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TEXAS A&M UNIVERSITY

# Surface Current Study, Northwestern Gulf of Mexico

by

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Project Coordinator

Study of Naturally Occurring Hydrocarbon

In the Gulf of Mexico

May 1974

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# SURFACE CURRENT STUDY, NORTHWESTERN GULF OF MEXICO

The method of determining current directions by using drift bottles has been in use for many years. The primary advantages of the drift bottle method is that it is inexpensive and relatively simple to conduct. The disadvantages are that only the drop and stranding points and the date of the drop are accurately known. The precise path of the bottle and its exact travel time will never be known and the time of the pick up represents a maximum travel time. In sparsely populated areas the bottle may have lain undiscovered for some time. However, by assuming straight line travel paths minimum average velocities can be determined which, while not exact, will give reasonable insights into surface current velocities and directions over the general area being considered.

Drift bottles in batches of 48 were dropped at the following locations and times:

| | | |
|---|---|---|
| 28°08.8'N, 92°49'W | 29 March 1973 | (Figs. 1, A&B) |
| 28°09.0'N, 92°41.4'W | 1 October 1973 | (Fig. 2) |
| 28°09.8'N, 91°48.6'W | 3 October 1973 | (Fig. 3) |
| 28°22.4'N, 92°35.1'W | 8 October 1973 | (Fig. 4) |
| 27°52'N, 85°55'W | 9 October 1973 | (Fig. 5) |

For the purposes of this report the drops shall be referred to as numbers 1, 2, 3, 4 and 5 in the chronological order listed above.

Twenty-four bottles were recovered from drop 1. The spread of the recovery extended from Bermuda Beach, Galveston, on the north to a beach near Matamoros, Mexico, on the south.

The first bottle was found at San Luis Pass south of Galveston 24 April, 26 days after the drop. This was the shortest straight line distance to the coast, 180 nautical miles. Eight more bottles were found along Galveston Island from the 2nd through the 5th of May. The remaining bottles were found in a nearly chronological succession down the coast extending from Pass Cavallo at the south end of Galveston Island to a beach in northern Mexico.

Examination of the geographical distribution and travel times of bottles recovered from drop number 1 suggests that probably two major drift paths were followed from drop point to strand points (Fig. 1A).

One group of bottles followed a general northwesterly path stranding along Galveston Island. The second group followed a more southwesterly path stranding from Matagorda Island south to Old Mexico.

Assuming straight line travel paths for first arrivals the travel distance and time to San Luis Pass, Galveston Island, was 180 nautical miles in 26 days. This would require a current of 14 cm/sec or 0.3 knots. The first bottle from the second group was recovered from Matagorda Island 255 miles from the drop point 34 days after release. A current of 16 cm/sec or slightly over 0.3 knots was required.

An alternative hypothesis is to assume that all bottles traveled toward Galveston and at some point near there one group of bottles was carried south along the coast. However, this would require a coastwise current of about 33 cm/sec or 0.6 knots as one bottle would have had to traverse about 165 nautical miles in 11 days (Fig. 1B).

Drop number 2 was made on the 1st of October 47 nautical miles west of drop point 1. Fourteen bottles were recovered. The geographical spread was much less than from drop 1. Extreme points of discovery ranged from ten miles west of the Colorado River to 55 miles south of Corpus Christi on Padre Island. The first bottle was recovered on the 30th of October at a point 30 miles south of Bob Hall Pier on Padre Island. This is a straight line distance of 240 nautical miles from the drop point. The second bottle was recovered a day later 40 miles north of the first recovery. On the 2nd of November a third bottle was found 30 miles north of the second bottle. Two days later a fourth bottle was found five miles north of bottle 3. On the 8th of October two more bottles were found 15 and 50 miles farther north along the coast. There appeared to be a progressive south to north stranding of bottles over a 10 day period. The last mentioned bottle represented the northernmost stranding and also the closest point to the drop location, a distance of 175 nautical miles.

In assessing the surface current pattern from this drop it appears that the bottles drifted southwest and then were distributed up the coast by a northward flowing coastal current. Later strandings occurred within the two extremes discussed except for one bottle found 20 miles south of the first stranding 25 days later.

If it is assumed that the first bottle to strand took a straight travel path from drop point to stranding point it drifted to the southwest at a velocity of 18 cm/sec.

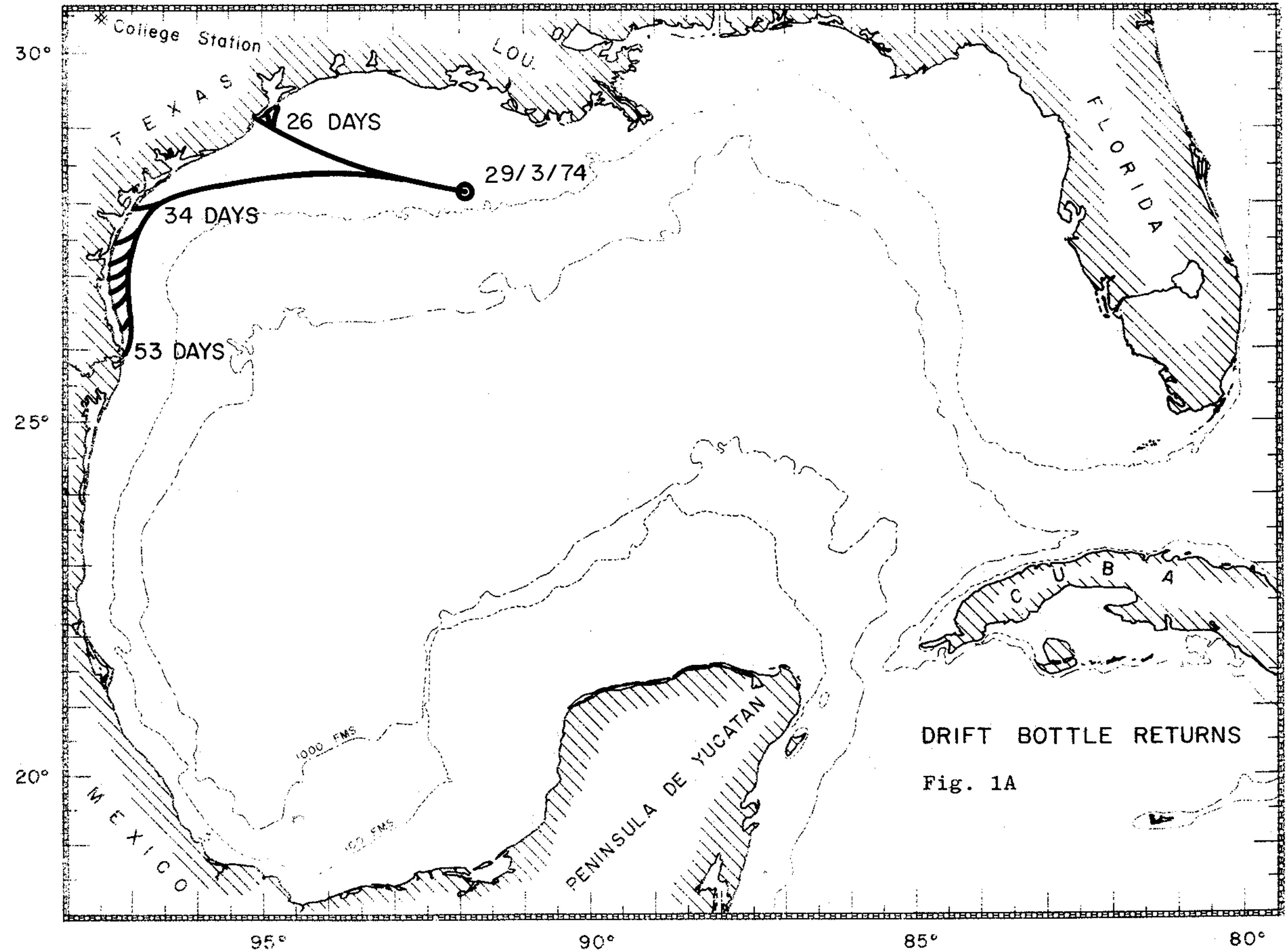
Computed wind stress currents indicate that there is a general westerly onshore current during the month of October. Drift bottle studies by Watson and Behrens (1970) for October 1967, and by Hunter et al. (1973, unpublished manuscript) for October 1972, indicate a general southwest flow of surface currents for this area extending to 30 miles offshore.

The studies by Watson and Behrens (1970) and Hunter et al. (1973) also show a more extensive southward drift than can be explained by Ekman currents. Hunter et al. (1973) suggest that this anomalous southward flow may in part be due to a "coastal jet" as described by Csanady (1967, 1968) and others.

Drop number 3 was made on the 3rd of October 1973 at approximately the same location as drop 1. Forty-eight bottles were dropped and thirty were recovered for a high recovery rate of 63%. The bottles were distributed along the Texas coast from Sargent Beach on the north to seven miles north of Andy Bowie Park on south Padre Island. The first bottle was found on Sargent Beach 10 November 1973, a straight line distance from drop point of 200 miles which requires an average velocity of 11 cm/sec. Twenty-four bottles stranded along a segment of coast extending from north Padre Island to the north end of Matagorda Island. Twenty-one of the bottles were found within a seven day period. Seven bottles were recovered on the 18th of November and five on the 21st of November. For both dates there was a spread of at least 60 miles between the northernmost and the southernmost strandings. The bottles from drop 3 did not display the apparent northward coastal drift illustrated by the early sequence of bottles from drop 2.

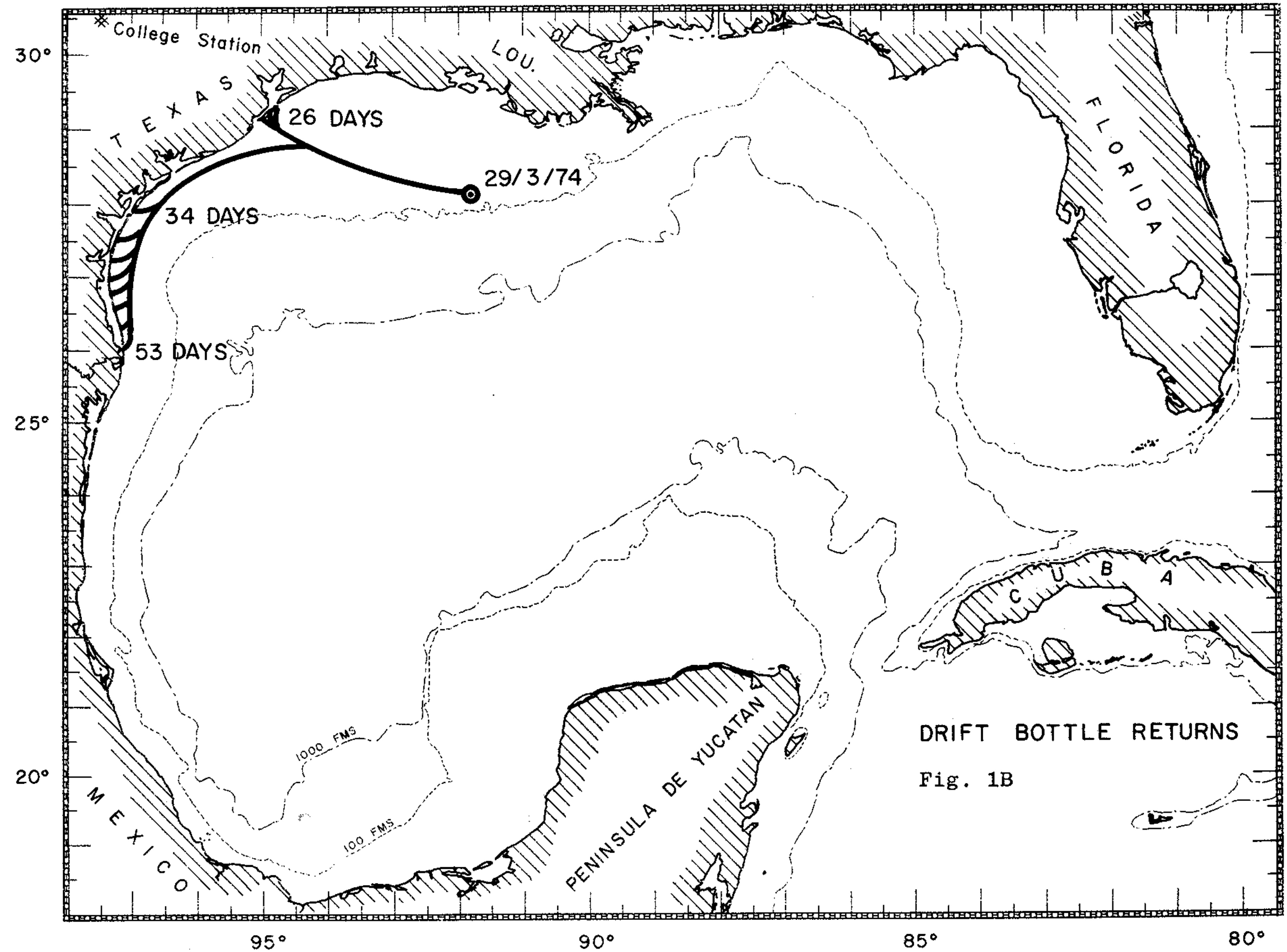
Drop number 4 on the 8th of October had only a 12% recovery. The first recovery was made on the 9th of December 1973, two and one-half miles south of the Mansfield Cut on Padre Island. This is a straight line distance of 265 miles and requires a 18 cm/sec current to the southwest. The other bottles were recovered from St. Joseph and Matagorda Islands from 80 to 120 miles north of the first recovery. If straight line travel paths are assumed for these later recoveries then the bottles on St. Joseph Island traveled at a velocity of 10 cm/sec in a slightly southwesterly direction and the bottles on Matagorda Island traveling the shortest distance drifted nearly due west at 9 cm/sec.

Drop number 5 was made in the eastern Gulf. Three bottles were recovered, one near Pensacola and two from the Keys, one as far around as Marathon. Other more definitive studies



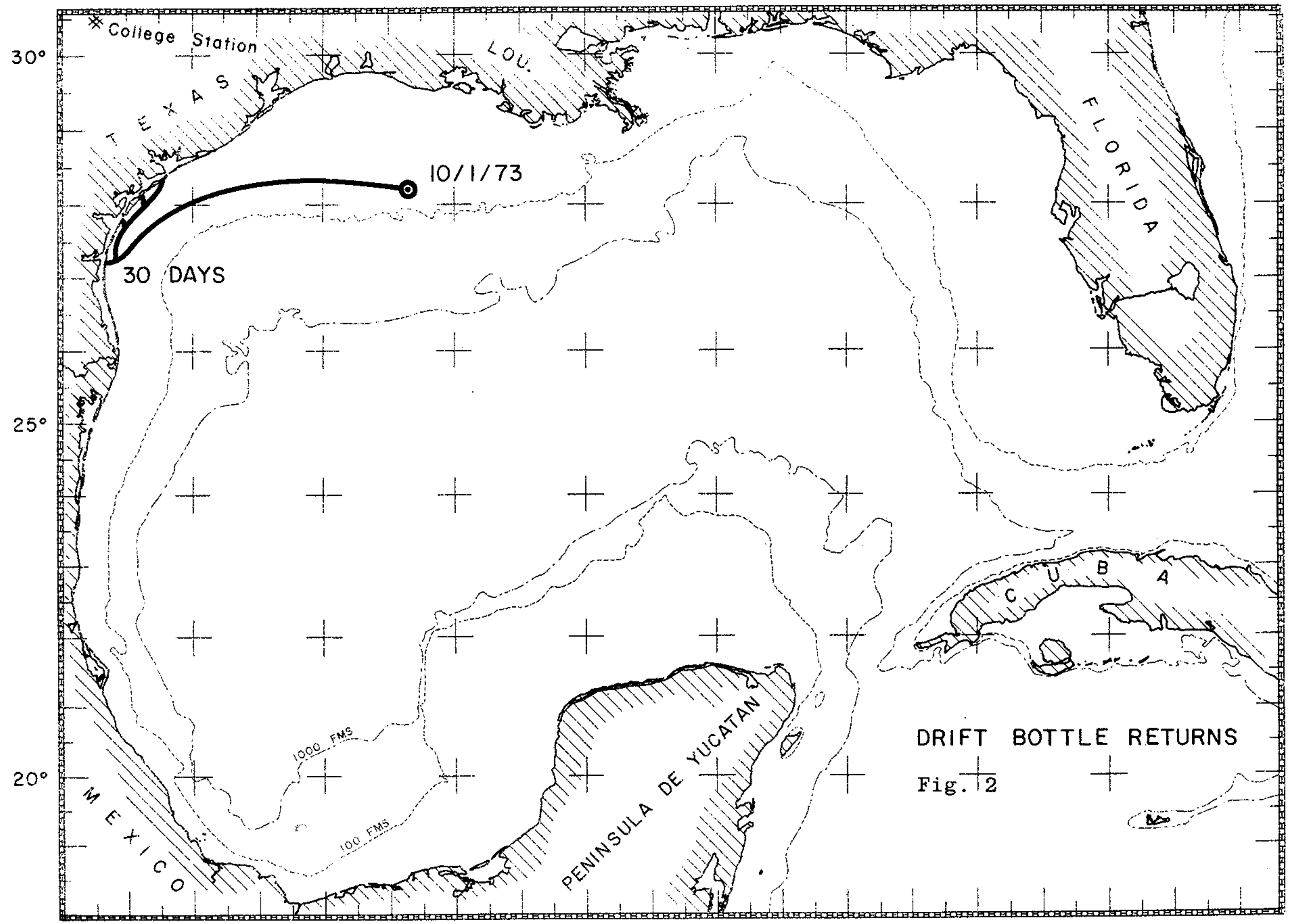

DRIFT BOTTLE RETURNS

Fig. 1A

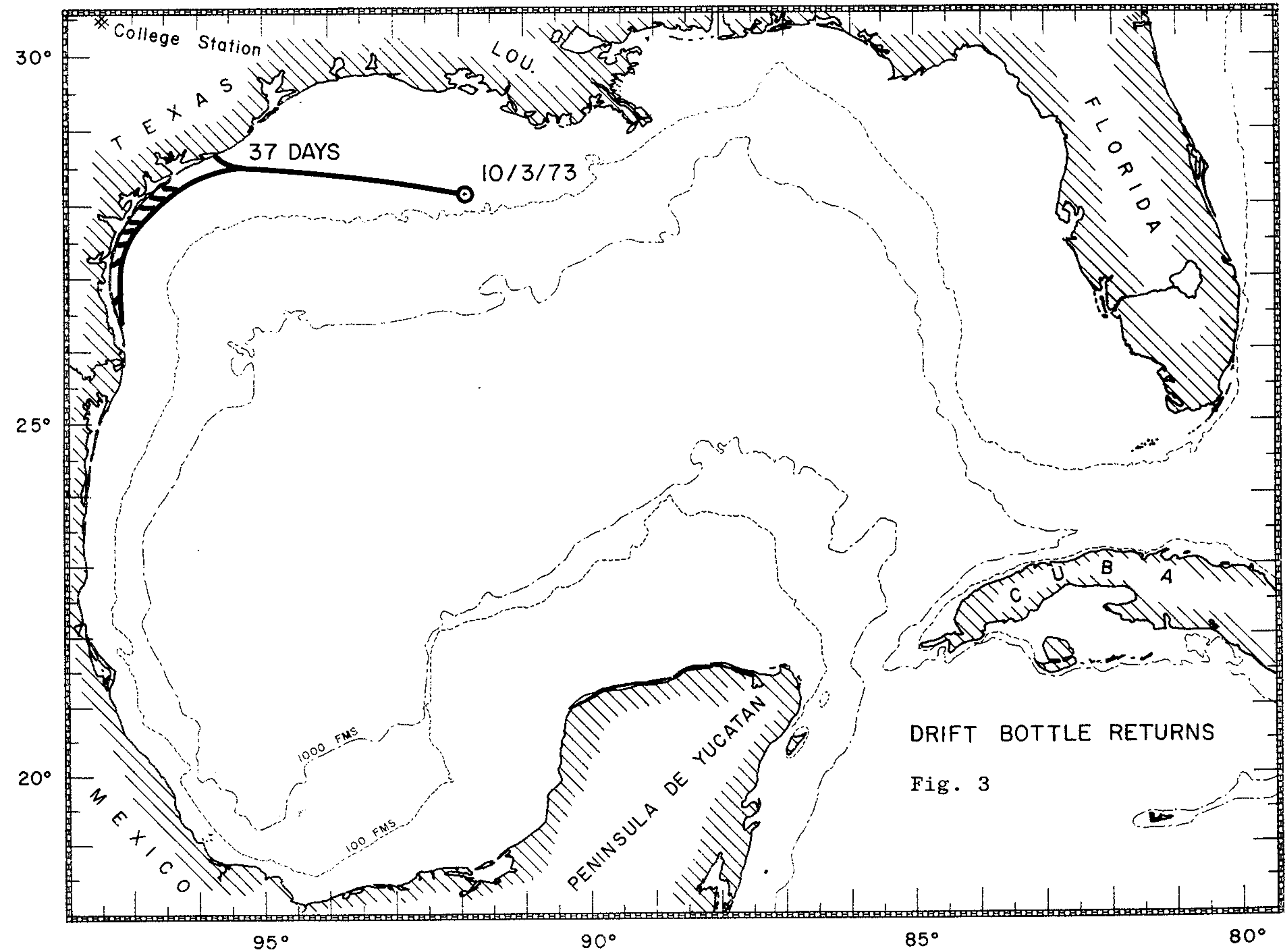



DRIFT BOTTLE RETURNS

Fig. 1B

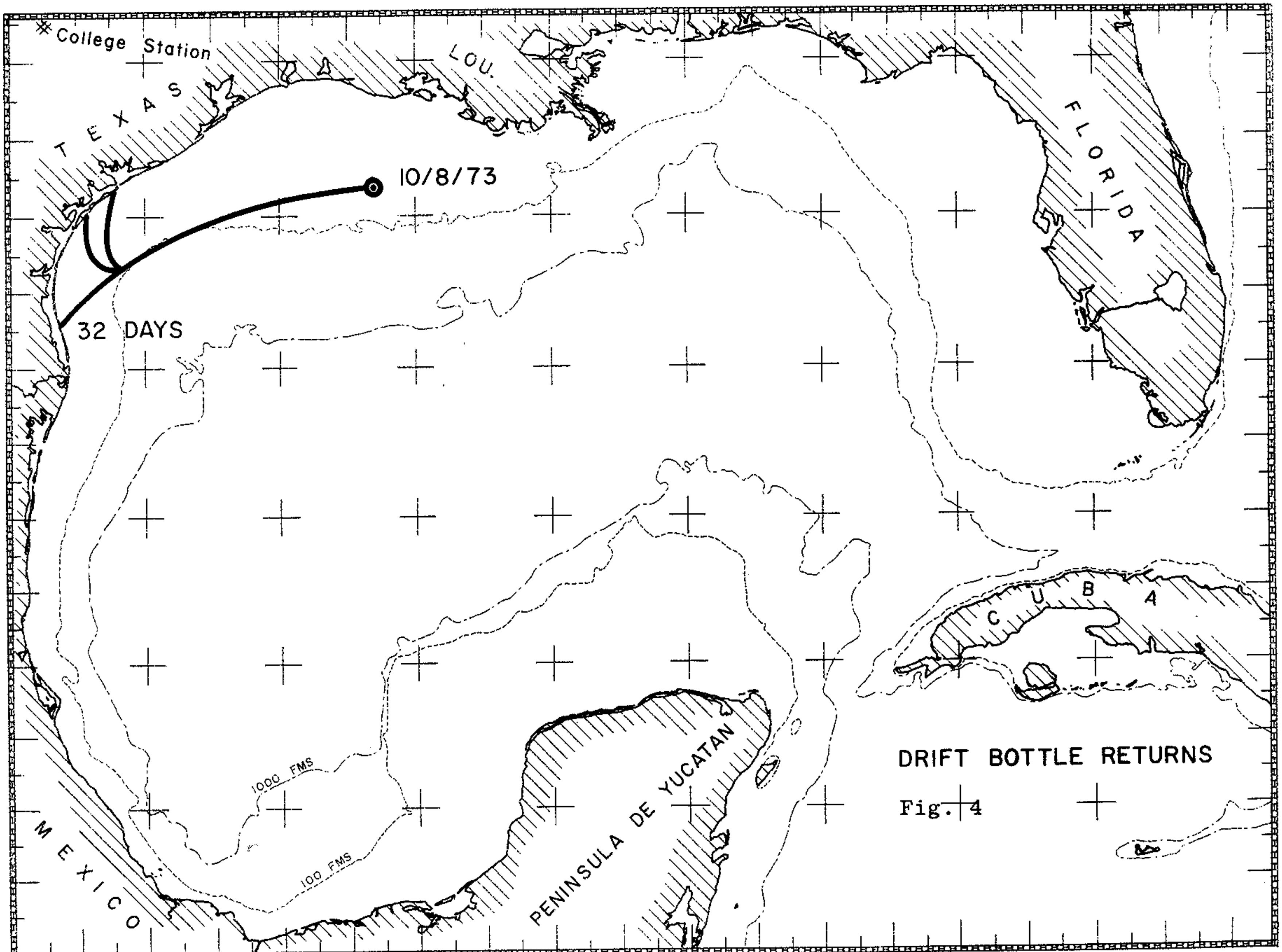



DRIFT BOTTLE RETURNS
Fig. 2



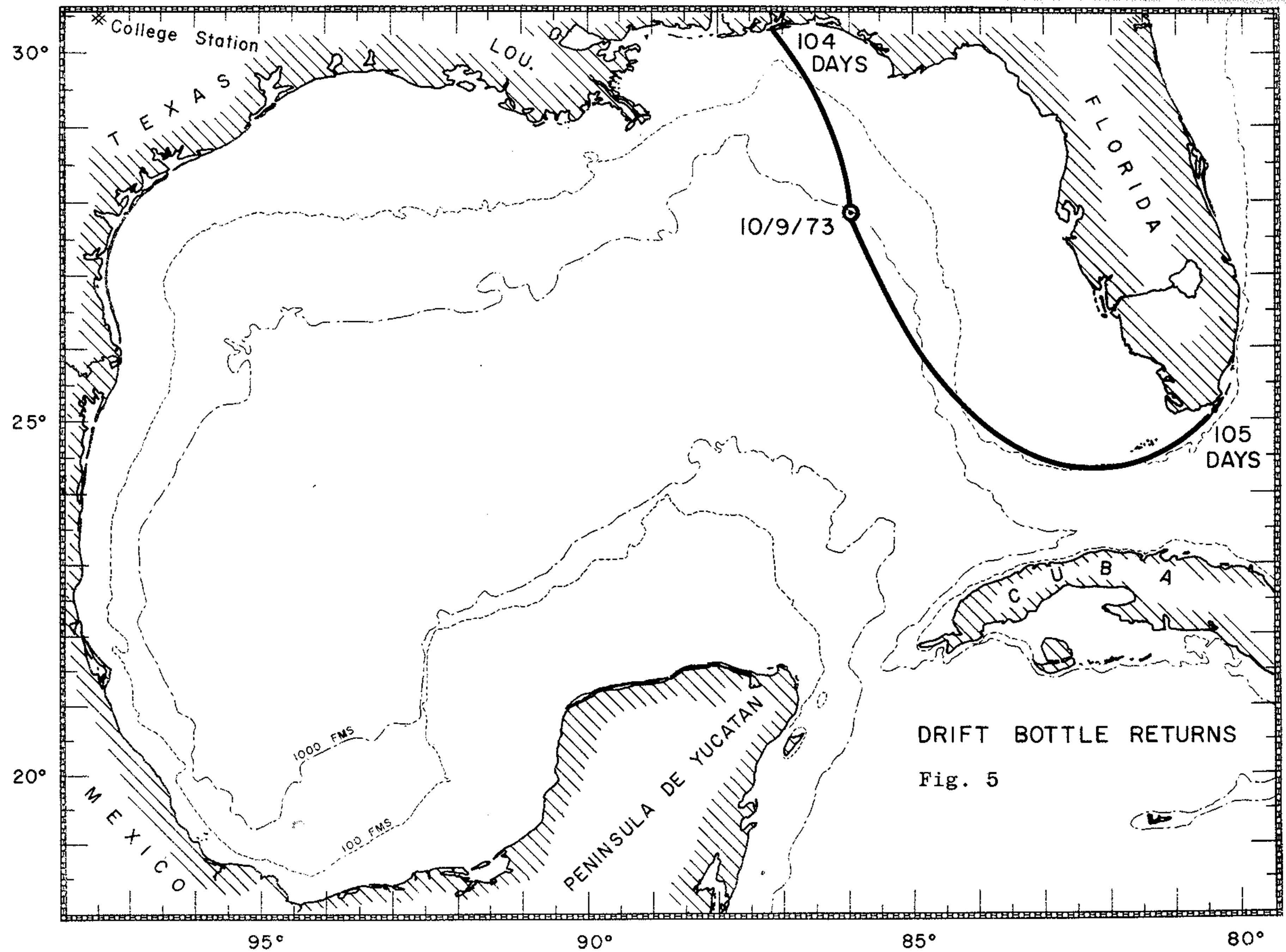

DRIFT BOTTLE RETURNS

Fig. 3




DRIFT BOTTLE RETURNS

Fig. 4




DRIFT BOTTLE RETURNS

Fig. 5

have been made in the eastern Gulf and will not be discussed here. For further information concerning currents in the eastern Gulf see Ichiye et al., 1973. The study also contains an annotated bibliography.

## WIND DRIVEN CURRENTS, WESTERN GULF OF MEXICO

A study of the surface currents in the western Gulf was undertaken to determine the general direction of transport of hydrocarbons floating on the surface.

Wind blowing across open water will set the water into motion and if the wind direction and intensity are maintained for 24 hours or longer a steady current speed and direction develops. Theoretical and experimental relationships between the wind and the induced current have been established by several researchers. Ekman (1906) formulated a theory for stationary wind driven currents. According to theory the rotation of the earth causes the surface water to move to the right of the wind direction at a 45° angle in the northern hemisphere in deep water. The deflection is known as the Coriolis effect. In the southern hemisphere the deflection is to the left of the direction of wind movement.

The Coriolis coefficient is defined as $2 \omega \sin \phi$ where $\omega$ is the angular velocity of earth's rotation and $\phi$ the latitude. Thus, the Coriolis force varies with the latitude, decreasing toward the equator.

The surface current velocity is given by:

$$V_o = \tau(2A\omega \mathrm{Sin}\phi)^{-\frac{1}{2}} \tag{1}$$

where $\tau$ is the wind stress and A the eddy viscosity.

The wind stress $\tau$ is obtained from monthly wind stress charts published by Franceschini (1953). The charts represent monthly mean wind stresses for $2^o$ squares in the Gulf of Mexico. Two assumptions are made in determining surface currents from the wind stress. First, the stationary state of the wind, second, that the ocean is deeper than the thickness of the Ekman, or wind-effected layer, which is 50-100 m. In water depths less than this the angle between wind and current direction would be less than $45^o$ and the velocity less than calculated. However, with the exception of the small segment off Matagorda Island the mean water depth for the remaining $2^o$ squares is probably deep enough to neglect depth corrections.

Following the work of Ichiye et al. (1973), A will be taken as equal to 100 $cm^2$/sec. They state that it is a reasonable value when compared with those determined in the ocean (Defant, 1961). However, since A can vary by one or two orders of magnitude depending upon wind speed, duration and vertical density stratification they present a graph (Ichiye et al., Fig. 2-13, 1973) of $V_o$ with A = 100 $cm^2$/sec vs different values of A.

The surface currents have been computed using formula

(1). These have been plotted by month as Figs. 6-17. The arrow shows the mean current direction and its length is proportional to the velocity. When the vector is very small a dashed line is used to indicate direction. In cases where the arrow is excessively long the shaft has been broken and shortened. The speed in cm/sec is given by the number in the square.

The Ekman surface currents for the month of January in the western Gulf of Mexico flow predominantly to the south and west. There are several exceptions along latitude $25^{\circ}$N where north and northwest currents are indicated. Current flow along the Louisiana-Texas coast is to the southwest. Current flow in the block immediately south of the Rio Grande is to the north-northeast. Current flow along the remainder of the Mexican coast down to its southernmost point is south-southwest. The current flow changes to a more southwesterly direction along the southern coast and finally to a direction north of west at the north end of the Yucatan Peninsula.

Current velocities along the Louisiana-Texas coast vary from 3.1 to 9.6 cm/sec, averaging 5.8 cm/sec.

In February the coastal currents in the northern Gulf vary from south at the delta to west then south-southwest and finally north in the Galveston area. Continuing down the Texas coast the flow is north by northwest. South of the Rio Grande and around to the southern half of the Yucatan Peninsula the flow is south. For the central part of the western half of the Gulf the flow is predominantly westward varying from southwest to northwest.

Coastal current velocities in the northwest Gulf along the Louisiana coast range from 1.8 to 5.7 cm/sec. Along the Texas coast the velocity varies from 2.1 cm/sec in the south to 1.7 cm/sec in the north.

In March most of the current flow in the western Gulf is to the northwest. Flow along the Louisiana, Texas and Mexican coasts varies from west to southwest down to the block immediately east of Vera Cruz. Eastward and up the Yucatan Peninsula the flow is to the northwest. The coastal block south of the Rio Grande also flows northwest opposing the rest of the coastal flow.

The velocity of coastal flow along the Louisiana-Texas coast ranges from 1.2 to 42.8 cm/sec. The extremely high reading for the south Texas coast may be questioned as a monthly average since it is based on only two observations. Average current velocity excluding the south Texas coast is 4.0 cm/sec.

For April most of the offshore current flow is to the northwest. Coastal currents flow from southwest to west. Flow along the south Texas coast is to the north, but this again is based on only three observations and may not represent an average monthly flow. Current velocities along the Louisiana-Texas coast range from 3 to 9.3 cm/sec averaging

5 cm/sec. Current flow directions in the coastal blocks is almost at right angles to current flow in the more offshore blocks. That is southwest vs northwest.

In May the dominant current direction is northwest and west. Currents along the Louisiana-Texas coast are northwest and west ranging from 0.6 cm/sec off the delta to 19.9 cm/sec along the south Texas coast. Current velocities along the south Texas coast were based on only four observations and may not represent a true monthly average. The figure for the Matagorda Island section is based on a single observation and certainly is not representative. The currents along the northern coast average 3.3 cm/sec.

In June all surface wind currents in the western Gulf flow to the northwest. Coastal currents along the Louisiana and north Texas coast average 1.6 cm/sec except for the western delta block where the velocity is 11.7 cm/sec. The velocity along the south Texas coast is 9.2 cm/sec based upon four observations.

In July the general current direction in the western Gulf is northwest and north. Currents along the Louisiana-Texas coast range from north-northeast to north. Velocities range from 0.6 cm/sec to 2.1 cm/sec, averaging 1.3 cm/sec. All current velocities in the western Gulf are reduced from previous months.

In August all currents are flowing northwest. Louisiana-Texas coastal currents flow northeast toward the shore and range in velocity from 0.7 cm/sec to 2.0 cm/sec averaging 1.1 cm/sec. A high reading of 8.6 cm/sec off Matagorda Island is based upon only three observations and may not be truly representative.

During September current velocities increase. The general flow direction is west to northwest with some southern flow along the Mexican coast. Flow along the Louisiana-Texas coast is west-northwest. Current velocities range from 0.7 to 3.9 cm/sec averaging 2.2 cm/sec.

By October average current velocities have increased to 8.3 cm/sec vs 4.4 cm/sec for September. Currents in the western central Gulf vary from south-southwest to west and north-northwest. Currents along the Louisiana and north Texas coast are west to southwest from 1.7 to 6.0 cm/sec averaging 4.1 cm/sec. The current along the south Texas coast is northwest at 4.2 cm/sec.

During November the dominant current flow direction in the western Gulf is west and southwest with notable variations along the coasts. The current flow along the Louisiana-Texas coast varies from southwest, to west, to northwest and then north-northeast at Galveston. The current velocities vary from 1.1 to 8.2 cm/sec. Along the south Texas coast the current flows southwest at 11.4 cm/sec. Immediately south of the Rio Grande the current is northwest at 5.6 cm/sec.

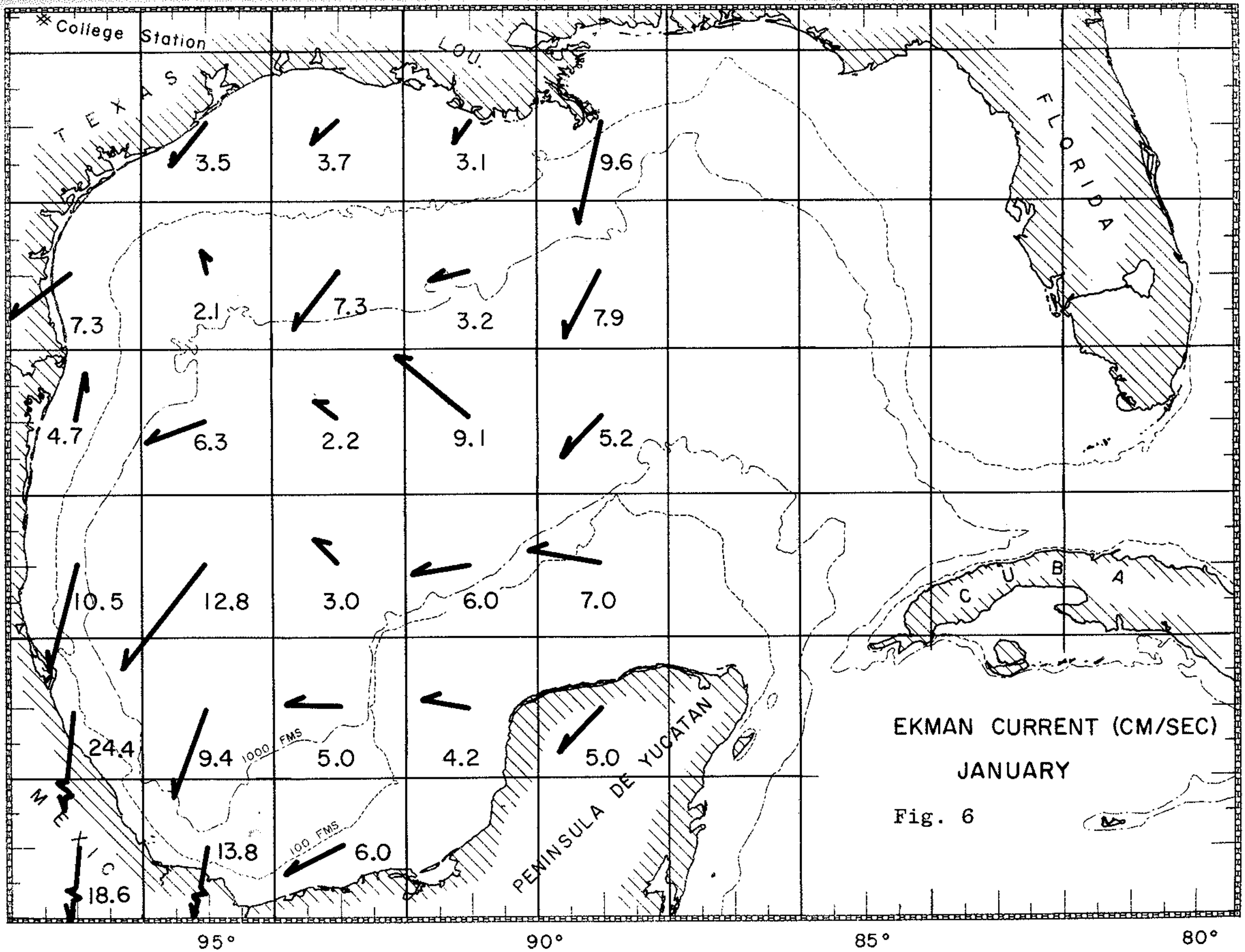
During December currents in the northern part of the Gulf are to the southwest except along the south Texas coast where flow is to the northwest. Currents in the central portion of the Gulf flow to the northwest and along the Mexican coast the flow is to the south. Current velocities along the Louisiana-north Texas coast ranges from 4.3 to 6.8 cm/sec, averaging 5.2 cm/sec. Current flow along the south Texas coast is to the northwest at 1.4 cm/sec.

Ekman current velocities vary considerably among the $2^{\circ}$ squares in the western Gulf of Mexico during any given month. A study of monthly average velocities also reveals significant seasonal current velocity variations (see Table 1). Table 2 presents current direction frequencies for the Gulf of Mexico west of longitude $88^{\circ}$ west.

Table 1 indicates that maximum current velocities are attained during the fall, winter and early spring and drop considerably during the summer months.

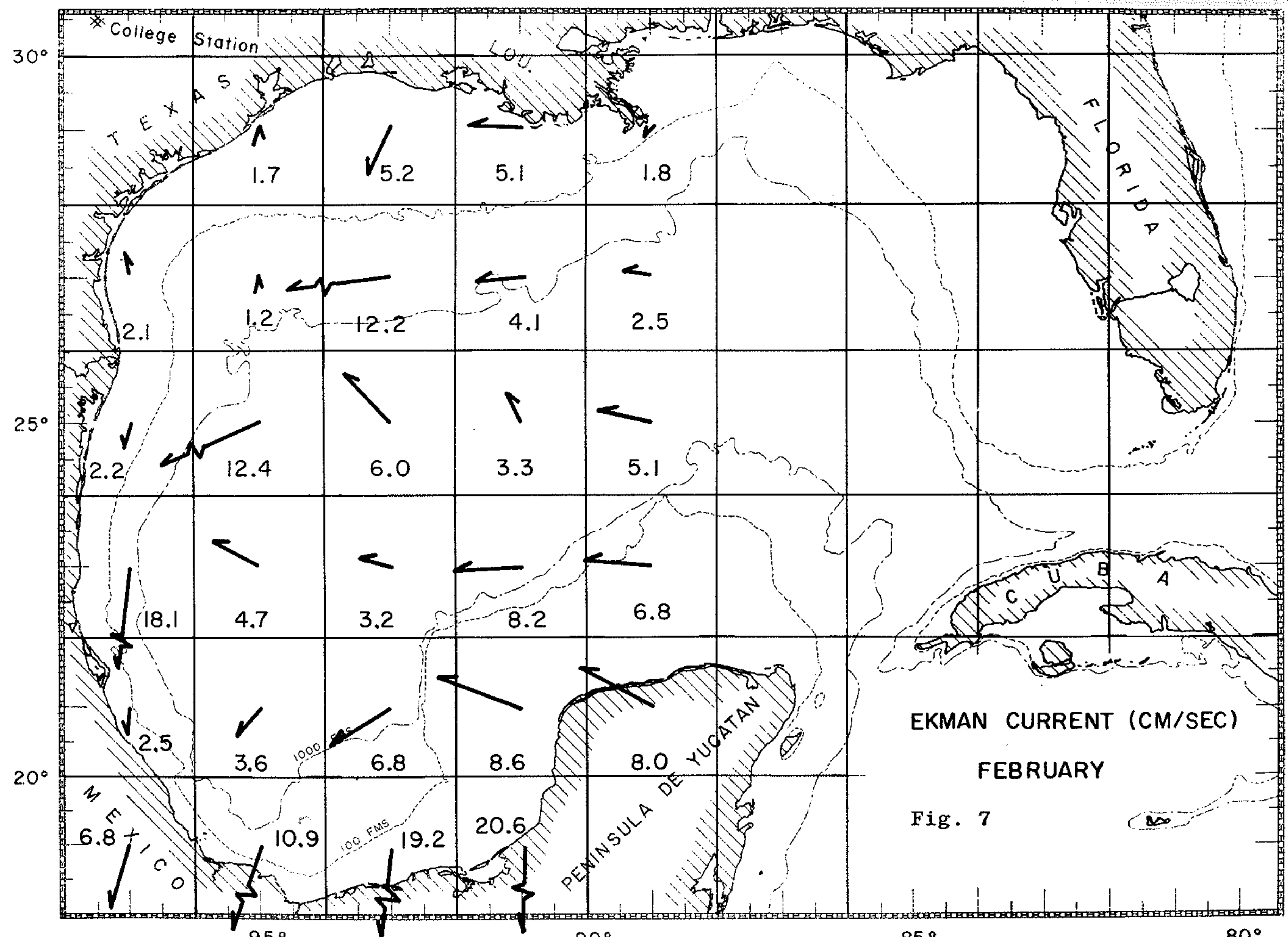
Table 2 shows that southwesterly currents dominate the surface flow from October through February. Northwesterly currents dominate from March through September.

It is pertinent to note that during the months when southwest currents predominate, northwest current flows do occur with significant frequency. However, during the summer months northwest flow accounts for 90% or more of the current direction except for July when some currents in the northern third of the area have rotated into a north-northeast direction.

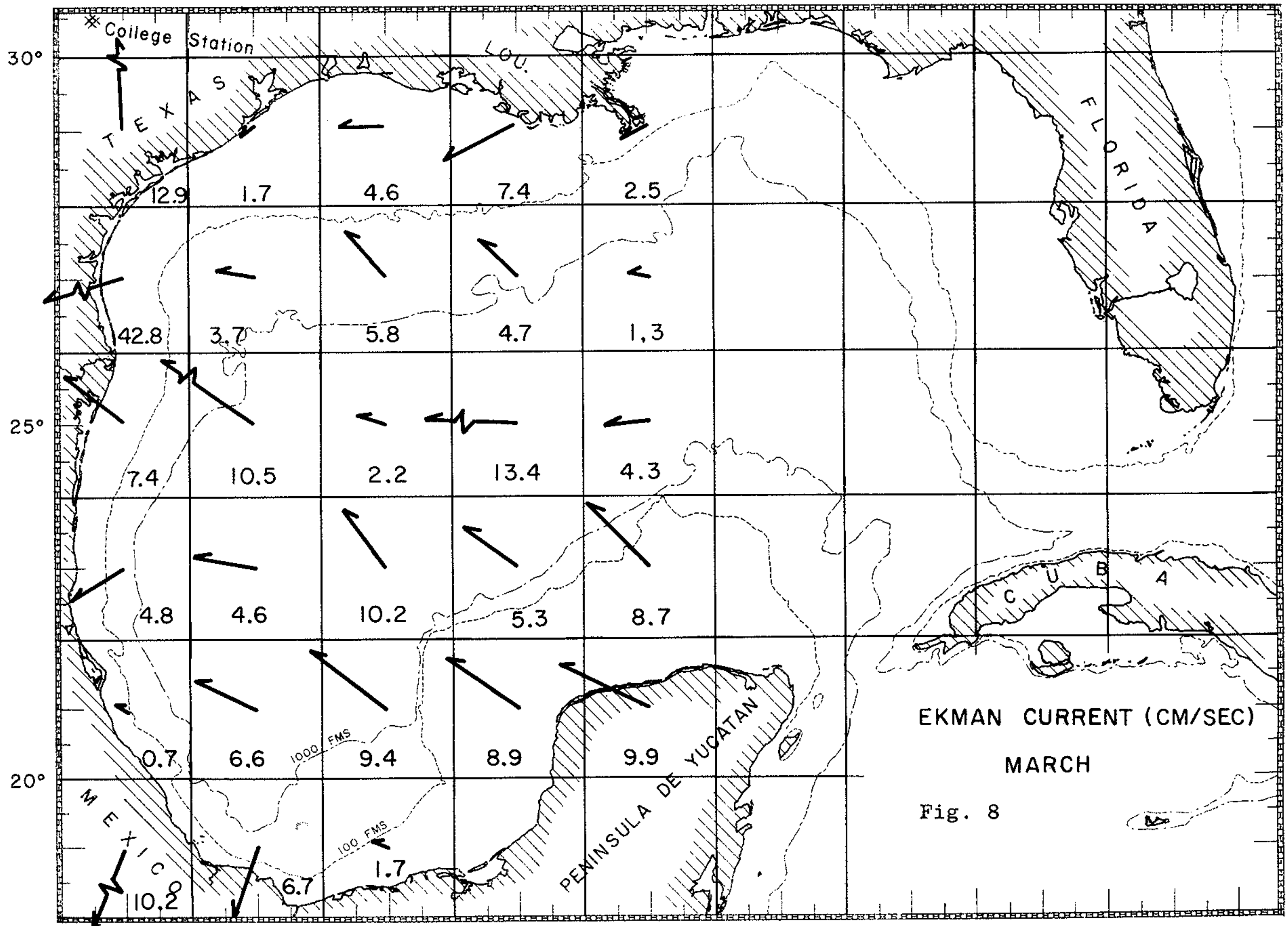



EKMAN CURRENT (CM/SEC)
JANUARY

Fig. 6



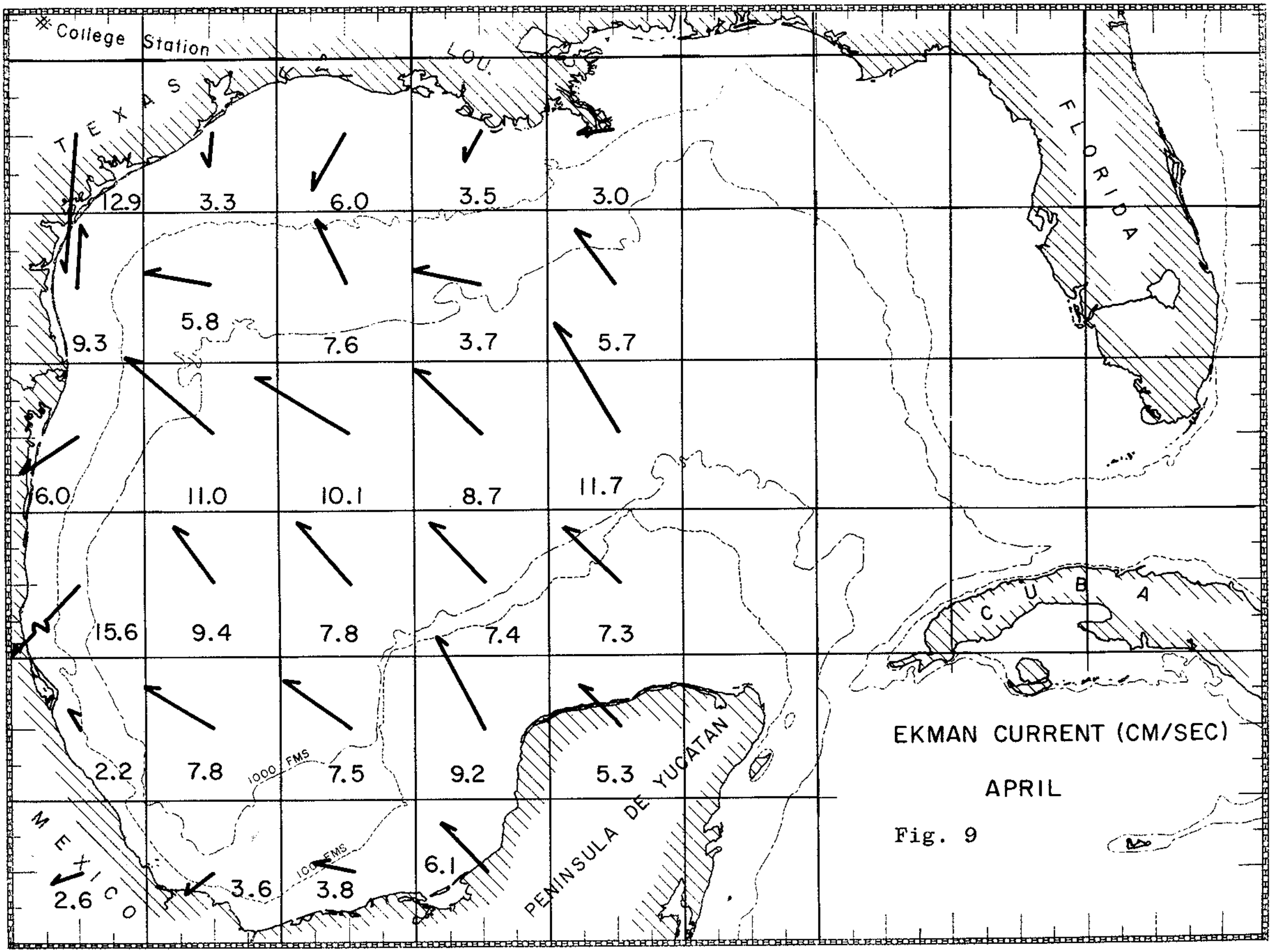

EKMAN CURRENT (CM/SEC)
FEBRUARY
Fig. 7




EKMAN CURRENT (CM/SEC)

MARCH

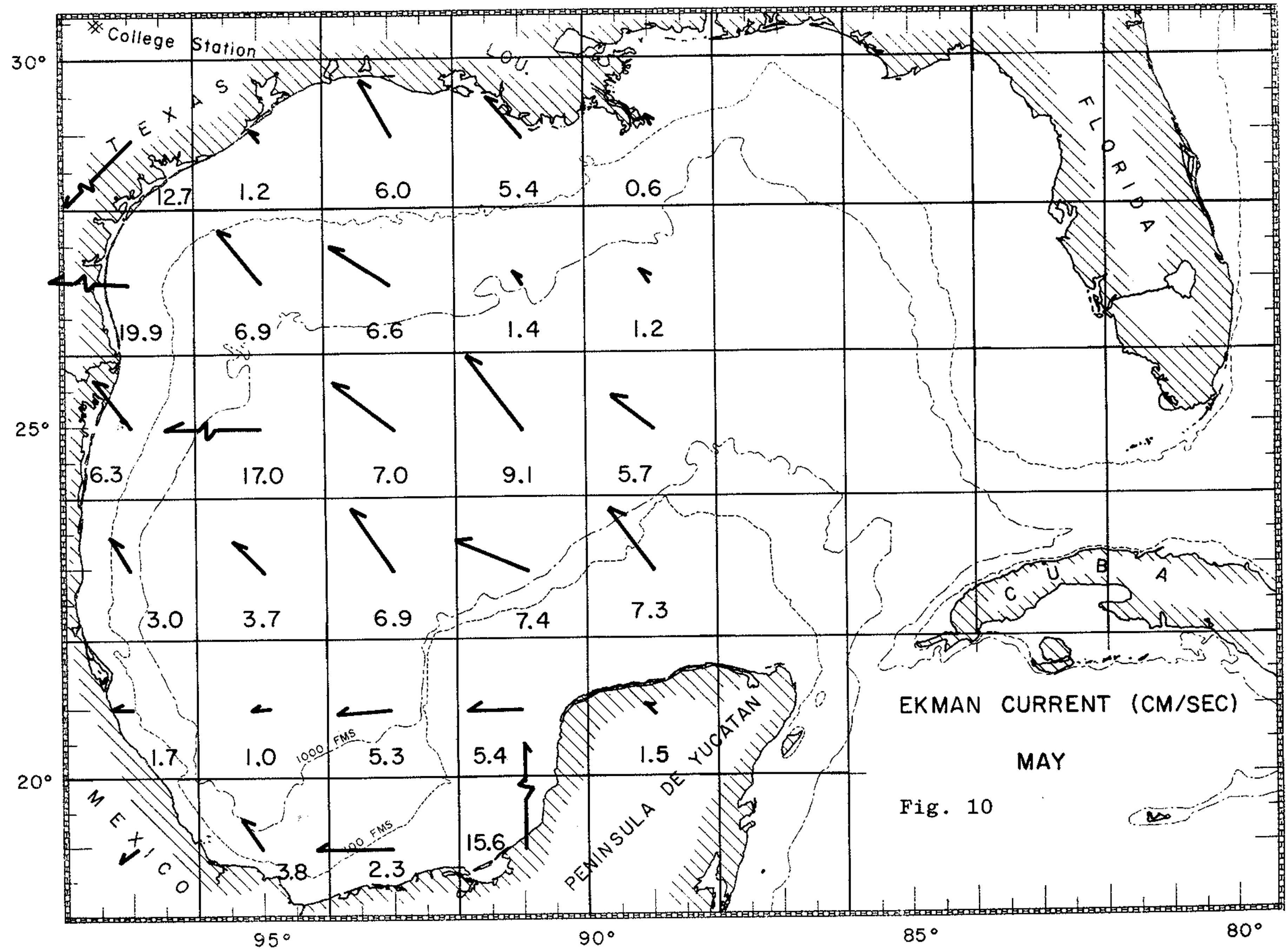
Fig. 8




EKMAN CURRENT (CM/SEC)

APRIL

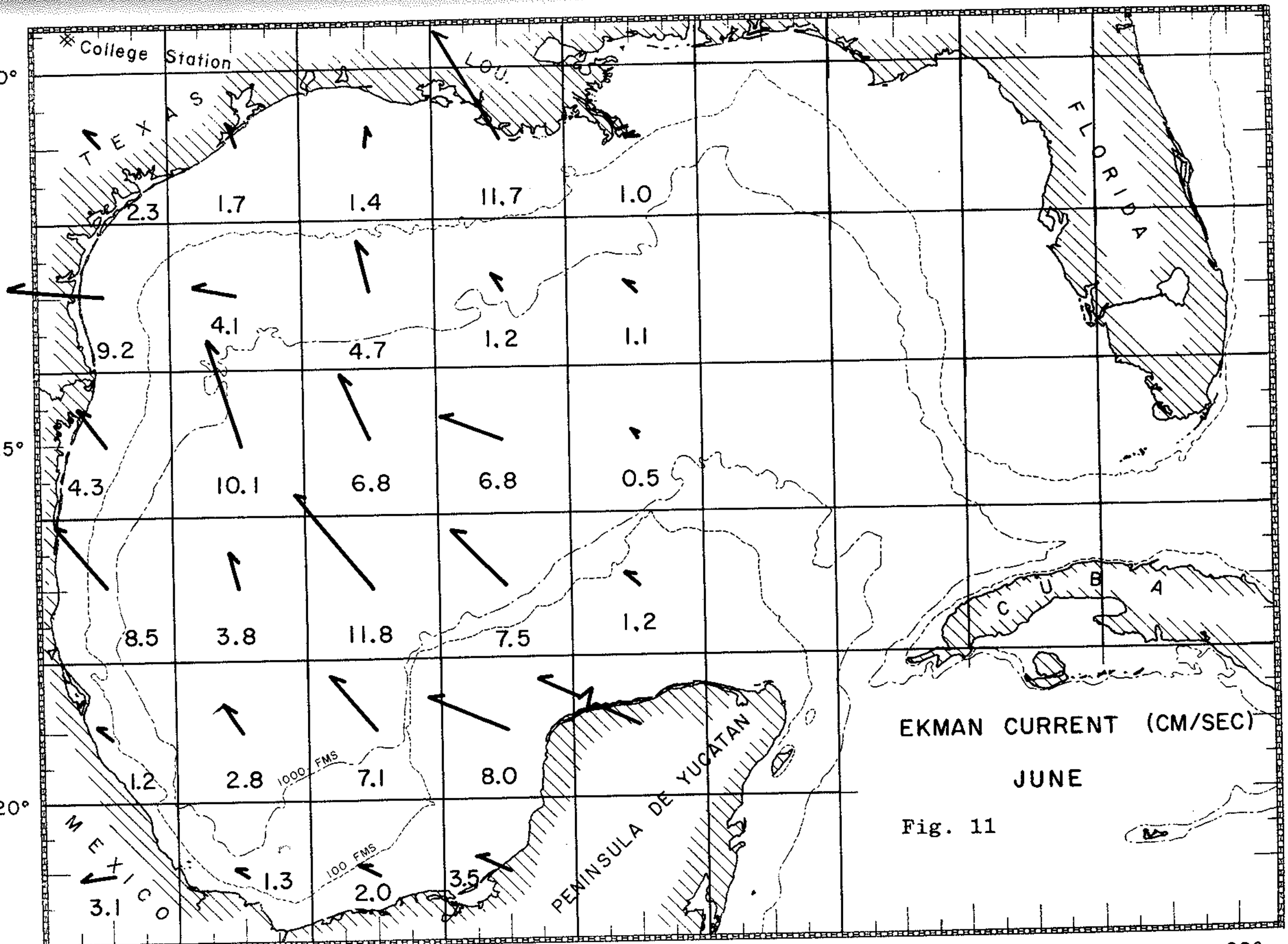
Fig. 9



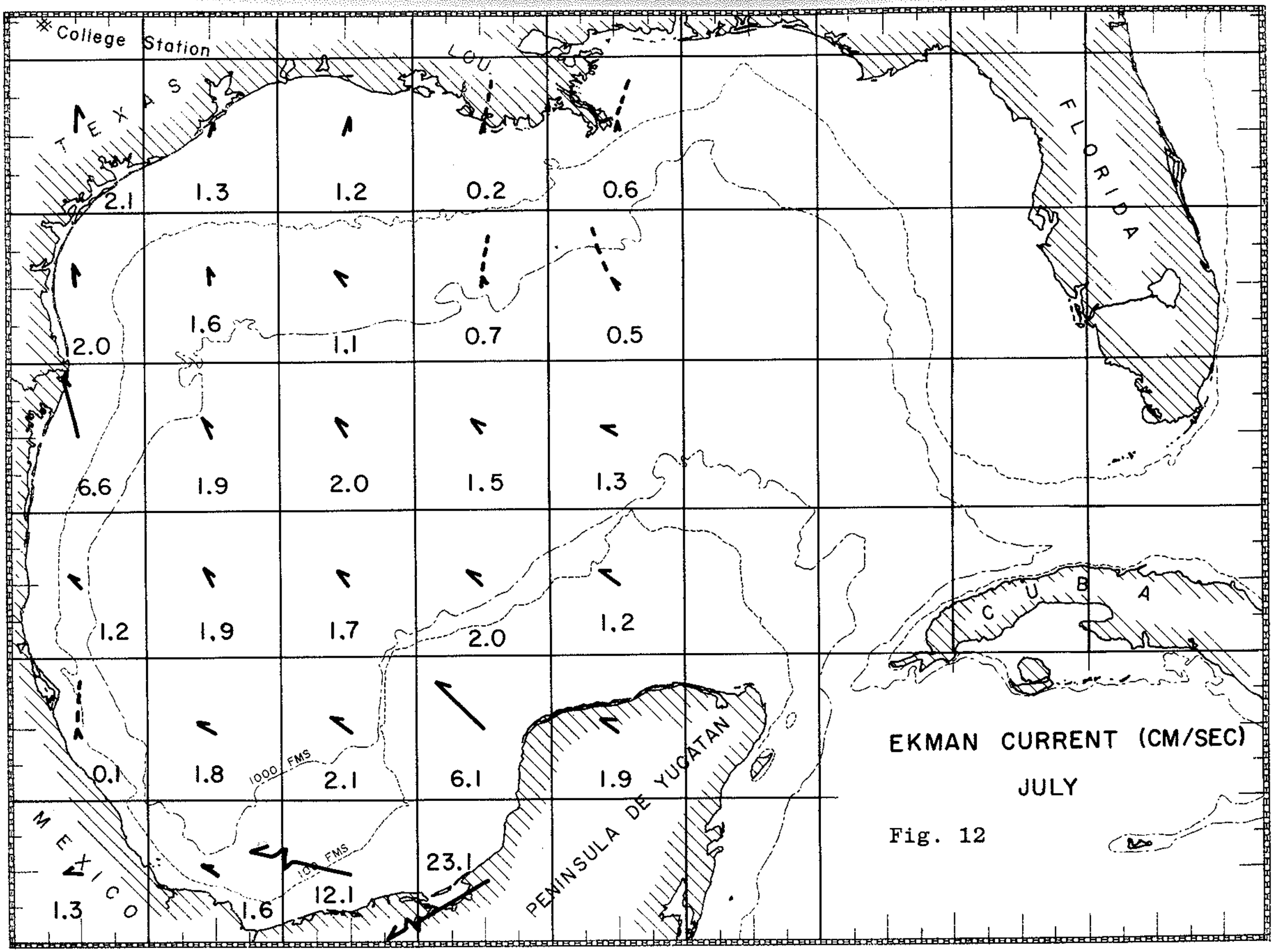

EKMAN CURRENT (CM/SEC)

MAY

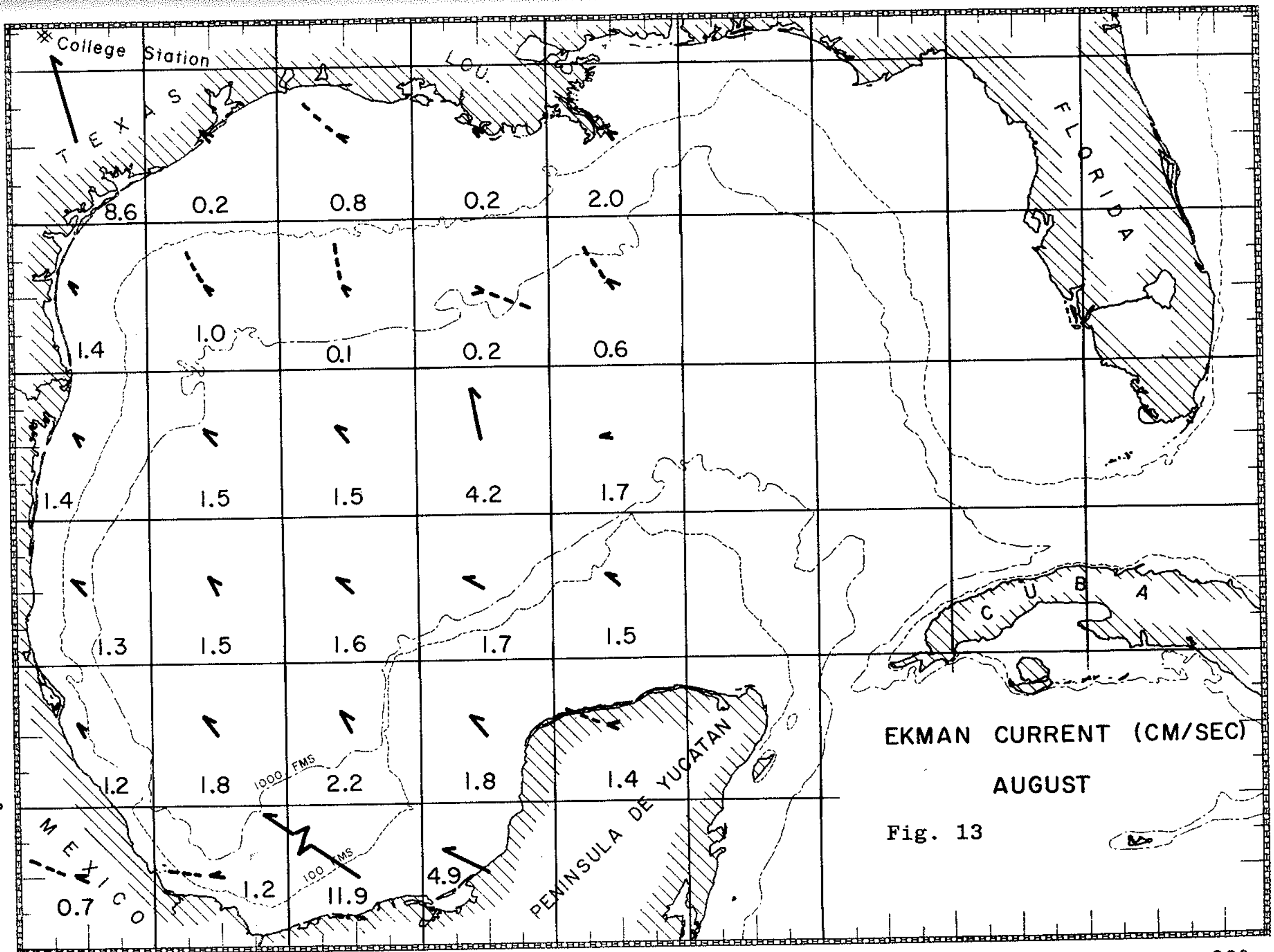
Fig. 10




EKMAN CURRENT (CM/SEC)
JUNE
Fig. 11

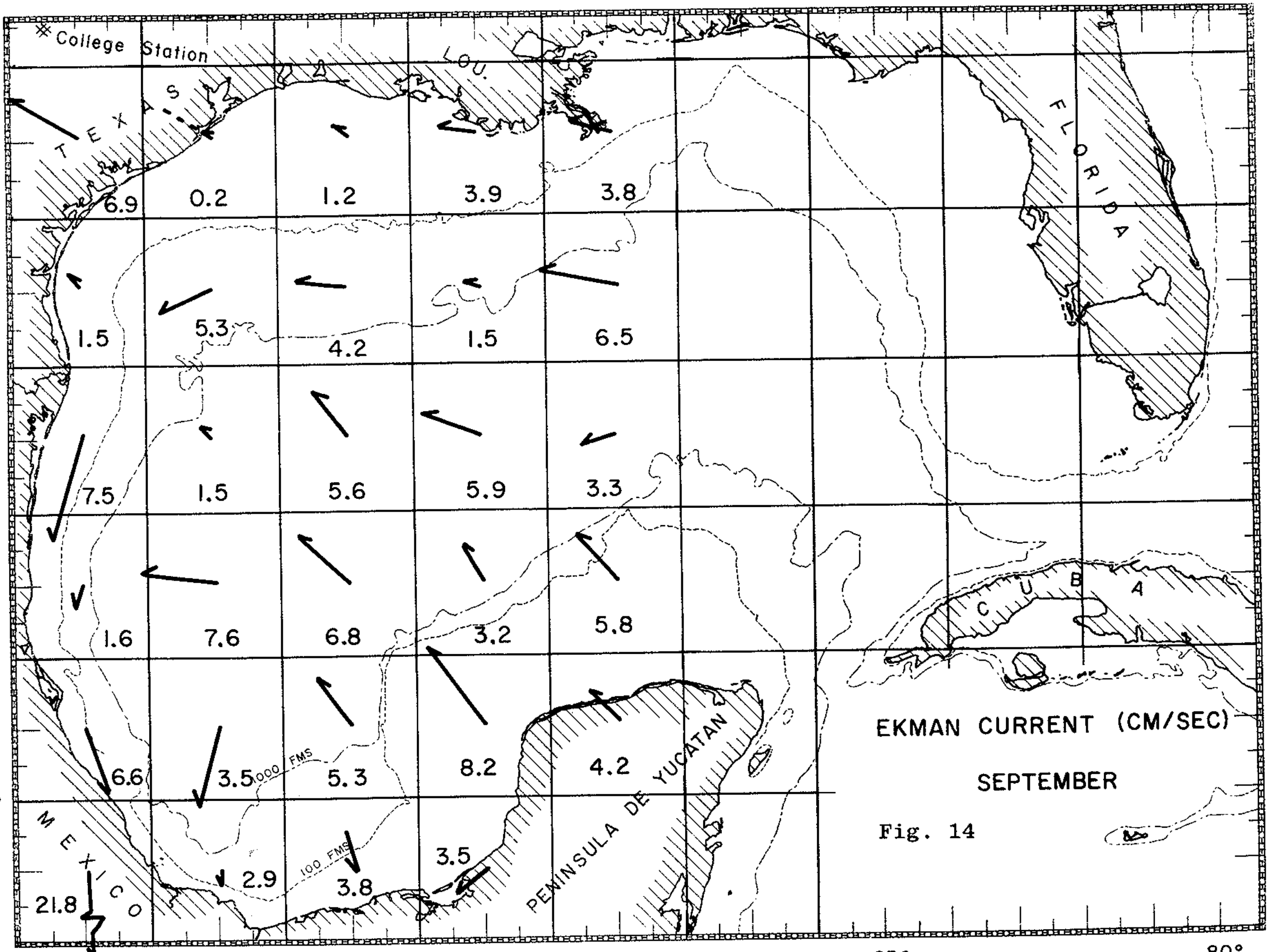


EKMAN CURRENT (CM/SEC)
JULY
Fig. 12




EKMAN CURRENT (CM/SEC)
AUGUST

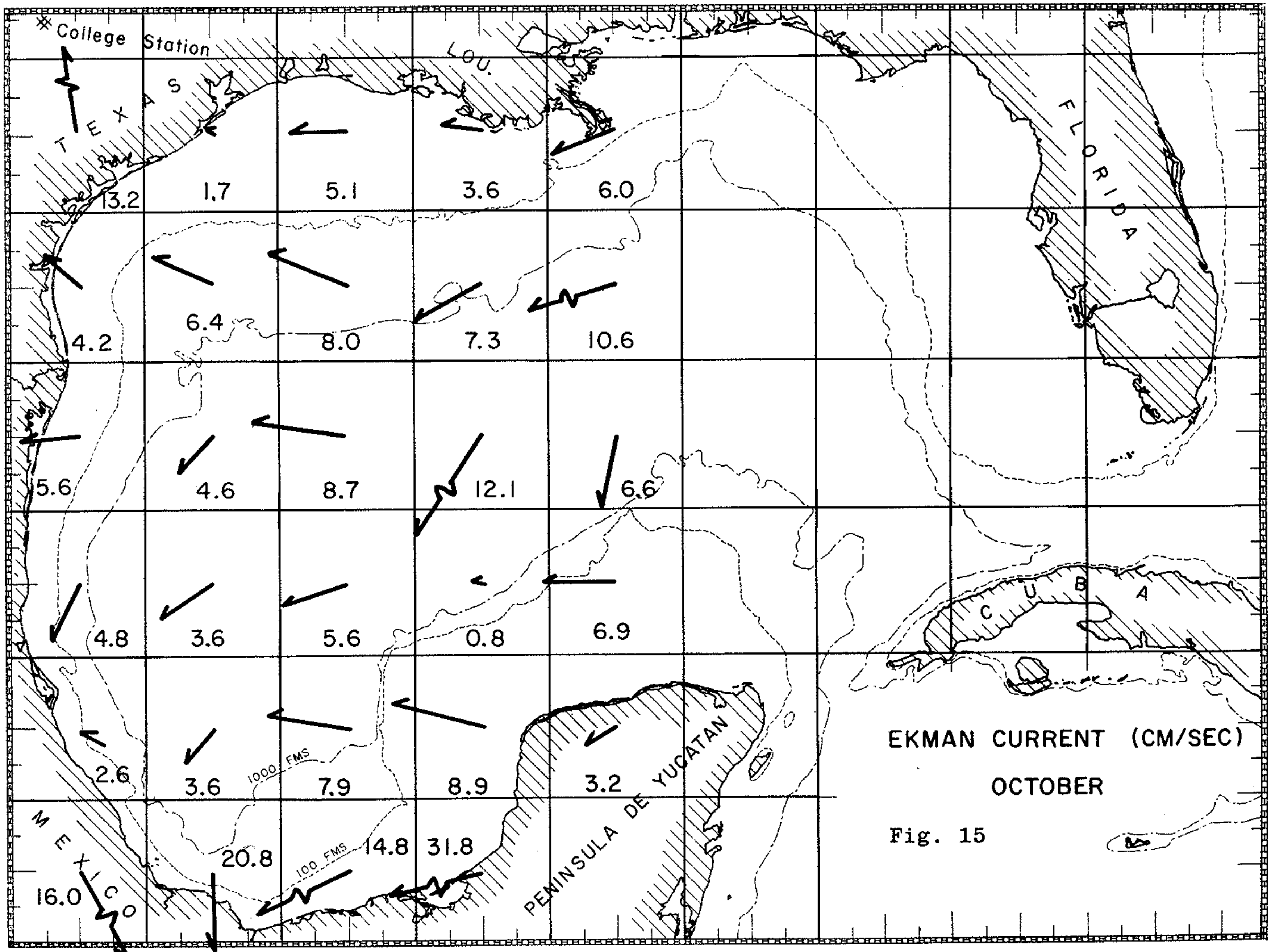
Fig. 13




EKMAN CURRENT (CM/SEC)

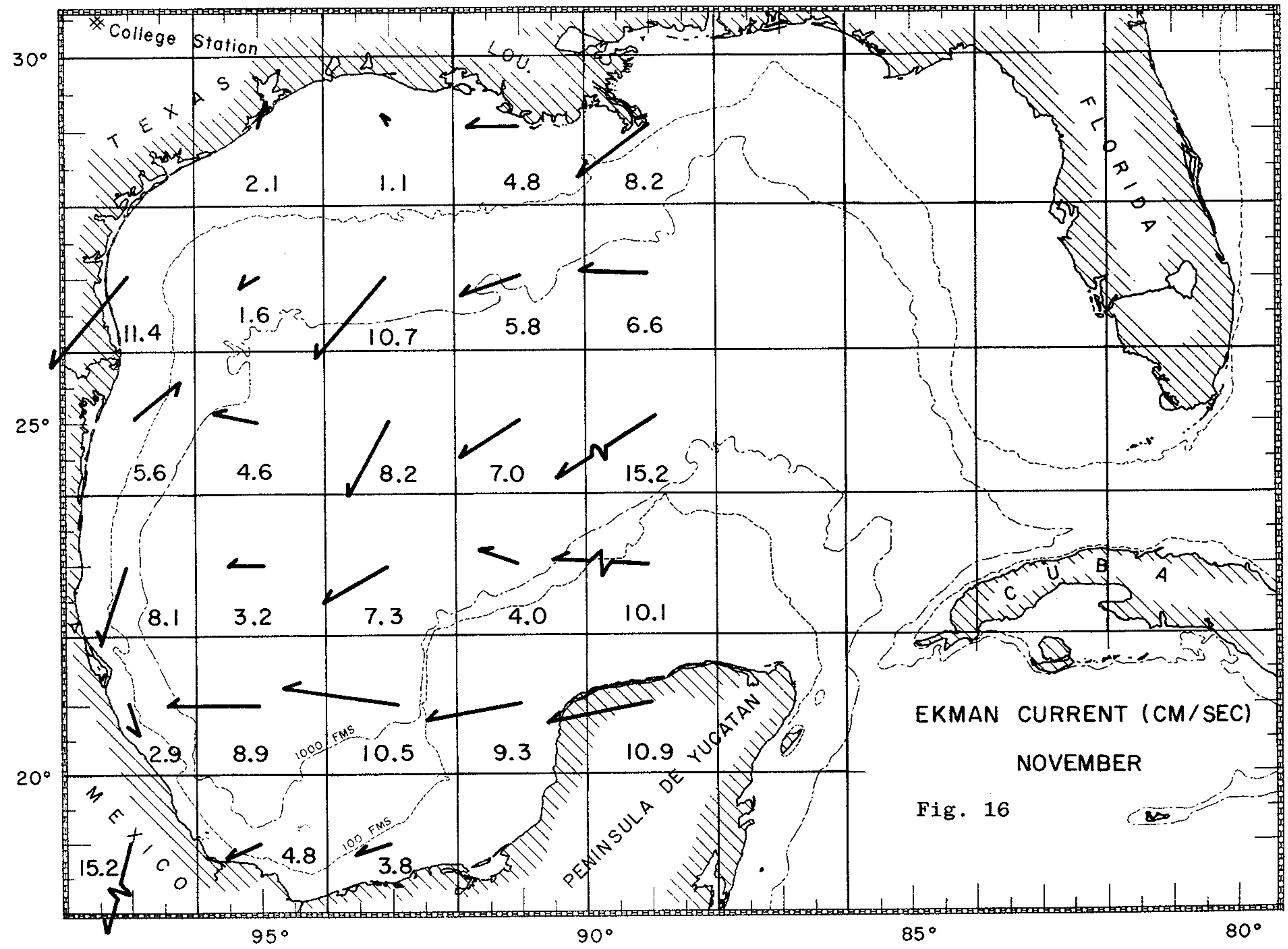
SEPTEMBER

Fig. 14




EKMAN CURRENT (CM/SEC)
OCTOBER

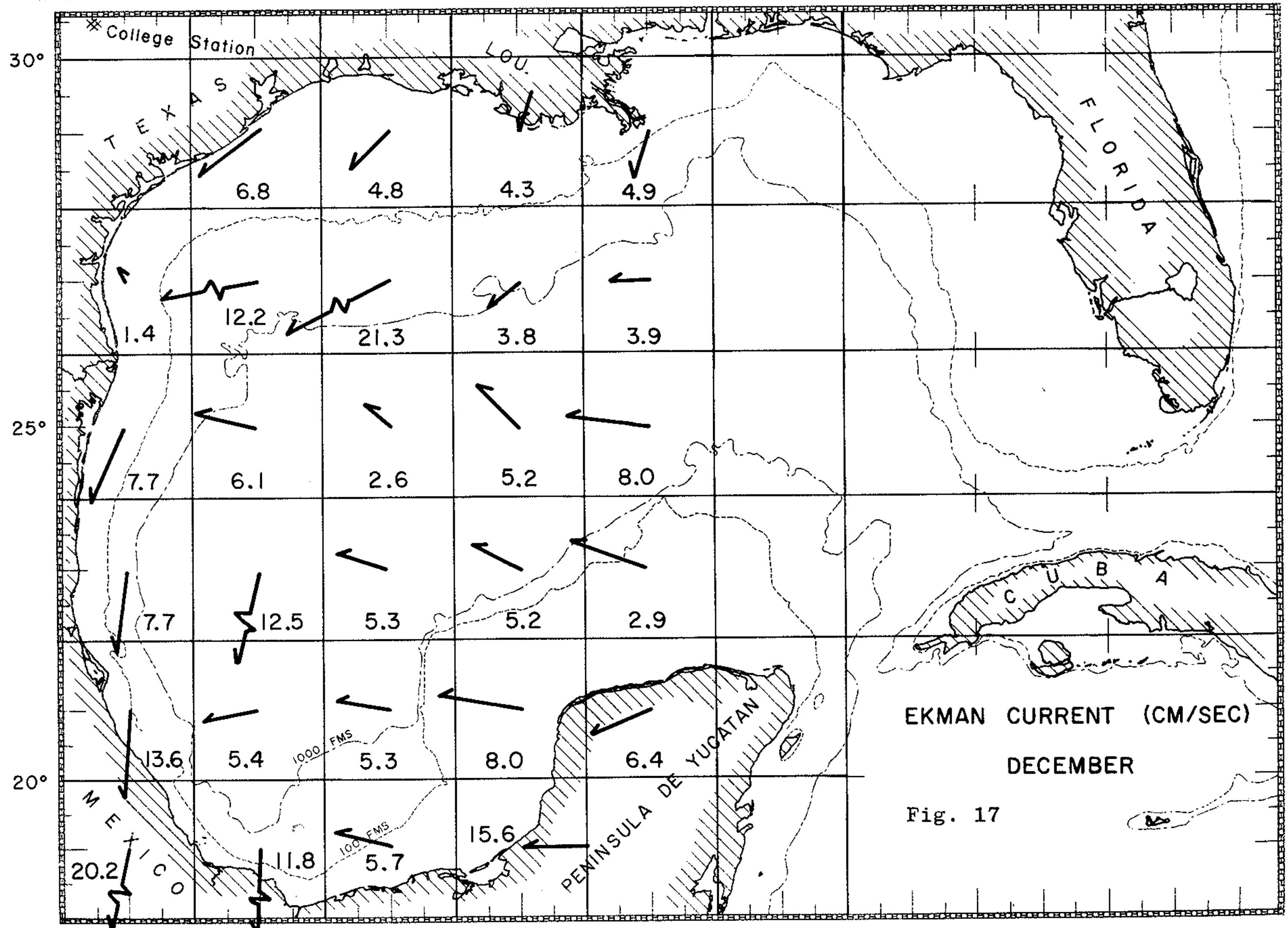
Fig. 15




EKMAN CURRENT (CM/SEC)

NOVEMBER

Fig. 16




EKMAN CURRENT (CM/SEC)
DECEMBER

Fig. 17

TABLE 1

Average monthly Ekman current velocities for the Gulf of Mexico west of longitude $88^{o}$W.

| Month | Velocity in cm/sec |
|---|---|
| January | 7.3 |
| February | 6.9 |
| March | 7.3 |
| April | 6.9 |
| May | 6.1 |
| June | 4.7 |
| July | 2.9 |
| August | 1.9 |
| September | 4.4 |
| October | 8.3 |
| November | 7.0 |
| December | 8.1 |

TABLE 2

Current direction frequency* for Gulf of Mexico west of longitude 88°W.

| Month | Current Direction | % Frequency |
|---|---|---|
| January | SW | 59% |
| | NW | 22% |
| February | SW | 46% |
| | NW | 36% |
| March | NW | 64% |
| | SW | 25% |
| April | NW | 66% |
| | SW | 21% |
| May | NW | 69% |
| | W | 21% |
| June | NW | 90% |
| July | NW | 69% |
| August | NW | 97% |
| September | NW | 66% |
| | SW | 21% |
| October | SW | 48% |
| | NW | 31% |
| November | SW | 56% |
| December | SW | 50% |
| | NW | 39% |

*Frequencies less than 20% not reported.

## SUMMARY AND CONCLUSIONS

Previous studies (Franceschini, 1953; Ichiye, 1962; Gaul and Boykin, 1964; Nowlin, 1971) indicate a westward surface current flow across the Louisiana-Texas shelf. Drift bottle studies by Kimsey and Temple indicate an eastward flowing current for this area in July-August 1962. Calculations of Ekman surface currents for this area in July show very weak currents developing to the north-northeast, shifting back to the northwest in August. Gaul's drift bottle studies for 1963 and 1964 indicate westward flow in this area for July and August. A reversal of the general westward flow of surface current would depend upon the wind stress which is normally weakest in July and August. However, great variations in strength and direction of shelf currents have been noted and it is possible that wind stresses could occasionally set up easterly flowing currents in this area during the late summer. In an earlier drift card study (Sweet, 1971) there were single card discoveries that indicated northwest drift from Claypile Bank and northeast drift from West Cameron Block 474.

Examination of the Ekman currents for the northwestern Gulf of Mexico show a general westward flow for most of the year.

There is a convergence on the Texas coast which has been recognized for years. It has been reported (Kimsey and

Temple, 1963, 1964) that a zone of convergence develops off Brownsville in March and shifts northward to the central Texas coast by July and August and then shifts southward in the fall. According to Hunter et al. (1973) the convergence is evidently complex in structure and may have reversals not evident from seasonally spaced studies.

This drift bottle study confirms a general westward drift across the shelf as indicated by plotted Ekman current vectors. However, first arrival times indicate current magnitudes greater than calculated Ekman velocities. The parameter A as indicated by Ichiye et al. may vary by one or two orders of magnitude. A vertical stratification would reduce A and thus give a higher current, but it would take an eddy viscosity of a magnitude of approximately 25 $cm^2$/sec to produce Ekman currents of the magnitude suggested by drift bottle travel times for April and October-November. This remains to be demonstrated.

The general conclusion of this study is that the surface currents in the northwestern Gulf of Mexico are primarily controlled by wind stresses. However, there are indications that other factors particularly along the south Texas coast may contribute to and at times control the surface currents.

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