HYDRODYNAMIC MODELLING BY UTILIZING GIS IN PARANAGUA BAY, PARANA, BRAZIL

Mauro Ribeiro Martins +
Mariane Alves Dal Santo ++
Juercio Tavares de Matos +++
Frederico Pereira Brandini ++++

+ Geologist - Laboratorio Associado deSensoriamento Remoto de SantaCatarina - LARS/SC - Brazil - Comission IV
++ Geographer - Laboratorio Associado de Sensoriamento Remoto de Santa Catarina - LARS/SC - Brazil - Comission IV
+++ Phd. Geosciense - Instituto Nacional de Pesquisas Espaciais - INPE - Brazil - Comission IV
++++ Phd. Biosciense - Centro de Biologia Marinha - UFPR/CBM - Brazil - Comission IV

Keywords - Coastal zone environment ; spacial database ; GIS

Abstract

The Paranagua bay estuary, situated in Parana State, Southern Brazil, has a great importance to the economy of region, its waters being aim of vast amount of works. This paper utilizes georreferencial databasegeneration and manipulation techiniques as well as some physical parameters statistical analysis water mass. The variables suspending particled matter water transparency, salinity, primary productivity and turbidity were achieved during field works in specific periods of the sazonal cycle. The results analysis and evaluation are displayed belone with the suggestion of a proposal for studing the water circulation pattern in that zone.

INTRODUCTION

The geoprocessing techniques are utilized worldwide by studing and applicating in several knowledge vanguard (DUEDALL, 1978; LANGRAN, 1989; NYERGES, 1989).

The estuaries, bays and laggons are ideal places for testing and applicating geographyc information systems, especially Digital Terrain Model manipulation and generation options (LATHROP and LILLESAND, 1989; LINDELL, et al. 1986; KHORRAM, 1985a and 1985b). This is due to the environmental dynamics and to space variations along the tide seazonal cycle, etc. Concerning to the water quality, in regions such those ones can be found the largest gradients of temperature, salinity, water color, and so.

The water masses circulation researches may be achieved fastly an exactness and visual understanding if the geoprocessing techniques are used.

Those ecossystems are considered, due to its natural characteristics, harmful efects aims because the human occupation, most of time planlessly. Because of the marine transport and as the coastal plains are ideal places for real state projects, the lagoons estuaries are sensitive to deep natural landscape alterations (DIOGENES, 1990).

In Paranaguá Bay one may find the grains larggest export harbor in Brazil which flows the Brazilian Southern Region goods and also the Paraguay ones.

The goal of this work is to study the water mass circulation pattern by using SIG, within a branch of the so called state of Paraná's Coastal Zone bay complex Paranaguá Bay (Fig.1). These region covers aproximately 400 km2 concerning to the submerged zone, since the rivers estuary up to the mixing with the sea water in Galleta Channel.

THE STUDIED AREA GENERAL SITUATION

The studing area is located in the latitudes 25°20'00' and 25° 35'00' and longitudes 48° 20'00'' and 48° 45'00'' situated in Brazil's Southern Regions. The Paranaguá Lagoon-Estuarine Complex encompasses about 5000 km2, and includes the associated drainage basins (BIGARELLA,1978).

Physiographicly, the region may be descibed as a water body projected into the continent over 50 km from the sea beaches within a natural landscape designated as a coastal plan (BIGARELLA op. cit.). At its west side one can see the Serra do Mar (Sea Hills) steep slope 1200 m high.

The natural sediment depositing of the estuary by rivers makes dificult the larger boats traffic. The slopes occupation processes near by the rivers accelerate the erosion and the consequent sedimentation.

For solving the problem constant dredging works are made along the ocean access channel.

Some works on aquatic environment monitoring for estimating those consequences generated within the water current patterns show that the environment is not get stabilized concerning its sedimentar balance (INPH, 1986; CBM, 1987).

Among some definitions of estuaries and similar environments (CAMERON & PRITCHARD, 1963; DYER, 1973; FAIRBRIDGE, 1980), the Paranaguá estuary region appears as a aquatic body depending of more than one continental water body receiving source as well as a moderate stratified behavior, evidencing its pattern controled by the seasonality. During the droughts the marine influences are more evident but in the rainy weather one can note a homogenation effect within the water body endowing continental characteristics to the environment.

SOARES (1990) says that the Paranaguá Complex estuary water bodies, represented by East-West branch (Baís de Paranaguá e Antonina) and by Norty-South branch (Baía das Laranjeiras e Guaraqueçaba) behave themselves as independent water bodies, with different drainage basins and circulation patterns (MANASSÉS, 1987). This is owned to the small contact sites among themselves and also to the submerged sandbanks that actuate to isolate the water masses.

The Paranaguá and Antonina bays, object of this study receives three rivers that born on Serra do Mar (Nhundiaquara, Faisqueira and Cachoeira) and, also the Guaraguaçú river which goes through the adjacent coastal plain. Those rivers drain all the material in sedimenting process within the estuary. The sedimentary balancing in the complex is mainly continental, owing to the oceanic currents its reworking and transport straight to the ocean (SOARES, 1990).

The dynamism factor in those bays is represented by the tide flow which oscilates even to 1,5 m about Paranaguá harbor (BRANDINI, 1985a).

The salinity is an important parameter for distinguishing the different water masses (BRANDINI, 1985b). The variation gradient is maintained aproximately the same one, independently of the tide direction, varging the absolute values in measured fixed points (fig. 8).One may observe its efects up to the rivers estuary at values of 2-5/1000 concentration (SINQUE, et al, 1982).

MATERIALS AND METHODS

It has been settled a sampling plan for the superficial water in Paranaguá and Antonina bays using two different seazonal cycle period. To achieve this goal, two collects had been done, one in summer (January,31,91) and the other in the winter (July,10,1991).There were distributed 63 sample sites in order to cover the whole aquatic region (Fig. 10).

It was intended to make a sampling covering all over the area so that the so generated data could show a very moment on the general aspect of the bays. The localization was achieved according the ships orienting buoys along the shipping traffic channel defined on nautical charts in the scale 1:25000 (MARINHA BR, 1990).

The following parameters were obtained: salinity, inorganic and organic suspending sediments chlorophyll a, water transparency and light absorption at 750nm (turbidity). These were processed in Centro de Biologia Marinha (CBM/UFPR), located in Pontal do Sul PR/BRAZIL.

The following meteorological conditions were checked: water and atmospheric temperature, precipitacion rate and wind speed and direction.

From now on the whole set of information related to each sampling point were tabulated and organized compatibly, in tables.

The works in the Geogrphical Information System, developed by INPE (Instituto Nacional de Pesquisas Espaciais) has their start in this stage. The INPE's GIS has, as work basic unit, sort of projects where are inserted data of a given interesting region. Each project is subdivided into informations plans (IP) having an isolated variable. So, those IP may be both polygonal or DTM, depending on the variable sort that is to say, lining under vetorial shape or a spacial ditribuition as a rastering of a givem parameter (FELGUEIRAS, 1987).

The location map, the aquatic body interesting limit, the drainage net among other preliminary information were digitalized under the form of polygons. The data related to the sampling points were digitalized as DTM so that there could generate regular grids, through interpolator and isolines.

Parallely, the tabled data were submetted to the statistical correlation anlysis, through Pearson's correlation index in order to observe which variables are more alike the spacial distributing pattern. This way one might distinguish which parameters were distributed both dependent and independent variables (BRAGA, 1988; MENDES, 1990).

A 99% assurance limit was settled to the mainly correlations owing to the great liberty values (62). Therefore the minimal correlation coefficient was >0.3 or <-0.3 (FISCHER, 1948).

After the regular grids creation related to the variables, a regular isoline map with spacement proporcional to the minimal and maximum limit of each variable. Also, the grid was refined allowing to obtain the image in grey levels that overdetailed the isolines. As an option to visualization and volume estimating, the grid was sliced so that for separating and comparimenting the water mass in fraction with alike characteristics. Mathematical decisions as well as field works drove to establish the classes. The vastest number of possible parameters allowed to achieve a classifications that satisfied the whole set of the responses.

Facing the information volume, a data selection and a graphic outing were achieved so that to allow a numerical support and a spacial vision of the water circulation general pattern in the study area as well to alow qualitative information to a circulation model proposition.

After the data digitalization relating to each variable, within the GIS, the geration of regular grids by interpolation of with 250 lines x 458 columns was established determining a 100x100m spatial resolution element. In order to restrict the grid values only in the aquatic body, a grid masking was done by using an information plan that limits the interest area (area border). The next stage consisted in refining these grids with later slicing into classes that depend on the minimal and maximum values.

DISCUSSION OF THE RESULTS

The two collect dates environmental conditions presented alike behavior in relation to the wind speed and direction and tide level. The variation was observed, as previosly suposed, only on the days that anteceded the field works rainy rates. In january, the pluviometrical rates was kept over the july ones. The monthy averages observed to those months were 280 mm, to january and 70 mm to july (tab. 2). The arrival of the contributing drainage basin water, in january, was much greater, transporting to greater amount of suspending wastes. As a consequence, the most evident parameters variation was the salinity. In january, the smallest salinity value was obtained on the point 63, having 2 parts/1000 and the greatest on point 1, having 30/1000. In july, on the same points, the salinity variation remained both between 8 and 32 parts/1000 (fig. 2 and 4). The particulated suspending material presented gradation rates from 17 to 79 mg/l an january and from 14 to 63 mg/l in july, with the tendency of increasing the concentration toward the continental waters. According to this pattern, the water transparency and the light absortion presented rater between 0.6m to 2m and from 2.6% to 13.7% both in january and betweem 0.7m to 4.25 m and from 1% to 11.4%, both in july (fig. 3 and 5). Those parameters measured near by point 11 are alike to those obtained by Rebello and Brandini (1988) (tab. 1).

Table 3 displays the descriptive characteristics of the utilized variables behavior. The ranges between minimal and maximum in january has been larger comparing with july in all the measured parameters, except concerning to water transparency measuring. However, if we

As it is an elongate shaped water mass, perpendicular to the coast line, the predominating hydrodynamics forcer are unidirectional ones (Eastward-Westward), presently impeling the water mass upward to the continent (high tide component resultant), presently, flowing the water mass to the ocean (low tide component resultant) (fig. 10). Within a period of heavy rains, followed by non-rainy days, it happens to occurr in the bays, from the rivers estuary, the development and displacement of a suspending material plume heading for the ocean. After passing, the water reacquires its normal condition. This feature was observed in january, when there were heavy rains, but the weather was stable on the sampling day.

The meteorological data monthly and annual average rates as well as the absolute data observed on the sampling day syntonizes themselves evidencing the suggestions and conclusions afirmed by Brandini (1985), Rebello & Brandini (1990), Sinque (1982), INPH (1986) and CBM (1987).

The deposition and sedimentation present conditions in Paranagua estuarine complex, characthizer an accented manage only the intermediary sampling point rates, we may verify a clear data homogenization once compared with the observations taken in july on the same ones.

Concerning to the correlation analysis the most correlationable variables are listed on table 4 within the established assurance limit, the best associations involve the total sedimentation and the salinity. Facing these context, we may consider those variables as independent ones in relation to the water transparency, primary productinty and turbidity (fig. 6 and 7).

CONCLUSION

Within the measured parameters, the salynity and the suspending sediments concentration demonstrate adequately the movements on the studied environment the used isoline patterns allowed, first of all, the water body compartmentation into three distinct segments (fig. 11 and 12):

The Antonina Bay inland sector, where one may find a continental predominance, counting with a greater suspending matter load in both sampled periods; The Paranagua Bay, in the intermediary sector, with transition characteristics; and the coastal area represented by Galheta Channel, where the water body behaves with more complexity due to the nearness of the sea and the connection with Laranjeiras Bay (Fig 1) The aquatic body coast line contour by itself suggests this compartmentation.

The rains influence is more emphasize on the continental sector, and the coast area is influenced by tide regime (Fig 11 and 12).

sedimentation on back side having a water flake a lesser them 1 meter water flake on the greater part of Antonina Bay.

Concerning to the geoprocessing performance applied on the work area, one may observe the fartness, facility and precision on the obtained results. As it is a SIG, the utilized algorythms demonstrate that the data manipulating option are really variety, and its whole potentiality was not completely explored.

The pattern shown by the isoline forms in the variables salinity, transparency and suspended solids totals were like a well-defined and continuous gradient Eart-Westward (fig. 9).

As the Nhundiaquara river in the bays most important tributary and as it emptier on the area intermediary sector (Paranagua Bay), its influence on the sediment flow is not observed in Antonina Bay and this strengthens the bays compartmentation proposal.

The seasonal variation concerning the water circulation behavior, the meteorological data and the sampling data, evidence that the precipitation rate had been the only responsable by the sedimentar dynamics changing.

All the analysed variables contributed for generating a georeferenced database which will allow, from now on, its actualization and therefore, will help in the improvement of a geoenvironmental modelling involving new variables.

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table 1 : Environmental conditions in day collect

HOUR	TIDE 1/31/91	WIND DIR	SPEED m/s	TIDE 7/10/91	WIND DIR	SPPED m/s
9	low	NW	3	high	clm	
10	high	NW	2.5	high	clm	
11	high	clm		high	NW	3
12	high	clm		high	clm	
13	high	clm		high	clm	
14	high	NE	3	high	clm	
15	high	clm		high	clm	
16	high	NE	3.5	low	SE	5
17	low	NE	3	low	SE	5

table 2 - Anual variations of environmental conditions

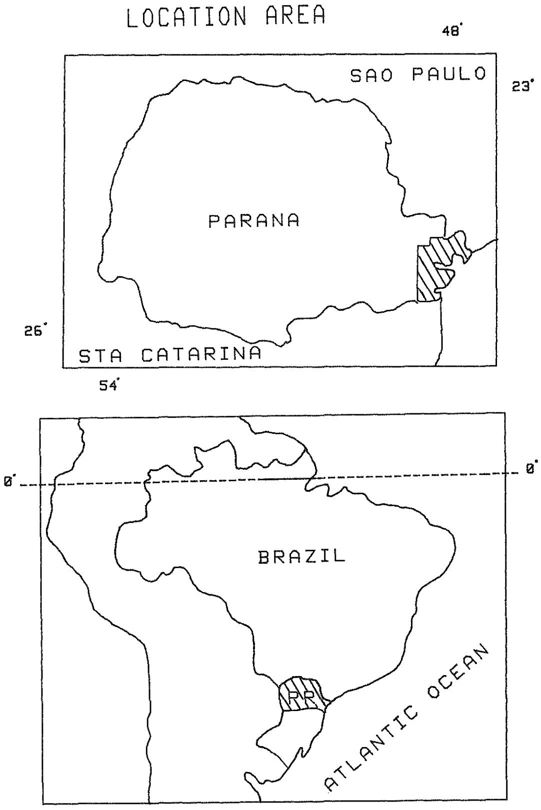
month	precip. (mm)	wind dir. avg.	wind sp. avg.(m/s)	wind dir. max.	wind sp. max.(m/s)
1	277	NE	1.6	W	32
2	330	NE	1.4	SW	30
3	249	NE	1.3	SW	26.6
4	167	NE	1.2	SW	18.6
5	115	NE	1.2	SW	24.2
6	92	NE	1.3	W	25.5
7	59	NE	1.3	SW	29.8
8	79	NE	1.4	SW	23.6
9	131	NE	1.5	S	21
10	161	NE	1.6	SE	27.4
11	145	NE	1.7	SW	22.8
12	175	NE	1.6	SW	20.4

font. IAPAR- 1979-1989

table 3 : Descritive statistical analyses

var.jan.	avg.	min.	max.	std.dev.	range
turbid.	6.08	2.3	13.7	3.65	11.4
transp.	1.3	0.5	2	0.56	1.5
sol.sus.	31.1	17.35	79.1	11.87	61.75
salin.	21.01	2	30	8.32	28
clor.	7.34	4	17.3	3.15	13.3
org.mat.	23.76	13.15	62.7	9.39	49.55
inorg.mat	17.46	2.2	50.53	13.46	50.53
var.jul.					
turbid.	4.79	1.1	16.9	3.73	17.8
transp.	1.94	0.7	4.25	0.82	3.55
sol.sus.	27.49	14.13	63.4	11.35	49.26
salin.	25.06	8	32	5.28	24
clor.	5.5	2.43	14.53	3.2	12.1
org.mat.	21.99	10.36	52.2	10.57	42.13
inorg.mat	24.98	6.62	40.35	9.35	33.72

LOCATION AREA



LARS\SC

table 4 : Siginificants correlations

	a1	b1	c1	d1	e1	f1	g1	h1	i1	j1
a2	0.7474									
b2	0.8007		-0.8259							
c2	-0.9039		0.8941		-0.766					0.8671
d2	-0.8756						0.9371			
e2	0.7214	0.9829		0.8487						
f2						0.7667	-0.8651	0.9495		-0.8117
g2						-0.8158	0.8296		0.74	
h2						0.6492	-0.8458			
i2						-0.7063				
j2	0.7622									

obs:

a1 : turbidity 01/31/1991
b1 : suspended inorganic solids 01/31/1991
c1 : salinity 01/31/1991
d1 : suspended organic solids 01/31/1991
e1 : chlorophill a 01/31/1991
f1 : turbidity 07/10/1991
g1 : salinity 07/10/1991
h1 : suspended inorganic solids 07/10/1991
i1 : suspended organic solids 07/10/1991
j1 : water transparency 07/10/1991

a2 : suspended inorganic solids 01/31/1991
b2 : chlorophill a 01/31/1991
c2 : water transparency 01/31/1991
d2 : salinity 01/31/1991
e2 : total of suspended sediment 01/31/1991
f2 : total of suspended solids 07/10/1991
g2 : water transparency 07/10/1991
h2 : suspended inorganic solids 07/10/1991
i2 : [illegible]
j2 : turbidity 07/10/1991

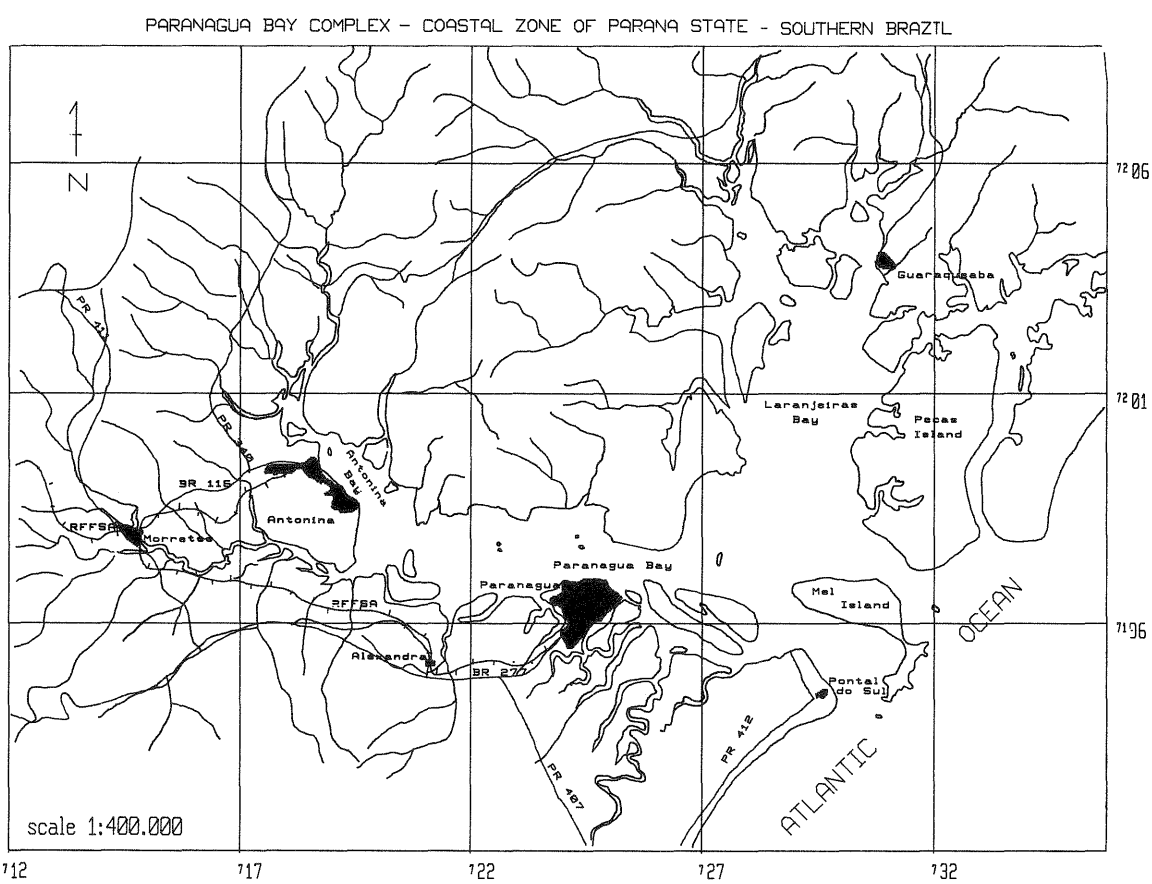
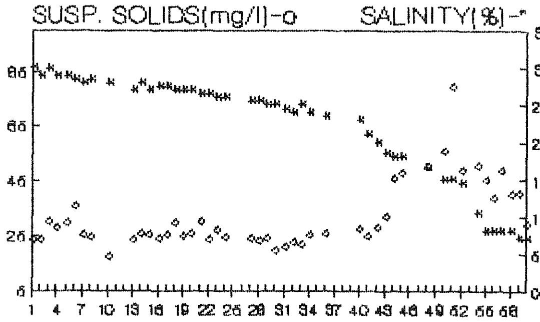


Fig. 1 - Location map

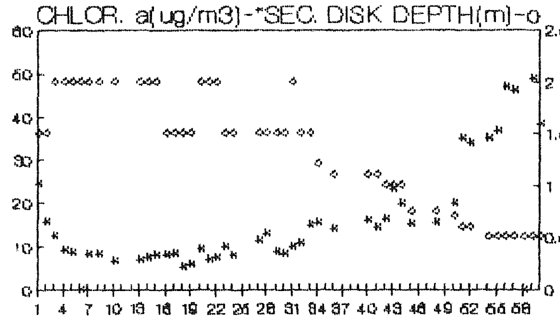
FIG.2-01/31/1991 RESULTS OF PARAMETERS MEASUREMENTS



COLLECT STATION

COEF.COR.- r = -0.49

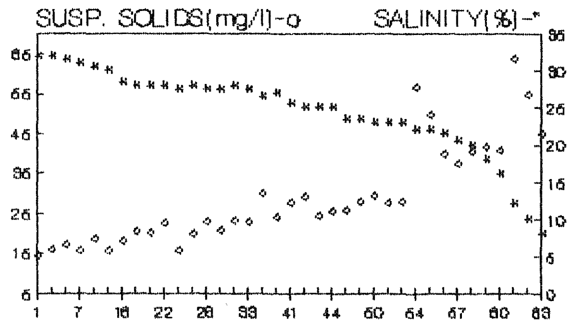
FIG.3-01/31/1991 RESULTS OF PARAMETERS MEASUREMENTS



COLLECT STATION

COEF.COR.- r = -0.7666

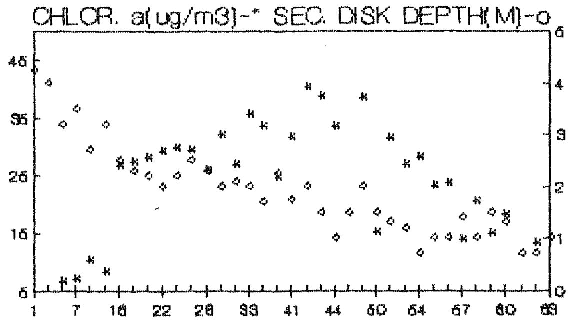
FIG.4-07/10/1991 RESULTS OF PARAMETERS MEASUREMENTS



COLLECT STATION

COEF. COR. - r = -0.8651

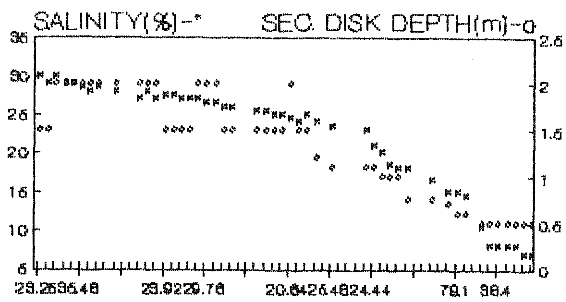
FIG.5-07/10/1991 RESULTS OF PARAMETERS MEASUREMENTS



COLLECT STATION

COEF. COR. - r = -0.40

FIG.06 - 01/31/1991 PARAMETERS ASSOCIATION

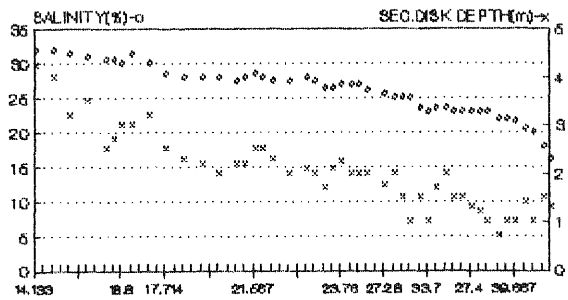


SUSPENDED SOLIDS (mg/l)

COEF.COR.- r = -0.4902 (SALINITY)

r = -0.5963 (SEC. DISK)

FIG.7 - 07/10/1991 PARAMETERS ASSOCIATION

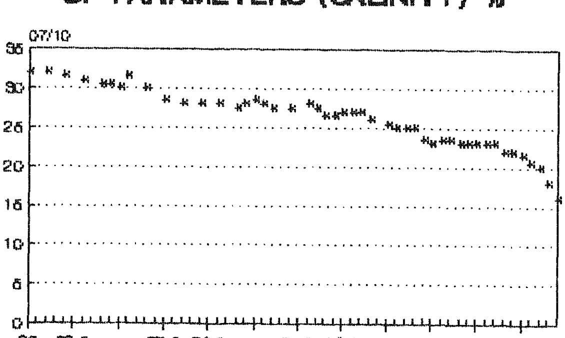


SUSPENDED SOLIDS (mg/l)

COEF. COR. - r = 0.8651 (SALINITY)

r = 0.8117 (SEC. DISK)

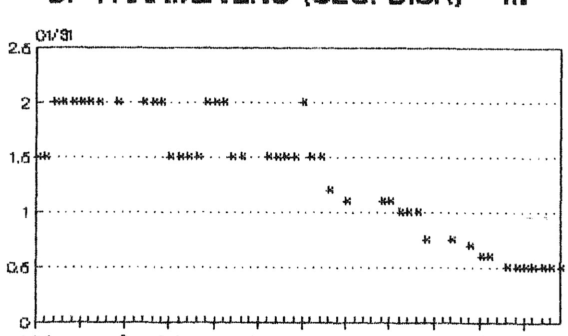
FIG.8 -TEMPORAL COMPARISON OF PARAMETERS (SALINITY)-%



01/31

coef. cor. - r = 0.9371

FIG.9 -TEMPORAL COMPARISON OF PARAMETERS (SEC. DISK) - m



07/10

coef. cor. - r = 0.4195

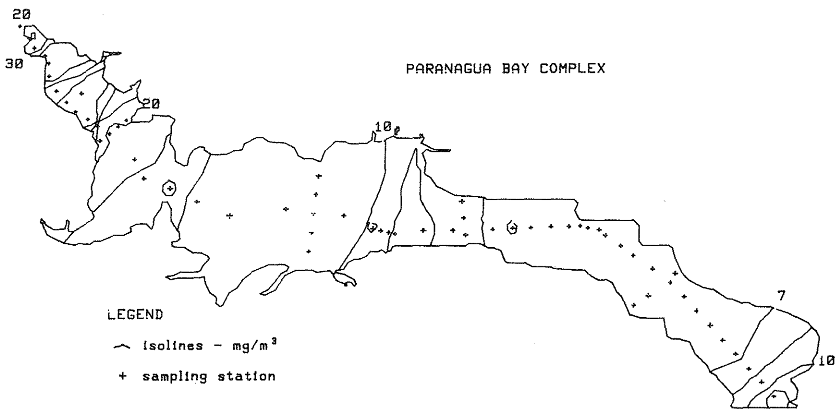


Fig. 10 - Isolines pattern of chlorophill-a - 01/31/91

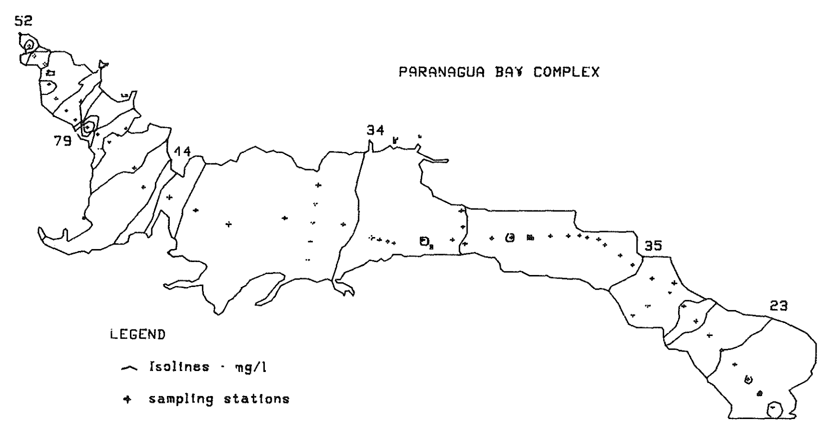


Fig. 11 - Isolines pattern suspended solids - 01/31/91

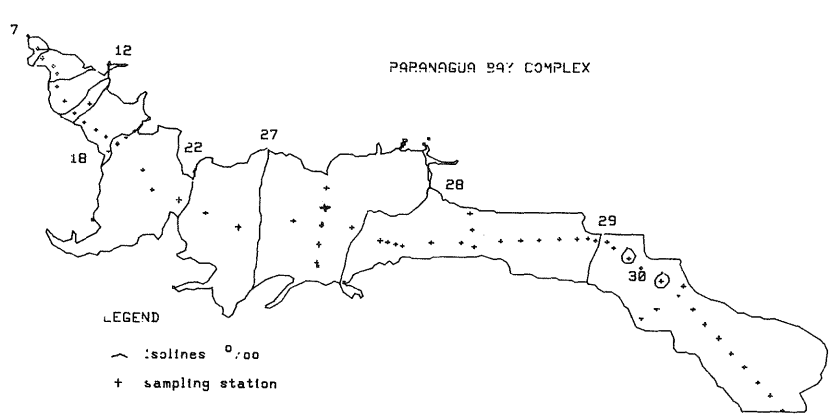


Fig. 12 - Isolines pattern of salinity - 01/31/91