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RESEARCH REPORT

ENHANCED HYDROGRAPHIC SURVEY FOR CPL DISCHARGE IN NUECES BAY

for

Central Power and Light Company

P.O. Box 2121

Corpus Christi, Texas 78403

by

Terry E. Whitledge, Ph.D.

Marine Science Institute

The University of Texas at Austin

P. O. Box 1267

Port Aransas, Texas 78373-1267

November 1993

The University of Texas Marine Science Institute
Technical Report No. TR/93-008

INTRODUCTION

Nueces Bay is a secondary/tertiary bay located at the terminus of the Nueces River and is one of several small bays in the Nueces Estuary (comprised of Corpus Christi, Oso, Nueces, and part of Redfish Bays). Nueces Bay borders on the principal industrial and port area of the City of Corpus Christi and has a surface area of approximately 7.87 X 10E7 m^2 (Collier and Hedgpeth, 1950) and a mean depth of about 0.7m. The calculated water volume is 5.51 X 10E7 m3 (44,690 acre-ft). The tidal range at the mouth of Nueces Bay can be as large as 0.5 m (Amos, 1989) but under storm conditions a weather tide can be much higher especially in the upper portions of the bay.

The Central Power and Light Company (CPL) Nueces Bay steam electric generating plant is sited between the inner harbor ship channel and Nueces Bay. The Nueces Bay Power Station withdraws water from a depth of 1-10 meters in the inner harbor, uses it for once-through cooling and discharges into the lower portion of Nueces Bay. The volume of water used in cooling varies according to the amount of power being generated and the ambient temperature of the water. The mean volume of cooling water discharged in 1989 was 312.47 mgd (1.186 X 10E6 m3/day; 13.73 m3/sec), in 1990 was 374.23 mgd (1.417 X 10E6 m3/day; 16.40 m3/sec), and for January through November in 1991 was 366.03 mgd (1.386 X 10E6 m3/day; 16.04 m3/sec).

The Nueces River flows into the upper portion of Nueces Bay. The annual streamflow measured over the period 1941 to 1987 at the Mathis gage averaged 720.1 X 10E6 m3 (584,303 acre-ft) while the median was 470.9 X 10E6 m3 (381,785 acre-ft). The minimum gaged inflow was recorded during the water year of 1962 with a value of 94.2 X 10E6 m3 (76,390 acre-ft) while the maximum of 2,220.2 X 10E6 m3 (1,799,910 acre-ft) was recorded in 1967. The total annual combined inflow (sum of gaged and ungaged inflows and return flows minus diversions) averaged 781.5 X 10E6 m3 (633,597 acre-ft) over the period 1941 to 1987. The median annual value for combined inflows was 511.1 X 10E6 m3 (414,337 acre-ft).

The certificate of adjudication in 1976 authorizing construction of Choke Canyon Reservoir stipulated that 151,000 acre-ft (1.86 X 10E8 m3) of freshwater must be released annually into the Nueces Estuary via return flows, releases and spills. Mandated inflows of 150,000 acre-ft were ordered in 1990 on an interim basis until a permanent set of operating rules could be determined. The average monthly return flows are about 6.16 X10E6 m3 (5000 acre-ft) for a yearly total of 7.4 X 10E7 m3 (60,000 acre-ft) so about 1.12 X 10E8 m3 (91,000 acre-ft) must be provided by releases or spills each year. Direct releases and natural spills of 2.43 X10E8 m3 (196,910 acre-ft) of freshwater occurred in 1990 as a result of summer and fall precipitation events. Releases and spills in 1991 were 1.17 X 10E8 m3 (94,672 acre-ft), a value that closely matched the target value of 1.12 X 10E8 m3.

Water current measurements in Nueces Bay have concentrated on the inflows and outflows over one or two tidal cycles but currents within the middle or upper bay have not been measured directly for more than a few days. A current meter, sited in the channel under the Nueces Causeway for eight months during 1987-1988, recorded current velocities which ranged from 25-75 cm/sec but exceeded 100 cm/sec during some short-lived events (Amos, 1989). The dominant influence on the currents was tidal but removal of the tides from the records indicated a nearly continuous net flow out of Nueces Bay at an approximate rate of 8.6 cm/sec (10 m3/sec). Limited deployments of a current meter occurred on two biological stations in the upper and middle bay for 24 hours each. The measured currents from the midbay deployments ranged from 6.9 to 14.1 cm/sec with typical values of about 10 cm/sec (Amos, 1989). The upper bay currents in midbay off Whites Point had current directions that were east and southeast in December 1987, February 1988 and May 1988. It is clear that currents in both the upper and lower bay respond to tidal forcing and tidal ellipses are more circular in the upper bay due to the smaller amount of channelization. The currents measured would move water about 8.5 km/day or roughly half the length of Nueces Bay if recirculation and return flow along the bay periphery did not occur. The observed distribution of properties shows strong gradients of physical and biological properties so a significant amount of recirculation must be occurring in some sections of Nueces Bay.

OBJECTIVES

The objectives of the enhanced hydrographic survey in Nueces were:

A. to monitor the vertical and horizontal distributions of temperature and salinity, nutrients and plant pigments in the nearby area of the CPL cooling water discharge channel in Nueces Bay.

B. to compare the distributions of the above parameters to those throughout other portions of Nueces Bay during freshwater release and non-release periods.

METHODS

The areal distribution of temperature, salinity, nutrients (nitrate, nitrite, ammonium, phosphate and dissolved silicon), chlorophyll a and water transparency (Secchi disk) were determined at 32 sampling sites in Nueces Bay (Figure 1). Ten of the sampling sites were specifically located in the vicinity of the CPL discharge to obtain high resolution in the nearfield distributions (Figure 2). Sampling occurred monthly from February 1991 through December 1991. Additional sampling trips were taken during plant maintenance in the spring of 1991. Water samples were collected from the surface by hand immediately below the surface film and near bottom samples were collected with a 2 liter horizontal water sampling bottle. If bottom disturbance was apparent, the samples were retaken. The samples were stored on ice in the dark for transportation to the laboratory.

The nutrient samples were analyzed on an automatic chemical analyzer utilizing the procedures of Whitledge et al (1981) which have been modified for small glassware to optimize stability and sensitivity. The analytical methods of Murphy and Riley (1962) were followed for reactive phosphate, and Armstrong et al (1967) for silicate and nitrate. Ammonium was measured by the phenolhypochlorite method of Koroleff and modified by Patton and Crouch (1977). The accuracy was determined by measuring the absorbances of known concentrations of each analyte (standards) at least once every 12 hours.

The temperature was profiled at each station with measurements at 3-5 cm depth increments throughout the water column. The temperature measurements were recorded to the nearest hundredth of a degree (0.01°C) Celcius using a Sea Bird Electronics model SBE19 SeaCat CTD. The temperature sensor was recalibrated at the factory at the beginning of the study period.

The salinity was profiled at each station at increments of about 10 cm using conductance measurements from the Sea Bird Electronics model SBE19 SeaCat CTD. Data were calculated using the Practical Salinity Unit scale (1978) and had a nominal resolution of 0.01 psu (ppt). The conductivity sensor was recalibrated at the factory at the beginning of the study period. Water transparency was determined on each station with a standard Secchi disk to the nearest 5 cm. The Secchi was also used to measure bottom depth in waters less than 3 m deep. Samples for chlorophyll were collected from the surface and bottom for later analysis in the laboratory. The samples were filtered with glass fiber filters and the samples were extracted for two hours with acetone/DMSO. The method of Holm-Hansen et al (1965) was used to analyze the samples fluorometrically. Primary production measurements were determined using C-14 tracer techniques at selected stations (Stockwell, 1989).

RESULTS

SALINITY

The distribution of salinity throughout Nueces Bay during 1991 illustrates the combined effects of precipitation events, freshwater releases, and water circulation patterns. The upper portion of Nueces Bay (defined as the area from Whites Point to Rincon Delta) had salinity values that ranged from 10.2 psu in July to 30.6 psu in January (Figure 3). The central portion of Nueces Bay (defined as the area from Whites Point to the western power line) had salinity values that ranged from 9.58 psu in July to 32.5 psu in January. The central region was the usual area for the strongest salinity gradients to occur as a result of the river mouth discharges into the southwestern corner. For instance, a salinity gradient of 17.2 psu was observed across the central area on 7 April. The lower portion of Nueces Bay (defined as the area from the western power line to the causeway) had salinity values that ranged from 18.0 psu in June to 33.15 psu in August. Lower Nueces Bay is the receiving water body for the CPL discharge of cooling water and is also the area in direct communication with Corpus Christi Bay via the navigation channel and shallow bay areas beneath the Nueces Bay Causeway. In all months there was a general distribution of lower salinity in the upper bay to higher salinity in the lower bay although the relative amount varied greatly.

The small scale differences of salinity were examined with a special set of stations located radially around the CPL discharge channel. During the time period of February through May salinity was concentrically distributed around the CPL discharge point but June through July had low salinities on the central bay side and higher salinities on the lower bay side (Figure 4). Salinities for the months of August through November were lower on the west side in the open bay but there were nearshore regions west of the CPL channel which had salinity enhancement. This effect was most dramatic in December when larger values occurred only to the west of the discharge point. The seasonal variation of salinity occurring near the CPL discharge channel was compared to: 1) the monthly mean salinity determined for all stations in Nueces Bay and 2) the channel at the Nueces Bay Causeway (Figure 5). The mean salinity for all stations in Nueces Bay was always at least 1 psu lower than the CPL discharge but was 10 psu lower in July. This difference in salinity was greatest during freshwater releases in the spring and fall. The difference in salinity between the Nueces Bay Causeway and the CPL channel was variable and less than 1 psu from February through June but differences of about 2.5 psu and 1.2 psu were observed in July and September. Overall the salinity differences observed at these sites were small except when relatively large amounts of freshwater discharge were occurring.

TEMPERATURE

The relatively warm temperatures of the CPL discharges into Nueces Bay result from the cooling requirements of the electric power generating plant. The distribution of temperature throughout Nueces Bay can be attributed to heating/cooling weather events, solar radiation, and water inflows including the CPL discharge. There is a general trend of relatively low temperature water during all seasons in the upper bay compared to the central or lower areas (Figure 6). The magnitude of temperature gradients across Nueces Bay without considering the local influence of the CPL discharge ranges from 1 to 3°C but is often at the low end of that range. The warmest water tends to reside along the south shoreline which may be influenced by the daily tidal exchange along the relatively deeper channels on the south side of the bay. The central region had the strongest temperature gradients, similar to the salinity distributions.

The small scale temperature distribution very clearly delineates the warm waters in the vicinity of the CPL discharge channel. The gradient of temperatures in the discharge embayment ranged from 2 to 7°C with the smallest range occurring in the winter months. During the months of February, May, July, September and October the "temperature plume" tended toward the east while in March, April, August and December the higher temperatures were shifted toward the west. The temperature distributions in the months of June and November were concentric around the discharge point. The similarities in the distribution patterns of salinity (Figure 4) and temperature (Figure 7) are evident for some of the months.

The seasonal variation of temperature occurring near the discharge channel was compared to: 1) the monthly mean temperature determined for all stations in Nueces Bay and 2) the channel at the Nueces Causeway (Figure 8). The mean temperature for all stations including those near the Nueces Bay Causeway were 4 to 8°C lower than the CPL discharge.

NUTRIENTS

The dissolved inorganic nutrients along with incident radiation in estuarine waters determines the capacity for plant growth. Nitrate and silicate are normally the allochthonous (brought into an ecosystem) forms while ammonium, nitrite and orthophosphate are autochthonous (originate within) forms. These differences are not rigid but within a given ecosystem the behavior of nutrient species often are indicative of the most important physical and/or biological processes.

The CPL discharge is relatively high with respect to nitrate content with values ranging from 6 to 90 μmole/liter at station 43 Figure 9). The gradient of nitrate was often quite strong indicating that biological uptake was very rapid. The normal Nueces Bay nitrate concentrations are often less than 5 μmole/liter (Figure 10) but freshwater inflow and direct precipitation often introduce concentrations of about 100 μmole/liter. Only in the month of April did the CPL discharge have lower concentrations than the mean concentration for the bay but September and October discharges were very high. It should be noted that these concentrations are large enough to stimulate phytoplankton production but are not large enough to be detrimental to the biota. The distribution of ammonium near the CPL discharge is relatively high for the months of March through August while lower levels were observed in November through February (Figure 11). The range of values was 1.25 to 40 μmole/liter at station 43. Normal Nueces Bay ammonium concentrations range up to 10 μmole/liter (Figure 12) or higher during times of intense water column or benthic regeneration. The maximum ammonium concentration in CPL discharges occurred in June although enhanced values were observed from March through August. These concentrations are large enough to stimulate phytoplankton production but are not large enough to be detrimental to biota.

The total dissolved inorganic nitrogen (DIN) is the sum of nitrate, nitrite and ammonium concentrations and represents the nitrogen readily available for primary production. In every month there was a substantial quantity of DIN available for primary production at the CPL discharge location (Figure 13). During the survey year most of the discharges at station 43 were larger than the Nueces Bay mean or causeway station (Figure 14).

The distributions of orthophosphate in Nueces Bay show some enhancement in concentrations near the CPL discharge (Figure 15). Phosphate distributions reflect the relatively normal concentrations in the CPL discharge waters except in August and September (Figure 16). The distributions of silicate (dissolved silicon) indicate the relative low concentrations (5 to 60 umole/liter) present in the CPL discharge (Figure 17). The silicate concentrations at station 43 were 30% to 50% of the open bay concentrations. The silicate concentrations in the Nueces River during 1987-1988 ranged from 64 to 270 μmole/liter with a mean value of 121 μmole/liter (Whitledge, 1989). The mean silicate concentration in Nueces Bay increased markedly starting in May when freshwater discharges were occurring and remained high during the remainder of the year (Figure 18).

PHYTOPLANKTON PIGMENTS AND PRIMARY PRODUCTION

The distribution of chlorophyll a pigments in Nueces Bay represents the biomass of phytoplankton. In general, the CPL discharge point has low phytoplankton biomass due to dilution but rapid increases occur nearby as a result of phytoplankton growth stimulated by the high nutrient content and light transparency. The phytoplankton grown in the vicinity of the discharge point are transported by water circulation hence their distribution can represent integrated water movement. In general, the chlorophyll concentration ranges from 2 to 10 μg/liter at station 43 while bay concentrations of 3 to 30 μg/liter were observed (Figure 19). Over the 12 month period, the mean chlorophyll for all Nueces Bay stations was between 8 and 16 μg/liter (Figure 20) while station 43 values were 5 to 9 μg/liter.

The primary production of phytoplankton in the water column of the open bay as determined by carbon isotopic experiments ranged from 0.2 to 5 gC/m3/day, with the highest values occurring in the upper and lower bay regions (Figure 21). The primary production rates measured at station 43 were low but were similar to values measured in the central portions of the bay.

DISCUSSION

SALINITY

The potential impact of the CPL discharge of cooling water into Nueces Bay needs to be addressed in context with other inputs and the natural variability within the estuarine ecosystem. The relatively long term variation is best shown with Texas Water Commission data from station 2482.01 near the Nueces Bay Causeway inside Nueces Bay (Figure 22). The 17 year record of conductivity converted to salinity shows a range of 2 to 44 psu with a mean value of 26.27 psu (N=63). This record is interesting because it shows that the mean represents a central value. Station 2482.04 near the power lines dividing the central and lower bay has a range of <1 to 35 psu and a mean value of 24.24 psu (N=57). The annual variations of salinity can be as small as 10 psu or as large as 30 psu depending on the occurrence of a tropical storm. The historical salinity data for the Corpus Christi Inner Harbor was obtained from the TWC. Stations 2484.01 (Avery Turning Basin) and 2484.02 (Navigation Blvd) showed variations of 15 to 20 psu around a mean of 32.6 psu during the 17 year period (Figure 23). It was interesting to note a definite trend toward higher salinities (~ 5 psu) in the Inner Harbor during the 17 year time period.

The residence time of water in Nueces Bay for 1991 was calculated using 1) the gaged inflow of the Nueces River, 2) the pumping rate of CPL cooling water, 3) the "normal" return flows of wastewater. When these daily data were compared to the volume of Nueces Bay, a range of 13 to 78 days turnover was calculated. The mean of the daily rate over the 1991 year was 33.1 days. However, this assumes that the CPL discharge was completely mixed within Nueces Bay but the effects of CPL's discharge was only observed in the lower portion of Nueces Bay. These calculations did not include tidal motion of water because there is no net movement of water over time periods longer than a day. When the volume of the tidal prism is added to the other inflows into the bay, the relative contribution of the CPL discharge is about 15% (Figure 24) and the river and return flows are 4% and 2% respectively. The nominal tidal height used in the calculation was 0.3 feet (9.1 cm) which was obtained from the CCSU Blucher Institute. The data demonstrate that the CPL discharge does not shorten the duration of a freshwater event in upper Nueces Bay.

It should be mentioned that adding salt is not the only process that alters the salinity of estuarine waters. The process of evaporation removes water thereby increasing the salt concentration. The evaporation rates in midsummer when prevailing winds are strong and temperatures are high should be addressed in a comprehensive assessment. Unfortunately evaporation data are not presently available for the 1991 time period.

The waters being discharged by CPL into Nueces Bay have normal Corpus Christi Bay salinity values and are therefore equivalent to having a slightly larger tidal input. The basic question becomes whether the CPL discharges are significantly increasing the influx of salt into the bay compared to the tides. When the full amount of tidal influx of salt is considered, the CPL discharge contributes only 15% of the water and salt compared to the tidal inputs of 80%.

The estimate of salinity fluxes from net tidal inputs, CPL discharges and other effects (i.e., evaporation) were calculated using discharge rates and residence times. The tides were included as tidal diffusion based on an exchange rate of 3.5% per day as estimated from the residence time calculation of 33.1 days. In other words, 3.5% of the salt entering into Nueces Bay each day on the flood tide remains after the complete tidal cycle. The first-order calculation assumes that the CPL discharge is homogeneously and completely mixed within the entire volume of water in Nueces Bay. Obviously, complete mixing does not occur within Nueces Bay so the calculated salt fluxes (68-82 %) into Nueces Bay by the CPL electric generating plant for a range of discharges is an overestimate. Measured current velocities in the lower Nueces Bay would move water 4 km or less into the bay during a flood tide, therefore only the Nueces Bay waters adjacent to Corpus Christi Bay are directly affected by the tidal advection. Other processes such wind driven currents and diffusive mixing must be considered in the regions of the middle and upper Nueces Bay. The salinities on the lower portion of Nueces Bay reflect a nearly direct discharge from the CPL plant as they flow along the south shoreline into Corpus Christi Bay. The distribution of measured properties (i.e., salinity, temperature and dissolved silicon) indicate that CPL discharge waters are confined in a narrow strip along the south shoreline of Nueces Bay. Therefore, the net salt influx from the CPL discharge is significantly lower than the first order calculation and perhaps are as low as 3-15% of the total influx.

The mean salinity content of Inner Harbor water (32.6 psu) used in this calculation was obtained from monthly surface samples for the year 1987-1988. The same data set was used to estimate the salt content of tidal waters entering Nueces Bay. The salinity content of Nueces River water and return flows was estimated to be zero.

TEMPERATURE

The natural variations in temperature occurring in Nueces Bay are generally associated with weather events that occur every 5-7 days and are superimposed upon the seasonal cyclic trend (Figure 25). The seasonal variation is about 20°C during normal years. The weather periodic events in the summer change the water temperature about 2-3°C but the most significant signal occurs in the winter where changes of more than 10°C can occur.

There are no apparent negative effects in Nueces Bay due to the elevated temperatures of the CPL discharge water. The temperature signal in the local vicinity of the discharge channel is quite obvious even during the warmest summer months.

NUTRIENTS AND PLANT PIGMENTS

The distribution of nutrients in Nueces Bay can be described as plentiful. There are no known historical data that would indicate nutrient impoverishment in the bay compared to other local estuarine ecosystems. The addition of nutrients via freshwater inflow, municipal wastewater or the CPL discharge will increase the ambient primary production rates if other critical factors are present. The CPL discharge in Nueces Bay follows two patterns. The first type is an enrichment of the local waters around the CPL discharge point. Nitrate, ammonium and orthophosphate are examples of this enhancement. The concentrations decrease rapidly after discharge as a result of phytoplankton uptake and growth. The increase of chlorophyll and the relatively large primary production rates in the nearby waters are indicative of this enrichment. This phytoplankton production is at a level that it should be considered an enhancement to Nueces Bay.

The second pattern of CPL nutrient discharge is a relative deficit compared to ambient Nueces Bay water and freshwater concentrations. This behavior is demonstrated by silicate whose concentrations are markedly lower in the waters around the discharge point and as a result is an excellent tracer of CPL discharge waters. Low silicate concentrations in Nueces Bay during 1991 were only associated with CPL discharge waters. The silicate requirements of certain phytoplankton groups such as diatoms is approximately equal to those of nitrogen. In all cases for the observation periods of 1987-1988 and 1990-1991 there was more than sufficient quantities for diatom growth.

The natural variations of nutrients in Nueces Bay are governed by inputs of freshwater inflow and direct precipitation patterns. The seasonal cycle of climatic conditions stimulate nutrient utilization during the spring and summer.

ZONE OF DETECTION

One of the prime objectives of this study was to ascertain the extent of possible impact of salinity and temperature effects of the CPL discharge in Nueces Bay in relation to other anthropogenic and natural activities. The special grid of stations was clustered within 1.55 km around the CPL discharge point. Three additional stations sampled during the routine hydrographic surveys were located within the range 3.4 to 4.2 km of the CPL discharge. The distributions of salinity were analyzed for each sampling period during 1991 for the distance from the CPL discharge point to location of salinity value within 2 psu of lowest of three midbay reference stations in the upper, central and lower bays regions (Stations 9, 11 and 13 shown in Figure 2). These reference stations all had salinity values that were less than 2 psu of the CPL discharge during February through April and November through December 1991. The salinity values at the CPL discharge point was 2 psu or larger than one of the three above stations during all samplings in May through October 1991. The size of the zone where salinity was greater than 2 psu than the lowest reference station was determined from the salinity distributions shown in Figure 4 and are shown in Table 1:

Table 1. Scalar distance (km) from CPL discharge point to a salinity value within 2‰ of the smallest value at the reference stations 9, 11 and 13.

Date	Lowest salinity at reference stations (psu)	Salinity at CPL discharge (psu)	Distance from CPL to 2psu value km
13 February	28.82	30.12	--
18 March	30.18	29.96	--
7 April	27.67	28.63	--
23 April	24[2]	25[2]	--
16 May	21.61	26.99	3.6
5 June	15[2]	25.52	1.5
18 June	16.81	24.41	2.2
9 July	16.05	28.28	2.0
21 August	29.00	33.40	3.0
14 September	26.74	31.77	1.2
14 October	26.73	32.15	1.6
14 November	29.00	30.81	--
11 December	29.86	30.26	--

[2]denotes refractometer values used due to instrument failure.

The zone of increased salinity values surrounding the CPL discharge location generally has the dimension of 1-2 km (0.6-1.2 miles). The exceptions occur on the 16 May and 21 August when the lateral extent was estimated at 3.6 and 3.0 km respectively. The two hydrosonde salinity sites are estimated to be 7 km and 3 km for the Whites Point and power line locations.

Upon the close examination of the salinity distributions, it is possible that the CPL discharge could influence the power line salinity monitoring site on these two occasions, however, there is no indication in any of the data that the Whites Point monitoring location would ever be affected. It should be noted that on 16 May there was a sharp salinity gradient established in the central region of Nueces Bay that could be due to the initiation of freshwater releases. This is supported by the silicate data which shows a relatively uniform distribution in all midbay sampling sites greater than 2 km from the CPL discharge site. The relatively low silicate concentrations which are tracers for the CPL discharge water remain within 1 km (0.6 mile) of the shoreline.

The silicate tend to confirm the presence of CPL discharge water at reference station 9 on 21 August but there is no indication that discharged waters are extending to the power line monitoring site.

CONCLUSIONS

1. Based on the distribution of salinity, temperature and dissolved inorganic nutrient properties, there is little, if any, effects of the CPL discharge in the upper and central portions of Nueces Bay. With just one or two exceptions, the data shows water movement eastward along the shoreline toward the causeway.

2. There is no indication that the CPL discharge reaches either of the two salinity monitoring instruments installed at Whites Point and the upper power line. The gradients of properties observed at midbay and the 7 km distance to the Whites Point monitoring site virtually assure that the CPL discharge does not elevate the salinity measurements. The monitoring site at the power line is 3 km (1.8 mile) from the CPL discharge point so there is a much greater potential for impact on the salinity measurements.

   When all of the properties measured in this study are considered, the potential impact of the CPL discharge on the power line monitoring site must be considered very small. In particular, the silicate distributions suggest that the power line monitoring site was bathed in water having upper bay characteristics even though the salinity data were inconclusive.

3. The CPL cooling water taken from the Corpus Christi Inner Harbor and discharged in Nueces Bay has salinity, temperature and dissolved inorganic nitrogen and phosphorus concentrations that are greater than ambient Nueces Bay levels, while dissolved silicate concentrations are lower. The area of enhanced concentrations is frequently very small and does not extend beyond the local area where the discharge occurs.

4. When flood tide volumes are combined with Nueces River inflows and wastewater return flows, the CPL discharge accounts for 14 to 19% of water inputs. Water current measurements collected at the Nueces Bay Causeway over an eight-month period indicate a net non-tidal outflow of water from Nueces Bay which probably results from the CPL discharge. No long-term water current measurements are available in any portion of the upper or central regions of Nueces Bay.

5. The CPL discharge accounts for about 3-15% of the total salt flux through Nueces Bay including an estimate of tidal effects and mixing exchanges.

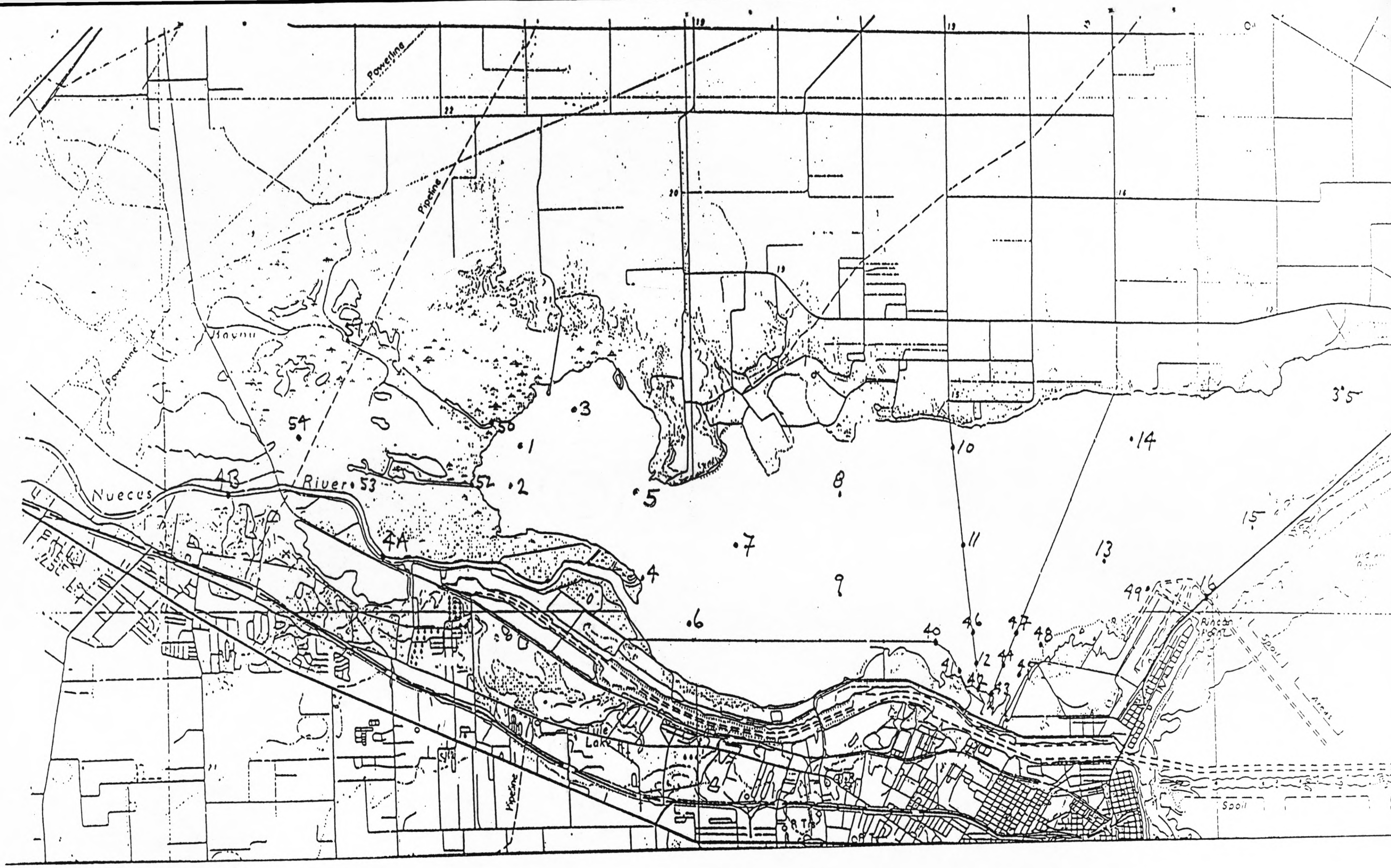


Figure 1. Hydrographic sampling stations in Nueces Bay and Rincon Delta during 1991.

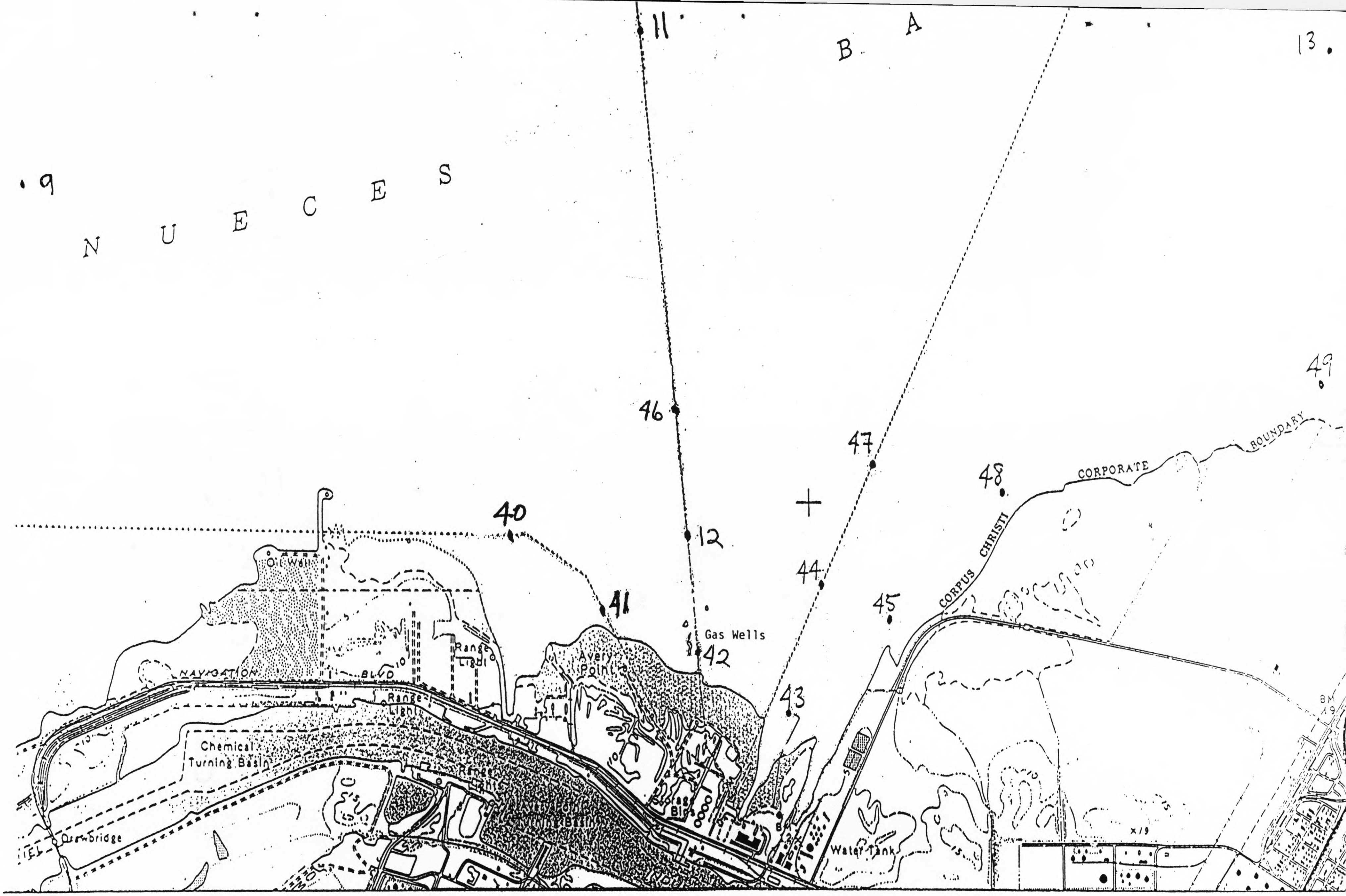


Figure 2. Hydrographic sampling stations (40-49) added to Nueces Bay sampling for enhanced CPL studies in 1991.

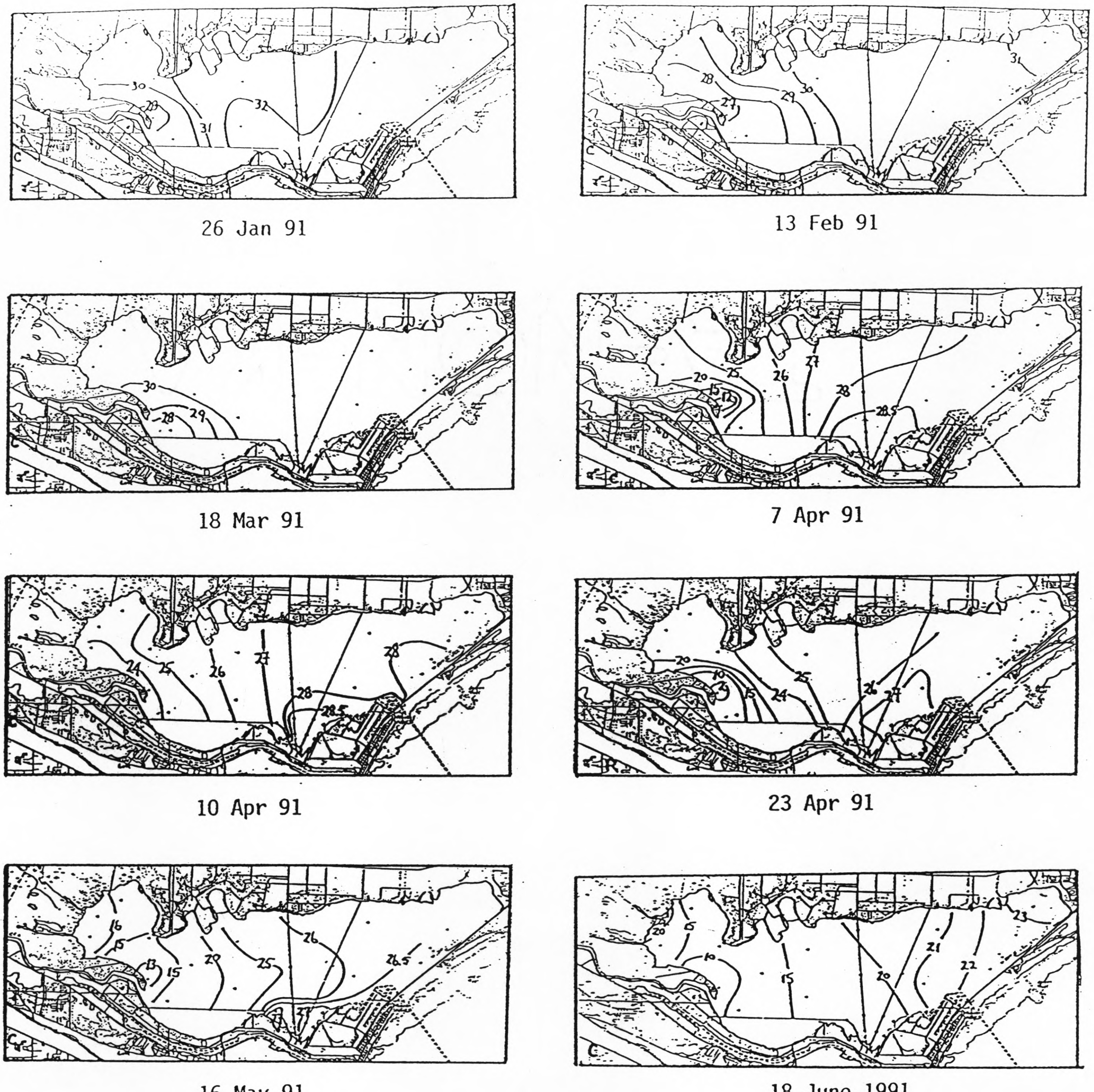
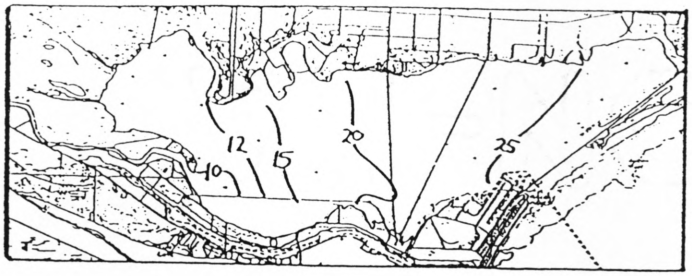


Figure 3. Monthly distributions of salinity (psu) in Nueces Bay during 1991 including CPL stations.



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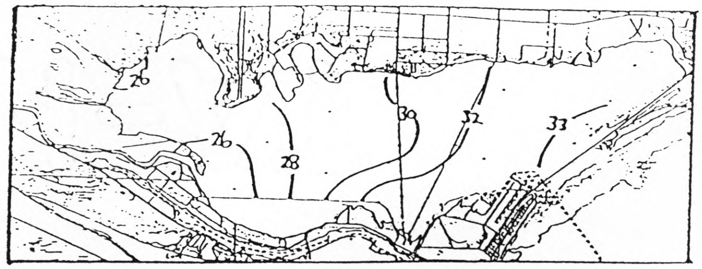

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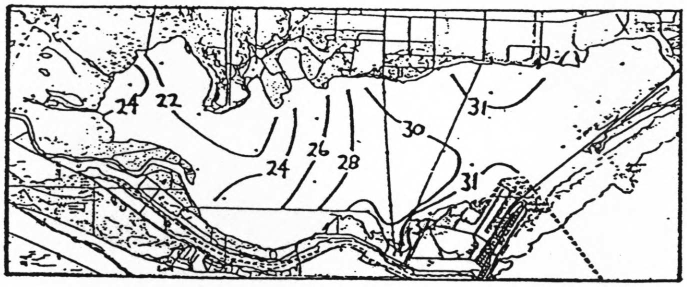

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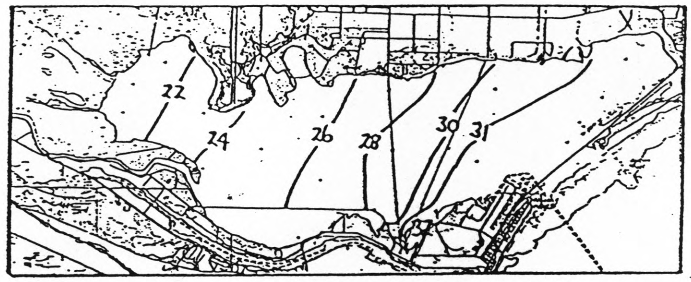

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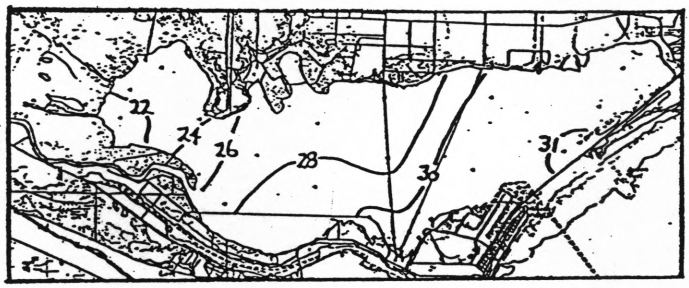

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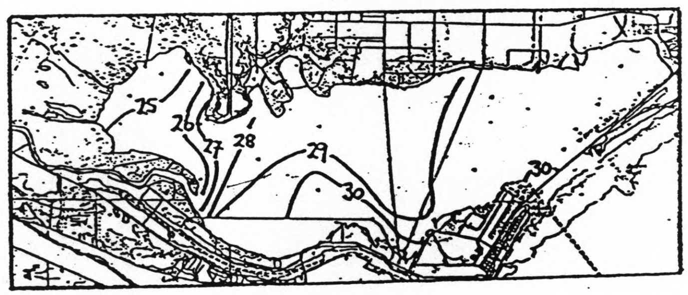

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Figure 3 cont.

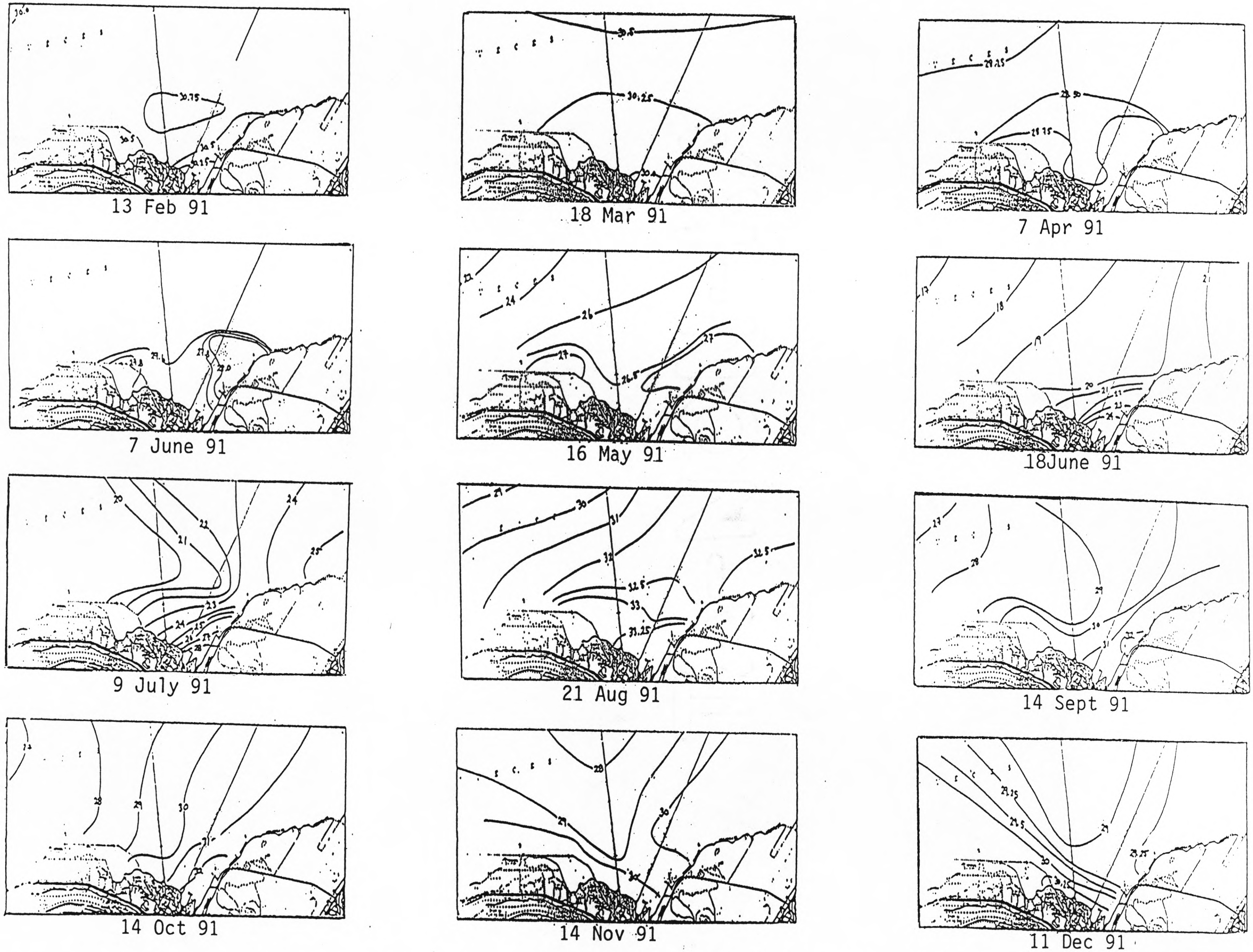


Figure 4. Small scale distributions of salinity (psu) near the CPL discharge channel in Nueces Bay during 1991.

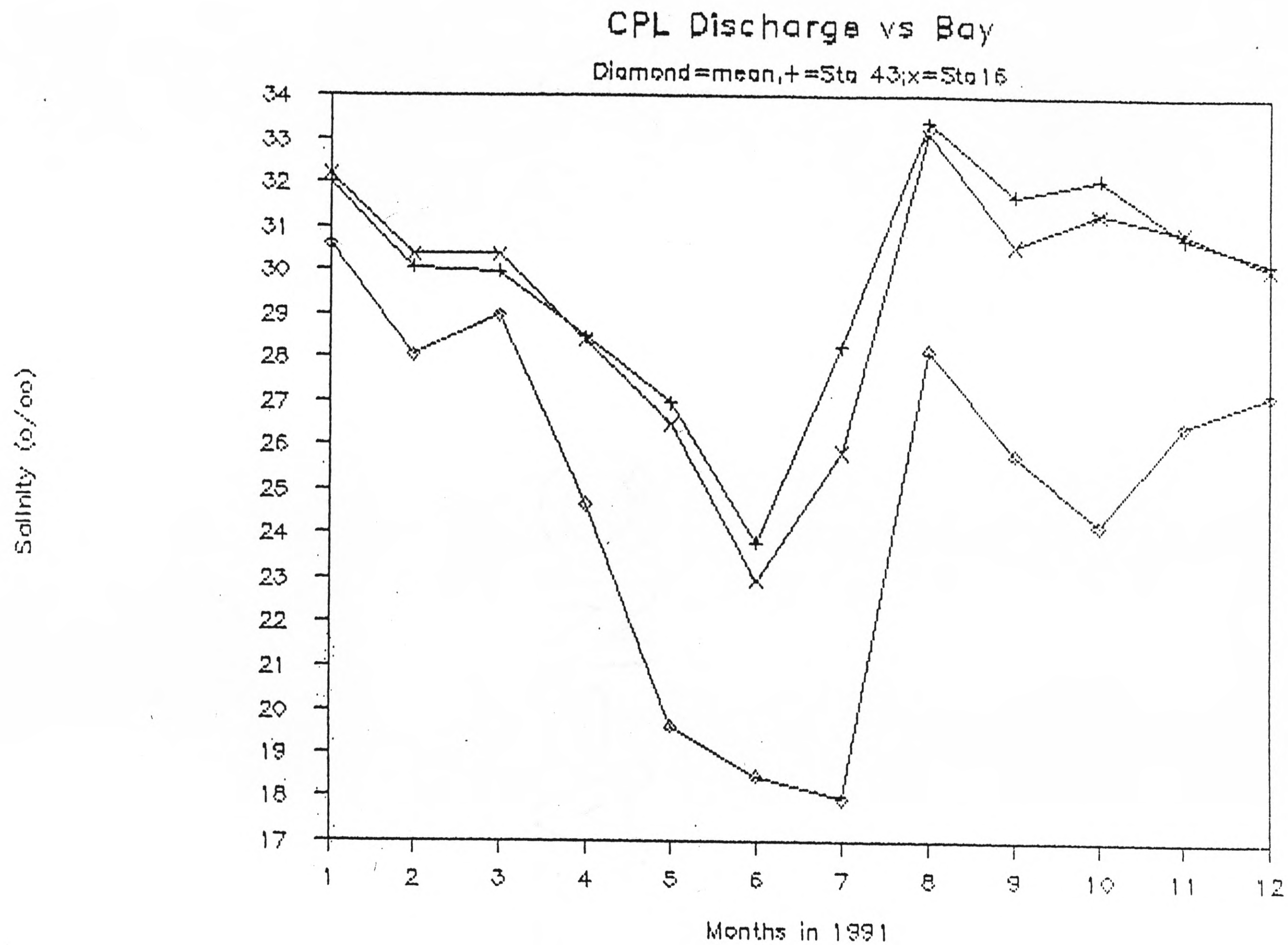


Figure 5. Mean salinity (psu) for all stations in Nueces Bay (diamond) by month during 1991. CPL discharge channel station 43 is denoted by (+) and station 16 under Nueces Causeway denoted by (x).

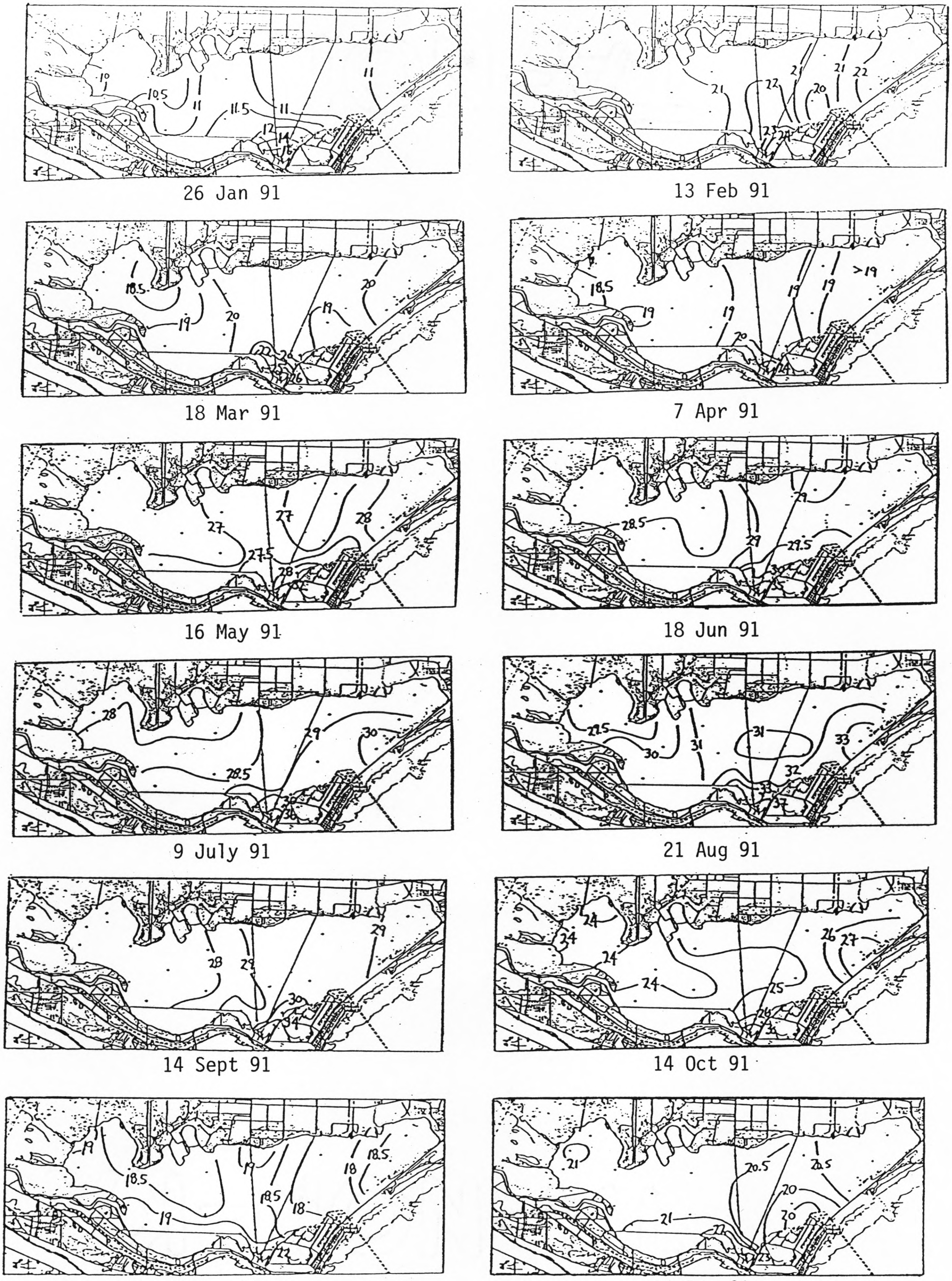


Figure 6. Monthly distributions of temperature (°C) in Nueces Bay during 1991 including CPL stations.

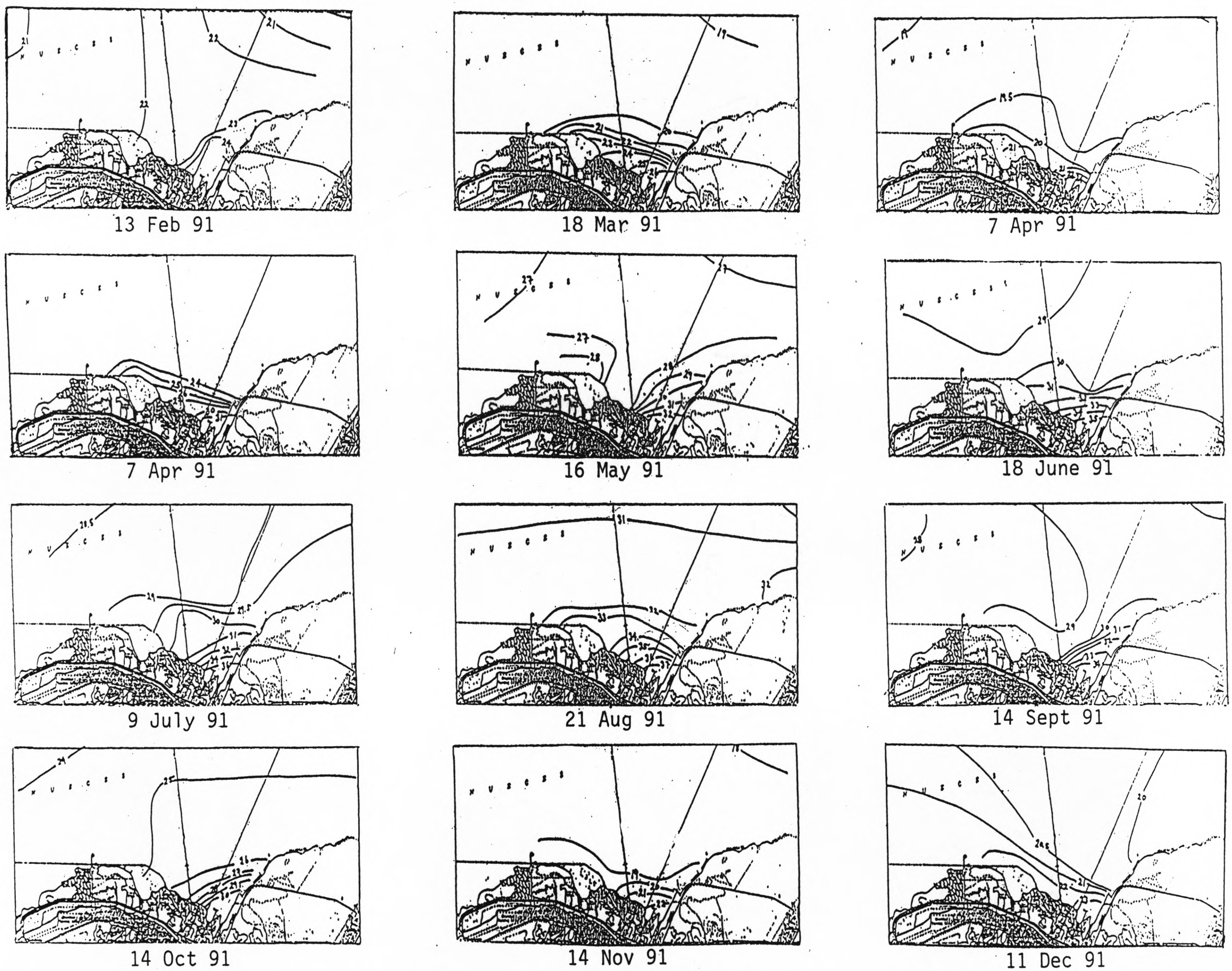


Figure 7. Small scale distributions of temperature (°C) near the CPL discharge channel in Nueces Bay during 1991.

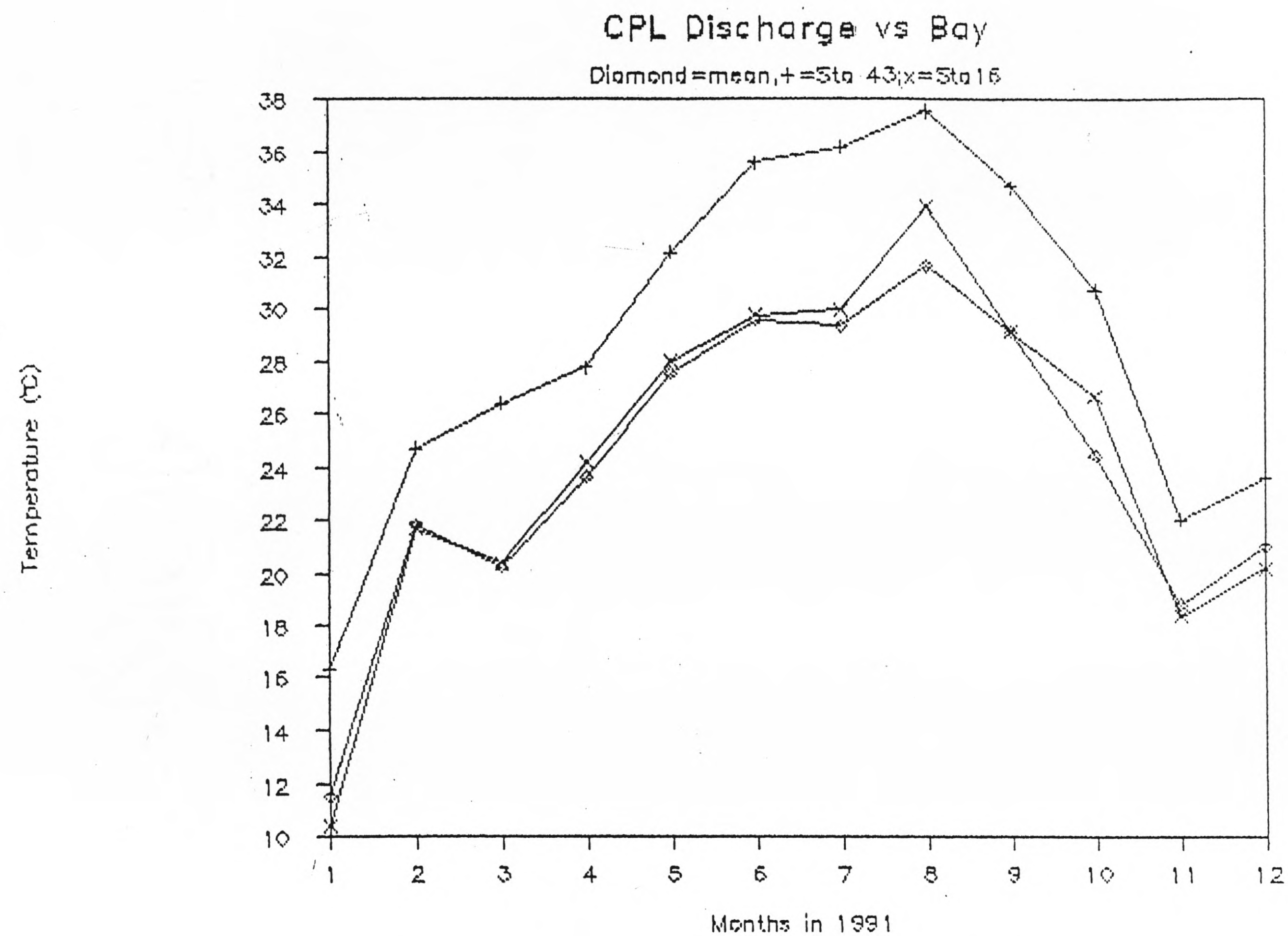


Figure 8. Mean temperature (°C) for all stations in Nueces Bay (diamond) by month during 1991. CPL discharge channel station 43 is denoted by (+) and station 16 under Nueces Causeway denoted by (x).

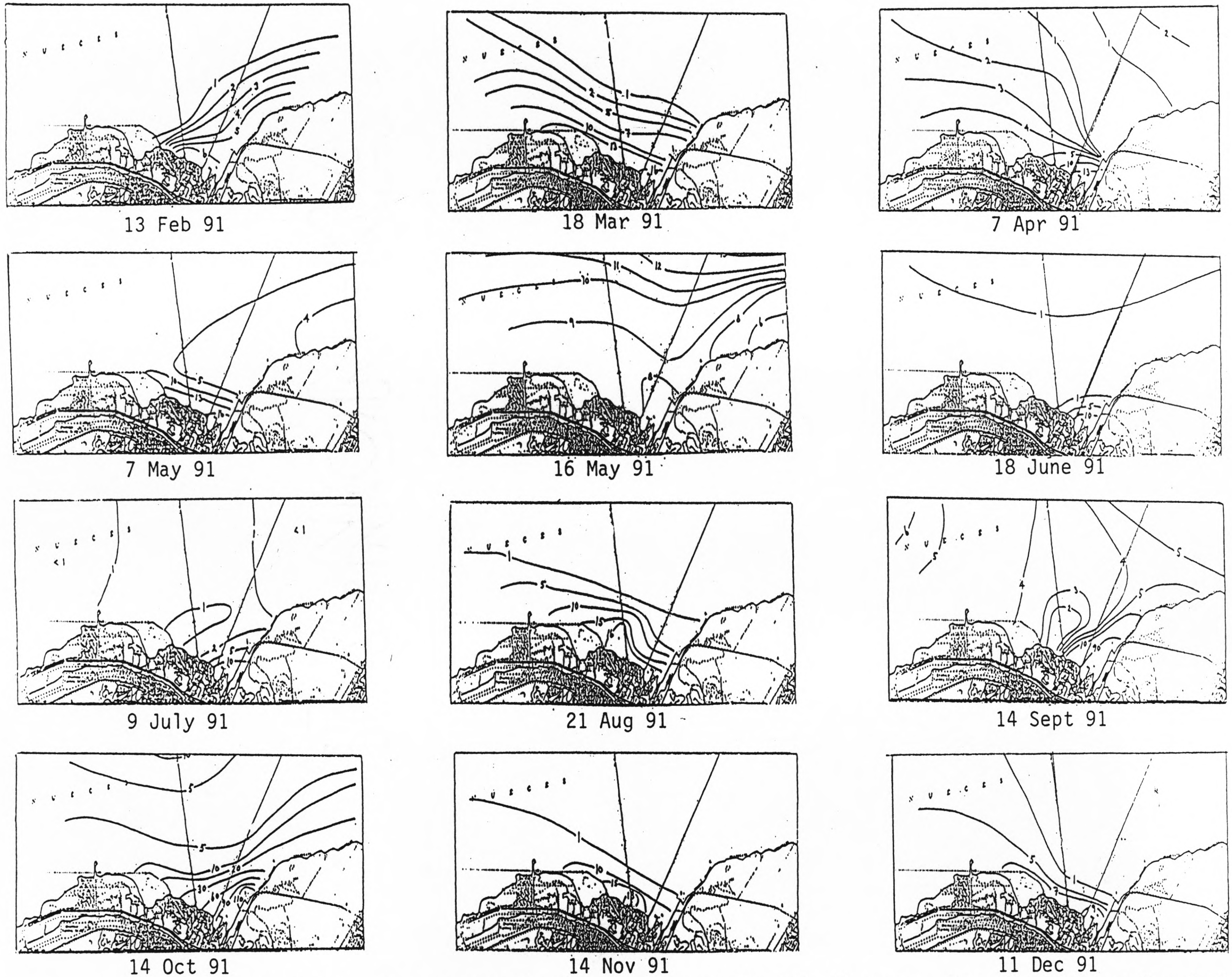


Figure 9. Small scale distribution of nitrite (μ mole/l) near the CPL discharge channel in Nueces Bay during 1991.

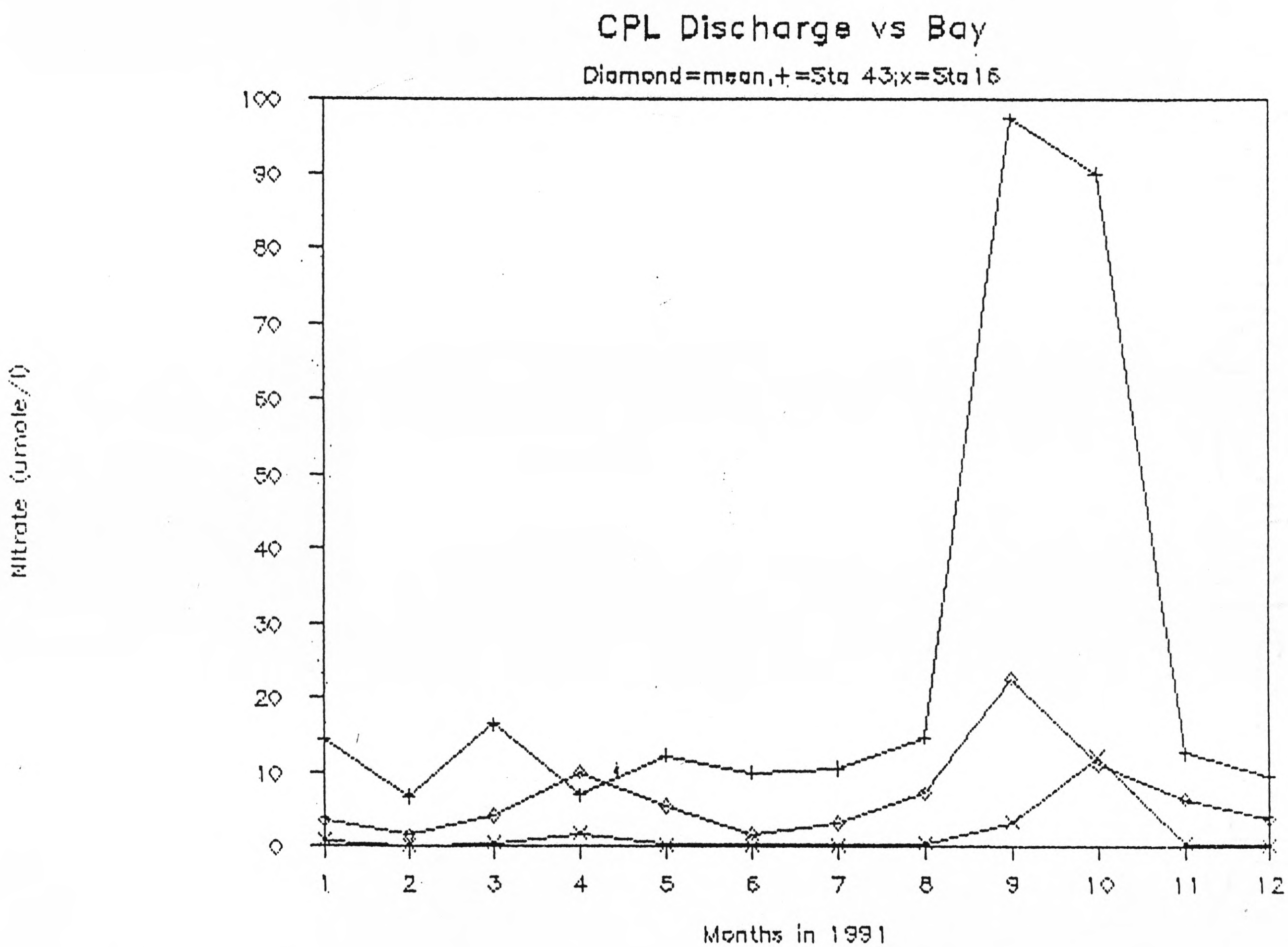


Figure 10. Mean nitrate concentration (u mole/l) for all stations in Nueces Bay (diamond) by month in 1991. CPL discharge channel station 43 is denoted by (+) and station 16 under Nueces Causeway denoted by (x).

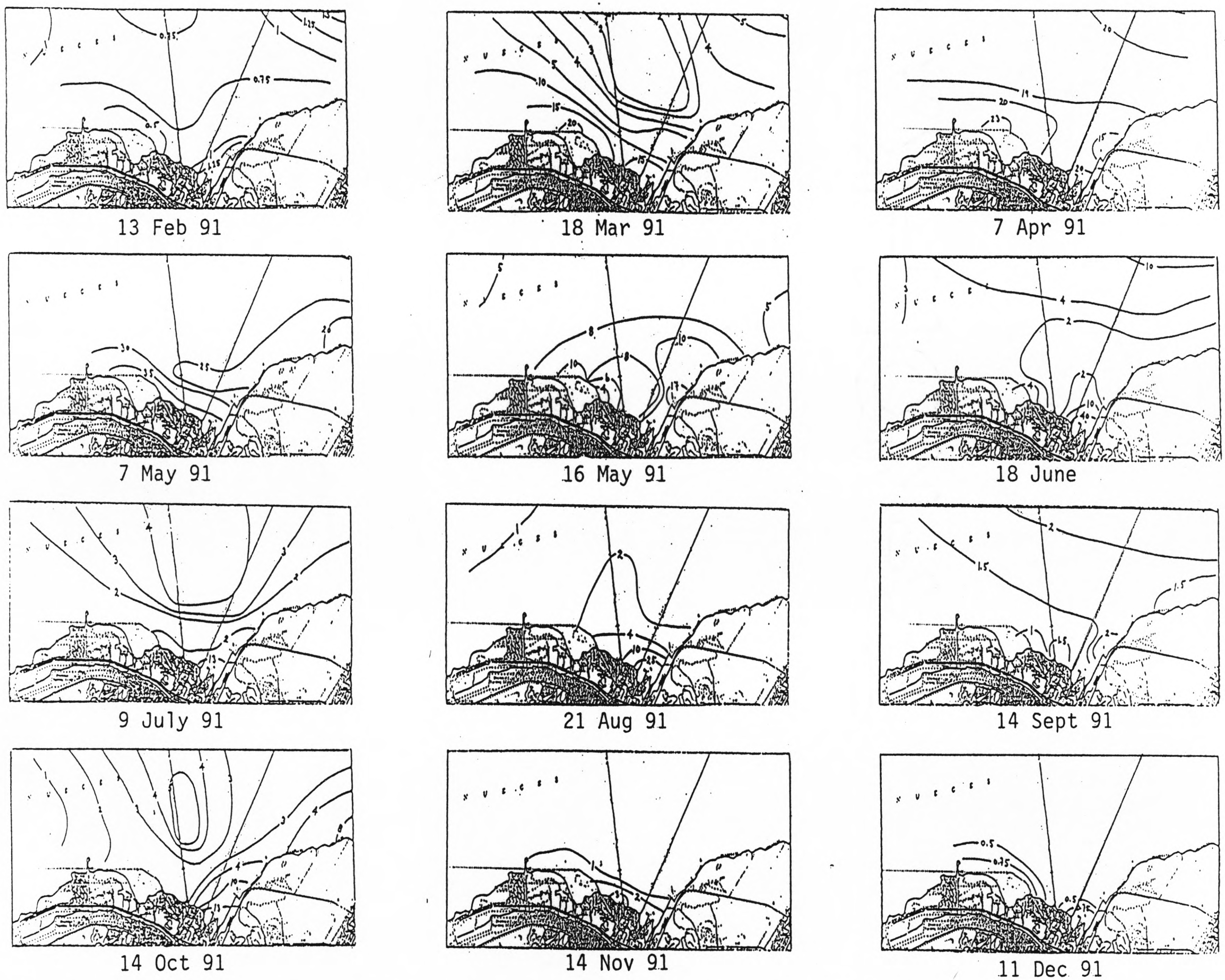


Figure 11. Small scale distributions of ammonium (μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

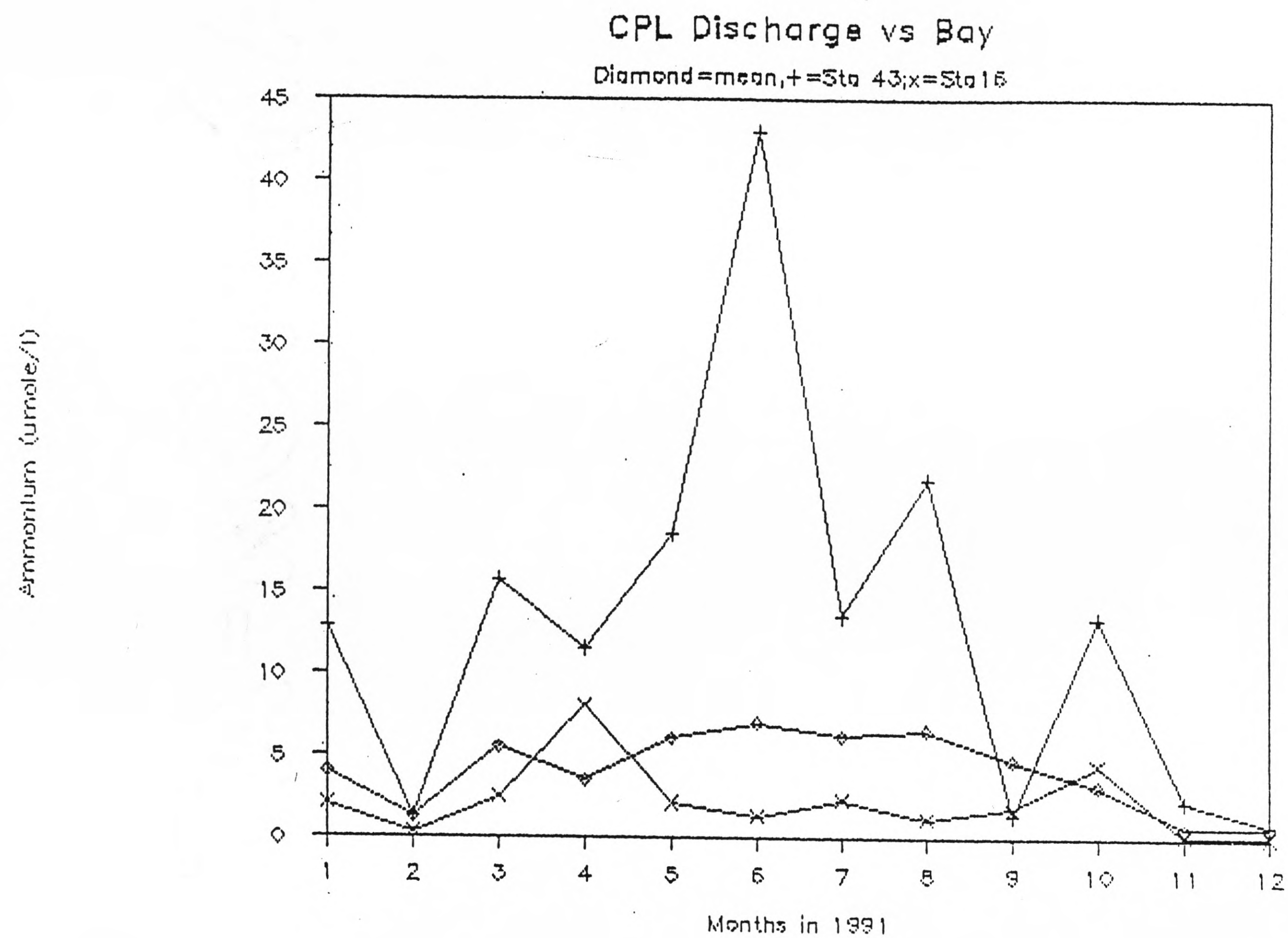


Figure 12. Mean ammonium concentration (μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

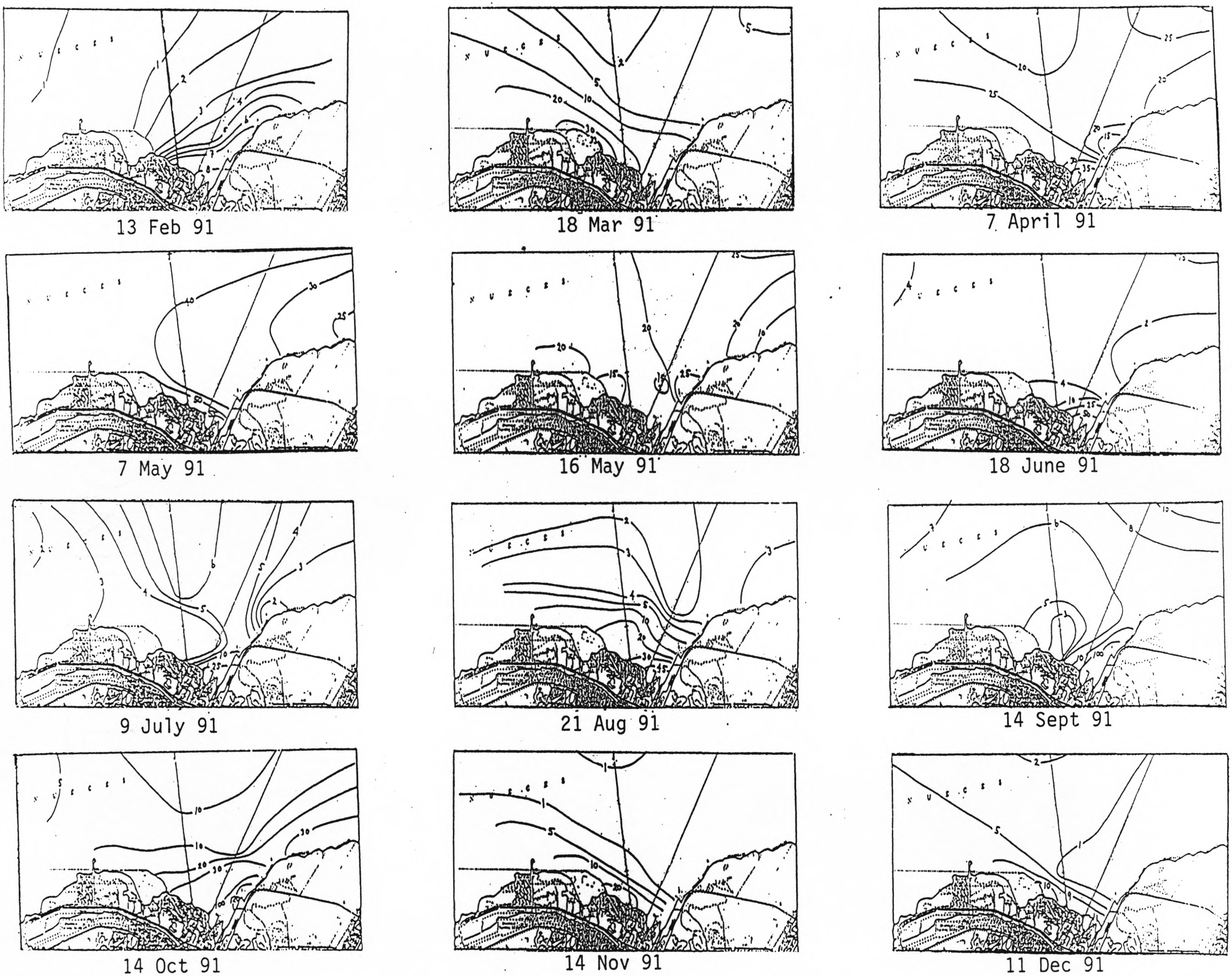


Figure 13. Small scale distribution of dissolved inorganic nitrogen (DIN = nitrate + nitrite + ammonium)(μ mole/l) near the CPI discharge channel in Nueces Bay in 1991.

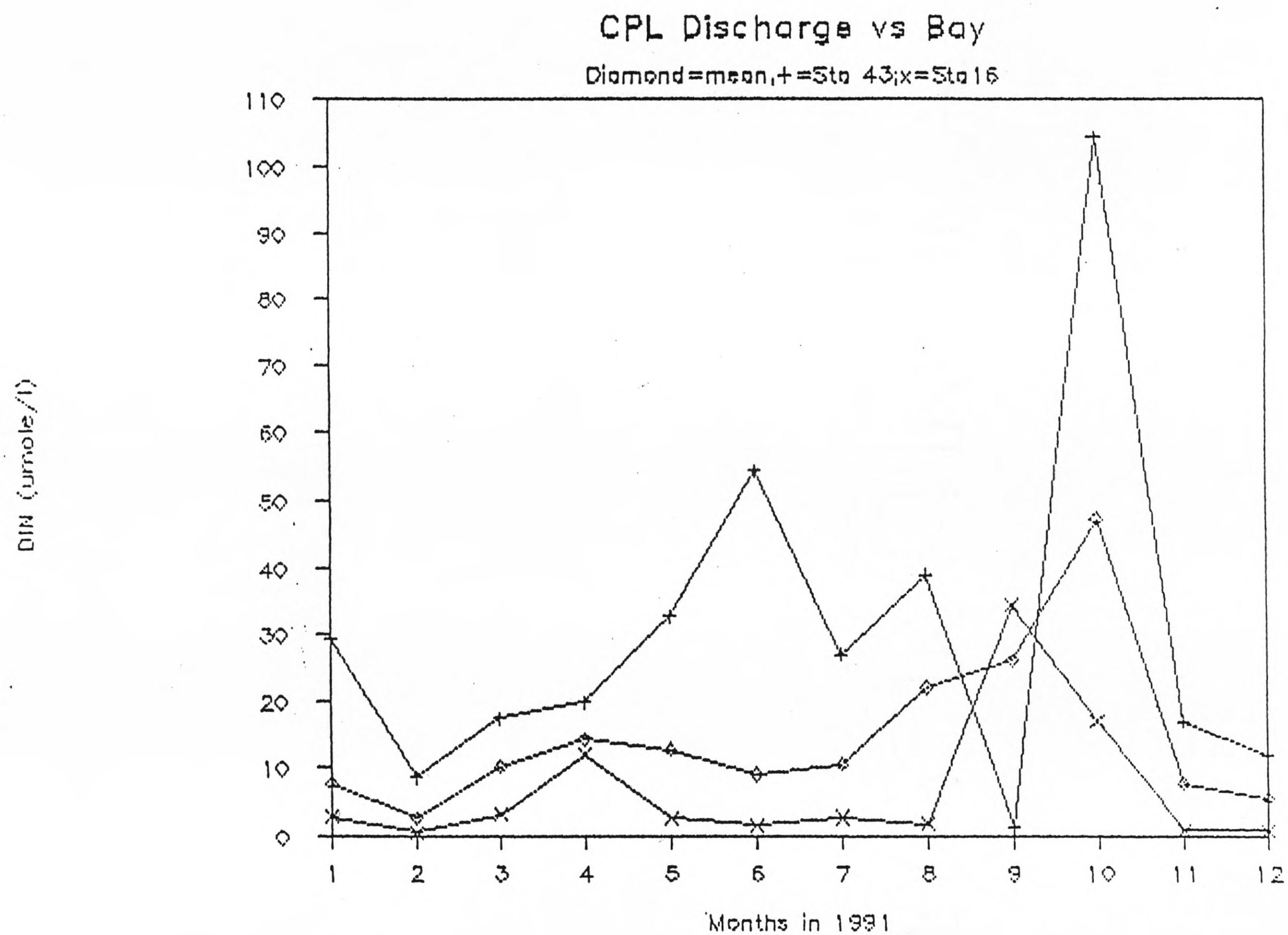


Figure 14. Mean disolved inorganic nitrogen (DIN=nitrate+nitrite+ammonium)(μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

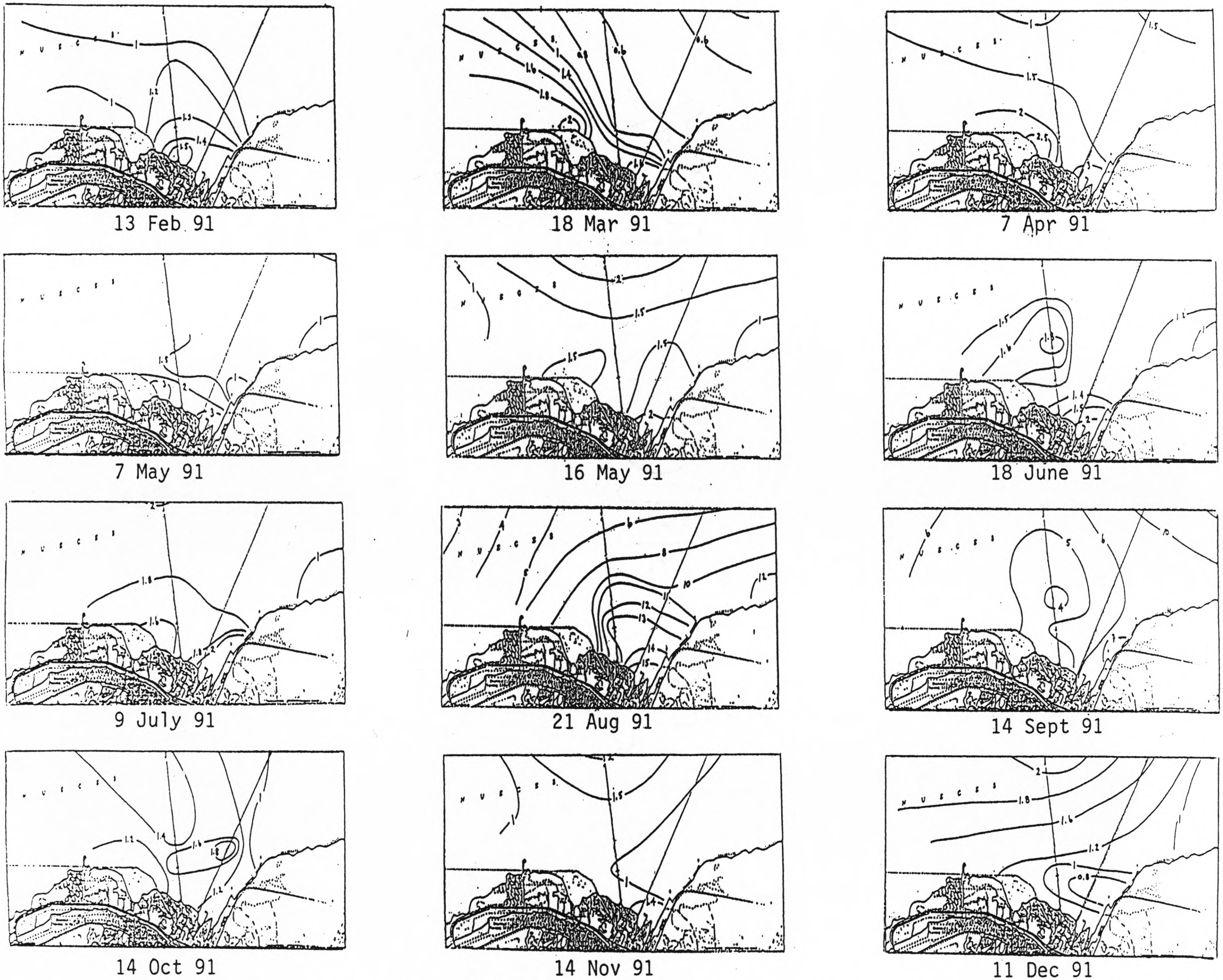


Figure 15. Small scale distribution of ortho phosphate (μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

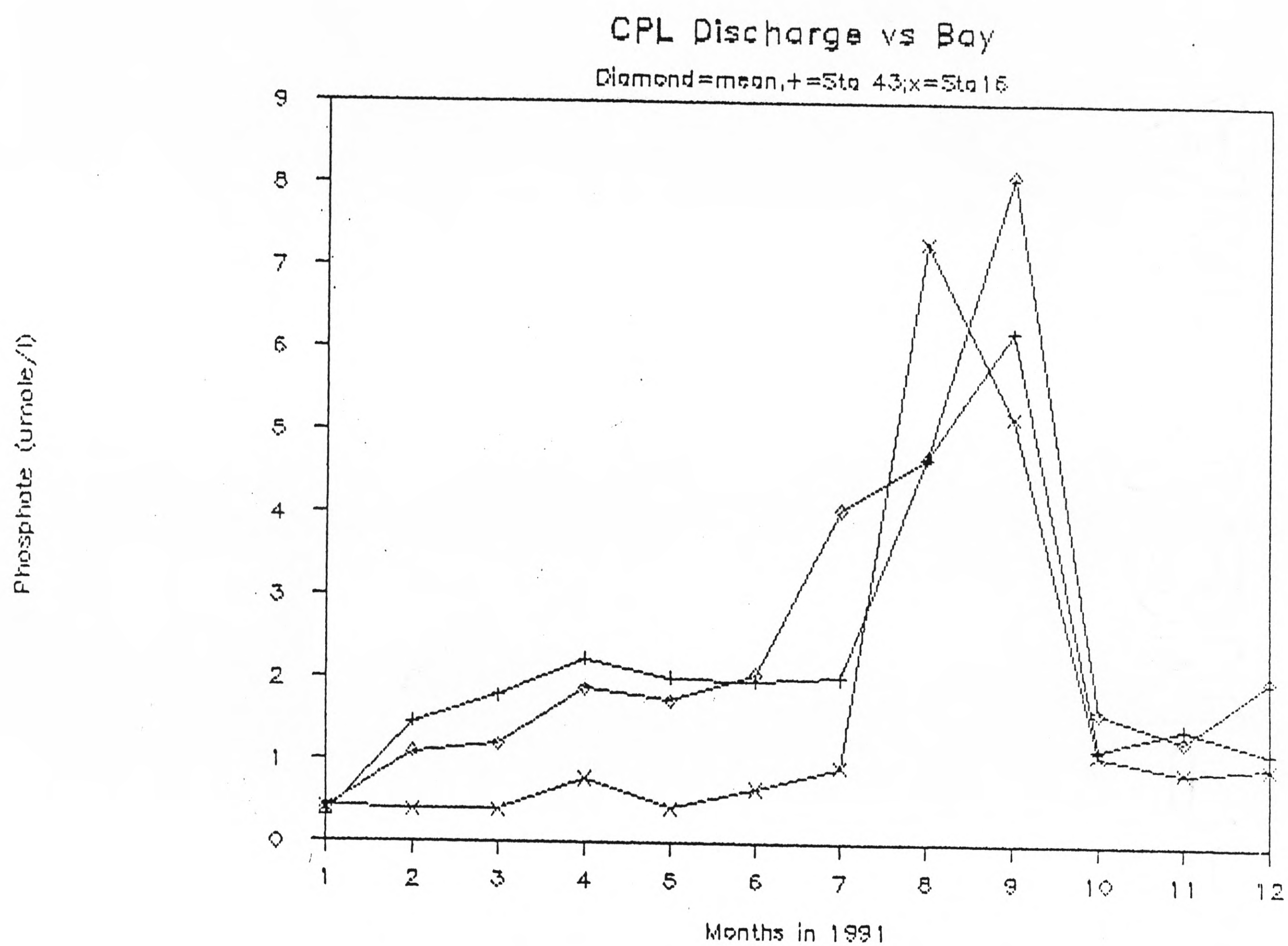


Figure 16. Mean ortho phosphate concentrations (μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

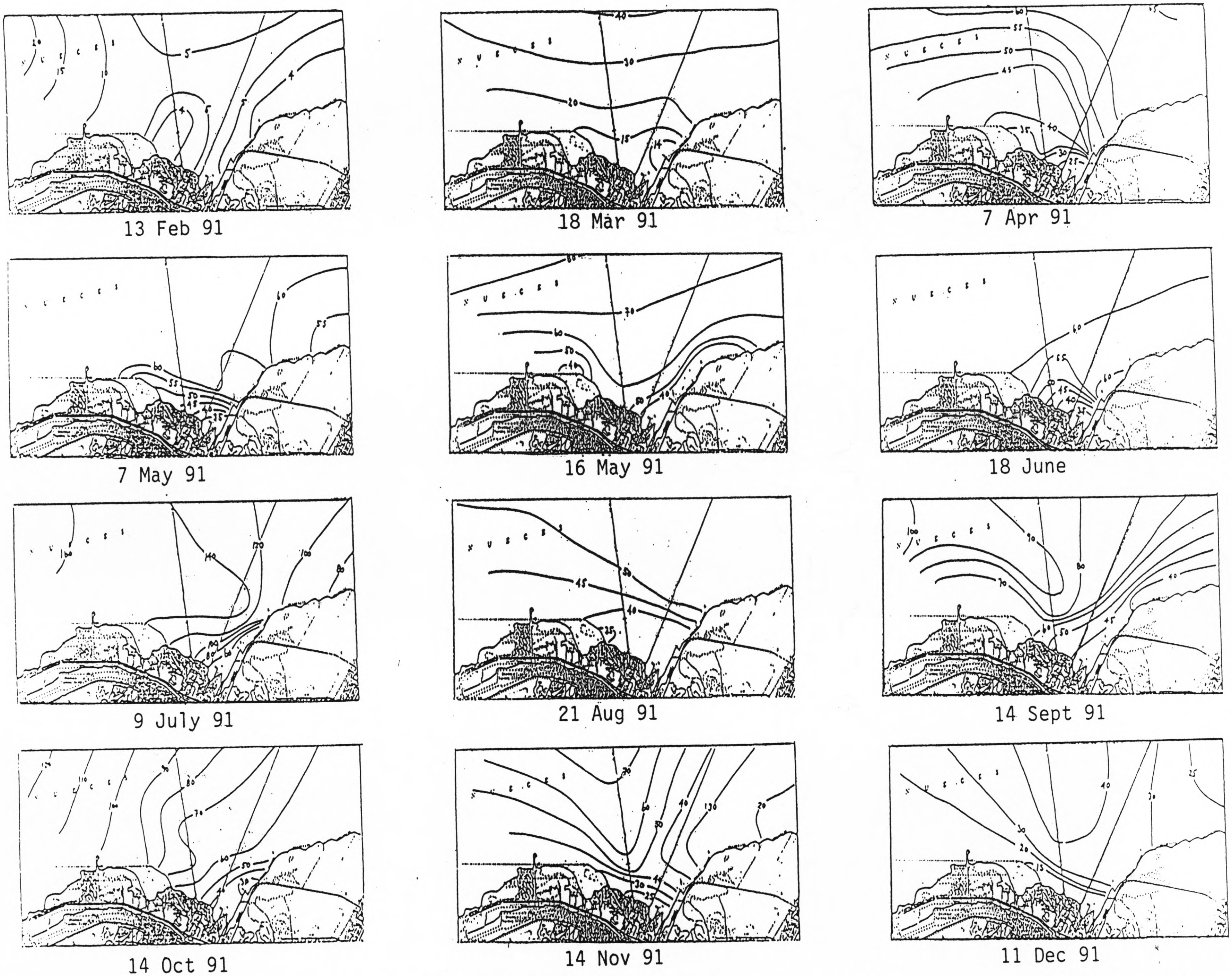


Figure 17. Small scale distribution of dissolved silicon (silicate)(μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

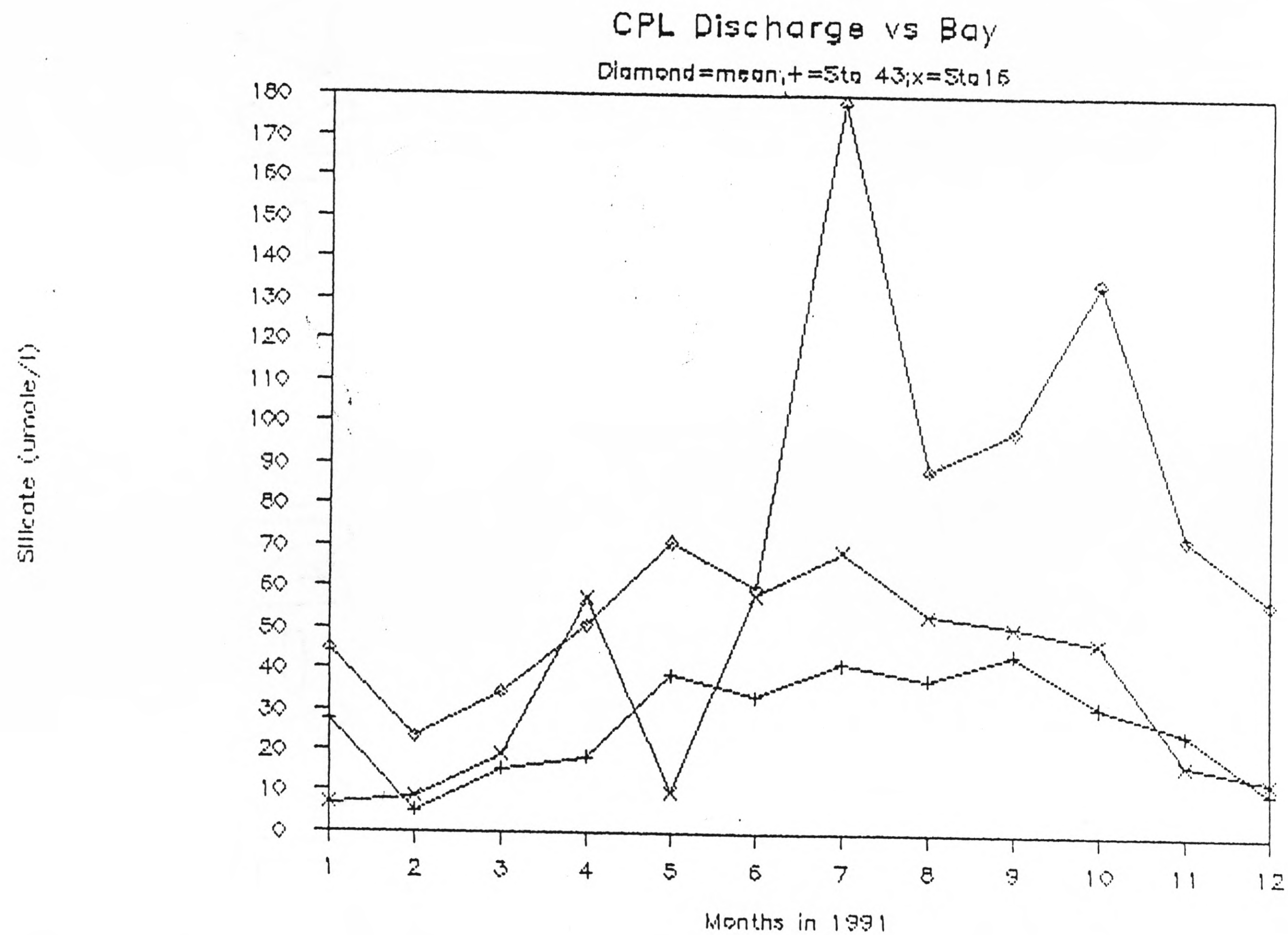


Figure 18. Mean disloved scilicon (silicate) concentrations (μ mole/l) near the CPL discharge channel in Nueces Bay in 1991.

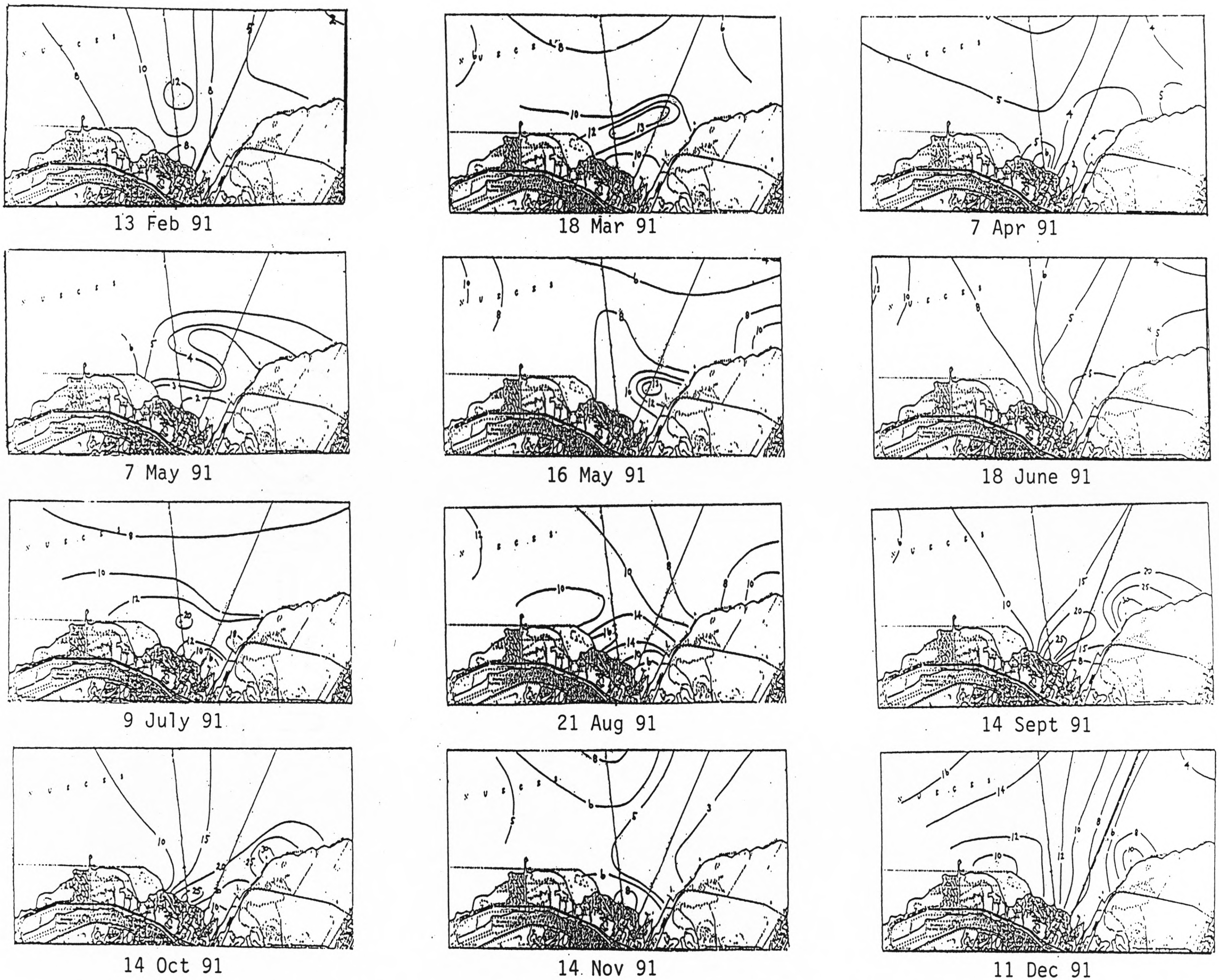


Figure 19. Small scale distributions of chlorophyll a (μg/l) near the CPL discharge channel in Neuces Bay in 1991.

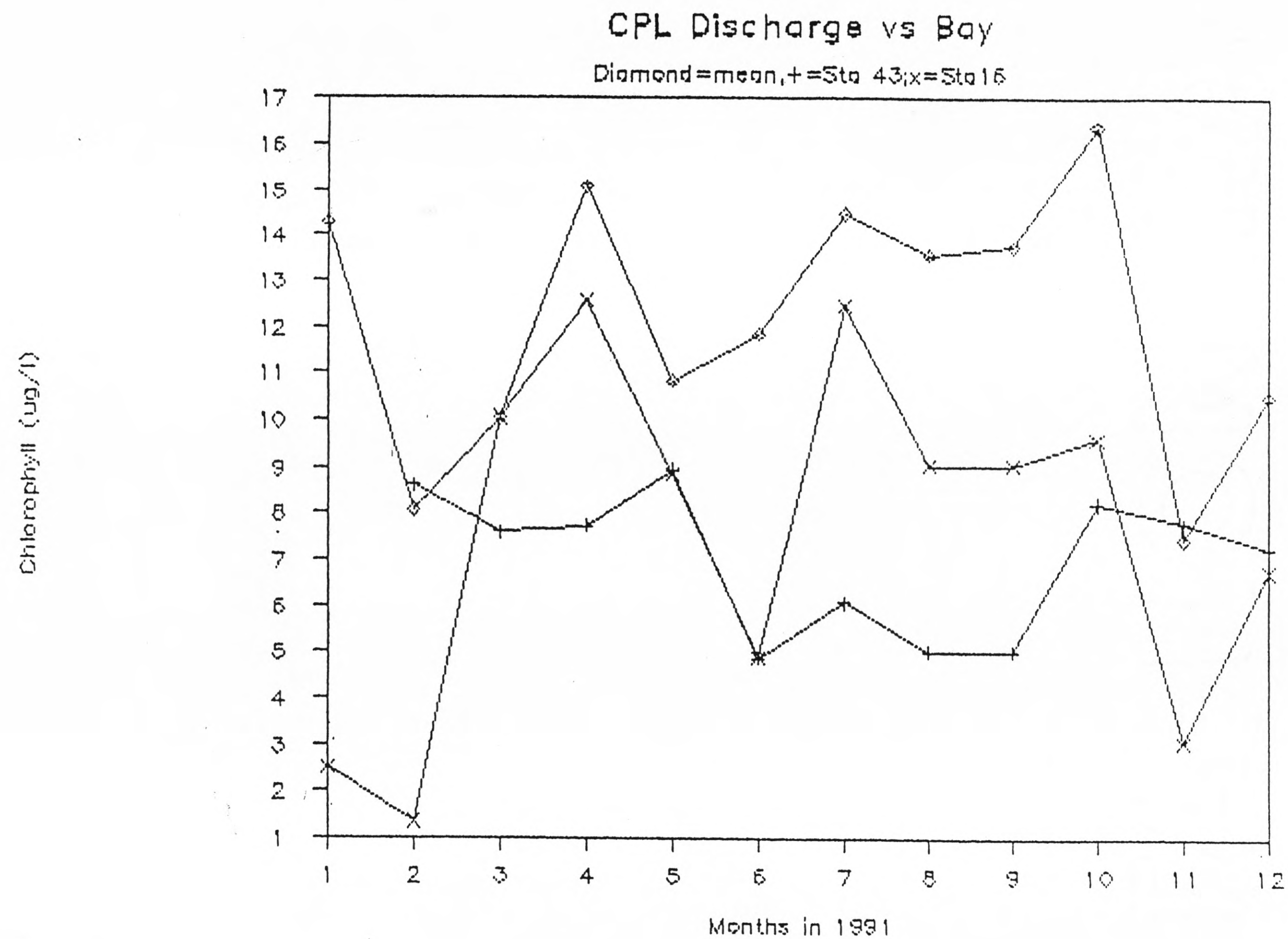


Figure 20. Mean chlorophyll a concentration (µg/l) near the CPL discharge channel in Nueces Bay in 1991.

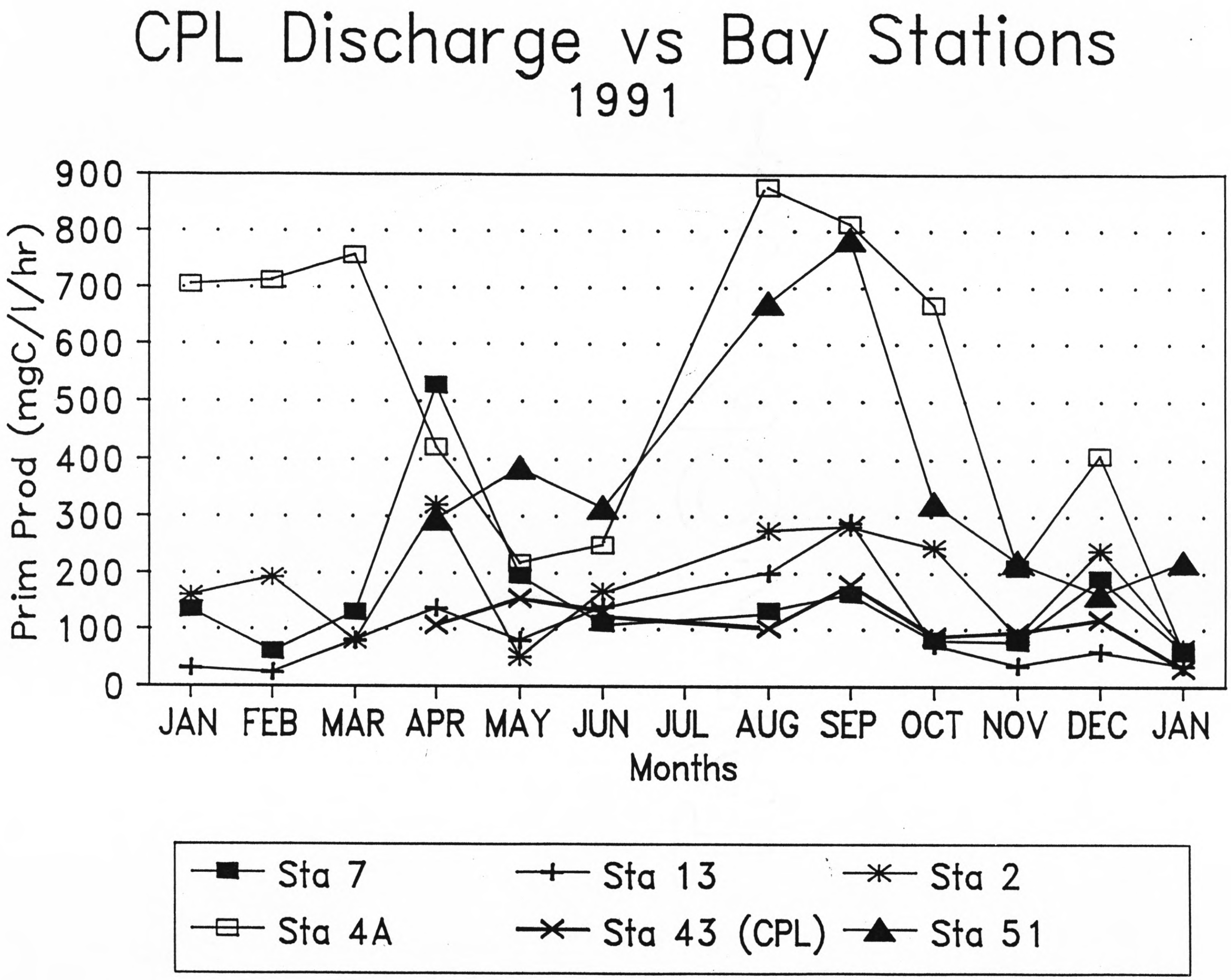


Figure 21. Primary production (mgC/l/hr) by month at the CPL discharge channel with respect to other locations in Nueces Bay, Nueces River and Rincon Delta during 1991.

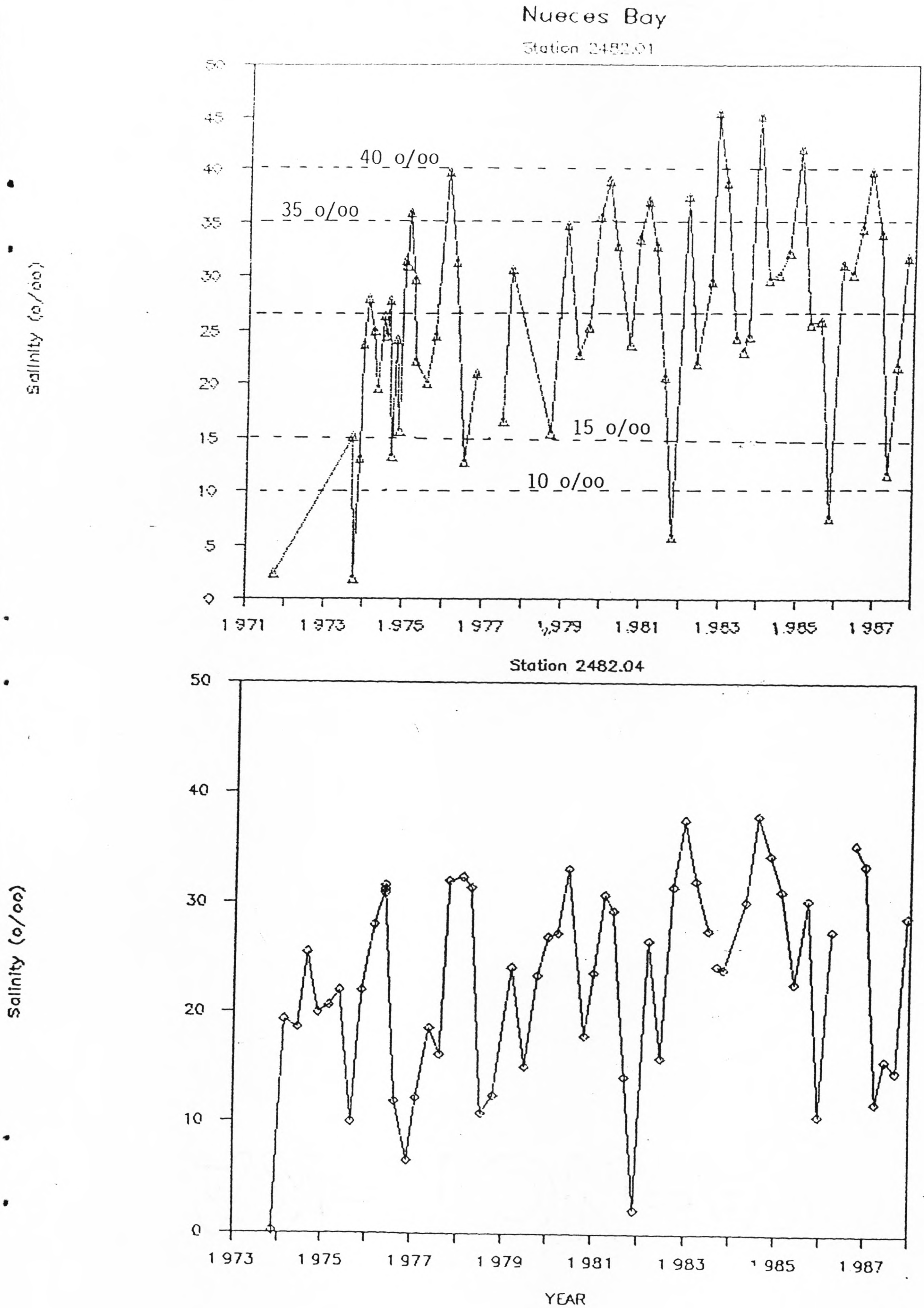
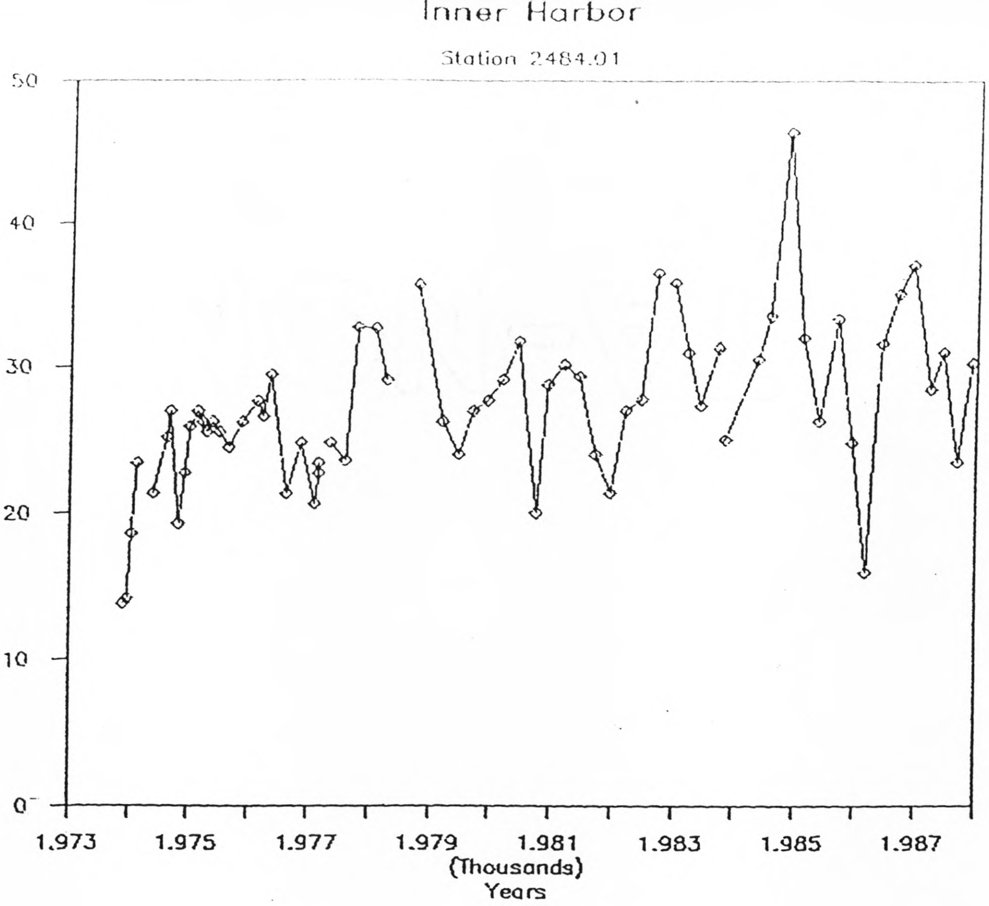


Figure 22. Salinity (psu) at TWC monitoring stations 2482.01 and 2482.04 in Nueces Bay for 1970's through 1987.



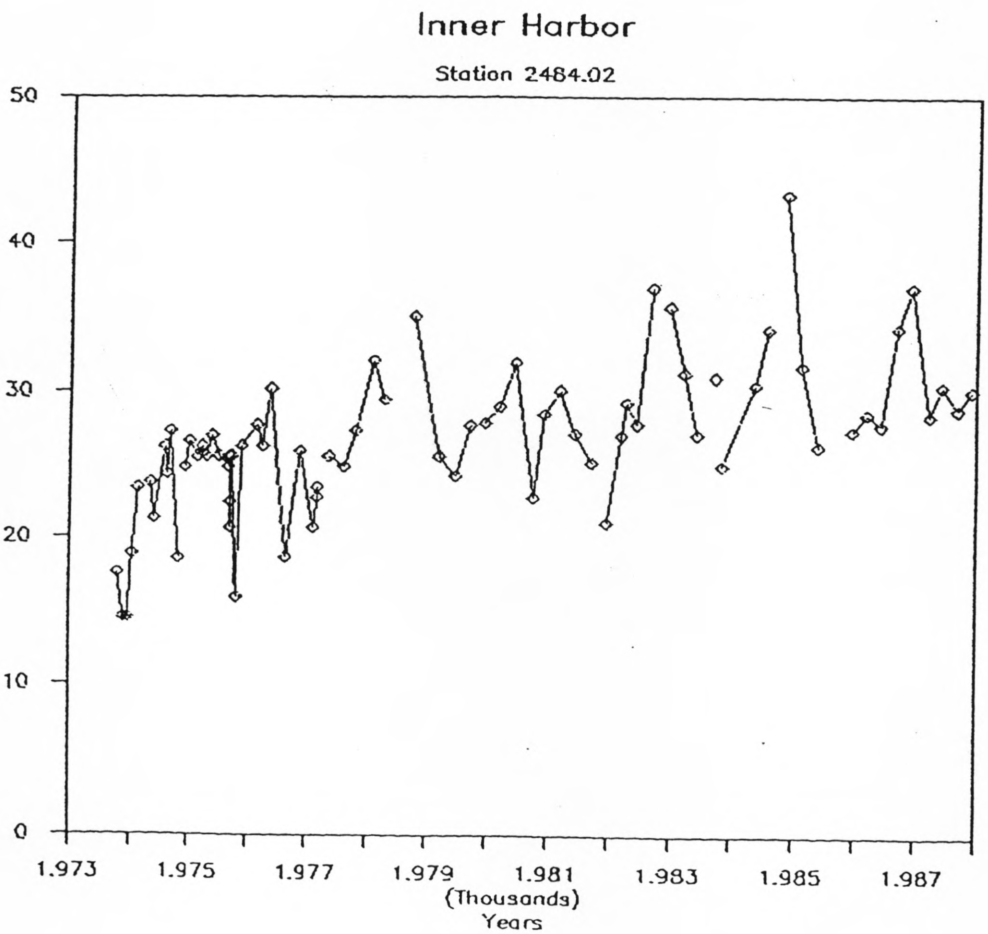


Figure 23. Salinity (psu) at the TWC monitoring stations 2484.01 and 2484.02 in the Corpus Christi Inner Harbor ship channel for the 1970's througr 1987.

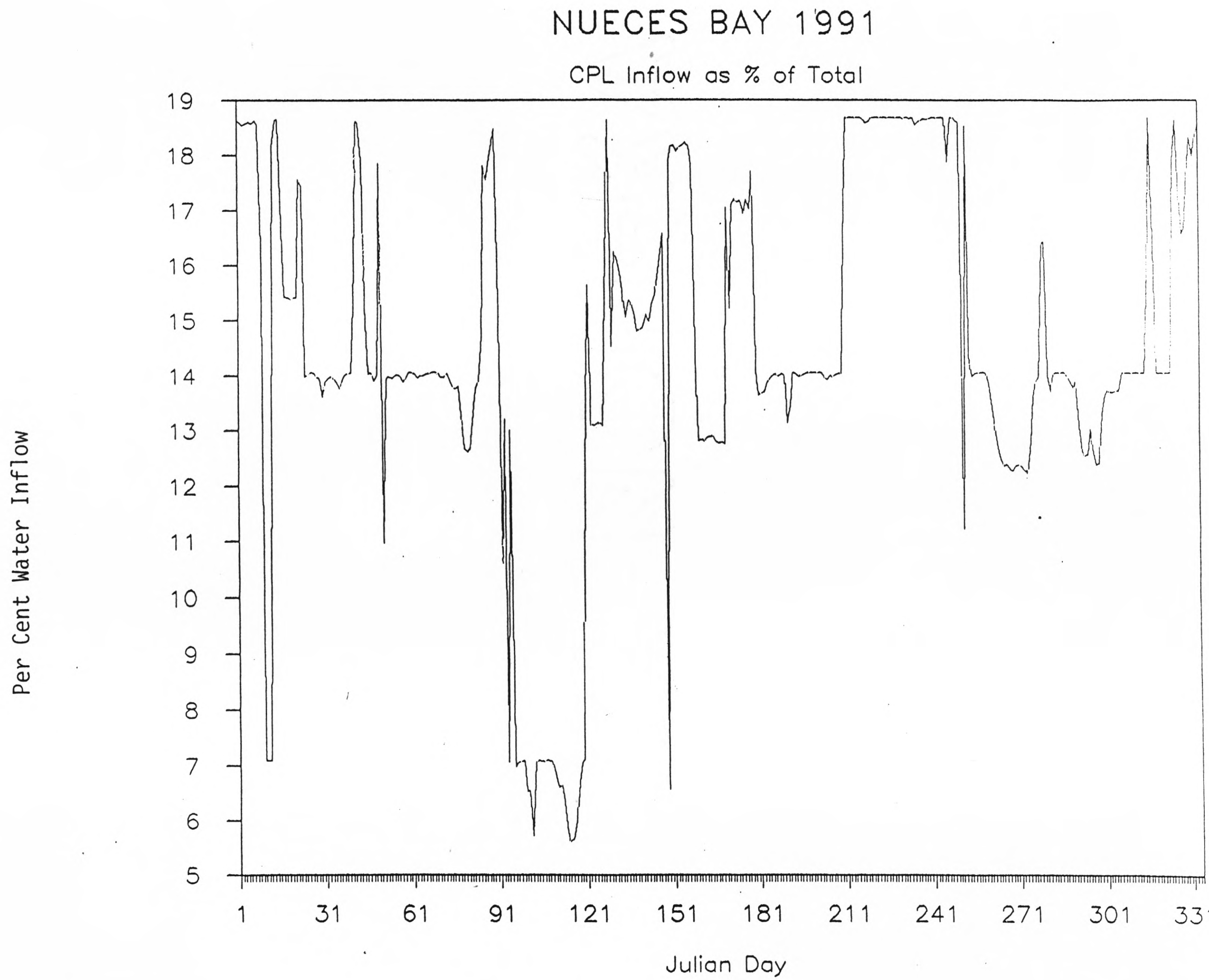


Figure 24. CPL discharge as a percentage of total inflows, return flows and tidal exchanges for the year 1991.

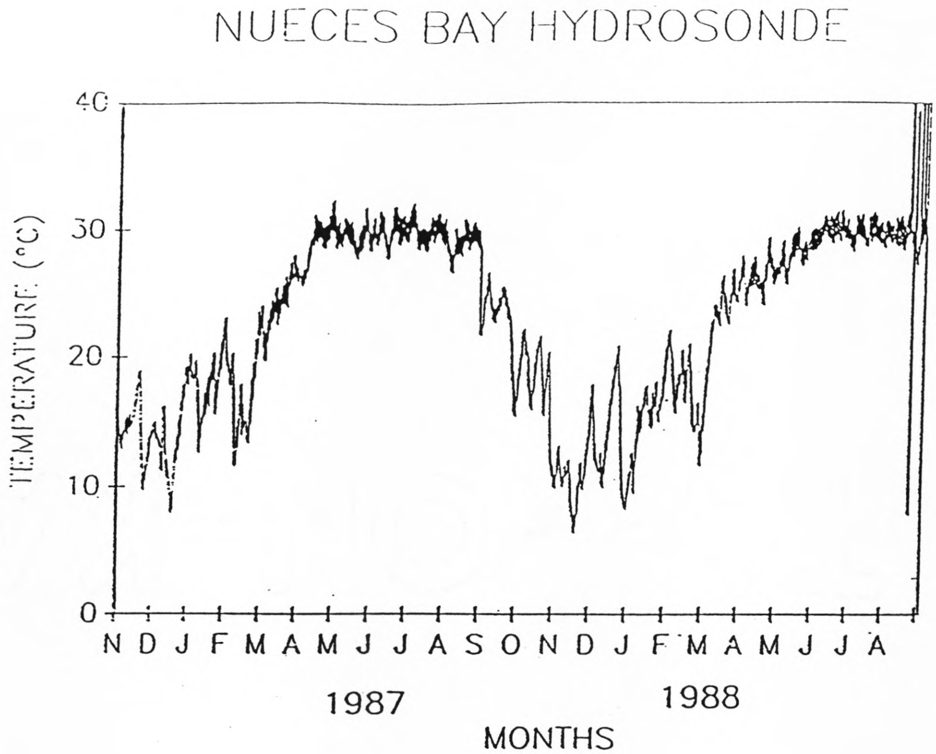


Figure 25. The temperature (°C) of Nueces Bay water at station location 11 collected by a hydrosonde during the years 1987-1988. (Courtesy of the TWDB).