NOAA Technical Memorandum NOS OES 14

Special 1995 Tidal Current Predictions for Galveston Bay, Texas

Silver Spring, Maryland
January 1995

noaa National Oceanic and Atmospheric Administration

U. S. DEPARTMENT OF COMMERCE
National Ocean Service

Office of Ocean and Earth Sciences
National Ocean Service
National Oceanic and Atmospheric Administration
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ABSTRACT

Improved tidal current predictions in Galveston Bay, Texas, are essential to enhancing the safety level for deep draft vessels navigating the main ship channels. The National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) conducted a quality assurance study to assess the adequacy of current predictions at Houston Ship Channel and Galveston Bay Entrance during late-summer and autumn, 1988. Measurements at two critical locations were made using acoustic Doppler current profilers (ADCPs) to obtain high quality data for comparison with the NOAA Tables. Results indicated that NOAA's existing tidal current information was outside established NOS working standards (Wilmot and Williams, 1987) and prompted a notice to mariners regarding caution in use of the NOAA tables. New predictions derived from harmonic analysis of the ADCP data show improvement over 1935 predictions. Descriptive statistics of differences between observed and predicted currents identify measurable improvement from a mean of 0.26 knots and a standard deviation of 0.54 knots for the 1935-based predictions to an average of 0.00 knots and standard deviation of 0.40 knots for the 1988-based predictions. Predictions for Galveston Bay Entrance (the reference station) based on averaged 29-day harmonic analyses from August through October, 1988, will appear in NOAA's **Tidal Current Tables 1996-Atlantic Coast of North America** and ensuing years. NOS recognizes that longer data sets should be employed to improve the quality of the predictions and that real-time systems should be installed in coastal areas for reporting wind, water level, and currents.

1. INTRODUCTION

The U.S. Coast Survey, which has evolved into the National Ocean Service (NOS), a branch of the National Oceanic and Atmospheric Administration (NOAA), first began measuring and reporting current information for the nation's waterways during the 1890's. Today's tidal current tables include predictions for the times of slack water and the times and velocities of maximum flood and ebb currents for reference stations with differences and ratios for estimating the currents at other nearby locations. Predictions of tidal currents in estuarine and coastal areas are essential to provide a starting point for the mitigation of hazardous material spills and to help improve the safety of navigation in ports and harbors. This is particularly true along the Texas Gulf coast where increases in commercial operations have resulted in the need for improved tidal current predictions. To address this need, new harmonic constants were computed for Aransas Pass using data collected during 1990 (Nichols, 1994). Most NOS predictions along the Texas coast are based on data acquired during the 1930s using current pole measurements.

Located along the Gulf of Mexico in Galveston Bay, the port of Houston handles the second largest amount of foreign tonnage in the United States (U.S. Army Corps of Engineers, 1992). Galveston Bay is crossed by two dredged channels, the Houston Ship Channel (HSC) and the Gulf Intracoastal Waterway (GICW). The HSC is 52.7 nautical miles long from Houston to the Gulf of Mexico and for the greater part of its length is 400 feet wide; the inner 9 miles have a width of 300 feet and the outer 9 miles have a width of 800 feet (Figure 1). There are approximately 50 ship movements per day within the Houston/Galveston vessel traffic system area, in addition to the approximately 300 movements of tug/barge combinations that can exceed the length of most ships. A well noted trouble spot is the intersection of HSC and GICW where barge tows emerging from the shelter of the Bolivar peninsula into a strong current have difficulty making the turn into the HSC (Baker, 1992). Maneuverability in this area is further complicated by approximately 7,000 recreational boats, 75% of which are sailboats.

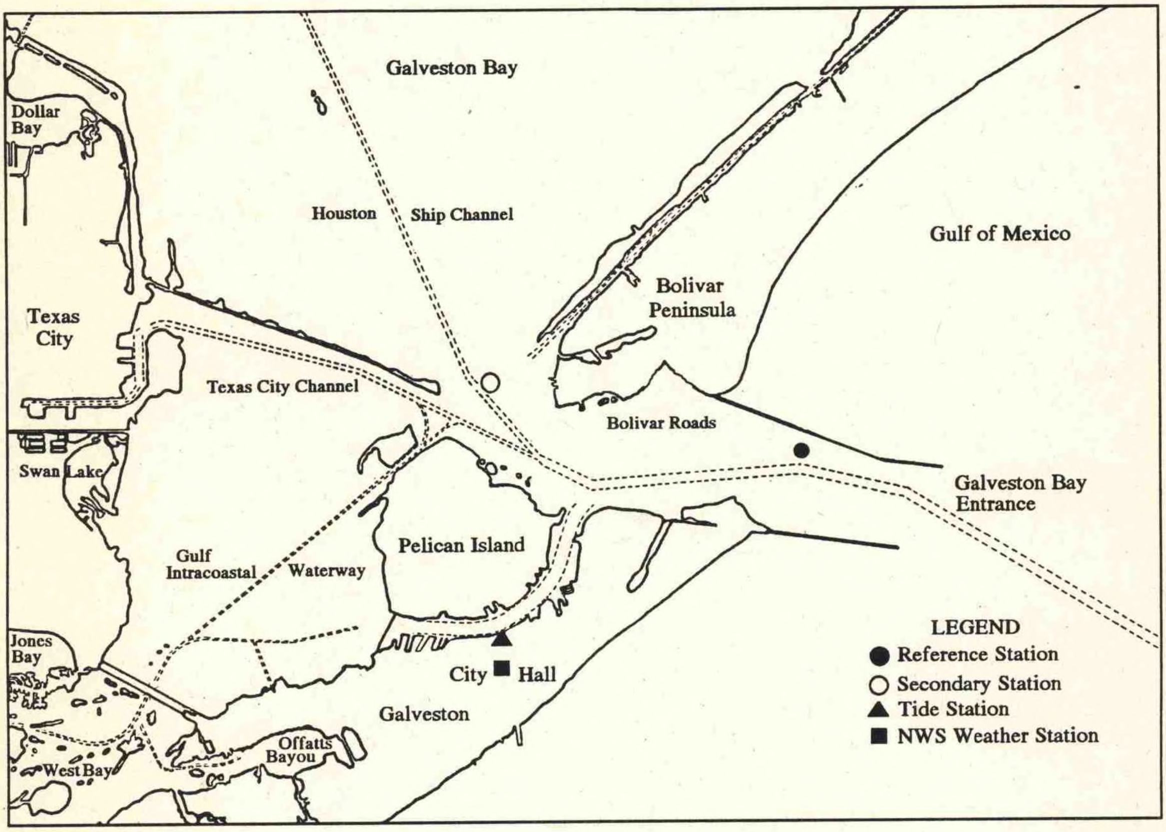


Figure 1. Galveston Bay project area. The key 1988 current meter locations are marked with a (●) for the reference station and (○) for the secondary station. Instrument siting details are given in Williams et al. (1990).

1.1. Prior Surveys

Hydrographic work in Galveston Bay was conducted by NOS during 1933, 1935 through 1937, 1962, 1963, and 1988. Evaluation of historical data at Galveston Bay Entrance from the November 13 through 15, 1933, survey indicates that nontidal currents were directed toward 100° with an amplitude of 0.41 knots. During this survey, slack waters were irregular due to the presence of a strong permanent current (Figure 2).

In 1935, NOS chose Galveston Bay Entrance as the tidal current reference station for 14 secondary stations along the Gulf Coast from Terrebonne Bay, LA, west to Matagorda Channel, TX. Galveston Bay current predictions were computed from harmonic constants derived from two 29-day current pole and Price current meter time series beginning on April 5, 1935.

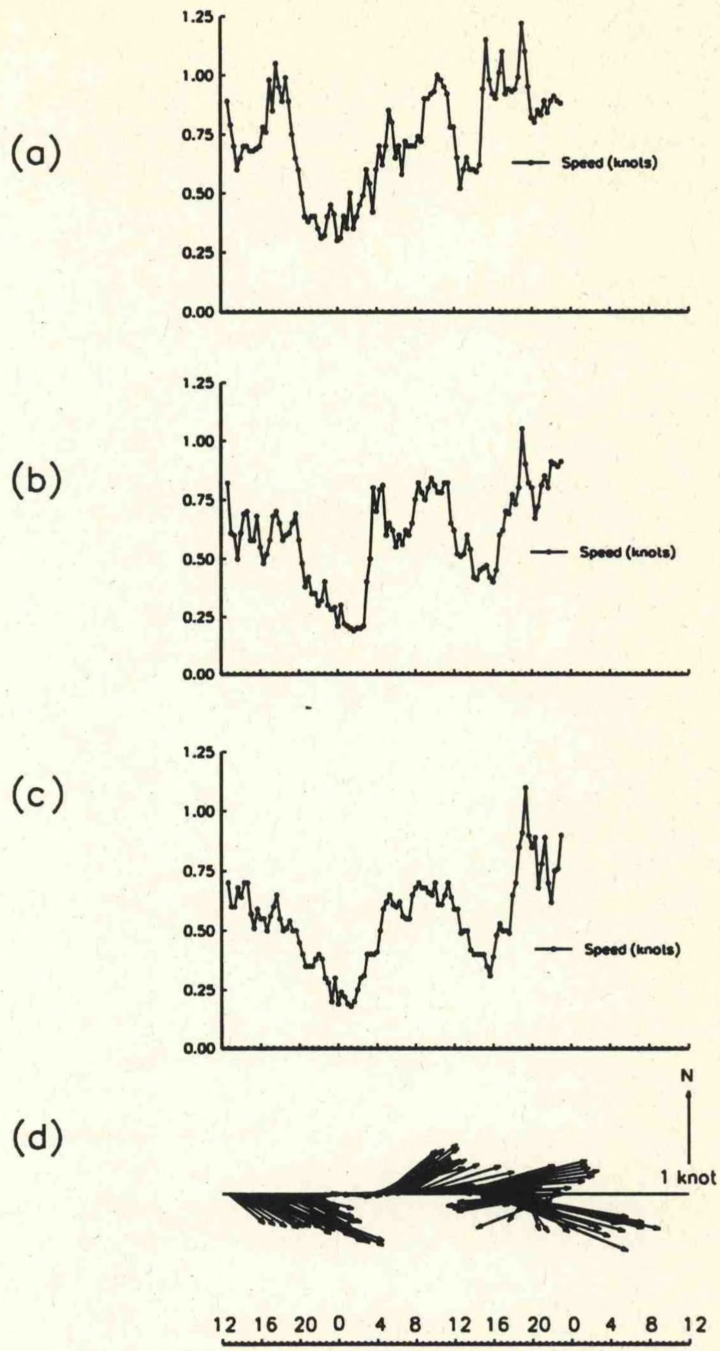


Figure 2. November 1933, Galveston Bay Entrance currents. Current meter speeds at the (a) 7-ft depth, (b) 18-ft depth, and (c) 29-ft depth; and (d) current pole velocities at 7 feet. Directions for subsurface currents in panels (a), (b), and (c) are unknown.

Since the 1935 survey, various bathymetric changes to Galveston Bay have changed circulation patterns. For example, using 1935-based predictions at Galveston Bay Entrance, maximum tidal currents during 1988 were predicted to be 1.49 knots, while mariners have reported current speeds in excess of 2.5 knots at the same location in Galveston Bay (NOS, 1992).

Predicted tidal currents are based on astronomical forces that do not include the effects of meteorological conditions or changed bathymetry. For this reason, mariners should be cautioned that circulation patterns change with respect to weather conditions or when the basin is physically changed by severe storms, dredging operations, or the development of new structures. Attempts are being made to modernize tidal current predictions by adding new reference or secondary stations, modeling estuarine environments, and installing physical oceanographic real-time systems (Appell et al., 1991; Frey, 1991; and Nichols, 1993).

1.2. Current Prediction Quality Assurance MiniProject

The tidal current predictions of this publication (Appendix A) are based on acoustic Doppler current profiler (ADCP) data obtained during the quality assurance (QA) survey conducted in Galveston Bay from August 2, 1988, through November 4, 1988 (Williams et al., 1990). Ten- minute data from the Galveston Bay Entrance (Figure 3) and Houston Ship Channel were rotated along their principal component direction and harmonically analyzed to predict tidal currents. Cross-channel currents were only significant during severe weather events. New predictions indicate changes in current patterns from the 1935 NOAA predictions owing to minor changes in station location, dredging of the navigational channel, and improved instrumentation. This is evidenced by differences that are depicted in Figure 4.

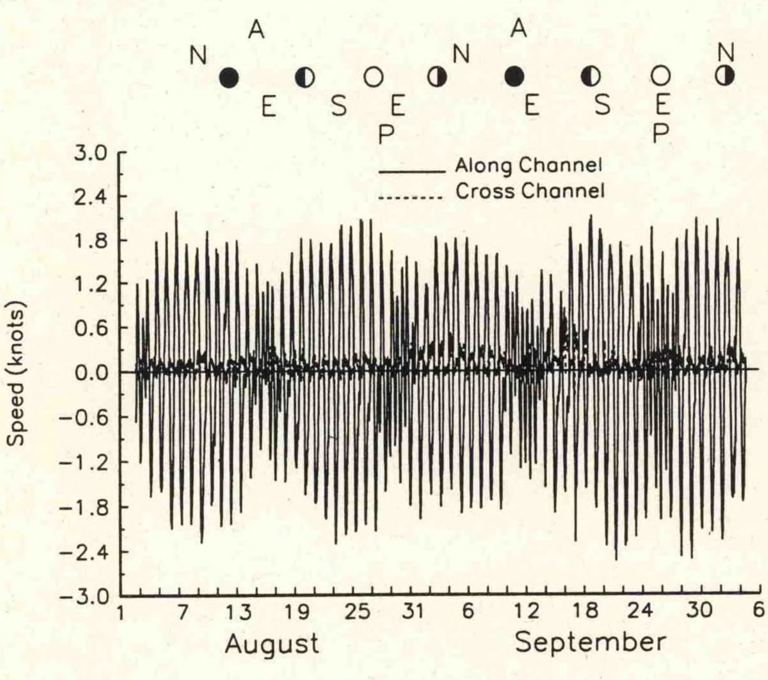


Figure 3. Observed Galveston Bay Entrance currents from August to October, 1988. Flood velocities are positive and ebb velocities are negative. The horizontal axis is Greenwich Mean Time (GMT). Lunar symbols and letters denoting declinations are listed on the inside back cover.

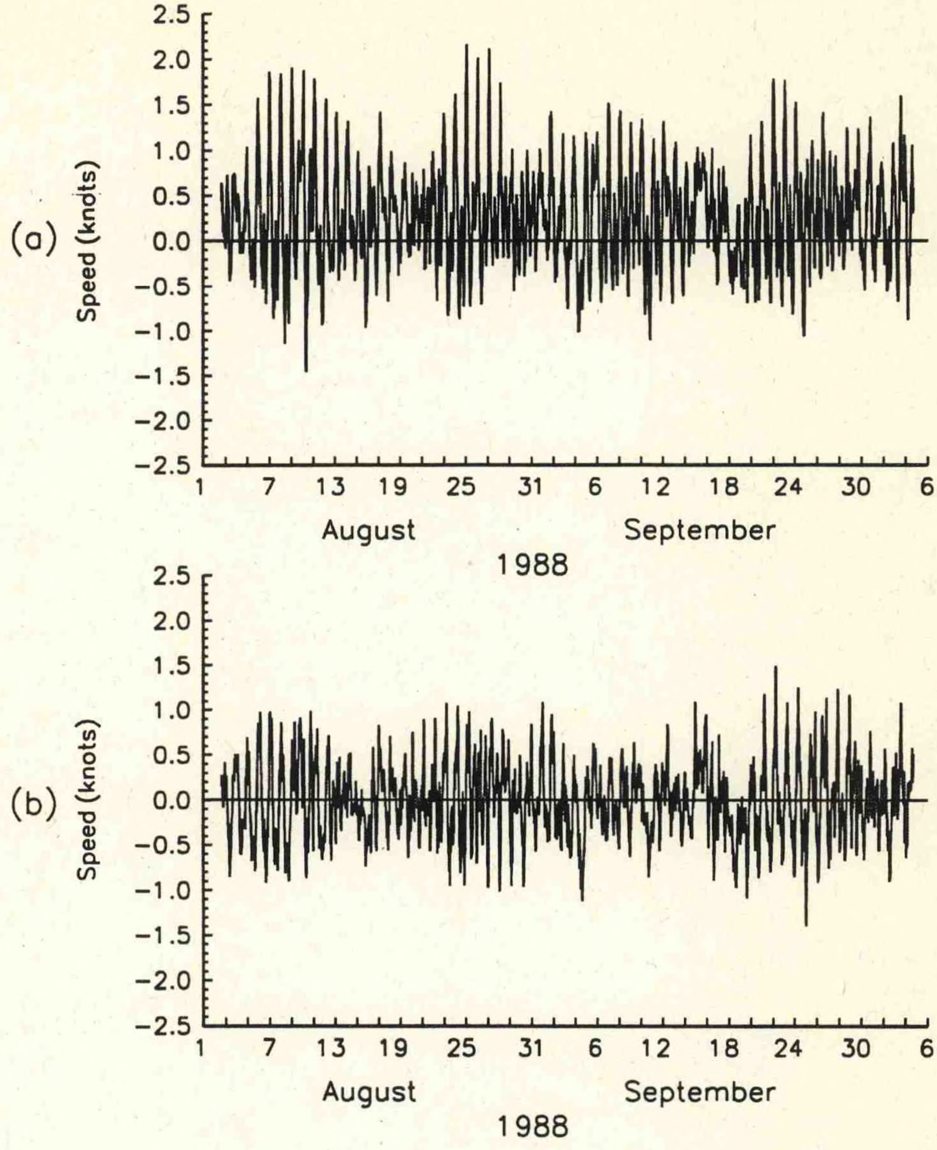


Figure 4. Galveston Bay Entrance residual currents. The residual is the component which remains after the predicted portion is removed. 1988 observed tidal currents minus predictions are based on (a) 1935 data and (b) recently-collected 1988 data.

The mean and standard deviation for residual currents at the Galveston Bay Entrance were reduced from 0.26 and 0.54 knots for 1935 predictions (Figure 4a) to 0.00 and 0.40 knots for 1988 predictions (Figure 4b). Beginning in 1996, harmonic predictions based on data collected from August 2 through November 4, 1988, will be published in NOAA's **Tidal Current Tables-Atlantic Coast of North America**.

1.3. Important Notice

These updated tidal current predictions for Galveston Bay and Houston Ship Channel do not appear in NOAA's **Tidal Current Tables 1995-Atlantic Coast of North America**. Updated predictions will appear in NOAA's **Tidal Current Tables 1996-Atlantic Coast of North America** and ensuing years.

Beginning in 1995, predictions will include near-surface and near-bottom current speeds and time differences for the Galveston Bay Entrance and the Houston Ship Channel (in Table 2, Appendix B).

NOAA Table 2 constants at the following 19 secondary stations which are referenced to Galveston Bay Entrance will be deleted in the **NOS Tidal Current Tables** following 1995 owing to the age of the data, subsequent changes along the Gulf of Mexico coastal zones, and more importantly, the lack of simultaneous observations from which to obtain the secondary station time differences. Do not use the following Table 2 stations from the **Tidal Current Tables 1995-Atlantic Coast of North America** with the updated predictions found in Appendix A.

Louisiana Coast

8516 Cat Island Pass, Terrebonne Bay
8521 Wine Island Pass
8526 Caillou Boca, Caillou Bay
8531 Calcasieu Pass
8536 Calcasieu Pass, 35 miles south of
8541 Calcasieu Pass, 67 miles south of

Sabine Pass, Texas

8546 Texas Point, 1.7 miles SSE of
8551 Sabine, channel east of
8556 Port Arthur Canal entrance
8561 Mesquite Pt., La. Causeway bridge

Galveston Bay, Texas

8571 Bolivar Roads, 0.5 mi. N of Ft. Point
8576 Quarantine Station, 0.3 mile S of
8581 Galveston Channel, west end
8586 Galveston Causeway RR. bridge
8591 Houston Channel, W of Port Bolivar
8596 Houston Ship Channel (Red Fish Bar)

Texas Coast

8601 Matagorda Channel (entrance jetty)
8611 Sabine Bank
8616 Heald Bank, 28 miles SSE of

2. DATA ANALYSIS

Data collected in support of the 1988 QA miniproject were used to predict tidal currents at Galveston Bay Entrance and the Houston Ship Channel for inclusion in NOAA's Tidal Current Tables for the Atlantic Coast of North America. Currents from the 15-ft depth at the reference station, Galveston Bay Entrance, were chosen for comparison with other tidal current measurements from Galveston Bay. Fourier harmonic analysis techniques were used to determine tidal current constituents from the data by matching amplitudes and phases at astronomically-determined frequencies and eliminating the disturbing effects of one tidal current constituent upon another (Schureman, 1958; Dennis and Long, 1971; and Zetler, 1982). Average speeds, directions, time differences and speed ratios were obtained by non-harmonic analyses (cycle-by-cycle) of the observed data. Tidal current characteristics are identified for Galveston Bay in Section 2.3 and residual current speed comparisons for 1935 and 1988 data are detailed in Section 2.4.

2.1. Harmonic Analysis

Harmonic predictions are the sum of constituents (Figure 5) which relate prevailing astronomical conditions such as the rotation of the earth, the revolution of the earth around the sun, the inclination of the moon's orbit to the earth's equator, and the obliquity of the ecliptic to a resultant velocity. Local epochs (κ) and amplitudes were determined from the observed current record. Longitude and time meridian corrections were applied to the local epochs to obtain a modified epoch designated kappa prime, κ′. Current amplitudes and κ′s form a basis for both reference and secondary station tidal current predictions.

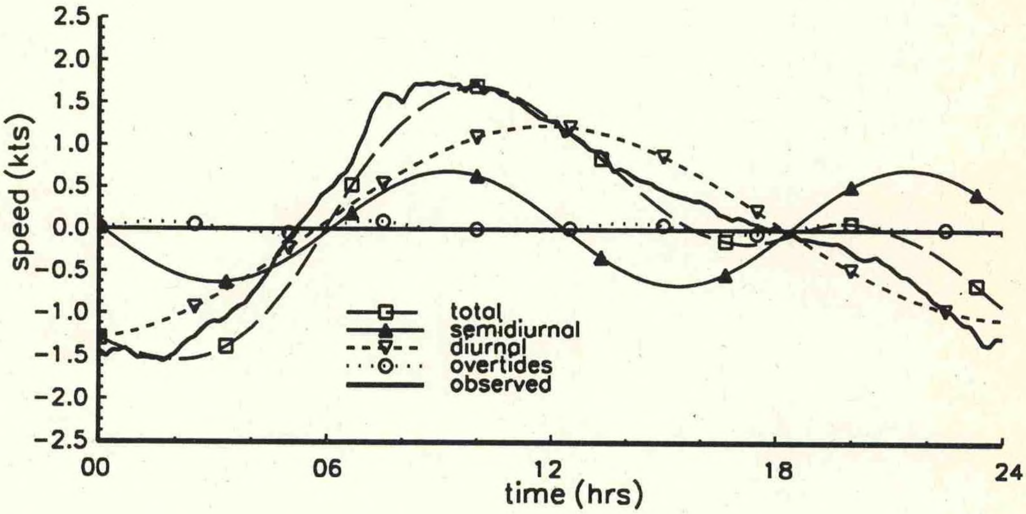


Figure 5. Computed tidal currents. By determining harmonic constants, one can compute predicted tidal currents, which better approximate the observed currents. (See Table 1 to identify all the semidiurnal species annotated with subscript 2 and all the diurnal species with subscript 1). In this case, semiduirnal current is the sum of all constituents with periods around 12 hours, and diurnal currents include all constituents with periods around 24 hours. The remaining constituents result from overtides.

Although NOS strives to obtain at least 6 months of data on which to perform harmonic analysis at reference stations, a record length of 29 days is sufficient to resolve the amplitudes and phase lags of 24 tidal current constituents. The amplitudes and phase lags of tidal current constituents at Galveston Bay Entrance were analyzed both parallel and perpendicular to the principal current direction of 273° T (Figure 6). The mean current at 15 feet below MLLW for the two-month time series is approximately 0.1 knot at 346° T.

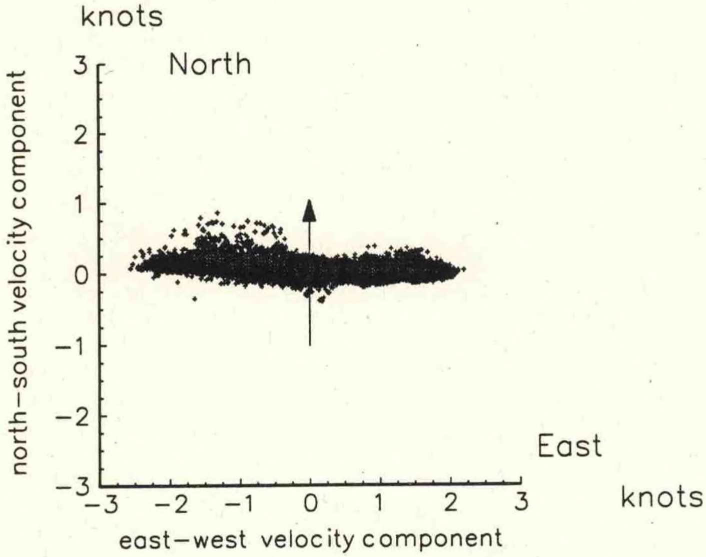


Figure 6. Galveston Bay Entrance velocity scattergram. The diagram illustrates alignment and degree of scatter in the current direction for August through October 1988.

All constituents including the primary constituents, M_2, S_2, K_1, and O_1, (Hicks, 1989) represent the tide-producing forces of the sun-earth-moon system. Ten of the constituents are determined directly from the data (i.e., M_2, S_2, N_2, O_1, K_1, M_4, M_6, M_8, S_4, and S_6), and the remaining 14 are derived from the M_2, S_2, N_2, O_1, and K_1 constituents using theoretical relationships (Schureman, 1958). The M_2, S_2, and N_2 constituents are corrected for the disturbing effects of other semidiurnal constants while O_1 and K_1 are corrected for the disturbing effects of other diurnal constituents. Constituent amplitudes and phases from Fourier harmonic analysis are presented in Table 1.

Table 1. Harmonic analysis results. Summary of results from Fourier harmonic analysis of currents for Galveston Bay Entrance from August 2 through October 4, 1988. Analysis at approximately 15 feet below MLLW in 42 feet of water produced a mean flood direction of 273°T and a permanent current of approximately 0.1 knots at 346° T.

Constituent	Amplitude (knots)	κ' (degrees)	Constituent	Amplitude (knots)	κ' (degrees)
J_1	0.067	280.5	OO_1	0.036	280.1
K_1	0.961	281.3	P_1	0.318	281.3
K_2	0.056	133.6	Q_1	0.165	281.9
L_2	0.016	94.3	$2Q_1$	0.022	282.2
M_1	0.060	281.1	R_2	0.002	133.4
M_2	0.608	126.7	S_2	0.207	133.2
M_4	0.077	236.2	S_4	0.020	294.4
M_6	0.014	271.6	S_6	0.008	6.4
M_8	0.014	35.6	T_2	0.012	132.9
N_2	0.113	100.8	λ_2	0.004	130.5
$2N_2$	0.015	75.2	ν_2	0.022	104.2
O_1	0.850	281.5	ρ_1	0.032	281.8

2.2. Non-Harmonic Analysis

Comparison of the updated NOS tidal current predictions using cycle-by-cycle non-harmonic analyses show that times of maximum flood current (MFC) and maximum ebb current (MEC) based on 1935 constituents occurred almost 15 minutes before the observed times of flood and ebb at the reference station. Comparison also indicated that 1935 predicted MFC speed was 27% higher than the 1988 tidal current predictions, while the MEC was 53% higher. Mean maximum flood speed for 1935 was 1.62 knots while mean maximum ebb speed was 1.88 knots.

The times of observed MFC at the Galveston Bay Entrance near-surface and near-bottom stations differed markedly from each other. MFC at the near-bottom (34-ft depth) occurred within a minute of maximum flood at the reference station. At the near-surface (2-ft) depth, MFC averaged about 15 minutes after the time of maximum flood at the reference station (15-ft depth).[1] Times of MEC at the same secondary stations occurred almost 15 minutes before (for near-bottom depths) and 5 minutes after (for near-surface depths) the time of maximum ebb at the reference station. At bottom depths, speed ratios of MFC and MEC averaged 85% of those at the reference depth. There was no change in near-surface speed ratio predictions from those predicted at the 15-ft depth (see Table 2, Appendix B).

[1]Note: analysis of the data revealed that tidal currents from the ADCP at the 2-ft and 5-ft depths were nearly identical, being within 0.039 knots of each other. For this reason, NOS investigators chose the 2-ft depth as representative of the near-surface currents.

Freshwater flow and synoptic scale winds produce buoyancy fluxes and pressure gradient forces that modify the tide as it propagates through the entrance to Galveston Bay. The total current at Galveston Bay Entrance is the sum of tidal and nontidal currents. These nontidal forces will enhance or diminish astronomically-predicted ebb and flood currents. During this investigation, nontidal current events at near-bottom depths at Galveston Bay Entrance lasted from 3 to 13 days with current velocities on the order 0.2 knots (Figure 7c). Nontidal events are identified here as currents in one direction. Near-surface events were more transient, lasting from 2 to 4 days with velocities ranging from 0.2 to 0.6 knots (Figure 7a). Nontidal events were of longer duration at the near-bottom and near-surface than at the 15-ft depth.

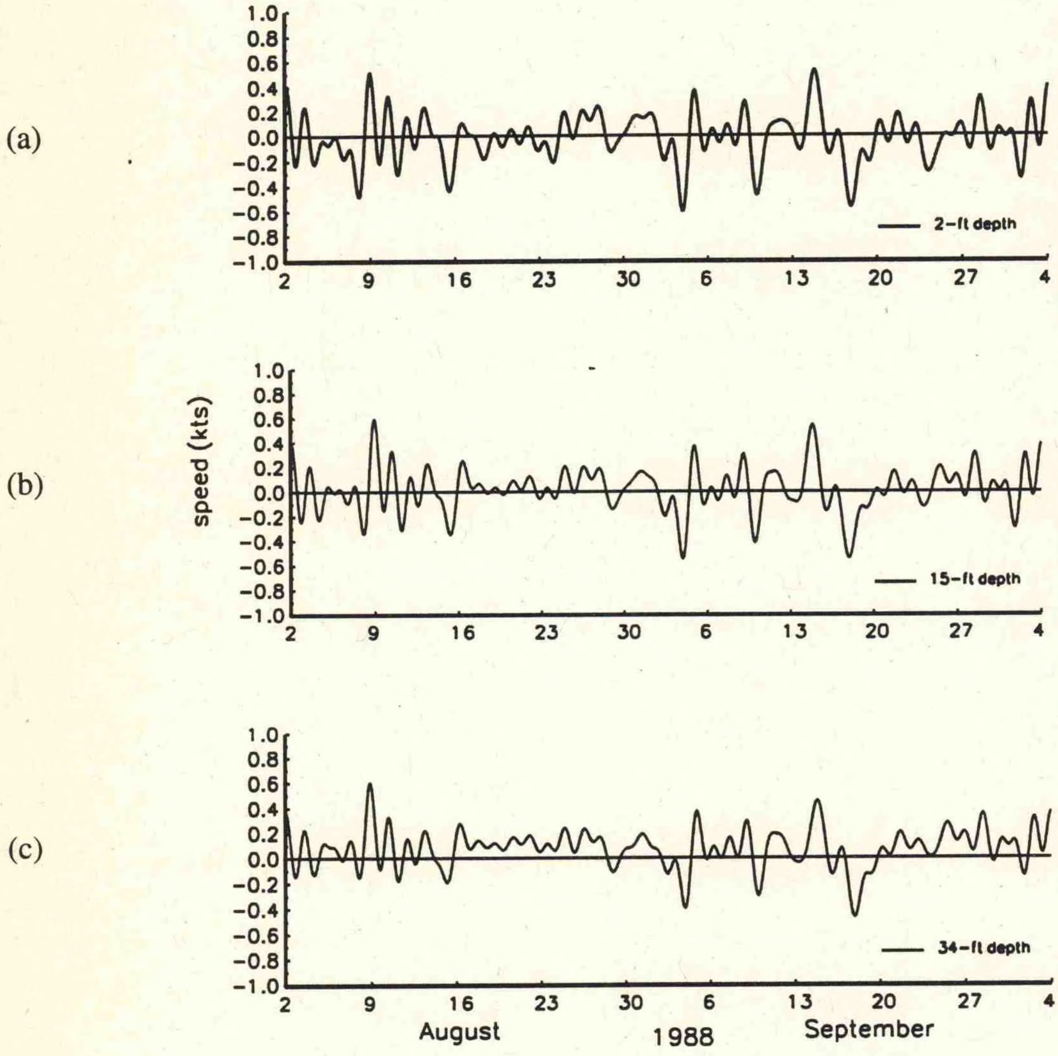


Figure 7. Nontidal currents at Galveston Bay Entrance along the principal current direction from August 2 through October 4, 1988. The observed data at the 2-ft, 15-ft and 34-ft depths were 30-hour low-pass Fourier filtered and rotated to 273°.

2.3. Tidal Current Characterization

Past investigators (Smith, 1974, and Nichols, 1994) have shown that currents along the south Texas coast are usually either mixed-mainly diurnal or mixed-mainly semidiurnal. The equation in Table 2 can be used to obtain the Defant Number which classifies tidal currents as diurnal, mixed-mainly diurnal, mixed, mixed-mainly semidiurnal, and semidiurnal. The tidal currents of Galveston Bay are characterized as mixed-mainly diurnal.

Table 2. Tidal current characterization (after Defant, 1961). The tidal current constituent amplitudes in knots at the reference station are given in Table 1.

Constituent Amplitudes (kts)	Constituent Ratio	Type of Current
$\frac{K_1 + O_1}{M_2 + S_2} =$	>3.0	Diurnal
	1.5 to 3.0	Mixed-Mainly Diurnal
	1.5	Mixed
	0.25 to 1.5	Mixed-Mainly Semidiurnal
	<0.25	Semidiurnal

The resulting ratio is 2.22 and classifies the currents at Galveston Bay Entrance as mixed-mainly diurnal. Currents had more semidiurnal energy when the moon was on the equator (Figures 3 and 8). Exaggerated floods coincided with storms and rain showers during the week of September 24 to October 1, 1988. Predicted tidal current speeds averaged 0.5 knots in excess of observed currents for 15 days during the month of August and 12 days during September. For August 8, 1988, predicted maximum flood current (MFC) occurred 2 hours and 27 minutes after the observed MFC and speeds were 10% higher. On September 1, 1988 predicted maximum ebb current (MEC) speeds were 67% higher than the observed MEC of 1.2 knots.

Galveston Bay Entrance currents on September 29, 1988, peaked at 2.5 knots at the 15-foot depth. Current directions were well established in the principal direction by the time that current speeds exceeded 0.1 knots. Therefore, slack water during this investigation is defined when current speeds are less than or equal to 0.1 knots. Periods of zero velocity are momentary. The scatter diagram (Figure 6) of velocity measurements at Galveston Bay Entrance shows symmetric reversing flow aligned with the navigation channel. The direction of flood currents at the Galveston Bay Entrance is oriented toward 273° T and ebb flow is directed toward 93° T. Mean maximum flood and maximum ebb speeds are approximately 1.41 and 1.33 knots, respectively. Measurements outside the principal current direction were influenced by severe weather such as the 35.6 knot winds on September 15, 1988 (NOAA, 1988).

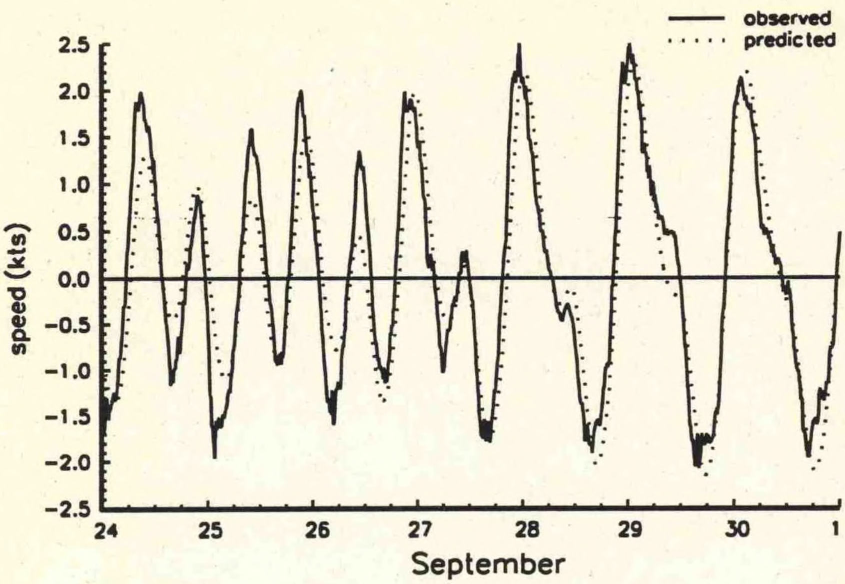


Figure 8. Observed and predicted 1988 tidal current speeds for Galveston Bay Entrance. The moon is on the equator on September 25, 1988.

2.4. Residual Current Velocity Comparisons

Residual currents as measured by differences between observed and predicted tidal currents can be quite significant. The maximum Galveston Bay Entrance residual current speeds diminished from 2.16 knots based on 1935 data to 1.49 knots using 1988 data (Figure 4). In the mixed-mainly diurnal environment of Galveston Bay, the flow is further complicated by nontidal flow out of the harbor during the rainy season as evidenced by the greatest amount of precipitation between September 29 and 30, 1988.

3. DAILY CURRENT PREDICTIONS

Predicted times of slack water and the predicted times and speeds of maximum flood and ebb current at 15 feet below MLLW for each day during 1995 at Galveston Bay Entrance are found in Appendix A. The predictions in Appendix A supersede the NOS Table 2 values for Station 5106, Galveston Bay Entrance, listed in NOAA's Tidal Current Tables. Local standard times are given in hours and minutes. Current amplitudes are in knots. For the users convenience, plotted tidal current predictions are provided in Appendix C.

4. SECONDARY STATION RATIOS AND DIFFERENCES

ADCP data from the HSC were non-harmonically analyzed at 15 feet below MLLW. Principal flood current direction is 313° T and principal ebb current direction is 133° T with a negligible permanent current. Time differences and ratios were determined at multiple depths by a cycle-by-cycle analysis of observed ADCP data for October 5 through November 3, 1988. Figure 9 shows a sample comparison of the time and velocity differences between the Galveston Bay Entrance reference station and the HSC secondary stations.

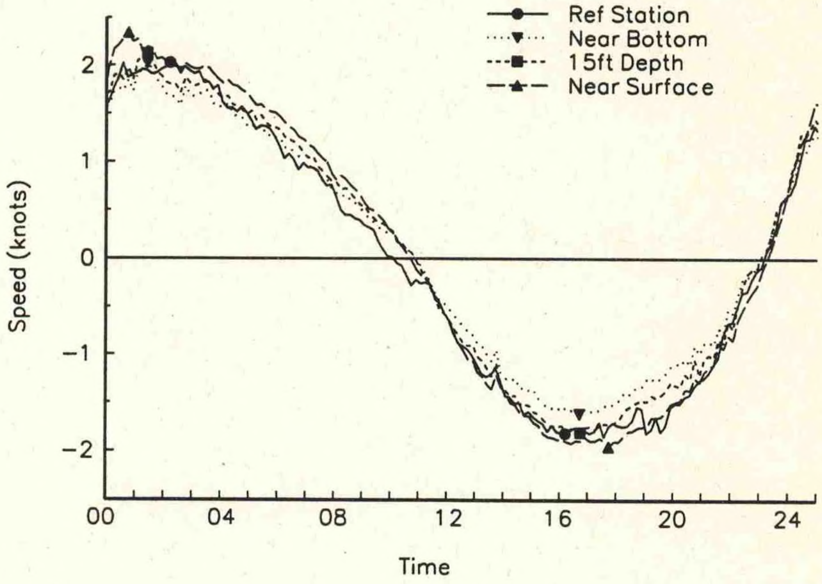


Figure 9. Cycle-by-cycle current comparison. Differences in time and velocity of maximum current at the reference station and three different depths at the secondary station are shown for October 16, 1988. Symbols indicate manual selections of maximum velocity.

Cycle-by-cycle analysis of the HSC data revealed that current directions were along the channel axis by the time current speeds exceeded 0.1 knot. The observed near-surface maximum ebb current directions occasionally varied in excess of 15° from the principal current direction at the 15-ft depth. It is assumed that these variations were caused by the effects of wind on the near-surface water layer.

Secondary station velocity ratios and time differences are provided in Appendix B. This information permits estimating times of minimum currents and times and speeds of maximum currents at each secondary station based on its relationship to currents at the 15-foot depth at Galveston Bay Entrance. By applying the specific corrections given in Appendix B to the corresponding predicted times and speeds of the current at the reference station, approximations of the current can be derived for the given secondary stations.

Speed ratio multipliers are used to approximate daily maximum flood and ebb speeds at a secondary station. The ratios should be applied to the corresponding current phases at the reference station. Speeds at the reference station and those resulting from the use of these ratios are expressed in knots. Directions of the four current phases are in degrees clockwise from 000° True North to 359° and are the directions toward which the water is flowing.

5. DATA AND INFORMATION PRODUCTS

The data used to develop these special predictions are archived and available to the public from NOAA. **The Tidal Current Tables 1996-Atlantic Coast of North America** will be revised to include the data in this publication. Additional copies of this publication can be obtained by writing or calling:

NOAA/National Ocean Service
Coastal and Estuarine Oceanography Branch
ATTN: Information, Products, and Services Section, N/OES334
1305 East-West Highway, SSMC4
Silver Spring, Maryland 20910-3281

Internet: rich@ceob-g30.nos.noaa.gov
Telephone: 301-713-2812
Facsimile: 301-713-4501.

6. CONCLUSIONS

Averaged 29-day harmonic analysis of 1988 ADCP measurements in 1-m layers from the near-bottom to the near-surface with a 10-minute sampling interval serves as a basis for tidal current predictions. Resources permitting, NOS would base tidal current predictions on time series of current speeds and directions lasting over a 6-month to 1-year period. Deviations from tidal current predictions in Galveston Bay are due in part to bathymetric changes and wind-induced nontidal currents. Physical oceanographic real-time systems along the Texas coast have been recognized as suitable instrumentation for obtaining total currents in shipping channels.

The updated tidal current predictions at the Galveston Bay Entrance reference station and the secondary station in the Houston Ship Channel should be beneficial to dockmasters, harbor pilots, and other mariners attempting to maneuver large vessels through the jetties which couple Galveston Bay with the Gulf of Mexico. This information is intended to assist the mariner in maintaining course and speed while conforming to the confined waters of the HSC and GICW. Results from this investigation will be published in NOAA's **Tidal Current Tables 1996-Atlantic Coast of North America**.

Future oceanographic efforts in Galveston Bay should examine the relationships between varying wind directions and the occurrence of exaggerated tidal currents and water level fluctuations in the navigation channels. Year-long or real-time data sets of currents, pressure, water temperature, air temperature, salinity, water level, and winds would be most useful for development of improved prediction and forecasting products.

7. ACKNOWLEDGMENTS

This work was accomplished by the newly formed Tidal Current Update Team from the Coastal and Estuarine Oceanography Branch of NOS. This project used data from the Houston Ship Channel/Galveston Bay Current Prediction Quality Assurance Miniproject which was completed by Dr. Robert Williams of CEOB during 1990.

Useful insights and technical guidance for establishing reference and secondary stations were provided by Dr. Chris Zervas, Mr. Richard Sillcox and Mr. Geoffrey French. Initial reviews benefitting this product were provided by CDR Donald A. Dreves, NOAA Corps, and Captain R. C. Schultheis, presiding officer of the Houston Pilots.

8. REFERENCES

Appell, G.F., T.M. Mero, and J.J. Sprenke, 1991. Design of a Current, Water Level and Meteorological Information System For Tampa Bay, **IEEE Oceans Proceedings**, Volume 2, 859-863.

Baker, J.E., 1992. May 13, 1992 Letter from James E. Baker, Director of Operations, Port of Houston Authority to Admiral J. Austin Yeager, Director, Coast and Geodetic Survey, National Ocean Service, NOAA, Rockville, MD, 4 pp.

Defant, A., 1961. **Physical Oceanography**, Vol. II. Pergamon Press, New York, NY, 598 pp.

Dennis, R.E., and E.E. Long, 1971. A user's guide to a computer program for harmonic analysis of data at tidal frequencies., **NOAA Technical Report**, NOS 41, 31 pp.

Frey, H.R., 1991. Physical Oceanographic Real-Time Systems for Operational Purposes, **Oceans '91 Proceedings**, 2, 859-863.

Hicks, S.D., 1989. Tide and Current Glossary, National Ocean Service, National Oceanic and Atmospheric Administration, Rockville, MD, 30.

Nichols, C.R., 1994. Special 1994 Tidal Current Predictions for Aransas Pass, Corpus Christi, Texas. **NOAA Technical Memorandum** NOS OMA 53, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, MD, 12 pp.

Nichols, C.R., 1993. Operational characteristics of the Tampa Bay Physical Oceanographic Real-Time System, **Proceedings, 1993 International Conference on Hydro Science & Engineering**, Volume 1, part B, Washington, DC, 1491-1498.

National Oceanic and Atmospheric Administration, 1988. Local Climatological Data: Annual Summary with Comparative Data, Houston, Texas, National Climatic Data Center, Asheville, N.C., pp. III-1.

National Ocean Service, 1992. **United States Coast Pilot, Atlantic Coast: Gulf of Mexico, Puerto Rico, and Virgin Islands**. Charting and Geodetic Services, National Oceanic and Atmospheric Administration, Rockville, MD, 348 pp.

Schureman, P., 1958. Manual of Harmonic Analysis and Prediction of Tides, U.S. Department of Commerce, **Coast and Geodetic Survey Special Publication** No. 98, Revised (1940 edition, reprinted 1988), Washington, DC, 317 pp.

Smith, N.P., 1974. Intracoastal Tides of Corpus Christi Bay, University of Texas, **Contributions in Marine Science**, v. 18, 205-219.

U.S. Army Corps of Engineers, 1992. Tonnage for selected U.S. ports in 1990, Navigation Data Center, Waterborne Commerce Station Center, August, 1992.

Williams, R.G., T. D. Bethem, G. W. French, and H.R. Frey, 1990. Houston Ship Channel/Galveston Bay Current Prediction Quality Assurance Miniproject. NOAA Technical Memorandum NOS OMA 53, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, MD, 12 pp.

Wilmot, W.L., and R.G. Williams, 1987. Charleston Harbor Oceanography Project Phase 1: Quality Assurance of NOS Tide and Tidal Current Predictions. NOAA, National Ocean Service, Rockville, MD, 70 pp.

Zetler, B.D., 1982. Computer Applications to Tides in the National Ocean Survey, Supplement to the Manual of Harmonic Analysis and Prediction of Tides (Special Publication No. 98), U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, MD, 85 pp.

APPENDIX A

SPECIAL 1995 TIDAL CURRENT PREDICTIONS FOR GALVESTON BAY ENTRANCE, TEXAS

1. GENERAL INFORMATION

This table provides the predicted times of slack water and the predicted times and speeds of maximum flood and ebb currents for each day of the year for Galveston Bay Entrance. The times are given in a 24-hour format in Central Standard Time, and the speeds are listed in knots.

Each day lists predicted times and current speeds in a three column format read from left to right. Times of slack water are provided in the first column followed by the predicted times and speeds of maximum current. "E" indicates an ebb current and "F" indicates a flood.

Owing to the mixed-mainly diurnal tidal currents of the Galveston Bay area, there are instances when there are no slack times listed between maximum current times. These instances reflect times of double or triple flood and ebb currents. In these cases, the currents will weaken to the velocity indicated between the two maximum current times, but will never actually reach a slack water condition. Extra currents are located on page A-6 for those days where there is inadequate space to list them with the daily predictions.

Daily predictions used in conjunction with Appendix B will provide the mariner with predicted times and speeds of tidal currents for other areas within Galveston Bay.

2. EXAMPLE:

The tidal current predictions for Galveston Bay Entrance on Friday, May 19, 1995 are:

Slack:	*0420*		
Flood:	*0813;*	*speed:*	*1.4 knots*
Slack:	*1424*		
Ebb:	*1728;*	*speed:*	*0.7 knots*
Ebb:	*1920;*	*speed:*	*0.6 knots*

Galveston Bay Entrance (between jetties), Texas, 1995

F–Flood, Dir. 300° True   E–Ebb, Dir. 100° True

January

Day	Slack h m	Maximum h m	knots
1 Su ●		0114	0.5E
		0217	0.5E
		0834	1.6E
	1311	1704	1.6F
	2343		
2 M		0138	0.5E
		0322	0.4E
		0921	1.5E
	1357	1738	1.6F
	2359		
3 Tu		0200	0.6E
		0417	*
		1006	1.4E
	1439	1811	1.5F
4 W	0004	0216	0.6E
		0514	*
		1050	1.2E
	1516	1844	1.3F
	2359		
5 Th		0229	0.7E
	0533	0619	0.3F
	0706	1139	1.0E
	1546	1916	1.2F
	2342		
6 F		0247	0.8E
	0621	0731	0.4F
	0900	1233	0.8E
	1605	1949	1.1F
	2333		
7 Sa		0313	0.9E
	0708	0850	0.6F
	1157	1321	0.4E
	1530	2023	0.9F
	2331		
8 Su ◐		0346	1.0E
	0753	1059	0.8F
		1406	0.6F
		1520	0.6F
		1806†	0.5F
9 M		0430	1.1E
	0837	1211	0.9F
		1953	0.4F
		2141	0.5F
	2324		
10 Tu		0516	1.1E
	0920	1315	1.1F
		2107	0.3F
		2225	0.3F
	2328		
11 W		0554	1.2E
	1002	1419	1.2F
		2204	*
		2310	*
12 Th		0625	1.3E
	1043	1506	1.3F
	2139	2255	0.4E
		2353	0.3E
13 F		0653	1.3E
	1123	1542	1.4F
	2210	2349	0.4E
14 Sa		0040	0.4E
		0722	1.3E
	1202	1611	1.4F
	2242		
15 Su		0038	0.5E
		0142	0.5E
		0756	1.4E
	1239	1636	1.4F
	2313		
16 M ○		0115	0.5E
		0244	0.5E
		0832	1.4E
	1315	1658	1.4F
	2337		
17 Tu		0145	0.5E
		0335	0.4E
		0909	1.3E
	1349	1722	1.4F
	2352		
18 W		0207	0.5E
		0421	0.3E
		0948	1.3E
	1420	1751	1.3F
	2350		
19 Th		0206	0.5E
		0511	*
		1029	1.2E
	1449	1823	1.3F
	2315		
20 F		0158	0.6E
	0503	0610	0.4F
	0711	1117	1.0E
	1514	1857	1.1F
	2250		
21 Sa		0156	0.7E
	0531	0718	0.6F
	0905	1213	0.8E
	1528	1930	1.0F
	2235		
22 Su		0143	0.9E
	0611	0829	0.8F
	1200	1314	0.4E
	1446	2003	0.8F
	2220		
23 M ◑		0200	1.1E
	0659	0953	0.9F
		1417	0.6F
		1545	0.6F
		1914†	0.5F
24 Tu		0235	1.2E
	0751	1131	1.1F
	2206		
25 W		0323	1.3E
	0846	1247	1.3F
	2053		
26 Th		0432	1.4E
	0941	1400	1.4F
	2113		
27 F		0549	1.4E
	1034	1458	1.5F
	2144		
28 Sa		0652	1.5E
	1126	1540	1.5F
	2213	2344	0.4E
29 Su		0103	0.4E
		0753	1.5E
	1216	1615	1.5F
	2232		
30 M ●		0011	0.4E
		0220	*
		0849	1.4E
	1304	1644	1.5F
	2237		
31 Tu		0034	0.5E
	0217	0324	0.4F
	0428	0938	1.3E
	1348	1709	1.4F
	2235		

February

Day	Slack h m	Maximum h m	knots
1 W		0048	0.6E
	0247	0418	0.6F
	0552	1022	1.2E
	1428	1734	1.3F
	2220		
2 Th		0059	0.7E
	0324	0511	0.7F
	0714	1109	1.1E
	1502	1801	1.2F
	2202		
3 F		0116	0.8E
	0406	0608	0.7F
	0842	1208	0.8E
	1529	1832	1.0F
	2157		
4 Sa		0135	0.9E
	0453	0710	0.8F
	1024	1310	0.6E
	1539	1905	0.9F
	2154		
5 Su		0148	1.0E
	0546	0815	0.8F
		1402	*
		1938	0.7F
	2151		
6 M		0151	1.0E
	0641	0936	0.9F
		1828	0.5F
		2013	0.6F
	2153		
7 Tu ◐		0212	1.1E
	0736	1122	1.0F
		1956	0.3F
		2048	0.4F
	2202		
8 W		0248	1.1E
	0831	1230	1.1F
	2044		
9 Th		0343	1.1E
	0924	1337	1.2F
	2042		
10 F		0532	1.2E
	1013	1437	1.2F
	2108		
11 Sa		0631	1.2E
	1059	1518	1.3F
	2135	2304	0.4E
12 Su		0029	0.3E
		0715	1.3E
	1141	1548	1.3F
	2159	2340	0.4E
13 M		0133	0.3E
		0758	1.3E
	1222	1611	1.3F
	2215		
14 Tu		0010	0.4E
		0237	*
		0838	1.3E
	1302	1628	1.3F
	2218		
15 W ○		0023	0.4E
	0206	0331	0.5F
	0448	0918	1.2E
	1341	1649	1.2F
	2156		
16 Th		0010	0.5E
	0223	0420	0.7F
	0607	0958	1.1E
	1417	1715	1.2F
	2118		
17 F		0010	0.6E
	0245	0509	0.8F
	0731	1044	1.0E
	1451	1744	1.0F
	2102	2359	0.8E
18 Sa	0316	0605	0.9F
	0907	1144	0.8E
	1518	1815	0.9F
	2047		
19 Su		0003	1.0E
	0358	0707	1.0F
	1107	1310	0.5E
	1524	1846	0.7F
	2037		
20 M		0035	1.1E
	0452	0813	1.1F
		1453	0.4F
		1645	0.4F
		1748†	0.4F
21 Tu		0114	1.3E
	0557	0930	1.2F
	2023		
22 W ◑		0157	1.3E
	0706	1106	1.3F
	1933		
23 Th		0247	1.3E
	0814	1221	1.3F
	1957		
24 F		0358	1.3E
	0919	1330	1.4F
	2024	2150	0.4E
		2257	0.4E
25 Sa		0555	1.3E
	1019	1431	1.4F
	2044	2211	0.4E
26 Su		0006	*
		0713	1.3E
	1114	1515	1.4F
	2051	2232	0.5E
27 M	0014	0117	0.4F
	0224	0818	1.3E
	1206	1548	1.3F
	2050	2246	0.6E
28 Tu	0043	0231	0.6F
	0430	0915	1.2E
	1254	1612	1.2F
	2042	2256	0.7E

March

Day	Slack h m	Maximum h m	knots
1 W ●	0118	0331	0.8F
	0557	1005	1.1E
	1340	1630	1.1F
	2023	2312	0.8E
2 Th	0155	0420	0.9F
	0713	1056	1.0E
	1421	1652	1.0F
	2013	2332	0.9E
3 F	0231	0506	1.0F
	0827	1155	0.8E
	1459	1718	0.9F
	2010	2346	0.9E
4 Sa	0306	0554	1.0F
	0945	1256	0.7E
	1532	1748	0.8F
	2006	2346	1.0E
5 Su	0344	0646	1.1F
	1131	1350	0.5E
	1555	1821	0.6F
	2004		
6 M		0006	1.1E
	0427	0741	1.1F
		1452	*
		1855	0.4F
	2009		
7 Tu		0039	1.1E
	0520	0841	1.1F
	2009		
8 W		0117	1.1E
	0622	0957	1.1F
	1837		
9 Th ◐		0158	1.1E
	0728	1127	1.1F
	1905		
10 F		0245	1.1E
	0833	1231	1.1F
	1935	2115	0.5E
		2222	0.4E
11 Sa		0353	1.1E
	0932	1334	1.1F
	2000	2144	0.5E
		2327	0.4E
12 Su		0604	1.1E
	1024	1429	1.2F
	2018	2208	0.5E
13 M		0027	*
		0714	1.1E
	1113	1503	1.2F
	2024	2221	0.5E
14 Tu	0011	0131	0.4F
	0300	0813	1.1E
	1201	1525	1.1F
	2013	2214	0.5E
15 W	0026	0236	0.7F
	0452	0907	1.1E
	1250	1543	1.1F
	1935	2213	0.6E
16 Th ○	0046	0330	0.9F
	0615	0957	1.0E
	1338	1607	1.0F
	1914	2210	0.8E
17 F	0114	0417	1.1F
	0735	1054	0.9E
	1427	1633	0.8F
	1859	2206	1.0E
18 Sa	0149	0505	1.2F
	0900	1209	0.8E
	1514	1702	0.7F
	1844	2227	1.1E
19 Su	0231	0558	1.3F
	1046	1324	0.6E
	1605	1730	0.4F
	1838	2302	1.2E
20 M	0318	0656	1.3F
	1316	1438	0.3E
		1757	*
		2346	1.3E
21 Tu	0412	0758	1.3F
	1635		
22 W		0036	1.4E
	0515	0907	1.3F
	1730		
23 Th ◑		0127	1.3E
	0627	1031	1.3F
	1807		
24 F		0219	1.3E
	0740	1143	1.3F
	1833	2024	0.5E
		2151	0.5E
25 Sa		0329	1.2E
	0851	1240	1.2F
	1846	2047	0.6E
		2312	*
26 Su		0614	1.1E
	0956	1335	1.2F
	1849	2106	0.6E
	2309		
27 M		0023	0.4F
	0206	0731	1.1E
	1054	1424	1.1F
	1844	2117	0.7E
	2335		
28 Tu		0141	0.7F
	0430	0839	1.0E
	1149	1457	1.0F
	1828	2129	0.8E
29 W	0008	0256	0.9F
	0600	0937	1.0E
	1243	1520	0.9F
	1816	2144	0.9E
30 Th ●	0042	0343	1.1F
	0717	1030	0.9E
	1336	1542	0.8F
	1812	2200	1.0E
31 F	0116	0422	1.2F
	0830	1129	0.8E
	1426	1607	0.7F
	1807	2204	1.1E

Time meridian 90° W. 0000 is midnight. 1200 is noon.
If three consecutive entries are marked (E) the middle one is not a true maximum but an intermediate value to show the current pattern.
* Current weak and variable.
† See page 104 for the remaining currents on this day.

Galveston Bay Entrance (between jetties), Texas, 1995

F–Flood, Dir. 300° True E–Ebb, Dir. 100° True

April

Day	Slack h m	Maximum h m	knots
1 Sa	0149	0459	1.2F
	0941	1237	0.7E
	1514	1636	0.5F
	1802	2208	1.1E
2 Su	0222	0539	1.3F
	1102	1336	0.6E
	1607	1706	0.4F
	1802	2230	1.2E
3 M	0255	0624	1.3F
	1231	1433	0.5E
		1737	*
		2303	1.2E
4 Tu	0332	0713	1.2F
	1407	1704	0.4E
		1809	0.4E
		2344	1.2E
5 W	0415	0805	1.2F
	1606		
6 Th		0029	1.2E
	0507	0902	1.2F
	1702		
7 F		0116	1.1E
	0610	1008	1.1F
	1737	2001	0.6E
◐		2054	0.6E
8 Sa		0203	1.1E
	0720	1110	1.1F
	1801	2028	0.6E
		2214	0.5E
9 Su		0258	1.0E
	0829	1158	1.1F
	1815	2050	0.6E
		2324	0.3E
10 M		0436	0.9E
	0935	1240	1.0F
	1812	2056	0.6E
	2311		
11 Tu		0026	0.4F
	0212	0716	0.8E
	1037	1323	0.9F
	1740	2043	0.7E
	2319		
12 W		0132	0.7F
	0440	0830	0.8E
	1138	1405	0.8F
	1716	2043	0.8E
	2337		
13 Th		0238	1.0F
	0613	0934	0.8E
	1244	1442	0.7F
	1700	2038	1.0E
14 F	0003	0330	1.2F
	0739	1037	0.8E
	1355	1516	0.5F
	1641	2043	1.1E
15 Sa	0039	0415	1.4F
	0907	1159	0.7E
	1510	1548	0.3F
○	1625	2110	1.3E
16 Su	0121	0501	1.5F
	1041	1330	0.6E
		1618	0.3E
		2145	1.4E
17 M	0207	0551	1.5F
	1213	1442	0.6E
		1646	0.5E
		2225	1.4E
18 Tu	0255	0646	1.5F
	1336	2312	1.4E
19 W	0347	0744	1.5F
	1459		
20 Th		0006	1.4E
	0445	0843	1.4F
	1559		
21 F		0102	1.3E
	0550	0947	1.3F
	1629	1856	0.6E
◑		2037	0.5E
22 Sa		0156	1.1E
	0659	1048	1.2F
	1641	1919	0.7E
		2206	0.4E
23 Su		0301	0.9E
	0809	1134	1.1F
	1640	1937	0.8E
	2218	2335	0.4F
24 M	0126	0626	0.8E
	0918	1211	1.0F
	1625	1950	0.9E
	2238		
25 Tu		0101	0.7F
	0437	0751	0.7E
	1023	1246	0.8F
	1611	2006	1.0E
	2309		
26 W		0228	1.0F
	0629	0908	0.7E
	1127	1324	0.7F
	1606	2026	1.1E
	2341		
27 Th		0318	1.1F
	0746	1011	0.7E
	1234	1405	0.5F
	1559	2045	1.1E
28 F	0014	0353	1.3F
	0850	1116	0.6E
	1348	1445	0.3F
	1546	2054	1.2E
29 Sa	0047	0423	1.3F
	0948	1229	0.6E
		1521	*
●		2059	1.2E
30 Su	0119	0453	1.4F
	1047	1328	0.6E
		1555	0.3E
		2119	1.3E

May

Day	Slack h m	Maximum h m	knots
1 M	0151	0527	1.4F
	1147	1420	0.6E
		1627	0.4E
		2149	1.3E
2 Tu	0224	0606	1.4F
	1244	1523	0.6E
		1657	0.5E
		2223	1.3E
3 W	0258	0650	1.4F
	1340	2302	1.3E
4 Th	0334	0737	1.3F
	1436	2347	1.2E
5 F	0414	0824	1.3F
	1526		
6 Sa		0037	1.1E
	0459	0914	1.2F
	1557	1912	0.7E
		2046	0.6E
7 Su		0127	1.0E
	0551	1005	1.1F
	1606	1932	0.7E
◐		2207	0.5E
8 M		0220	0.8E
	0655	1053	1.0F
	1536	1930	0.7E
	2230	2322	0.3F
9 Tu	0029	0335	0.6E
	0814	1134	0.9F
	1510	1913	0.8E
	2224		
10 W		0027	0.7F
	0431	0729	0.5E
	0947	1213	0.7F
	1453	1913	0.9E
	2239		
11 Th		0136	1.0F
	0648	0906	0.5E
	1118	1252	0.5F
	1426	1907	1.1E
	2304		
12 F		0243	1.2F
	0810	1030	0.6E
		1333	*
		1922	1.3E
	2338		
13 Sa		0332	1.4F
	0919	1204	0.6E
		1416	0.5E
		1955	1.4E
14 Su	0019	0415	1.6F
	1028	1317	0.7E
		1457	0.6E
○		2035	1.5E
15 M	0105	0458	1.6F
	1135	1411	0.7E
		1535	0.6E
		2118	1.5E
16 Tu	0153	0545	1.6F
	1234	1502	0.6E
		1610	0.6E
		2202	1.5E
17 W	0242	0636	1.6F
	1323	1603	0.6E
		1649	0.6E
		2250	1.5E
18 Th	0331	0726	1.5F
	1401	1656	0.6E
		1756	0.6E
		2344	1.4E
19 F	0420	0813	1.4F
	1424	1728	0.7E
		1920	0.6E
20 Sa		0042	1.2E
	0511	0859	1.3F
	1431	1753	0.7E
		2043	0.4E
21 Su		0137	0.9E
	0605	0944	1.1F
	1419	1811	0.8E
◑	2123	2229	0.3F
22 M	0001	0235	0.6E
	0702	1026	1.0F
	1406	1826	1.0E
	2139		
23 Tu		0014	0.7F
	0512	0642	0.3E
	0810	1104	0.8F
	1401	1845	1.1E
	2209		
24 W		0130	1.0F
	0705	0826	0.3E
	0933	1141	0.7F
	1353	1909	1.2E
	2243		
25 Th		0233	1.1F
	0811	0939	0.4E
	1057	1218	0.4F
	1338	1932	1.2E
	2316		
26 F		0318	1.3F
	0900	1041	0.5E
		1258	*
		1950	1.3E
	2350		
27 Sa		0353	1.4F
	0946	1146	0.5E
		1343	0.4E
		2000	1.3E
28 Su	0024	0422	1.4F
	1031	1249	0.6E
		1432	0.5E
		2019	1.3E
29 M	0058	0449	1.4F
	1117	1340	0.6E
		1516	0.5E
●		2048	1.3E
30 Tu	0132	0518	1.5F
	1200	1425	0.6E
		1554	0.6E
		2122	1.4E
31 W	0205	0551	1.4F
	1239	1516	0.6E
		1628	0.6E
		2157	1.3E

June

Day	Slack h m	Maximum h m	knots
1 Th	0237	0630	1.4F
	1314	2235	1.3E
2 F	0308	0710	1.4F
	1343	2318	1.2E
3 Sa	0339	0750	1.3F
	1359	1758	0.7E
		1919	0.7E
4 Su		0008	1.1E
	0409	0831	1.2F
	1348	1817	0.7E
		2034	0.6E
5 M		0101	0.9E
	0437	0913	1.1F
	1327	1809	0.7E
		2156	*
6 Tu		0156	0.6E
	0449	0956	1.0F
	1316	1747	0.8E
◐	2122	2318	0.6F
7 W		0304	*
		0504	0.4F
		0550	0.4F
		1037	0.8F
	1259	1745†	1.0E
8 Th		0027	1.0F
		0850	0.3F
		1115	0.5F
	1242	1741	1.2E
	2205		
9 F		0143	1.2F
	0901	1011	0.3E
		1150	*
		1807	1.3E
	2240		
10 Sa		0248	1.4F
	0930	1844	1.5E
	2322		
11 Su		0335	1.6F
	1016	1928	1.5E
12 M	0008	0415	1.6F
	1105	2015	1.6E
○			
13 Tu	0056	0456	1.7F
	1151	1407	0.6E
		1502	0.6E
		2103	1.6E
14 W	0145	0537	1.6F
	1227	1434	0.6E
		1557	0.5E
		2151	1.5E
15 Th	0232	0619	1.6F
	1250	1501	0.6E
		1653	0.5E
		2239	1.4E
16 F	0316	0700	1.5F
	1300	1524	0.6E
		1801	0.4E
		2331	1.2E
17 Sa	0357	0738	1.4F
	1256	1544	0.7E
		1919	0.3E
18 Su		0030	1.0E
	0433	0813	1.2F
	1241	1609	0.8E
	1947	2041	0.3F
	2203		
19 M		0126	0.7E
	0457	0849	1.0F
	1232	1643	1.0E
◑	2019	2252	0.6F
20 Tu		0220	*
		0927	0.9F
	1229	1718	1.1E
	2057		
21 W		0011	0.9F
		0714	0.4F
		1007	0.7F
	1224	1751	1.2E
	2136		
22 Th		0117	1.1F
		0843	0.3F
		1048	0.5F
	1219	1821	1.2E
	2214		
23 F		0220	1.2F
		0948	*
		1128	0.3F
	1216	1848	1.3E
	2252		
24 Sa		0308	1.3F
	0936	1046	0.3E
		1207	0.3E
		1911	1.3E
	2329		
25 Su		0345	1.4F
	1008	1148	0.5E
		1249	0.4E
		1930	1.3E
26 M	0006	0416	1.4F
	1045	1246	0.5E
		1345	0.5E
		1957	1.4E
27 Tu	0043	0443	1.5F
	1120	1329	0.6E
		1443	0.5E
●		2030	1.4E
28 W	0118	0507	1.5F
	1152	1405	0.6E
		1532	0.5E
		2105	1.4E
29 Th	0152	0534	1.4F
	1219	1441	0.6E
		1615	0.5E
		2141	1.3E
30 F	0222	0605	1.4F
	1238	1516	0.6E
		1700	0.5E
		2220	1.3E

Time meridian 90° W. 0000 is midnight. 1200 is noon.
If three consecutive entries are marked (E) the middle one is not a true maximum but an intermediate value to show the current pattern.
* Current weak and variable.
† See page 104 for the remaining currents on this day.

Galveston Bay Entrance (between jetties), Texas, 1995

F–Flood, Dir. 300° True   E–Ebb, Dir. 100° True

July

Day	Slack h m	Maximum h m	knots
1 Sa	0250	0639	1.3F
	1244	1550	0.6E
		1758	0.5E
		2302	1.1E
2 Su	0316	0715	1.3F
	1224	1524	0.6E
		1908	0.4E
		2353	1.0E
3 M	0337	0751	1.1F
	1200	1517	0.7E
		2019	*
4 Tu		0049	0.7E
	0344	0827	1.0F
	1148	1452	0.8E
	1950	2138	0.6F
5 W	0053	0147	0.3E
	0244	0902	0.8F
	1131	1459	1.0E
◐	2016	2307	0.9F
6 Th		0256	0.6F
		0406	0.7F
		0800	0.5F
		0938	0.6F
	1120	1537†	1.2E
7 F		0022	1.1F
	1106	1633	1.3E
	2135		
8 Sa		0138	1.3F
	0923	1731	1.4E
	2222		
9 Su		0244	1.5F
	0950	1823	1.5E
	2310		
10 M		0331	1.6F
	1029	1916	1.6E
11 Tu	0000	0410	1.6F
	1107	2010	1.6E
12 W	0050	0445	1.6F
	1136	1322	0.5E
		1457	0.4E
○		2102	1.5E
13 Th	0138	0519	1.6F
	1147	1340	0.5E
		1557	*
		2151	1.4E
14 F	0222	0551	1.5F
	1145	1351	0.6E
	1559	1655	0.4F
	1748	2239	1.3E
15 Sa	0302	0623	1.3F
	1132	1400	0.7E
	1641	1758	0.5F
	1920	2334	1.1E
16 Su	0337	0655	1.2F
	1111	1417	0.8E
	1733	1910	0.6F
	2116		
17 M		0040	0.8E
	0401	0728	1.1F
	1103	1441	0.9E
	1827	2026	0.7F
	2353		
18 Tu		0143	0.4E
	0349	0802	0.9F
	1102	1508	1.0E
	1918	2220	0.8F
19 W		0518	0.5F
		0838	0.7F
	1059	1542	1.1E
◑	2008	2344	1.0F
20 Th		0727	0.5F
		0916	0.6F
	1101	1639	1.1E
	2056		
21 F		0047	1.1F
		0844	0.3F
		1001	0.4F
	1109	1732	1.2E
	2142		
22 Sa		0152	1.2F
		0942	*
		1049	*
		1813	1.2E
	2226		
23 Su		0248	1.3F
	0927	1031	0.3E
		1136	0.3E
		1848	1.3E
	2308		
24 M		0328	1.3F
	0957	1119	0.4E
		1223	0.4E
		1920	1.3E
	2349		
25 Tu		0400	1.4F
	1028	1206	0.4E
		1322	0.4E
		1952	1.3E
26 W	0028	0426	1.4F
	1056	1247	0.5E
		1427	0.4E
		2025	1.3E
27 Th	0105	0447	1.4F
	1117	1319	0.5E
		1522	0.3E
●		2100	1.3E
28 F	0139	0507	1.4F
	1128	1342	0.5E
		1609	*
		2136	1.2E
29 Sa	0211	0532	1.3F
	1123	1343	0.5E
	1600	1657	0.3F
	1750	2216	1.1E
30 Su	0239	0603	1.2F
	1045	1336	0.6E
	1622	1751	0.5F
	1912	2300	1.0E
31 M	0304	0635	1.1F
	1023	1334	0.7E
	1652	1855	0.6F
	2056	2355	0.8E

August

Day	Slack h m	Maximum h m	knots
1 Tu	0320	0709	0.9F
	1009	1318	0.9E
	1732	2001	0.8F
	2327		
2 W		0056	0.4E
	0256	0741	0.8F
	0954	1334	1.1E
	1821	2115	0.9F
3 Th		0158	0.5F
		0429	0.6F
		0649	0.5F
◐		0809	0.5F
	0947	1407†	1.2E
4 F	0937	1450	1.3E
	2012		
5 Sa		0007	1.3F
	0832	1548	1.4E
	2109		
6 Su		0119	1.4F
	0854	1707	1.4E
	2205		
7 M		0226	1.5F
	0927	1819	1.5E
	2259		
8 Tu		0315	1.5F
	0959	1119	0.4E
		1234	0.3E
		1924	1.5E
	2351		
9 W		0353	1.5F
	1018	1143	0.4E
		1351	*
		2027	1.4E
10 Th	0042	0423	1.4F
	1016	1159	0.4E
	1333	1502	0.5F
○	1621	2123	1.3E
11 F	0130	0448	1.4F
	1005	1207	0.6E
	1408	1600	0.7F
	1752	2214	1.2E
12 Sa	0213	0512	1.2F
	0942	1222	0.7E
	1448	1654	0.8F
	1919	2310	1.1E
13 Su	0252	0539	1.1F
	0925	1244	0.8E
	1531	1750	0.9F
	2048		
14 M		0022	0.8E
	0325	0610	1.0F
	0921	1306	0.9E
	1619	1852	0.9F
	2231		
15 Tu		0128	0.6E
	0346	0643	0.8F
	0919	1324	1.0E
	1711	1958	1.0F
16 W		0231	*
		0718	0.7F
	0917	1334	1.1E
	1809	2113	1.0F
17 Th		0605	0.4F
		0754	0.5F
	0923	1356	1.1E
◑	1908	2257	1.0F
18 F		0726	0.3F
		0833	0.3F
	0933	1431	1.1E
	2006		
19 Sa		0004	1.1F
	0752	1521	1.1E
	2102		
20 Su		0106	1.2F
	0811	0919	0.3E
		1025	0.3E
		1733	1.1E
	2154		
21 M		0209	1.2F
	0839	0956	0.4E
		1123	0.3E
		1833	1.2E
	2242		
22 Tu		0257	1.2F
	0906	1030	0.4E
		1218	*
		1919	1.2E
	2326		
23 W		0331	1.3F
	0926	1102	0.4E
		1318	*
		2002	1.2E
24 Th	0008	0355	1.3F
	0938	1128	0.4E
	1309	1422	0.4F
	1533	2040	1.2E
25 F	0049	0411	1.2F
	0937	1132	0.5E
	1332	1518	0.6F
●	1657	2116	1.1E
26 Sa	0128	0429	1.2F
	0911	1130	0.5E
	1354	1605	0.7F
	1811	2152	1.1E
27 Su	0205	0453	1.1F
	0841	1132	0.6E
	1418	1652	0.9F
	1930	2234	0.9E
28 M	0241	0521	1.0F
	0827	1109	0.8E
	1448	1743	1.0F
	2057	2331	0.7E
29 Tu	0312	0551	0.8F
	0812	1125	1.0E
	1526	1841	1.1F
	2246		
30 W		0113	0.5E
	0328	0622	0.6F
	0802	1200	1.1E
	1614	1944	1.1F
31 Th		0243	0.3F
		0648	0.4F
	0756	1242	1.2E
	1714	2053	1.2F

September

Day	Slack h m	Maximum h m	knots
1 F	0632	1327	1.3E
	1824	2219	1.3F
2 Sa	0646	1416	1.3E
	1935	2341	1.3F
◐			
3 Su	0720	1516	1.3E
	2043		
4 M		0046	1.3F
	0751	1657	1.3E
	2147		
5 Tu		0150	1.3F
	0813	0947	0.5E
		1145	*
		1840	1.3E
	2245		
6 W		0242	1.3F
	0818	1002	0.5E
	1141	1253	0.4F
	1409	1952	1.3E
	2339		
7 Th		0319	1.3F
	0813	1008	0.6E
	1207	1407	0.7F
	1621	2055	1.2E
8 F	0031	0345	1.2F
	0756	1017	0.7E
	1243	1512	0.9F
○	1752	2151	1.1E
9 Sa	0121	0406	1.1F
	0736	1034	0.8E
	1322	1604	1.0F
	1912	2246	1.0E
10 Su	0208	0428	1.0F
	0728	1052	0.9E
	1402	1651	1.1F
	2031	2349	0.8E
11 M	0251	0455	0.8F
	0725	1102	1.0E
	1441	1739	1.1F
	2155		
12 Tu		0056	0.7E
	0331	0525	0.7F
	0721	1111	1.1E
	1520	1831	1.2F
	2353		
13 W		0156	0.5E
	0412	0557	0.5F
	0721	1137	1.1E
	1603	1926	1.2F
14 Th		0315	*
		0633	0.3F
	0724	1215	1.1E
	1654	2024	1.1F
15 F	0504	0612	0.3E
		0711	*
		1257	1.1E
	1755	2135	1.1F
16 Sa	0545	0718	0.4E
		0756	0.4E
		1340	1.1E
◑	1902	2305	1.1F
17 Su	0620	0806	0.5E
		0859	0.4E
		1426	1.1E
	2008		
18 M		0006	1.1F
	0651	0842	0.5E
		1013	0.4E
		1528	1.0E
	2110		
19 Tu		0059	1.1F
	0714	0912	0.5E
		1118	0.3E
		1813	1.0E
	2205		
20 W		0152	1.1F
	0729	0936	0.5E
		1217	*
		1916	1.0E
	2255		
21 Th		0232	1.1F
	0733	0946	0.6E
	1146	1318	0.5F
	1522	2012	1.0E
	2343		
22 F		0257	1.0F
	0716	0942	0.6E
	1205	1422	0.7F
	1701	2103	1.0E
23 Sa	0032	0318	1.0F
	0646	0945	0.7E
	1226	1516	0.9F
	1817	2152	0.9E
24 Su	0122	0343	0.9F
	0632	0940	0.8E
	1252	1602	1.1F
●	1932	2247	0.8E
25 M	0214	0410	0.7F
	0617	0935	1.0E
	1325	1646	1.2F
	2053	2359	0.7E
26 Tu	0307	0438	0.6F
	0603	0958	1.1E
	1404	1735	1.3F
	2236		
27 W		0119	0.6E
	0409	0505	0.3F
	0553	1030	1.3E
	1447	1829	1.4F
28 Th	0054	0242	0.4E
		0527	0.3E
		1111	1.3E
	1537	1929	1.4F
29 F	0323	1200	1.4E
	1635	2033	1.4F
30 Sa	0445	1254	1.3E
	1743	2147	1.3F

Time meridian 90° W. 0000 is midnight. 1200 is noon.
If three consecutive entries are marked (E) the middle one is not a true maximum but an intermediate value to show the current pattern.
* Current weak and variable.
† See page 104 for the remaining currents on this day.

Galveston Bay Entrance (between jetties), Texas, 1995

F–Flood, Dir. 300° True   E–Ebb, Dir. 100° True

October

Day	Slack h m	Maximum h m	knots
1 Su	0528	1348	1.3E
	1858	2303	1.3F
◐			
2 M	0556	0804	0.6E
		0923	0.5E
		1449	1.2E
	2011		
3 Tu		0000	1.3F
	0608	0823	0.6E
		1049	0.3E
		1731	1.1E
	2120		
4 W		0048	1.2F
	0610	0837	0.7E
	1049	1203	0.4F
	1343	1903	1.0E
	2223		
5 Th		0133	1.1F
	0559	0844	0.8E
	1110	1318	0.7F
	1618	2016	1.0E
	2322		
6 F		0212	1.0F
	0539	0855	0.9E
	1141	1437	1.0F
	1757	2120	0.9E
7 Sa	0019	0244	0.8F
	0530	0913	1.0E
	1216	1530	1.1F
	1921	2218	0.8E
8 Su	0116	0313	0.7F
	0527	0929	1.1E
	1252	1610	1.2F
○	2038	2321	0.7E
9 M	0213	0342	0.6F
	0520	0936	1.1E
	1328	1647	1.3F
	2152		
10 Tu		0038	0.7E
	0309	0412	0.4F
	0516	0945	1.2E
	1403	1726	1.3F
	2311		
11 W		0143	0.6E
		0443	*
		1009	1.2E
	1438	1809	1.3F
12 Th	0030	0247	0.5E
		0514	0.3E
		1040	1.2E
	1515	1857	1.3F
13 F	0148	0442	0.5E
		0544	0.5E
		1119	1.2E
	1556	1948	1.3F
14 Sa	0316	1205	1.2E
	1644	2042	1.2F
15 Su	0419	1254	1.1E
	1743	2144	1.2F

Day	Slack h m	Maximum h m	knots
16 M	0456	0729	0.6E
		0843	0.6E
		1343	1.0E
◑	1852	2246	1.1F
17 Tu	0519	0758	0.7E
		1003	0.5E
		1436	0.9E
	2001	2333	1.1F
18 W	0529	0820	0.7E
		1116	0.3E
		1559	0.8E
	2109		
19 Th		0012	1.0F
	0521	0825	0.7E
	1055	1218	0.5F
	1435	1912	0.7E
	2212		
20 F		0051	0.9F
	0451	0817	0.8E
	1106	1321	0.8F
	1652	2023	0.7E
	2314		
21 Sa		0131	0.8F
	0435	0819	0.9E
	1125	1426	1.0F
	1822	2127	0.7E
22 Su	0021	0211	0.6F
	0420	0814	1.0E
	1149	1517	1.2F
	1946	2229	0.7E
23 M	0137	0248	0.4F
	0359	0818	1.2E
	1220	1559	1.4F
●	2109	2357	0.6E
24 Tu		0322	*
		0844	1.3E
	1258	1642	1.5F
	2235		
25 W		0132	0.6E
		0353	0.4E
		0918	1.4E
	1341	1728	1.5F
26 Th	0001	0240	0.6E
		0420	0.5E
		0957	1.5E
	1427	1820	1.5F
27 F	0118	1041	1.5E
	1517	1915	1.5F
28 Sa	0229	1131	1.4E
	1610	2012	1.5F
29 Su	0327	1228	1.3E
	1710	2110	1.4F
30 M	0358	0641	0.7E
		0806	0.6E
		1326	1.2E
◐	1816	2209	1.3F
31 Tu	0408	0658	0.7E
		0936	0.5E
		1426	1.0E
	1927	2259	1.1F

November

Day	Slack h m	Maximum h m	knots
1 W	0401	0712	0.8E
	1004	1114	0.4F
	1251	1752	0.7E
	2039	2338	1.0F
2 Th	0339	0721	0.9E
	1018	1242	0.7F
	1632	1927	0.7E
	2150		
3 F		0014	0.8F
	0327	0737	1.0E
	1047	1406	1.0F
	1830	2051	0.6E
	2257		
4 Sa		0050	0.7F
	0322	0758	1.1E
	1120	1503	1.2F
	1947	2159	0.6E
5 Su	0007	0130	0.5F
	0311	0819	1.2E
	1154	1542	1.3F
	2051	2305	0.6E
6 M		0213	*
		0833	1.3E
	1229	1615	1.4F
	2148		
7 Tu		0017	0.6E
		0254	0.3E
		0843	1.3E
○	1303	1644	1.4F
	2246		
8 W		0118	0.6E
		0332	0.4E
		0903	1.3E
	1337	1716	1.4F
	2343		
9 Th		0210	0.6E
		0406	0.5E
		0932	1.3E
	1411	1752	1.4F
10 F	0035	0306	0.6E
		0437	0.5E
		1005	1.3E
	1445	1834	1.4F
11 Sa	0125	1042	1.3E
	1520	1918	1.3F
12 Su	0212	1125	1.2E
	1556	2004	1.3F
13 M	0253	1214	1.1E
	1635	2050	1.2F
14 Tu	0319	0648	0.7E
		0828	0.7E
		1305	1.0E
	1719	2139	1.1F
15 W	0320	0708	0.7E
		0950	0.5E
		1357	0.8E
◑	1811	2226	1.0F

Day	Slack h m	Maximum h m	knots
16 Th	0248	0709	0.8E
	1022	1112	0.3F
	1225	1501	0.5E
	1920	2309	0.9F
17 F	0233	0656	0.9E
	1013	1219	0.7F
	1748	1923	0.3E
	2104	2347	0.7F
18 Sa	0217	0657	1.0E
	1029	1328	1.0F
	1916	2108	0.4E
	2247		
19 Su		0025	0.5F
	0154	0652	1.1E
	1052	1433	1.2F
	2020	2227	0.5E
20 M		0103	*
		0702	1.3E
	1123	1519	1.4F
	2119	2352	0.6E
21 Tu		0143	0.5E
		0733	1.4E
	1200	1600	1.5F
	2221		
22 W		0108	0.6E
		0226	0.6E
		0812	1.5E
●	1243	1640	1.6F
	2325		
23 Th		0203	0.6E
		0307	0.6E
		0854	1.6E
	1329	1723	1.6F
24 F	0022	0252	0.6E
		0343	0.6E
		0938	1.6E
	1417	1810	1.6F
25 Sa	0109	1024	1.5E
	1504	1858	1.6F
26 Su	0144	1114	1.4E
	1551	1945	1.5F
27 M	0203	0508	0.6E
		0646	0.6E
		1211	1.2E
	1639	2029	1.3F
28 Tu	0204	0529	0.7E
		0811	0.4E
		1311	1.0E
	1727	2112	1.2F
29 W	0147	0544	0.8E
		0950	*
		1408	0.6E
◐	1817	2155	1.0F
30 Th	0134	0558	1.0E
	0915	1153	0.7F
		1814	*
		2236	0.8F

December

Day	Slack h m	Maximum h m	knots
1 F	0129	0619	1.1E
	0948	1307	1.0F
		2008	*
		2314	0.7F
2 Sa	0121	0645	1.2E
	1023	1414	1.2F
	2017	2124	0.3E
	2226	2352	0.5F
3 Su	0111	0712	1.3E
	1059	1504	1.3F
	2100	2225	0.4E
4 M		0031	*
		0736	1.3E
	1135	1542	1.4F
	2141	2327	0.5E
5 Tu		0115	0.4E
		0753	1.3E
	1211	1614	1.5F
	2223		
6 W		0030	0.6E
		0205	0.5E
		0811	1.4E
○	1246	1642	1.5F
	2306		
7 Th		0122	0.6E
		0255	0.5E
		0838	1.4E
	1321	1709	1.5F
	2348		
8 F		0206	0.6E
		0337	0.5E
		0910	1.4E
	1354	1738	1.5F
9 Sa	0025	0249	0.6E
		0415	0.6E
		0944	1.3E
	1426	1813	1.4F
10 Su	0057	0342	0.6E
		0452	0.6E
		1020	1.3E
	1456	1850	1.4F
11 M	0121	0446	0.6E
		0543	0.6E
		1100	1.2E
	1525	1929	1.3F
12 Tu	0133	0528	0.7E
		0657	0.6E
		1146	1.1E
	1550	2007	1.2F
13 W	0118	0552	0.7E
		0811	0.5E
		1239	0.9E
	1610	2047	1.1F
14 Th	0059	0549	0.7E
		0930	*
		1332	0.6E
◑	1604	2128	0.9F
15 F	0049	0526	0.8E
	0907	1100	0.6F
		1431	0.3F
		2210	0.8F

Day	Slack h m	Maximum h m	knots
16 Sa	0033	0526	1.0E
	0923	1216	0.9F
		2046	0.4F
		2249	0.5F
17 Su	0018	0516	1.1E
	0950	1329	1.2F
		2201	*
		2325	*
18 M		0544	1.3E
	1024	1434	1.4F
	2127	2315	0.4E
		2352	0.4E
19 Tu		0623	1.4E
	1104	1521	1.5F
	2206		
20 W		0706	1.5E
	1148	1600	1.6F
	2252		
21 Th		0753	1.6E
	1235	1637	1.7F
	2338		
●			
22 F		0842	1.6E
	1323	1715	1.7F
23 Sa	0014	0217	0.6E
		0335	0.5E
		0930	1.6E
	1410	1754	1.6F
24 Su	0035	0237	0.5E
		0430	0.4E
		1018	1.5E
	1455	1834	1.5F
25 M	0041	0250	0.6E
		0533	0.3E
		1109	1.3E
	1535	1911	1.4F
26 Tu	0031	0258	0.7E
		0648	*
		1207	1.1E
	1611	1947	1.2F
27 W	0011	0319	0.8E
	0700	0808	0.4F
	0943	1307	0.7E
	1634	2022	1.1F
28 Th	0001	0354	1.0E
	0743	0959	0.6F
		1405	*
◐		2059	0.9F
	2358		
29 F		0437	1.1E
	0828	1147	0.9F
		1855	0.5F
		2138	0.7F
	2353		
30 Sa		0521	1.2E
	0912	1254	1.1F
		2027	0.3F
		2221	0.5F
	2351		
31 Su		0559	1.2E
	0955	1401	1.2F
		2133	*
		2304	0.3F
	2352		

Time meridian 90° W. 0000 is midnight. 1200 is noon.
If three consecutive entries are marked (E) the middle one is not a true maximum but an intermediate value to show the current pattern.
* Current weak and variable.

EXTRA CURRENTS, 1995

Galveston Bay Entrance, Texas

January

	Slack	Maximum	
	h m	h m	knots
8		2100	0.6F
	2329		
23		2031	0.3F
	2217		

February

	Slack	Maximum	
	h m	h m	knots
20		1913	*

June

	Slack	Maximum	
	h m	h m	knots
7	2135		

July

	Slack	Maximum	
	h m	h m	knots
6	2051		

August

	Slack	Maximum	
	h m	h m	knots
3	1913	2246	1.2F

APPENDIX B

SPECIAL 1995 CURRENT DIFFERENCES AND OTHER CONSTANTS FOR GALVESTON BAY, TEXAS

1. GENERAL INFORMATION

This table provides the corrections to the daily predictions at the reference station, Galveston Bay Entrance, provided in Appendix A, which allows one to calculate the predicted currents at any of the listed secondary locations.[2]

First, note the predicted times and speeds on the desired day at the reference station provided in Appendix A. Also note the last time and speed from the preceding day and the first time and speed of the next day. One of these two predicted currents may occur at the secondary location on the desired day, once the time differences are applied.

Secondly, determine the appropriate time differences and speed ratios to the predicted times and speeds at the reference station. The time differences are listed in four columns; Slack Before Flood (SBF), Flood (F), Slack Before Ebb (SBE), and Ebb (E). The speed ratios are in two columns, Flood and Ebb.

Next, apply the appropriate time differences to the predicted times of slacks and maximum flood and ebb currents to obtain the predicted times at your chosen location. Be sure to apply the proper time corrections. Lastly, multiply the appropriate speed ratios to the predicted speeds of the flood and ebb currents. Again be sure to apply the proper corrections.

2. EXAMPLE:

The tidal current predictions for the Houston Ship Channel (15 ft depth) on March 4, 1995 are:

March 3				
Ebb:	*2346 + 0021*	=	*0007 (March 4);*	*speed: 1.0 * 1.0 = 1.0 knots*
March 4				
Slack:	*0306 + 0017 (SBF)*	=	*0323*	
Flood:	*0554 + 0001*	=	*0555;*	*speed: 1.0 * 1.0 = 1.0 knots*
Slack:	*0945 + 0022 (SBE)*	=	*1007*	
Ebb:	*1256 + 0021*	=	*1317;*	*speed: 0.7 * 1.0 = 0.7 knots*
Slack:	*1532 + 0017 (SBF)*	=	*1549*	
Flood:	*1748 + 0001*	=	*1749;*	*speed: 0.8 * 1.0 = 0.8 knots*
Slack:	*2006 + 0022 (SBE)*	=	*2028*	
Ebb:	*2346 + 0021*	=	*0007(March 5);*	*speed: 1.0 * 1.0 = 1.0 knots*
March 5				
Slack:	*0344 + 0017 (SBF)*	=	*0401*	

[2] See Section 1.3 for an Important Notice about the Table 2 stations.

Table 2. Current differences and other constants. Results were derived from ADCP data collected during the Houston Ship Channel/Galveston Bay current prediction QA miniproject from August through November, 1988. Time differences, speed ratios, and average speed and directions were computed using non-harmonic analyses.

No.	Place	Meter Depth	POSITION				TIME DIFFERENCES				SPEED RATIOS		AVERAGE SPEED AND DIRECTIONS							
			Lat.		Long.		Slack before Flood	Flood	Slack before Ebb	Ebb	Flood	Ebb	Slack before Flood		Maximum Flood		Slack before Ebb		Maximum Ebb	
		feet	° North	'	° West	'	h. m.	h. m.	h. m.	h. m.			knots	°T	knots	°T	knots	°T	knots	°T
1	Galveston Bay Ent.	2	29	20.92	94	42.85	0 17	0 15	0 02	0 05	1.0	1.0	0.01	318	1.43	272	0.03	181	1.31	91
2	Galveston Bay Ent.	15	29	20.92	94	42.85	*Daily Predictions*				NA		0.07	179	1.41	274	0.00	358	1.33	93
3	Galveston Bay Ent.	34	29	20.92	94	42.85	-0 18	-0 01	-0 03	-0 13	0.9	0.8	0.05	188	1.12	274	0.04	7	1.10	94
4	Houston Ship Channel	2	29	21.88	94	47.80	0 11	-0 04	0 15	0 16	1.1	1.1	0.06	226	1.69	314	0.09	38	1.31	134
5	Houston Ship Channel	15	29	21.88	94	47.80	0 17	0 01	0 22	0 21	1.0	1.0	0.02	59	1.54	312	0.00	242	1.19	133
6	Houston Ship Channel	24	29	21.88	94	47.80	0 11	0 08	0 18	0 17	1.0	0.9	0.01	170	1.39	312	0.01	233	1.11	133

APPENDIX C

SPECIAL 1995 TIDAL CURRENT CURVES FOR GALVESTON BAY ENTRANCE, TEXAS

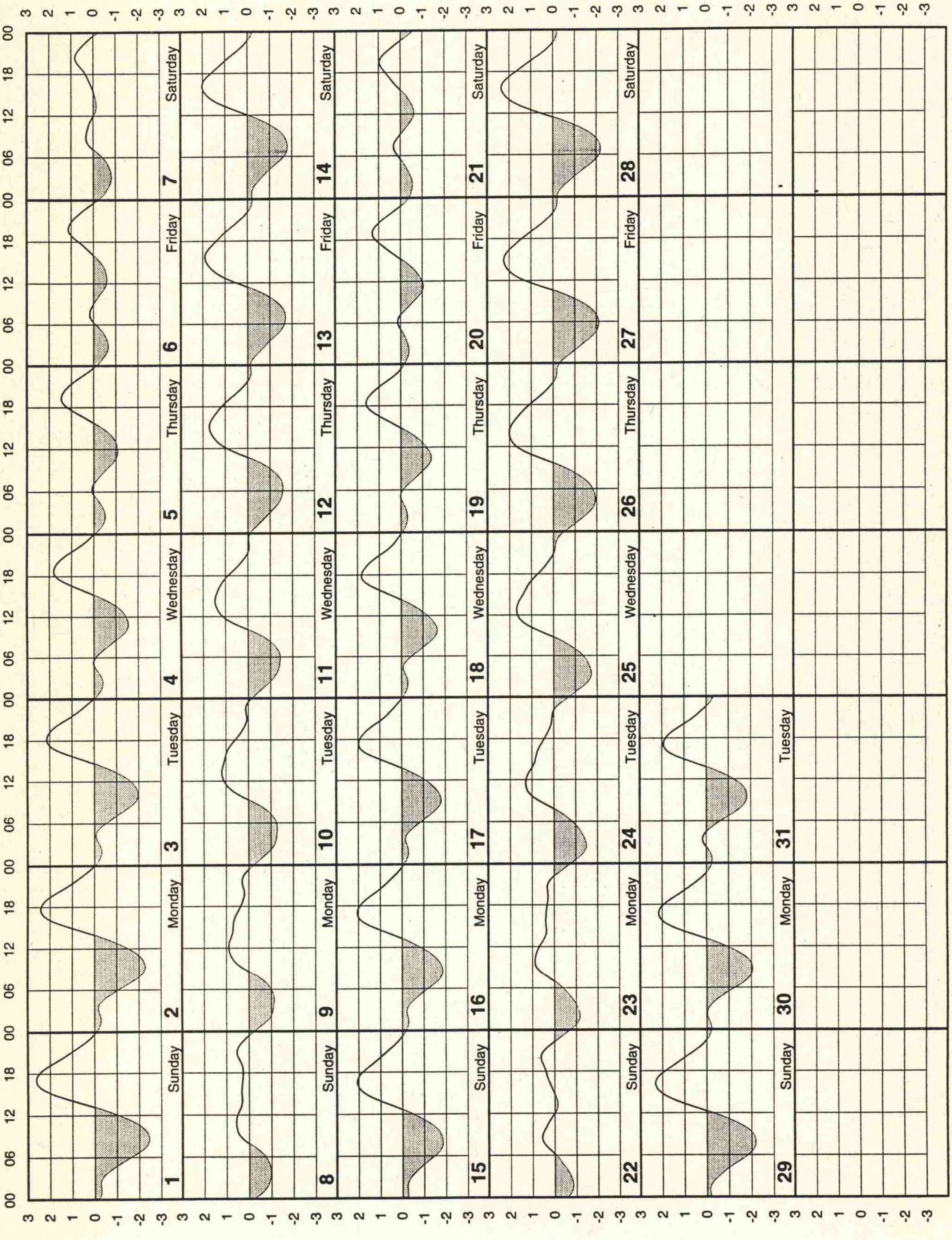
1. GENERAL INFORMATION

Galveston Bay Entrance tidal currents are shown in weekly panels for each month of 1995. The ebbs are shaded and speeds are in knots.

Galveston Bay Entrance, 1995

January

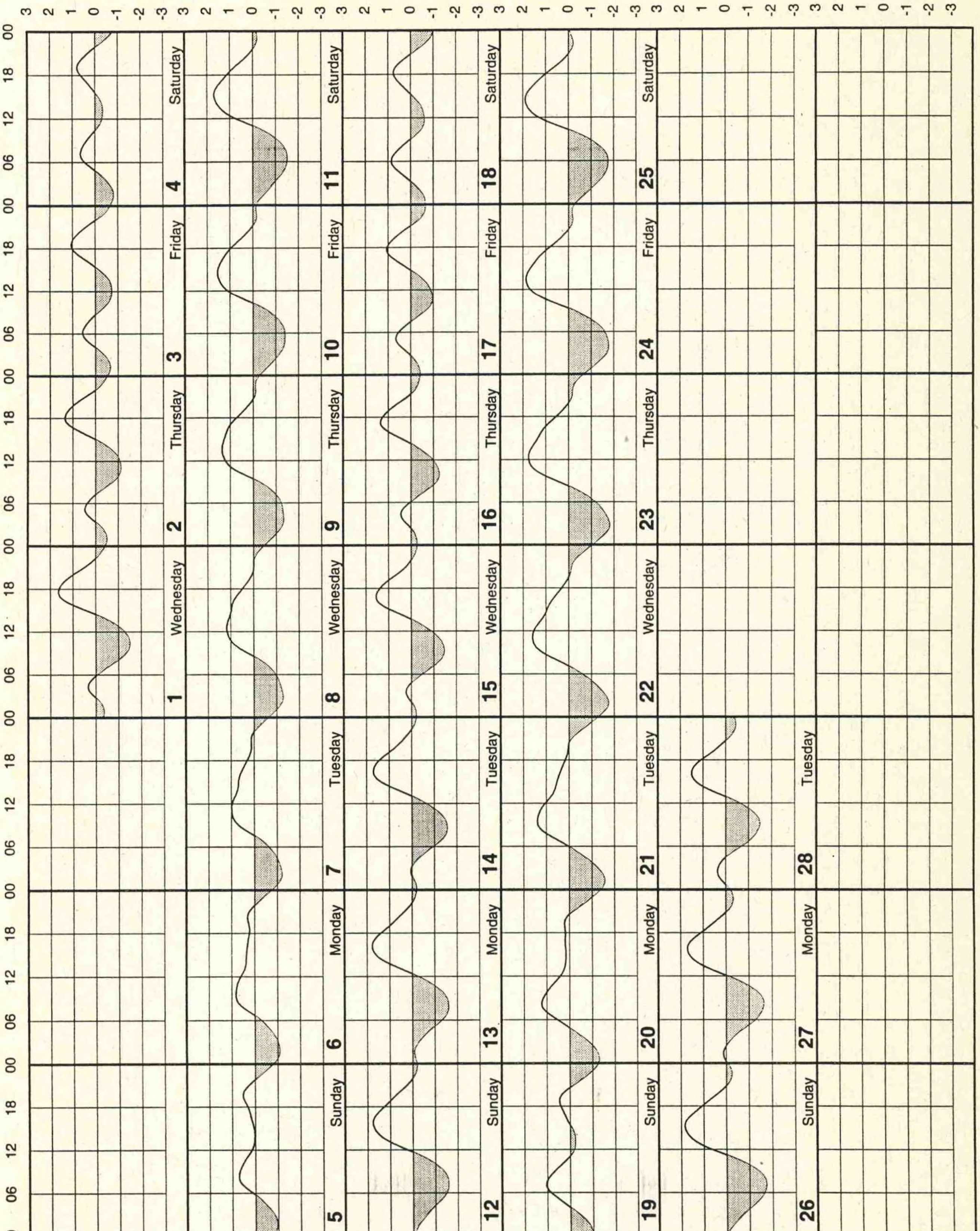
Velocity in Knots



Galveston Bay Entrance, 1995

February

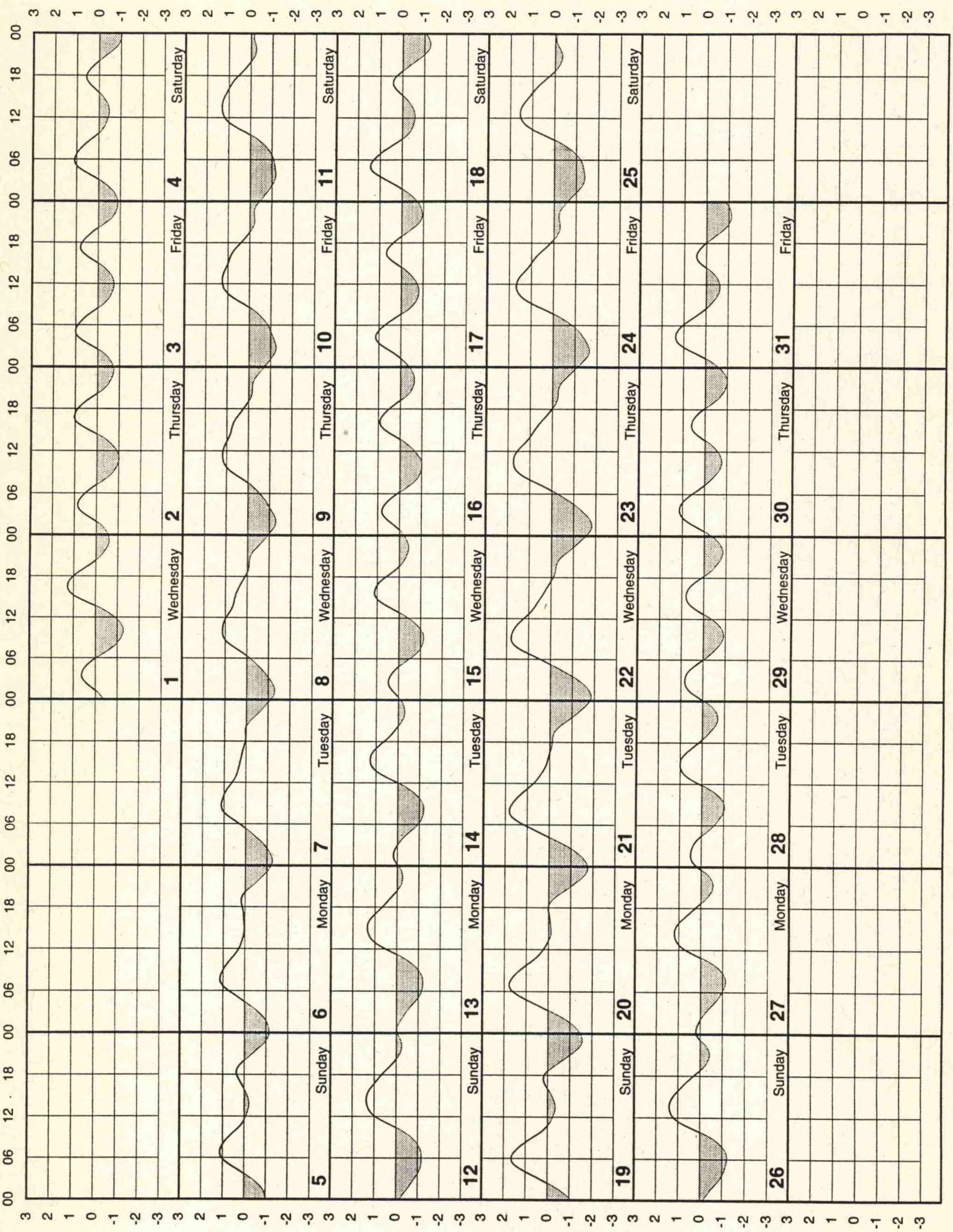
Velocity in Knots



Galveston Bay Entrance, 1995

March

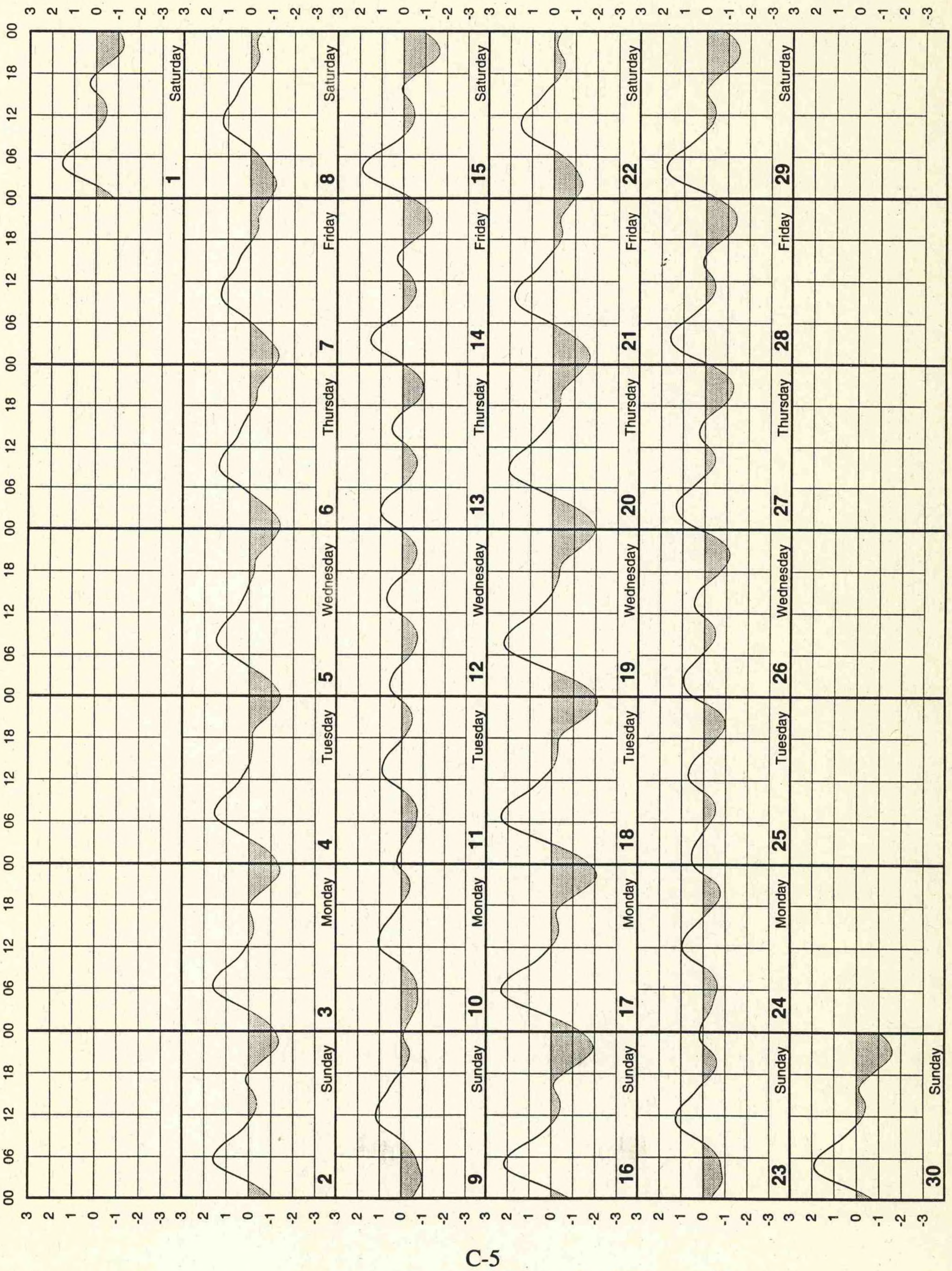
Velocity in Knots



Galveston Bay Entrance, 1995

April

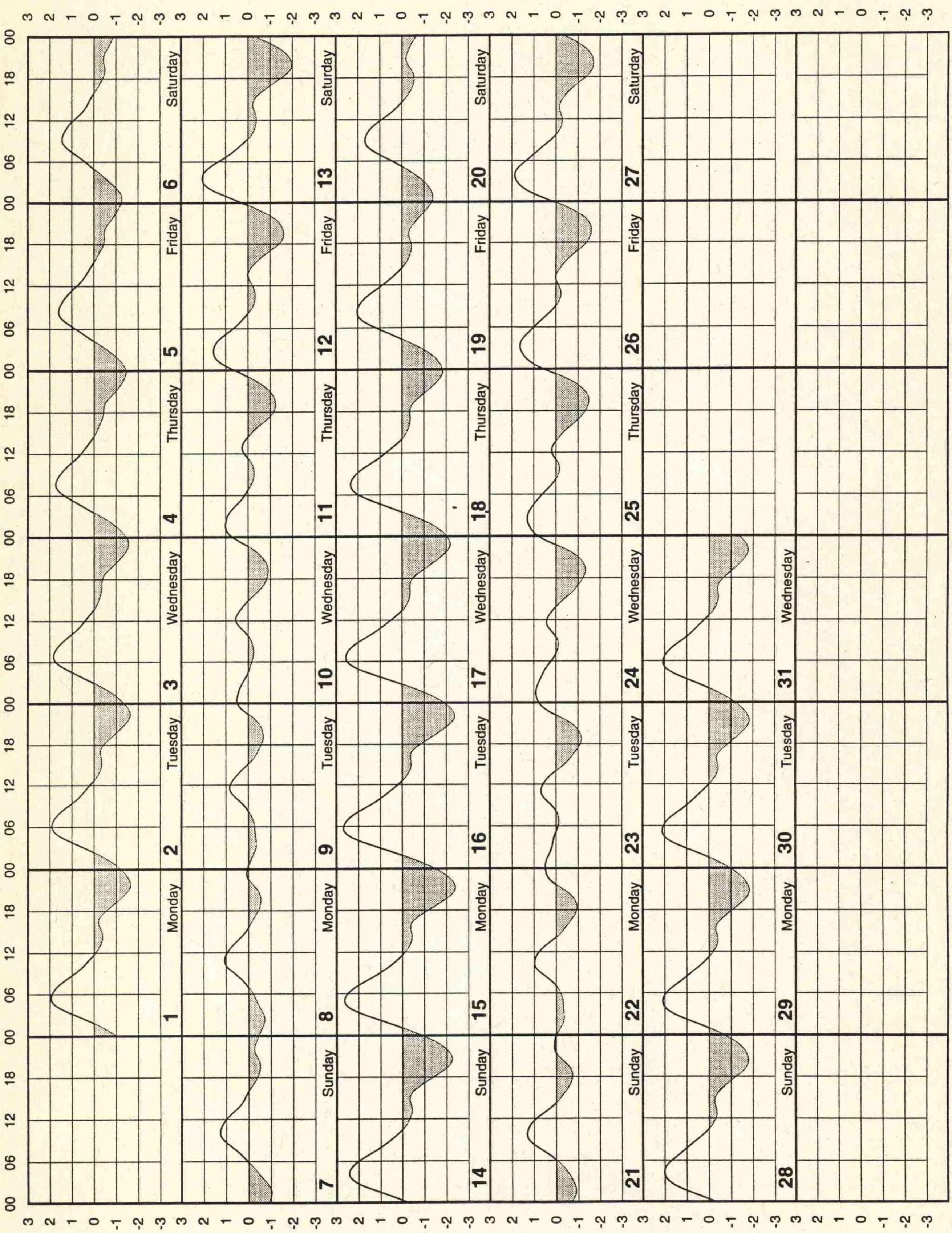
Velocity in Knots



Galveston Bay Entrance, 1995

May

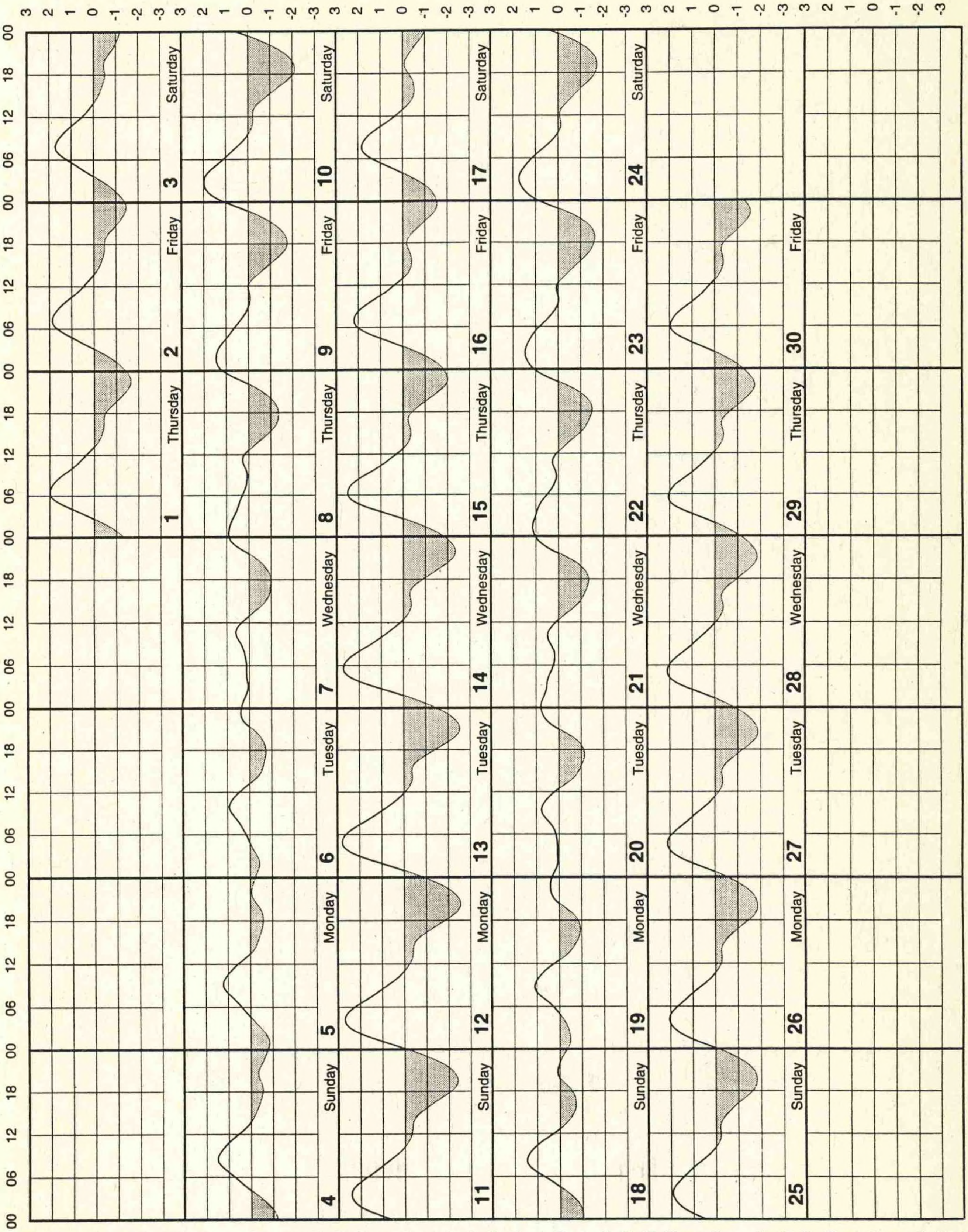
Velocity in Knots



Galveston Bay Entrance, 1995

June

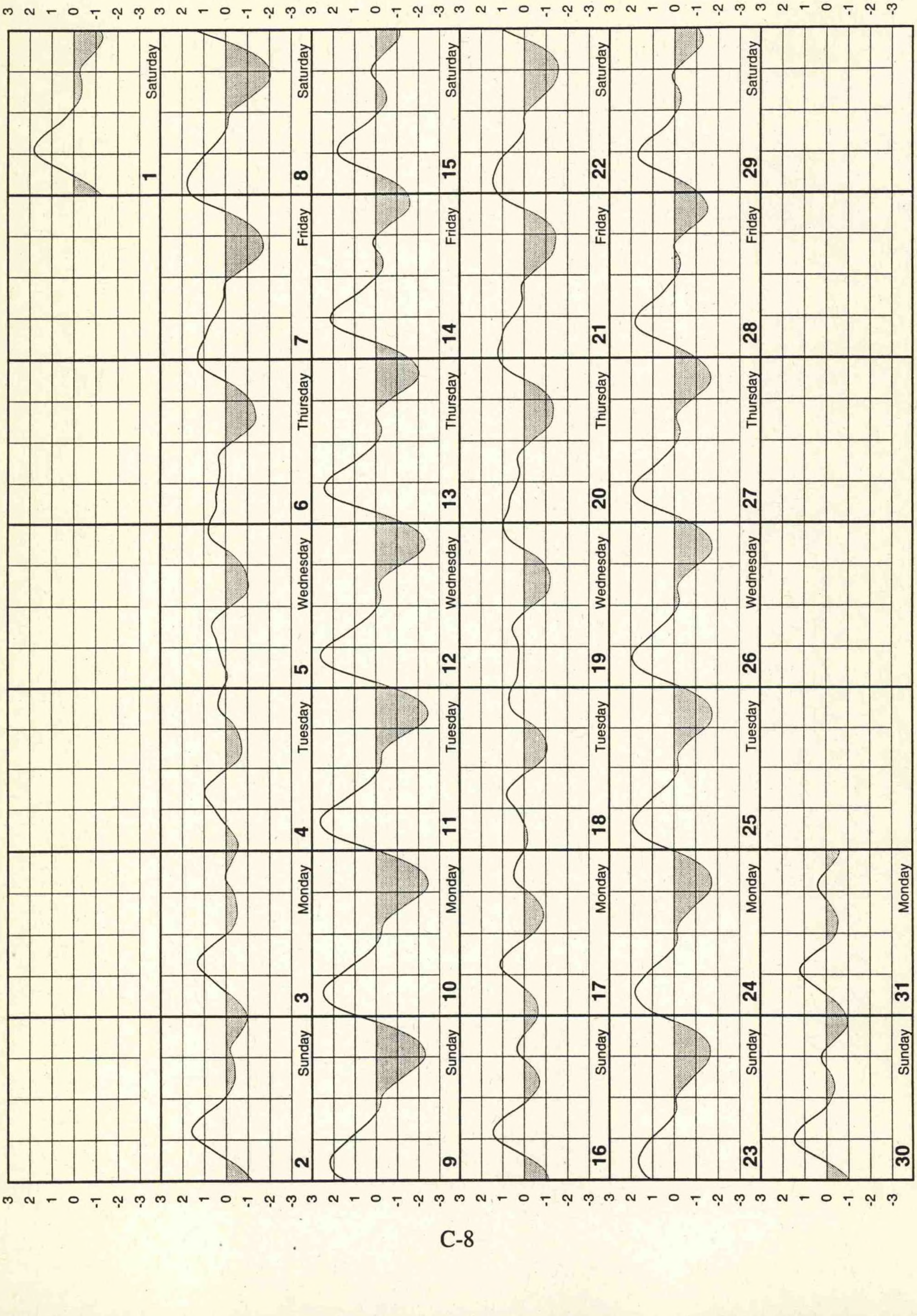
Velocity in Knots



Galveston Bay Entrance, 1995

July

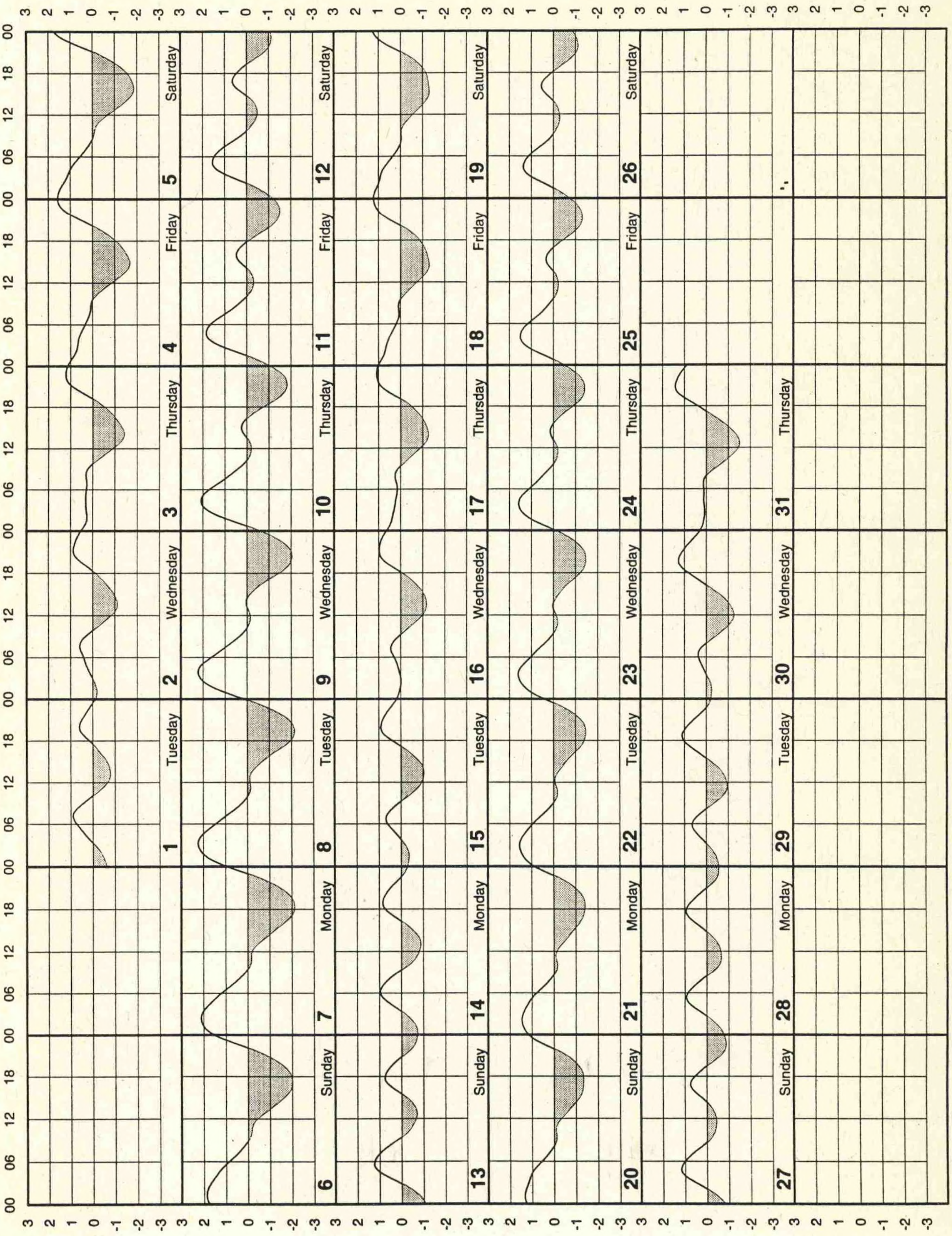
Velocity in Knots



Galveston Bay Entrance, 1995

August

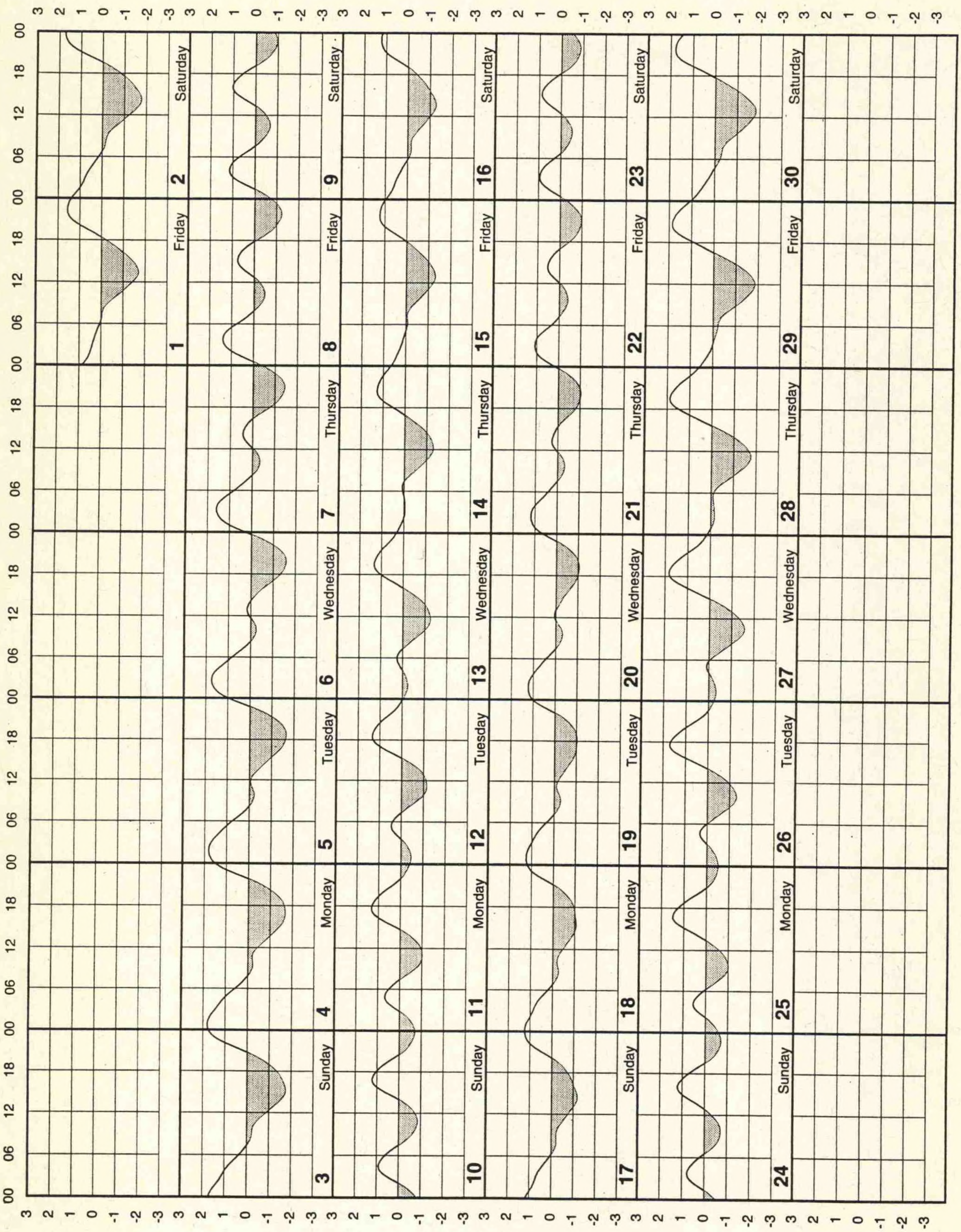
Velocity in Knots



Galveston Bay Entrance, 1995

September

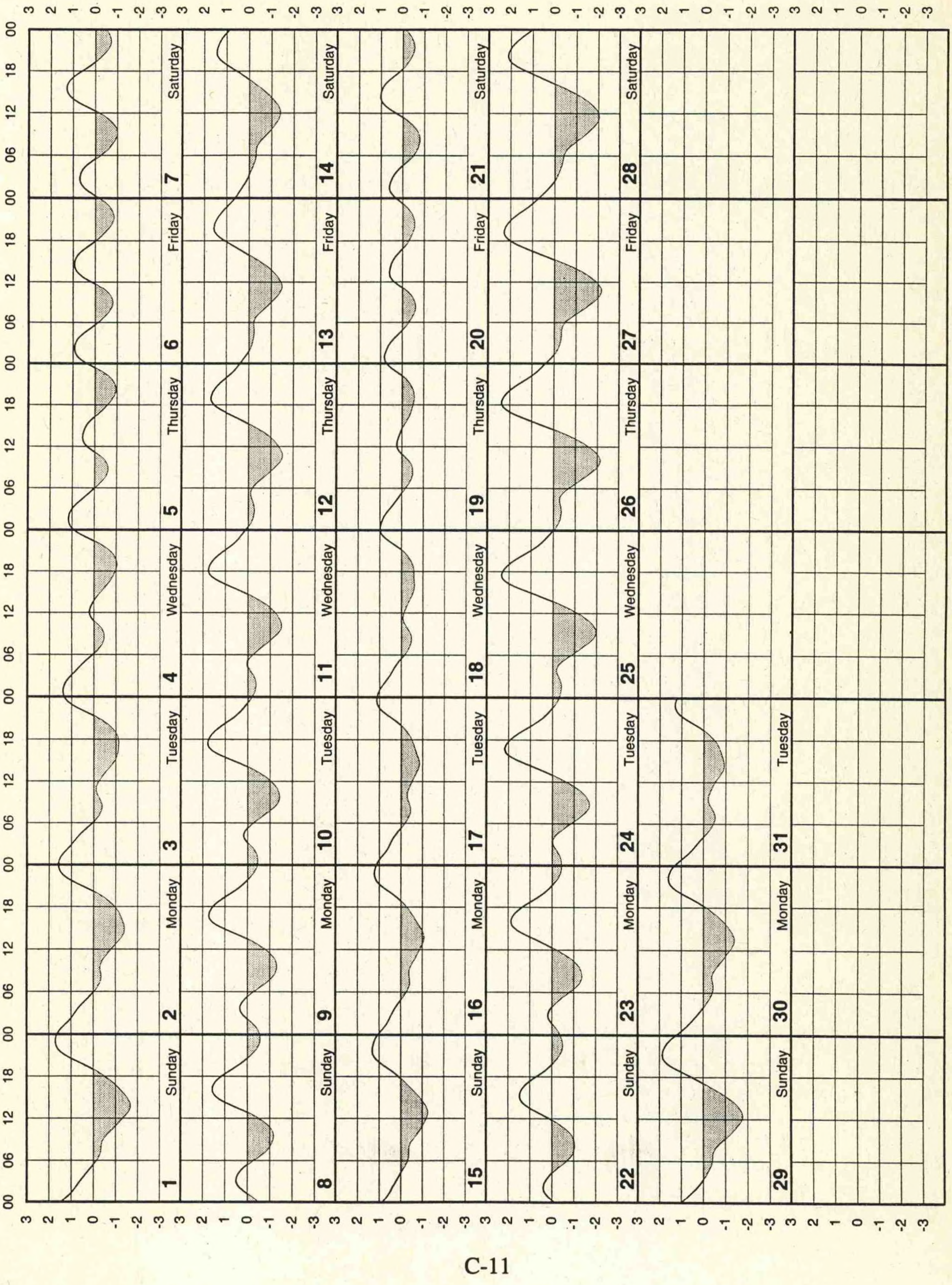
Velocity in Knots



Galveston Bay Entrance, 1995

October

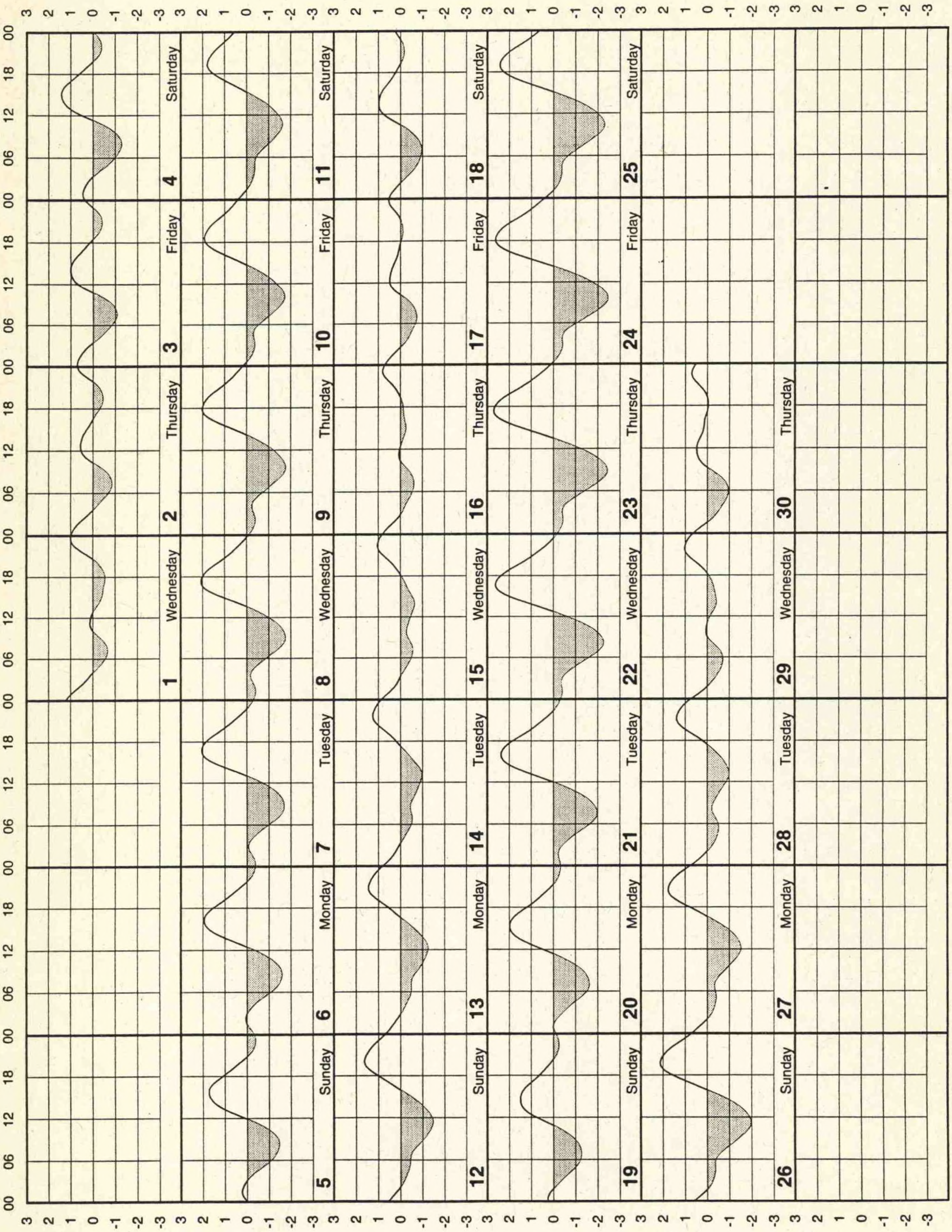
Velocity in Knots



Galveston Bay Entrance, 1995

November

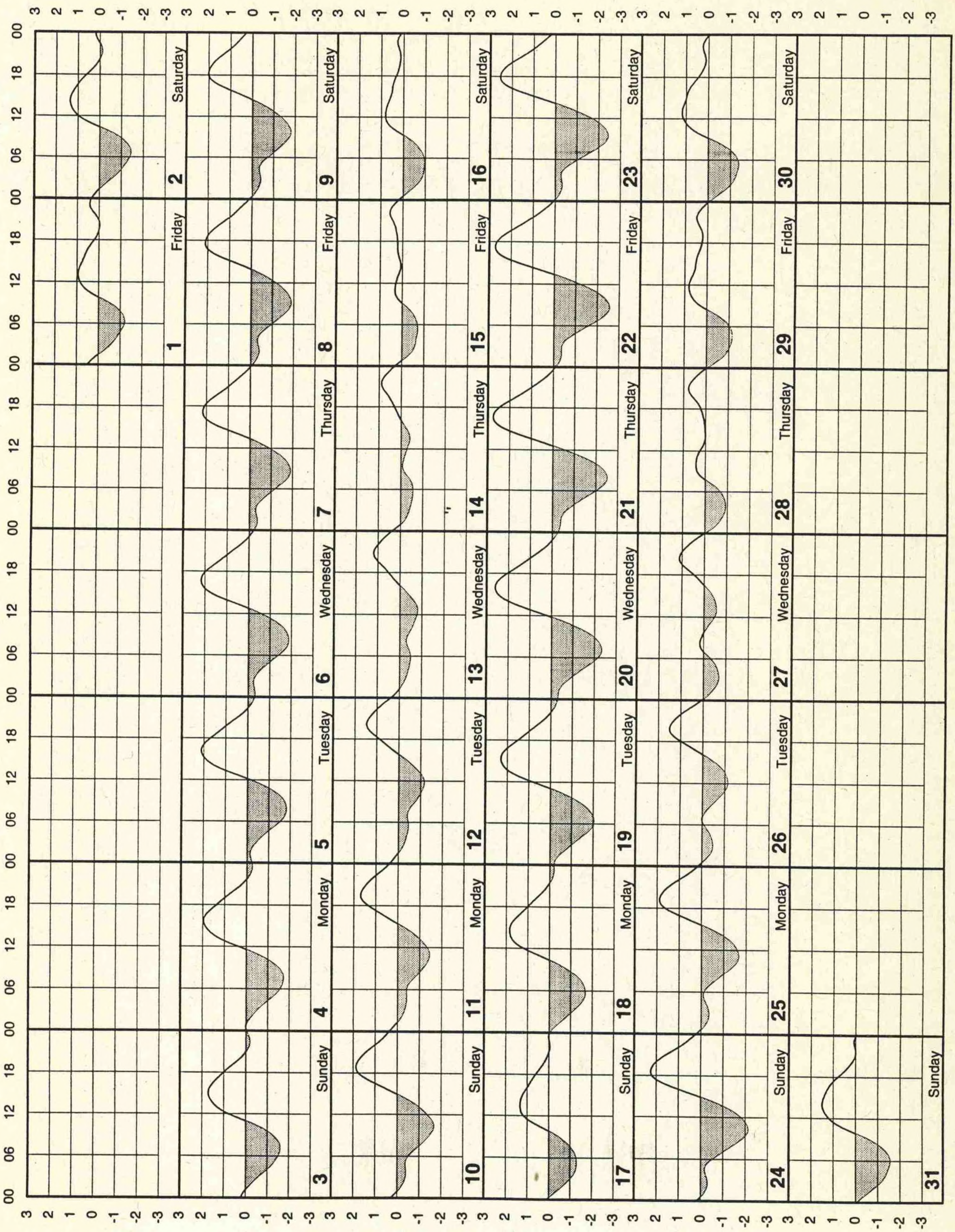
Velocity in Knots



Galveston Bay Entrance, 1995

December

Velocity in Knots



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Coastal and Estuarine Oceanography Branch
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ASTRONOMICAL DATA, 1995

January

	d.	h	m
●	1	10	56
E	6	11	..
◐	8	15	46
A	11	22	..
N	13	23	..
○	16	20	26
E	21	02	..
◑	24	04	58
S	27	12	..
P	27	23	..
●	30	22	48

February

	d.	h	m
E	2	22	..
◐	7	12	54
A	8	18	..
N	10	07	..
○	15	12	15
E	17	09	..
◑	22	13	04
P	23	02	..
S	23	19	..

March

	d.	h	m
●	1	11	48
E	2	08	..
A	8	15	..
◐	9	10	14
N	9	16	..
E	16	18	..
○	17	01	26
P	20	13	..
$\odot_1$	21	02	14
S	23	01	..
◑	23	20	10
E	29	16	..
●	31	02	09

April

	d.	h	m
A	5	10	..
N	6	0	..
◐	8	05	35
E	13	04	..
○	15	12	08
P	17	08	..
S	19	07	..
◑	22	03	18
E	25	21	..
●	29	17	36

May

	d.	h	m
A	3	01	..
N	3	07	..
◐	7	21	44
E	10	13	..
○	14	20	48
P	15	15	..
S	16	17	..
◑	21	11	36
E	23	03	..
●	29	09	27
A	30	08	..
N	30	14	..

June

	d.	h	m
◐	6	10	26
E	6	22	..
P	13	01	..
○	13	04	03
S	13	04	..
E	19	11	..
◑	19	22	01
$\odot_2$	21	20	34
A	26	11	..
N	26	20	..
●	28	00	50

July

	d.	h	m
E	4	06	..
◐	5	20	02
S	10	15	..
P	11	10	..
○	12	10	49
E	16	20	..
◑	19	11	10
A	23	20	..
N	24	04	..
●	27	15	13
E	31	12	..

August

	d.	h	m
◐	4	03	16
S	7	01	..
P	8	14	..
○	10	18	15
E	13	06	..
◑	18	03	04
A	20	12	..
N	20	12	..
●	26	04	31
E	27	19	..

September

	d.	h	m
◐	2	09	03
S	3	08	..
P	5	01	..
○	9	03	37
E	9	16	..
N	16	20	..
◑	16	21	09
A	17	06	..
$\odot_3$	23	12	13
E	24	03	..
●	24	16	55
P	30	04	..
S	30	13	..

October

	d.	h	m
◐	1	14	36
E	7	01	..
○	8	15	52
N	14	04	..
A	15	02	..
◑	16	16	26
E	21	12	..
●	24	04	36
P	26	21	..
S	27	20	..
◐	30	21	17

November

	d.	h	m
E	3	07	..
○	7	07	20
N	10	12	..
A	11	21	..
◑	15	11	40
E	17	22	..
●	22	15	43
P	23	23	..
S	24	05	..
◐	29	06	28
E	30	13	..

December

	d.	h	m
○	7	01	27
N	7	20	..
A	9	10	..
◑	15	05	31
E	15	08	..
S	21	17	..
●	22	02	22
$\odot_4$	22	08	17
P	22	10	..
E	27	21	..
◐	28	19	06

LUNAR DATA

● – new Moon
◐ – first quarter
○ – full Moon
◑ – last quarter

A – Moon in apogee
P – Moon in perigee
N – Moon farthest north of Equator
E – Moon on Equator
S – Moon farthest south of Equator

SOLAR DATA

$\odot_1$ – March equinox
$\odot_2$ – June solstice
$\odot_3$ – September equinox
$\odot_4$ – December solstice

Greenwich mean time (GMT) or universal time (UT) is the mean solar time on the Greenwich meridian reckoned in days of 24 mean solar hours written as 00^h at midnight and 12^h at noon. To convert the above times to those of other standard time meridians, add 1 hour for each 15° of east longitude of the desired meridian and subtract 1 hour for each 15° of west longitude. This table was compiled from data supplied by the Nautical Almanac Office, United States Naval Observatory.