUNTER-CLOCKWISE
N2	7.20	0.11	111.5	11.8	353.6	COUNTER-CLOCKWISE
M2	57.74	1.51	108.6	22.4	216.5	COUNTER-CLOCKWISE
S2	15.72	0.44	109.4	5.5	96.9	COUNTER-CLOCKWISE
M4	2.21	0.75	94.8	356.0	73.0	COUNTER-CLOCKWISE

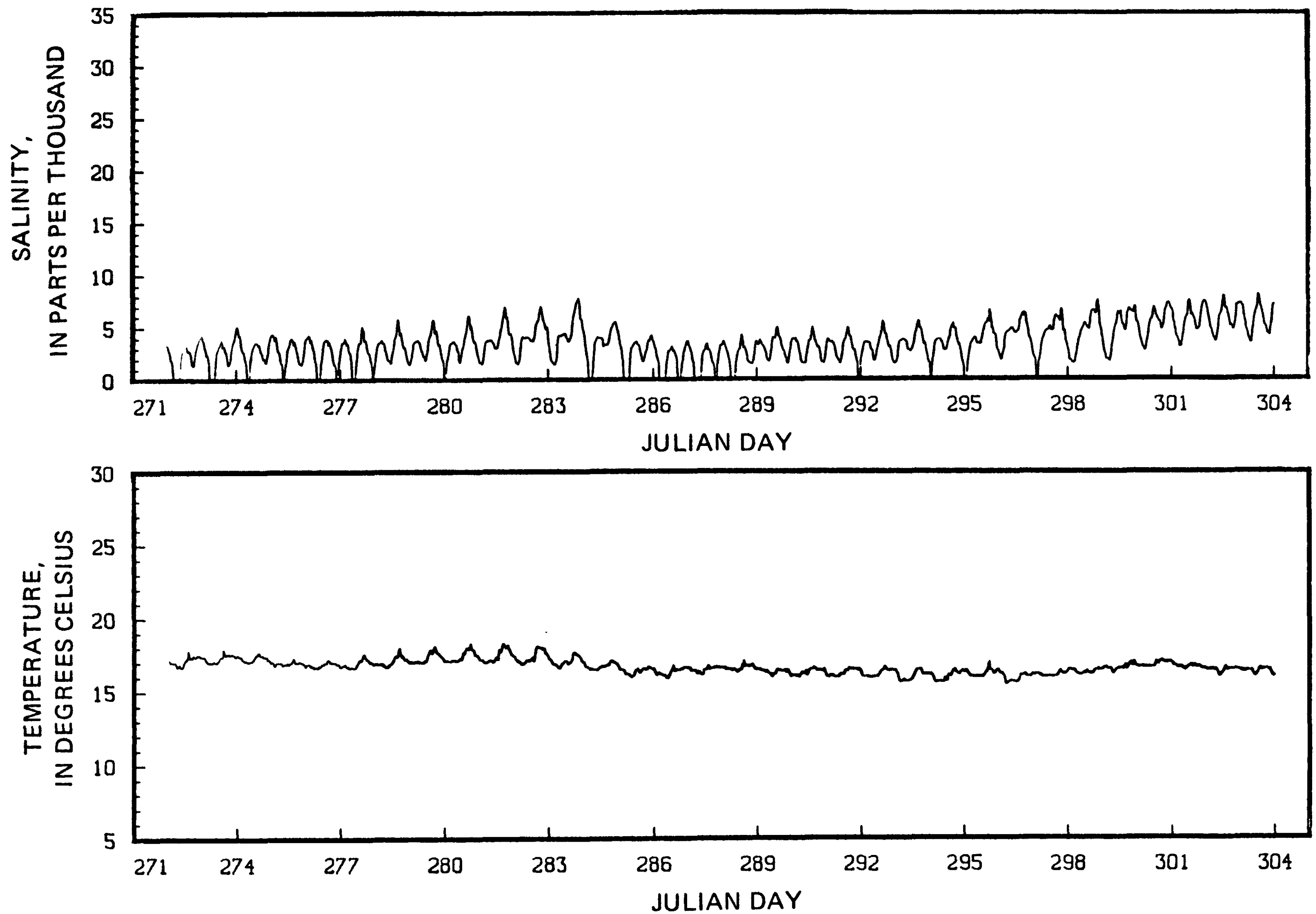
ROOT-MEAN-SQUARES SPEED, (CM/S)= 45.51
STANDARD DEVIATION, U SERIES (CM/S)= 9.84
STANDARD DEVIATION, V SERIES (CM/S)= 5.20
TIDAL-FORM NUMBER= 0.39
SPRING TIDAL CURRENT MAXIMUM (CM/S)= 101.92
NEAP TIDAL CURRENT MAXIMUM (CM/S)= 37.29
PRINCIPAL CURRENT DIRECTION (DEG. T.)= 108.10

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	1.3	-2.4	442
2	12	3.0	-3.0	404
3	12	2.2	-2.9	386
4	12	3.6	-3.0	283
5	12	2.5	-0.6	239
ALL	60	2.5	-2.4	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI3 38- 4-28N 122- 1-30W
METER 4.8 METERS BELOW MLLW. WATER DEPTH 9.8 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)

USGS STATION OSI3 38- 4-~~28N~~ 122- 1-30W

METER 4.8 METERS BELOW MLLW. WATER DEPTH 9.8 METERS

STATION NUMBER= OSI3
START TIME OF THE SERIES (PST): YEAR=1986 MONTH= 9 DAY=28 HOUR=1513
TIME MERIDIAN= 120 W
STATION POSITION= 38- 4-28N 122- 1-30W
METER DEPTH= 7.8M BELOW MLLW WATER DEPTH= 9.8M
RECORD LENGTH IS 60 M2 CYCLES: 1491 DATA POINTS

RESULTS FOR U (+EAST) SERIES

NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	10.42624	72.70	83.16
K1	1.00274	15.48758	92.78	94.46
N2	1.89598	6.92160	8.09	24.59
M2	1.93227	50.76469	17.75	29.90
S2	2.00000	13.67556	14.32	18.33
M4	3.86455	1.43684	305.23	329.52

RESULTS FOR V (+NORTH) SERIES

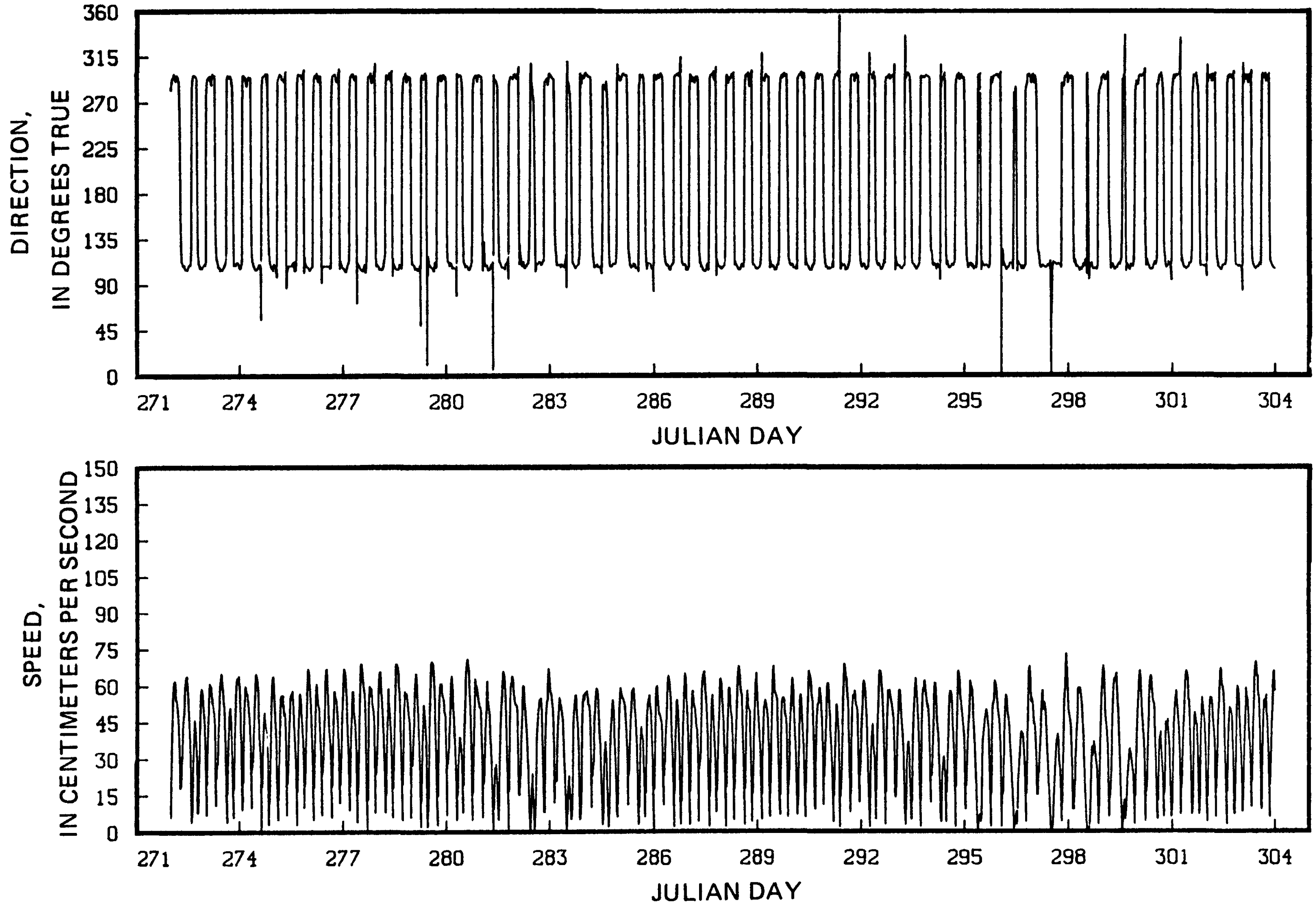
NAME	CYCLES PER DAY	MEAN AMPLITUDE	LOCAL EPOCH	MODIFIED EPOCH
O1	0.92954	4.35170	254.71	265.17
K1	1.00274	5.81120	273.43	275.11
N2	1.89598	2.55169	185.20	201.70
M2	1.93227	19.16268	195.90	208.04
S2	2.00000	5.14112	195.08	199.09
M4	3.86455	1.98456	65.51	89.80

NAME	MAJOR CM/S	MINOR CM/S	DIR. DEG.T.	PHASE DEG.	E DEG.	ROTATION
O1	11.30	0.14	112.6	83.5	74.4	CLOCKWISE
K1	16.54	0.06	110.6	94.5	140.6	CLOCKWISE
N2	7.38	0.12	110.2	24.2	350.7	COUNTER-CLOCKWISE
M2	54.26	0.58	110.7	29.7	213.6	COUNTER-CLOCKWISE
S2	14.61	0.06	110.6	18.4	93.9	CLOCKWISE
M4	2.17	1.13	151.5	285.6	67.2	COUNTER-CLOCKWISE

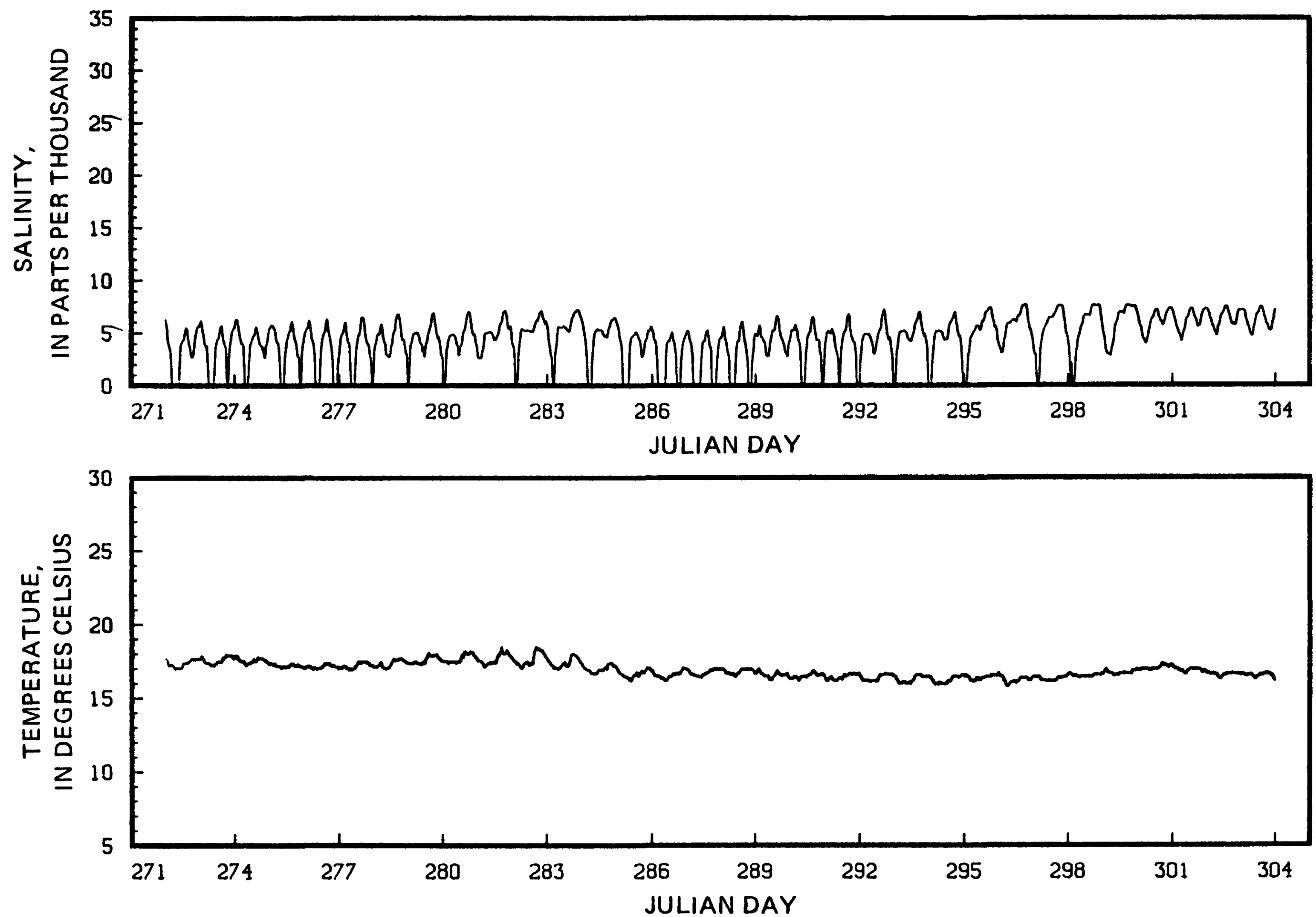
ROOT-MEAN-SQUARES SPEED, (CM/S)=	43.18
STANDARD DEVIATION, U SERIES (CM/S)=	9.05
STANDARD DEVIATION, V SERIES (CM/S)=	4.39
TIDAL-FORM NUMBER=	0.40
SPRING TIDAL CURRENT MAXIMUM (CM/S)=	96.71
NEAP TIDAL CURRENT MAXIMUM (CM/S)=	34.40
PRINCIPAL CURRENT DIRECTION (DEG. T.)=	110.87

TIME-AVERAGED VELOCITY AND MEAN DELTA OUTFLOW

INTERVAL	NO OF M2 CYCLES	EAST-WEST (CM/S)	NORTH-SOUTH (CM/S)	OUTFLOW CHIPPS IS. (CMS)
1	12	5.2	0.3	442
2	12	6.5	-0.7	404
3	12	5.6	0.0	386
4	12	6.7	-0.4	283
5	12	6.1	-0.7	239
ALL	60	6.0	-0.3	



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI3 38- 4-28N 122- 1-30W
METER 7.8 METERS BELOW MLLW. WATER DEPTH 9.8 METERS



CURRENT-METER OBSERVATIONS (30-MINUTE AVERAGES)
USGS STATION OSI3 38- 4-28N 122- 1-30W
METER 7.8 METERS BELOW MLLW. WATER DEPTH 9.8 METERS