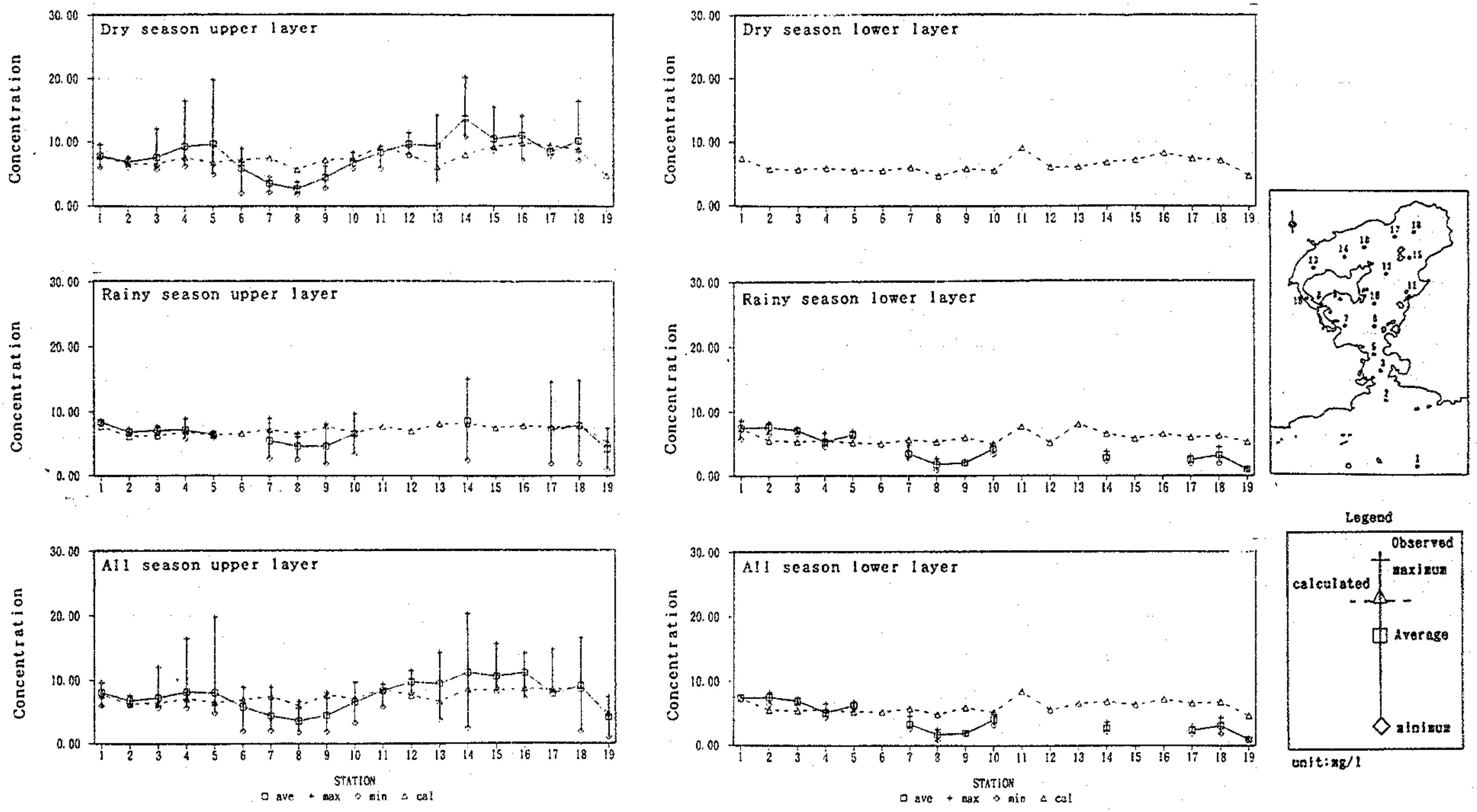


Fig. 2.6-4(6) Comparison of Observed and Calculated DO

CHAPTER 3

WATER POLLUTION MECHANISM IN THE BAY BY NUMERICAL SIMULATION

3.1 Inflowing Load on Dry Season and Rainy Season

We already showed the present distribution of the organic matters and nutrient salts in the bay in previous chapter, which was calculated by the numerical simulation method for the dry season, rainy season and annual mean.

Now, we separated the present external loads flowing into the bay to loads from each basin of the eastern basin, northeastern basin, northwestern basin, western basin and the islands for BOD, COD, O-P and PO_4-P in the dry and rainy season, and the results are shown in Fig.3.1-1 and Table 3.1-1 together with the river discharge from each basin.

Fig.3.1-1 shows that the load in the rainy season is larger than that in the dry season for BOD and COD accompanying with the increase of the river discharge. Contrastly, the load of O-P and PO_4-P is larger in the dry season than in the rainy season.

Regarding the amount of the load, the load from the western basin is the largest in all indices and the northwestern basin follows. The load from the northeastern basin is not so large in spite of its largest discharge.

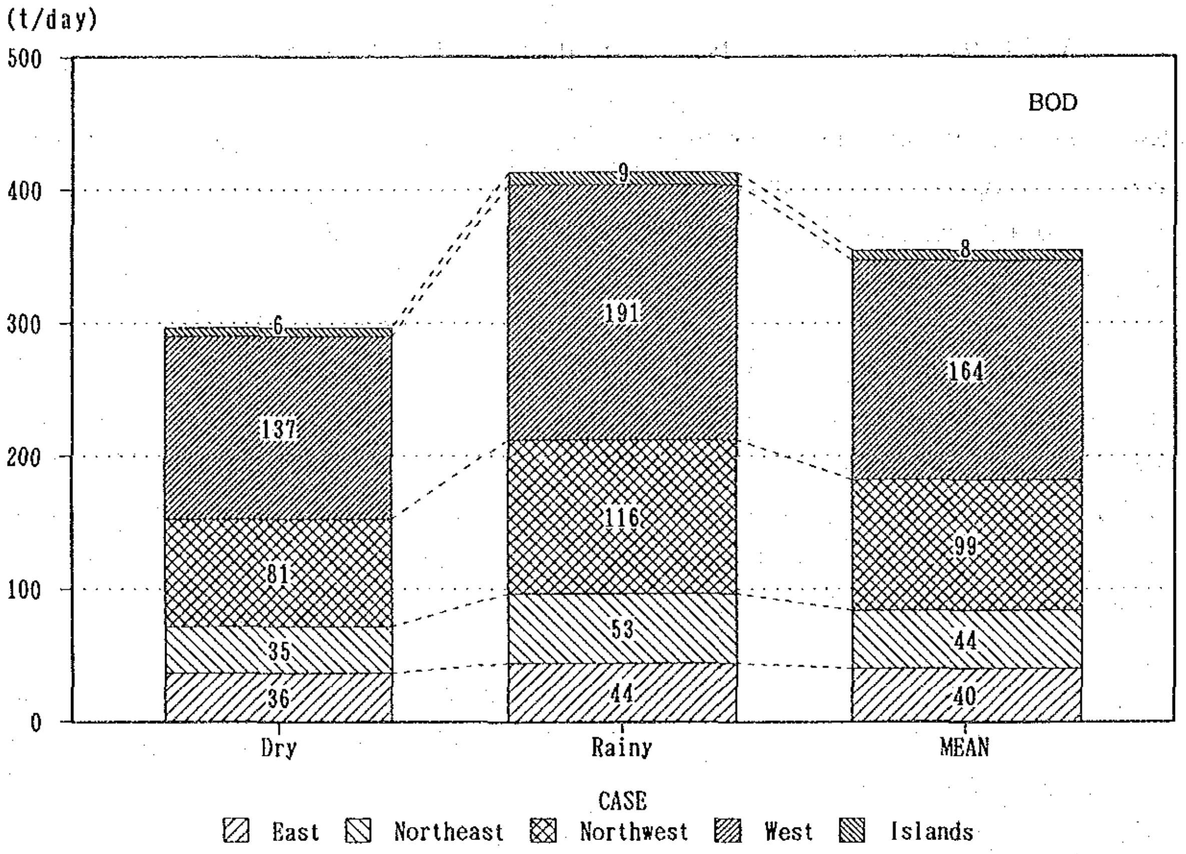


Fig. 3. 1-1(1) BOD External Load used for Simulation in Present Cases

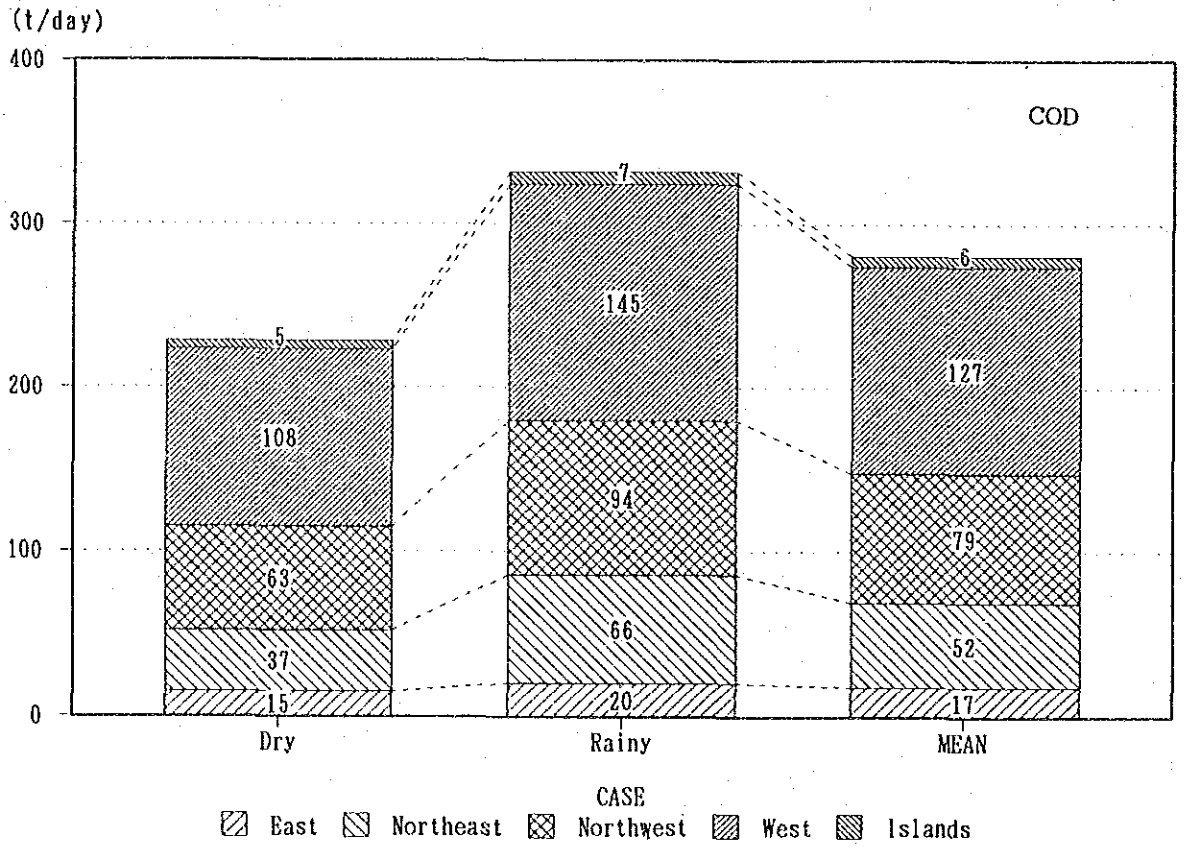


Fig. 3. 1-1(2) COD External Load used for Simulation in Present Cases

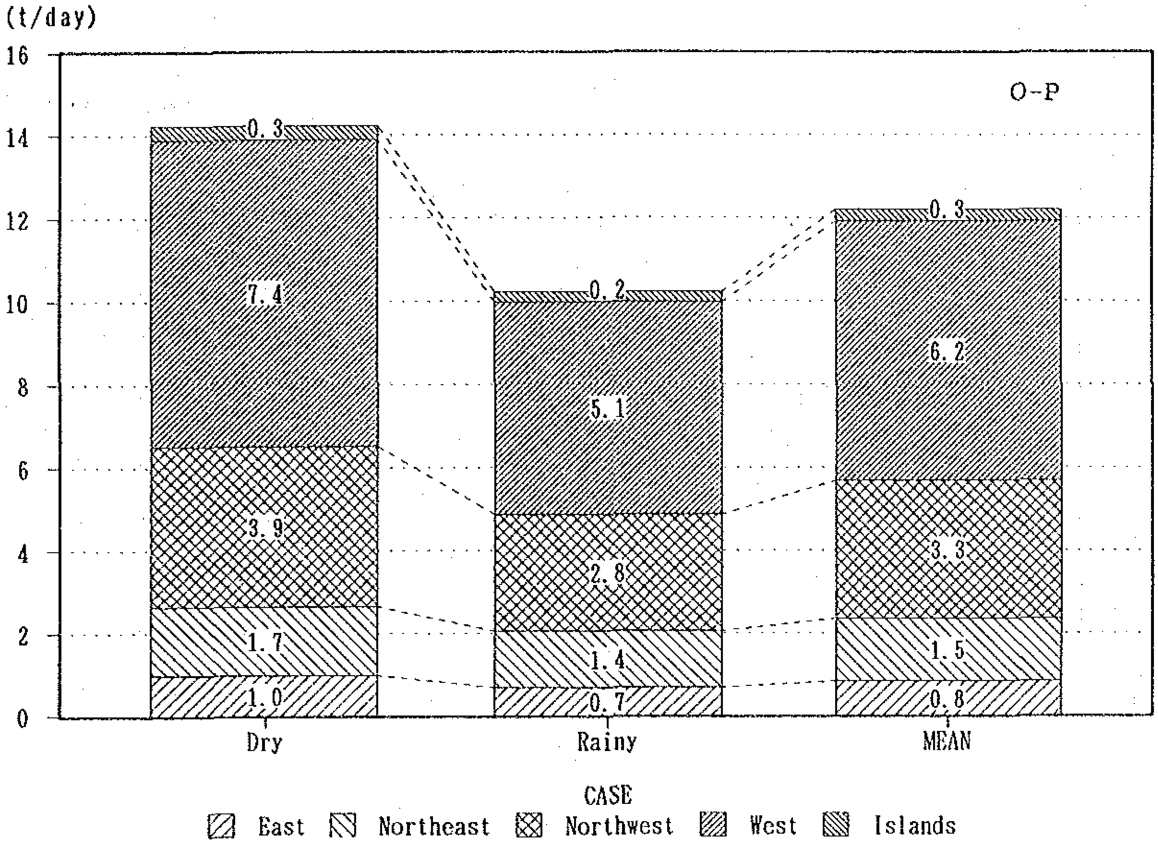


Fig. 3.1-1(3) O-P External Load used for Simulation in Present Cases

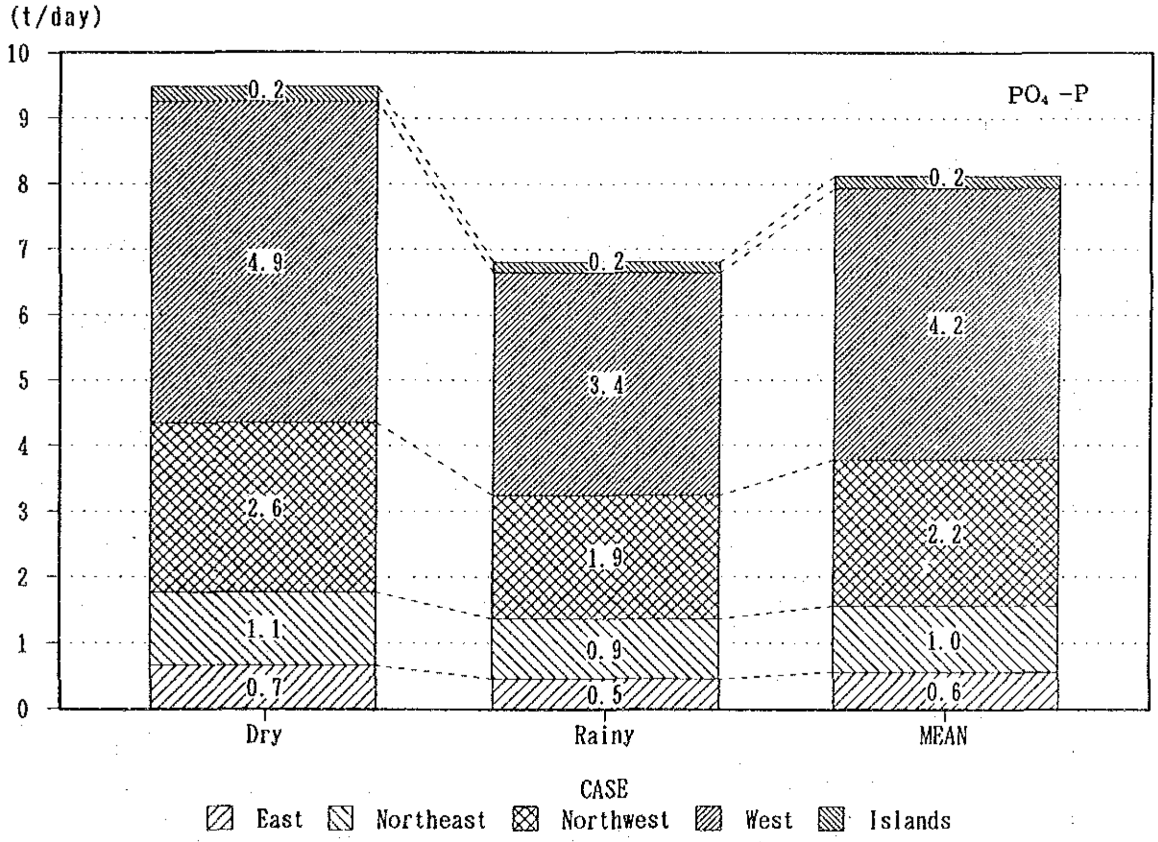


Fig. 3.1-1(4) PO_4-P External Load used for Simulation in Present Cases

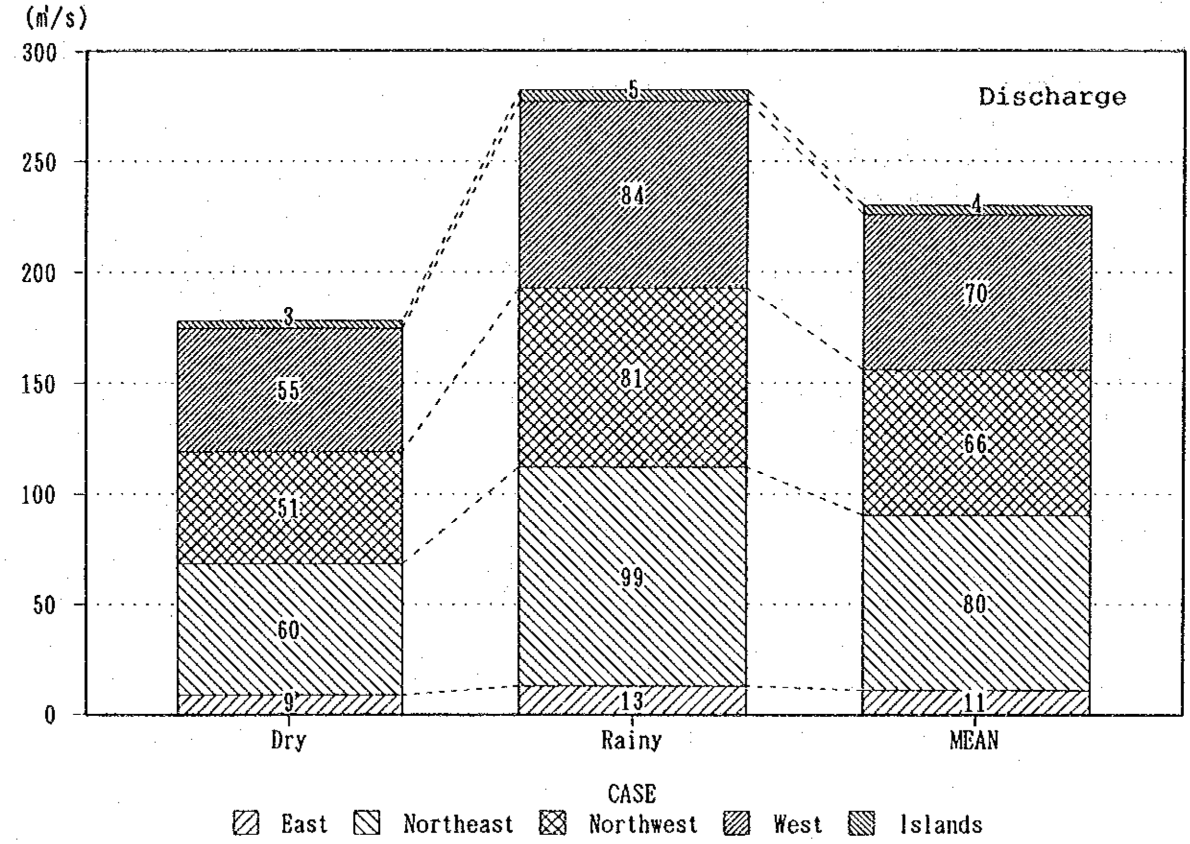


Fig. 3.1-1(5) River Dicharge used for Simulation in Present Cases

Table 3.1-1 load used in Numerical Simulation in Present Cases

Case	Sub Basin Group	Discharge (m3/s)	BOD (t/day)	COD (t/day)	PO4-P (t/day)	O-P (t/day)
Dry Season	East	8.58	36.47	14.79	0.656	0.984
	Northeast	59.86	35.29	37.20	1.108	1.662
	Northwest	50.68	81.30	62.91	2.576	3.864
	West	55.48	137.02	108.48	4.908	7.362
	Islands	3.41	6.42	5.24	0.228	0.342
	Total	178.01	296.49	228.62	9.476	14.214
Rainy Season	East	13.00	43.76	20.00	0.456	0.684
	Northeast	99.36	52.95	65.94	0.916	1.374
	Northwest	80.52	115.79	94.10	1.876	2.814
	West	84.21	191.37	144.71	3.408	5.112
	Islands	5.20	9.09	7.30	0.160	0.240
	Total	282.29	412.95	332.05	6.816	10.224
Annual Mean	East	10.80	40.10	17.40	0.556	0.834
	Northeast	79.62	44.11	51.56	1.012	1.518
	Northwest	65.61	98.55	78.50	2.224	3.336
	West	69.85	164.19	126.60	4.156	6.234
	Islands	4.31	7.75	6.27	0.188	0.282
	Total	230.19	354.69	280.33	8.136	12.204

3.2 Water quality on High tide and Low tide

Distribution of annual mean BOD concentration in high tide, ebb, low tide and flood are shown in Fig.3.2.1.

Water quality varies by the tidal motion from high tide to low tide, and the concentration is apt to be high in flood stream and low in ebb stream.

For example, at the near the rivermouth of Meriti, average BOD concentration for one tidal is 9.4mg/l in annual mean value, but 10.0mg/l in flood and 8.6mg/l in ebb.

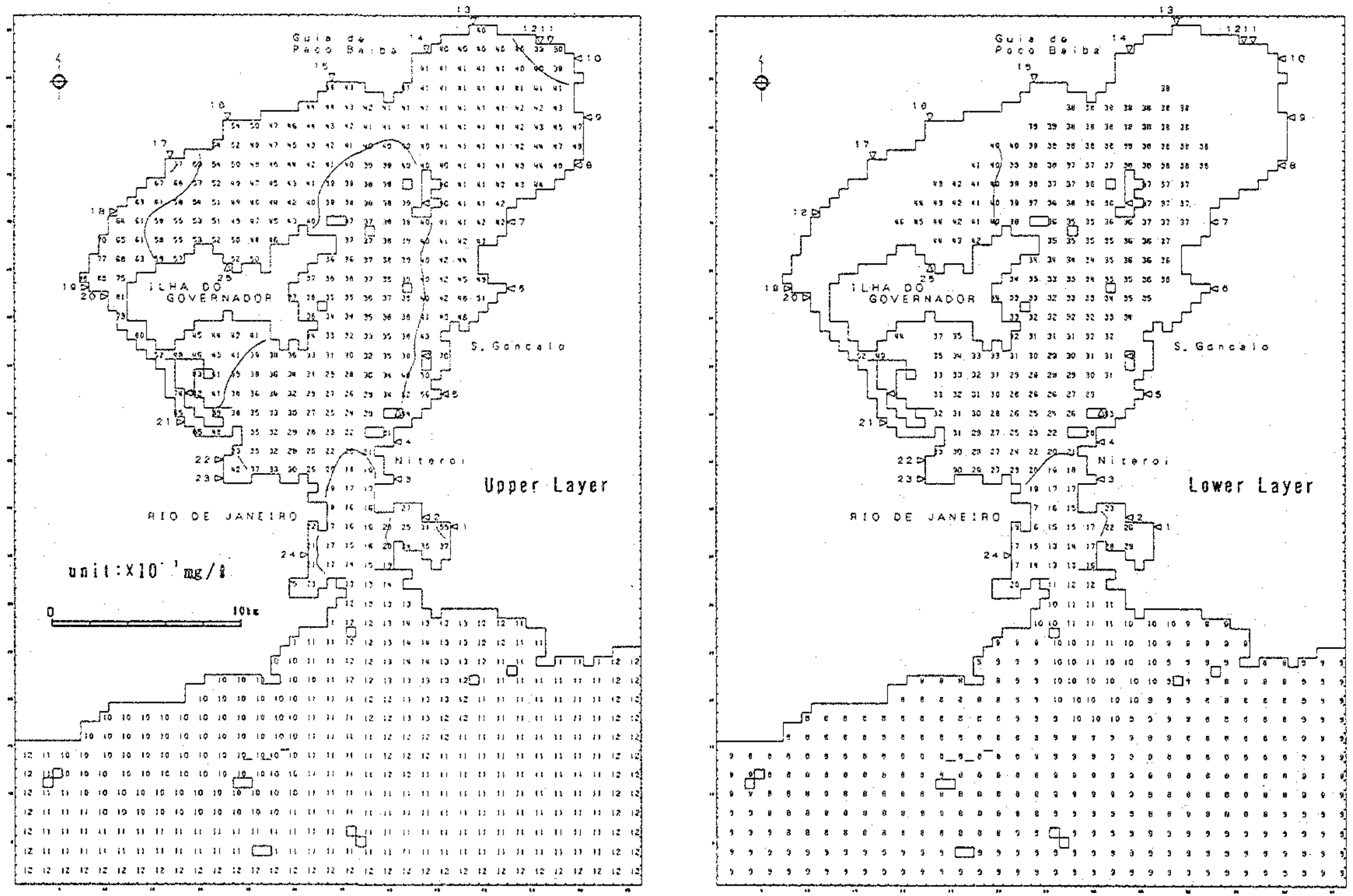


Fig. 3.2-1(1) Calculated BOD Distribusion in High Tide in 1991

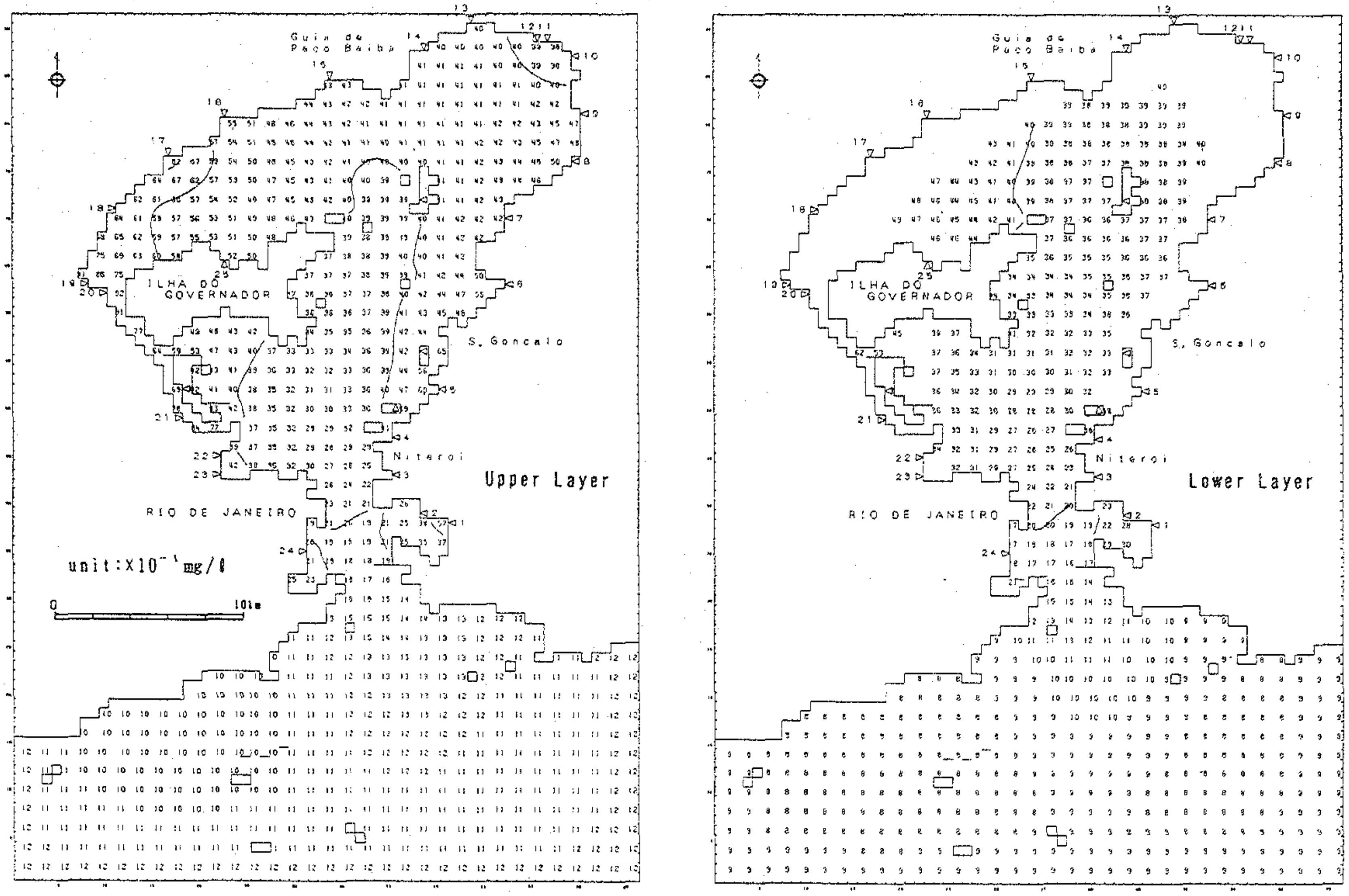


Fig. 3.2-1(2) Calculated BOD Distribusion in the time of Ebb Stream in 1991

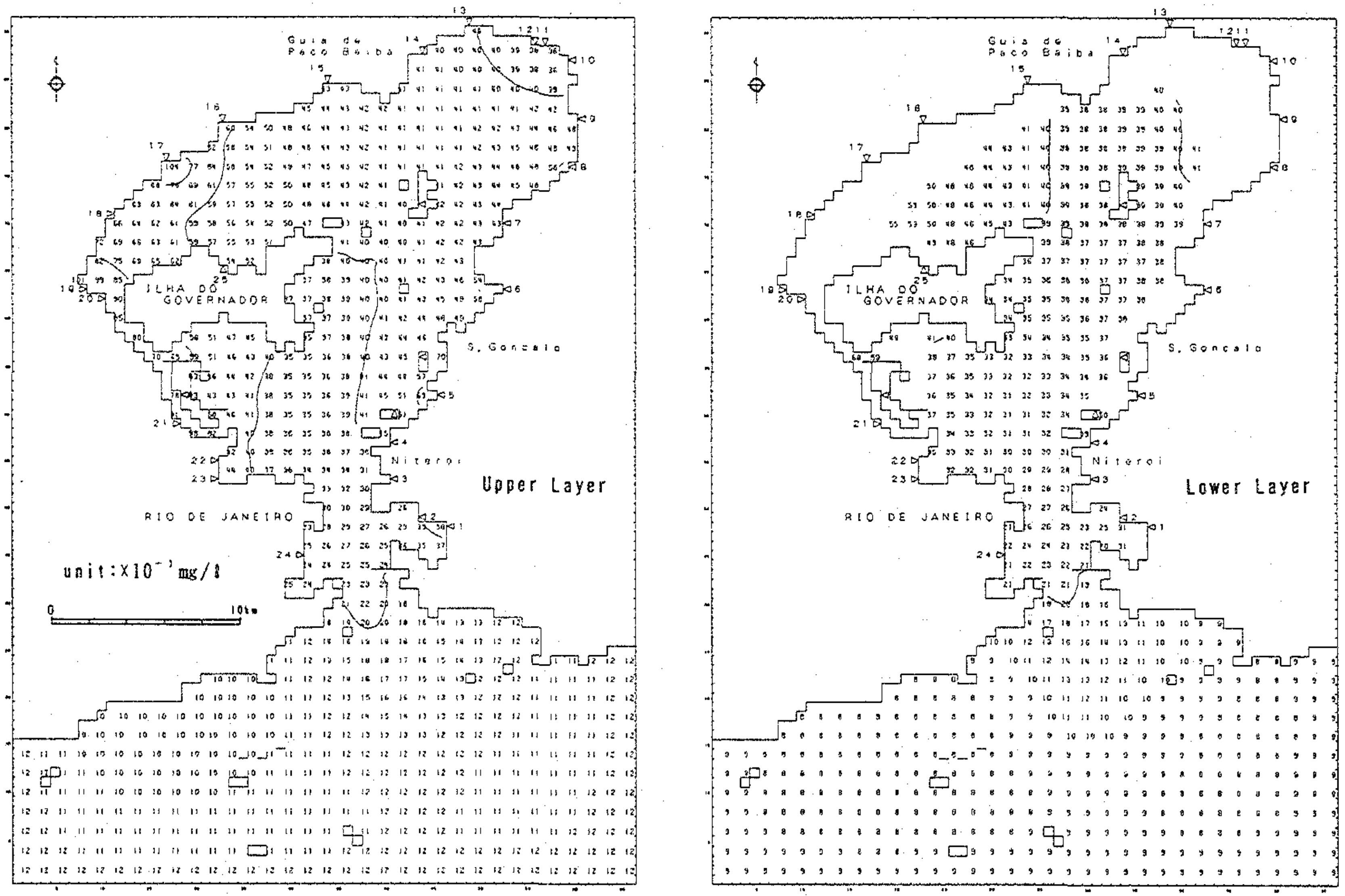


Fig. 3.2-1(3) Calculated BOD Distribusion in Low Tide in 1991

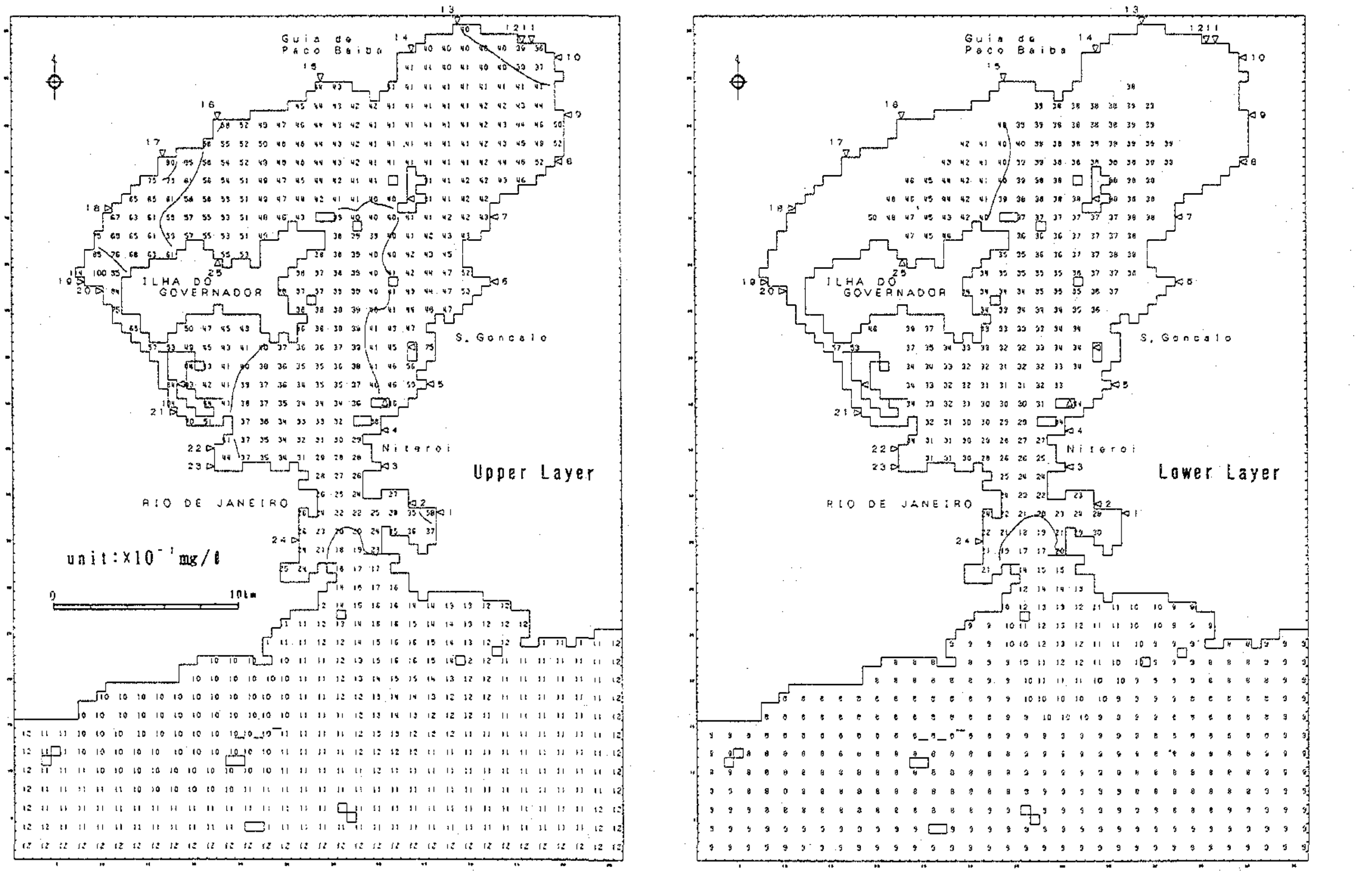


Fig. 3. 2-1 (4) Calculated BOD Distribusion in the time of Flood Stream in 1991

3.3 Contribution Rate of Primary Production to BOD Concentration

Distribution of annual mean BOD concentration based on primary production is shown in Fig.3.3-1. And the distribution of transparency converted from calculated T-P concentration are shown in Fig.3.3-2 in same case.

Fig.3.3-3 shows the itemization of calculated BOD concentration. We devide the present concentration in each block by external load (river) and phytoplankton.
The ratio of primary production is smaller than external load in block C and E1, but the primary production is about 60% and 3mg/l as the concentration in other blocks.

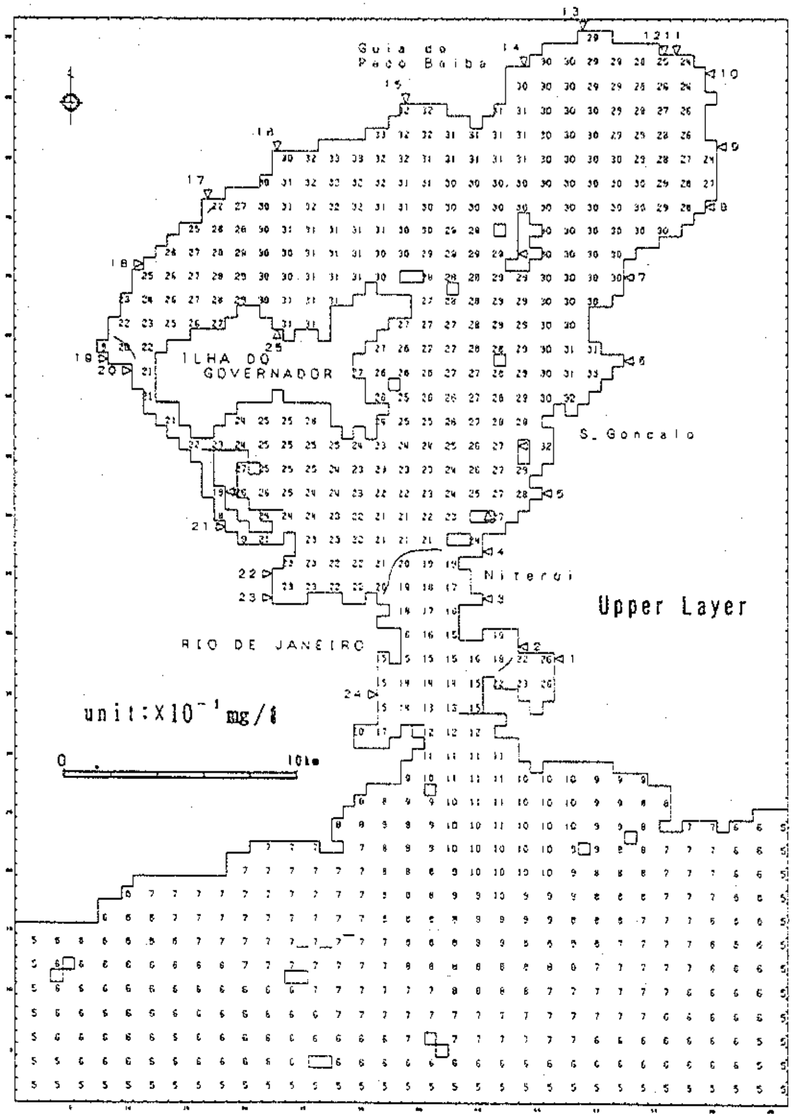


Fig. 3. 3-1 Calculated BOD Distribution contributed Production of Phytoplankton in 1991

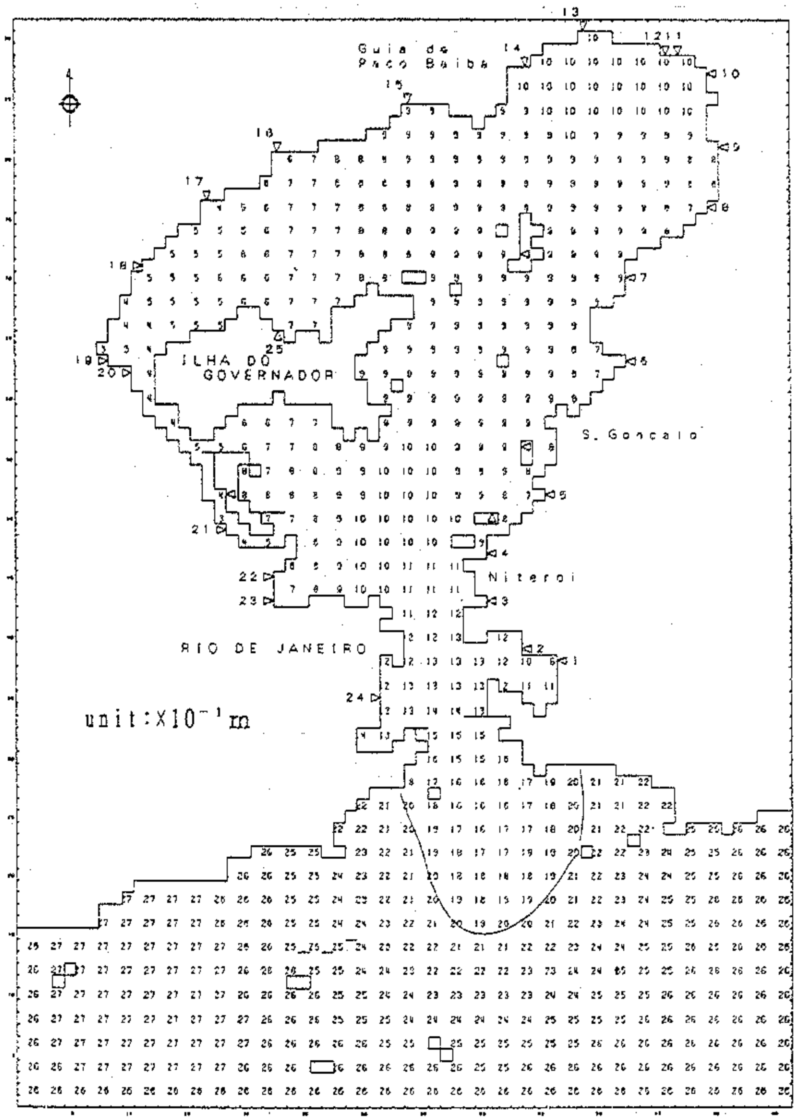


Fig. 3. 3-2 Transparency Distribution converted by Calculated T-P in 1991

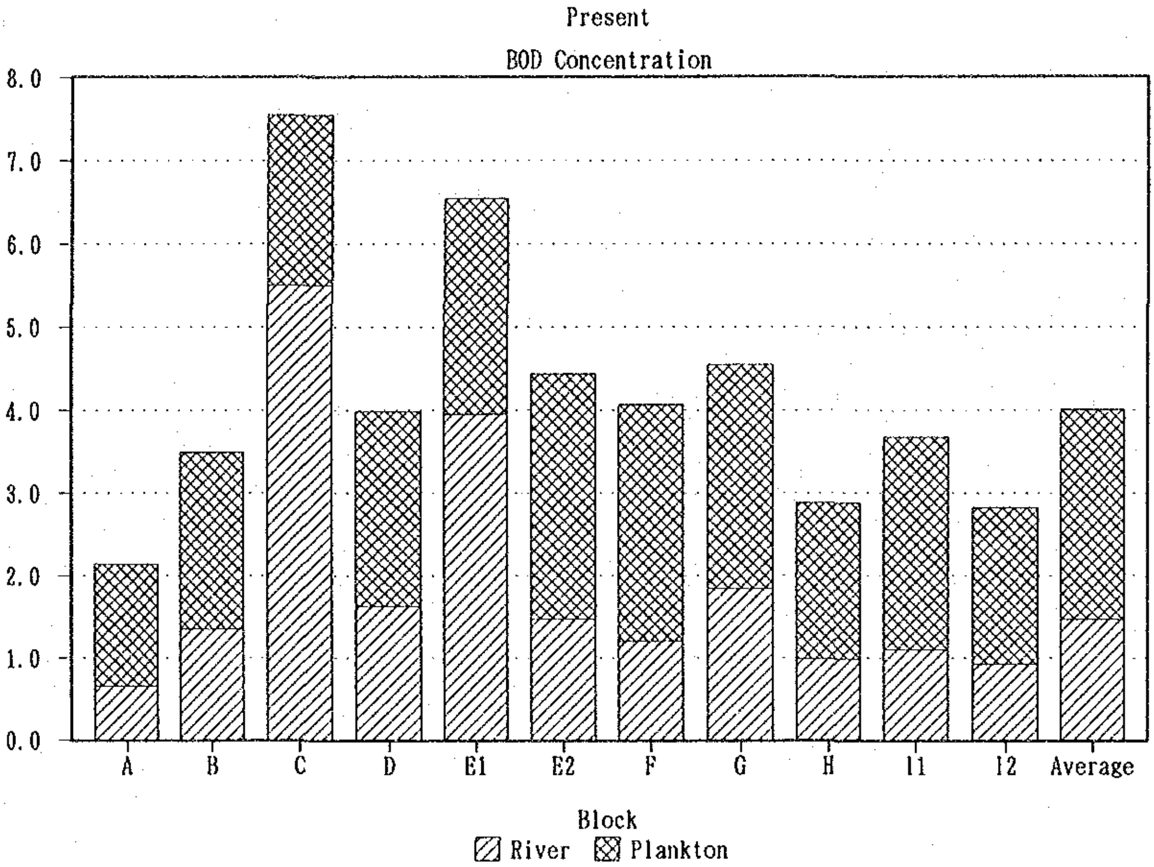


Fig. 3. 3-3 Itemization of Calculated BOD Concentration in 1991

3.4 Contribution Rate of External Loads

3.4.1 Method of Calculation

We divided the basin into five basins including one basin of islands and the water area in the bay was also divided into eleven areas as shown in Fig.3.4-1.

the contribution rate of each basin to the water quality in each water area was calculated by the following procedure;

(1) We calculated the present mean water quality in each water area (Block A to I2) using present annual mean inflowing loads.

(2) We calculated the mean water quality in each water area on the assumption that the load of BOD and O-P from each basin and the release from sediments of each water area are zero.

(3) We calculated the variation rate (decreasing rate) in each water area as a difference between (1) and (2).

(4) We supposed the variation rate (decreasing rate) for every basins to be a contribution rate in each water area.

(5) We also calculated the effect of the release from sediments.

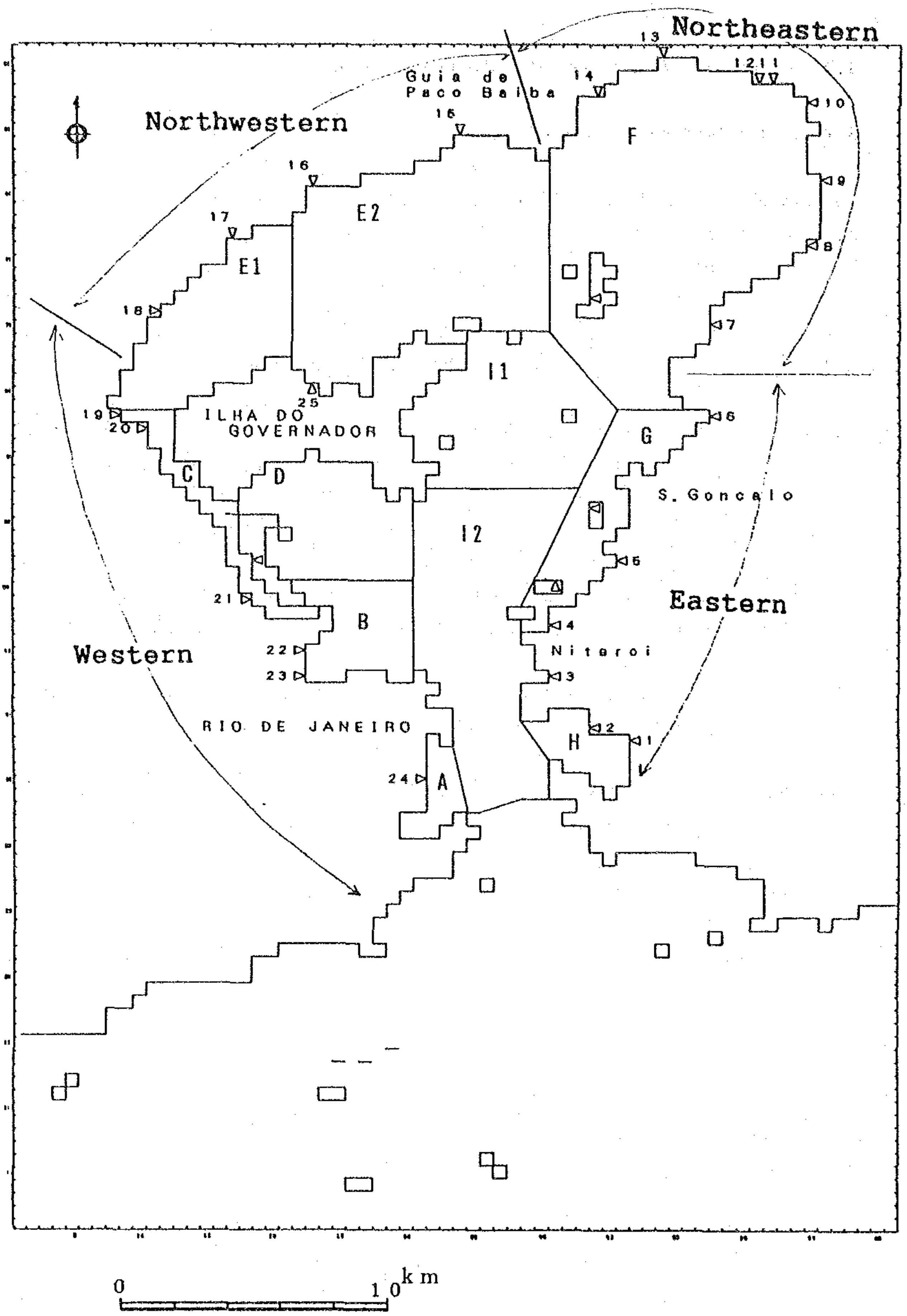


Fig. 3. 4-1 Area Divison of Sub-Basin Group and Water Area

3.4.2 Results of Calculation

The results in the case that the load from each basin in zero are shown in Fig.3.4-2 as a concentration distribution of BOD.

Fig.3.4-3 is a concentration distribution of BOD in the case that the release from sediments in each water area is zero.

The contribution rate of each basin to the water quality in each water area, which is calculated from the above, is shown in Fig.3.4-4.

Moreover, the effluent loads from each basin are shown in Fig.3.4-5 as well as the release loads from each water area. With regard to the release load, each water area is called as follows;

Block G & H : East
Block F : Northeast
Block E : Northwest
Block A, B, C & D : West
Block I : Islands

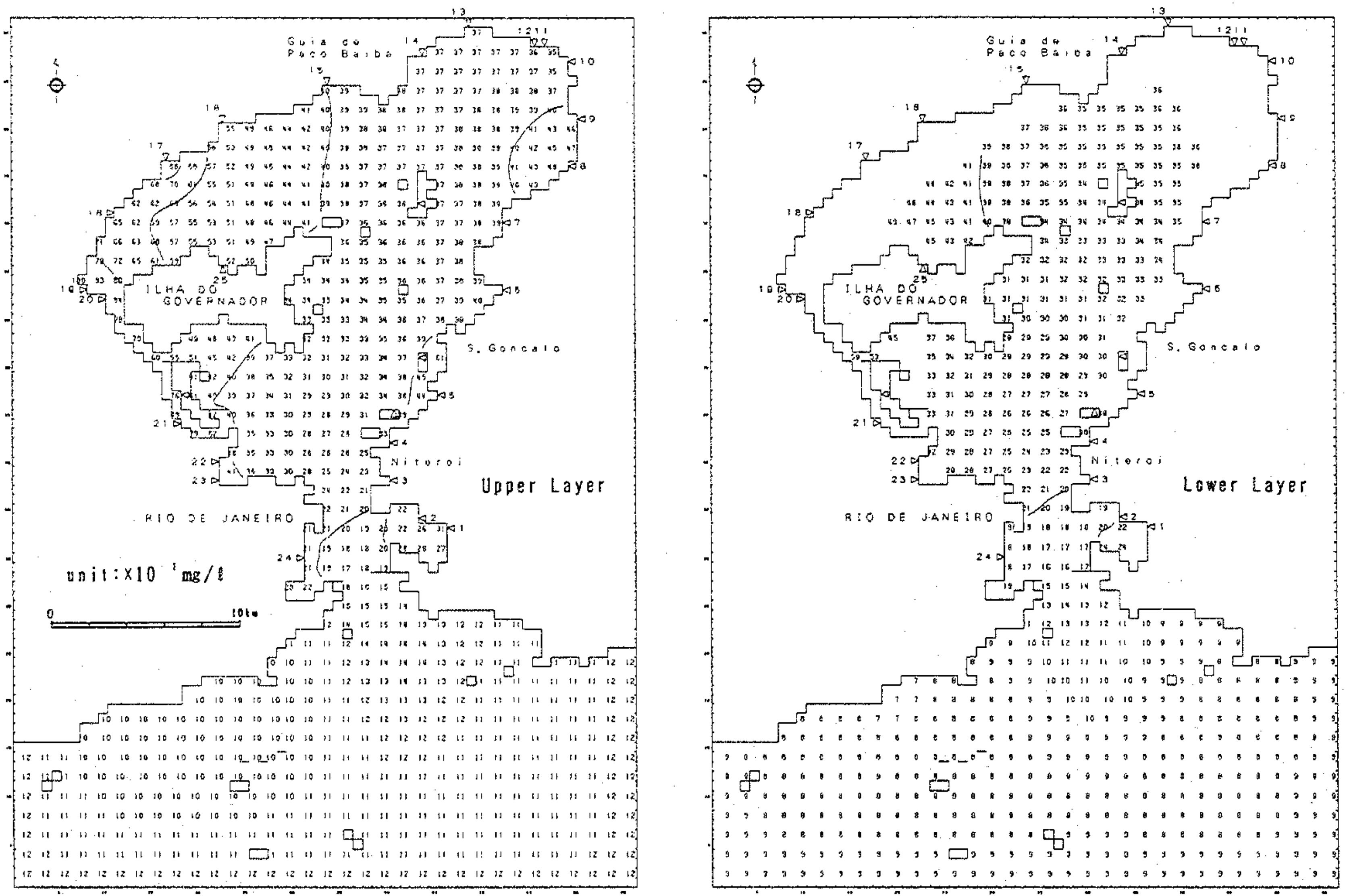


Fig. 3. 4-2(1) Calculated BOD Distribution in the Hypothetical Case (BOD Effluent Load from Eastern Basin Group is Zero)

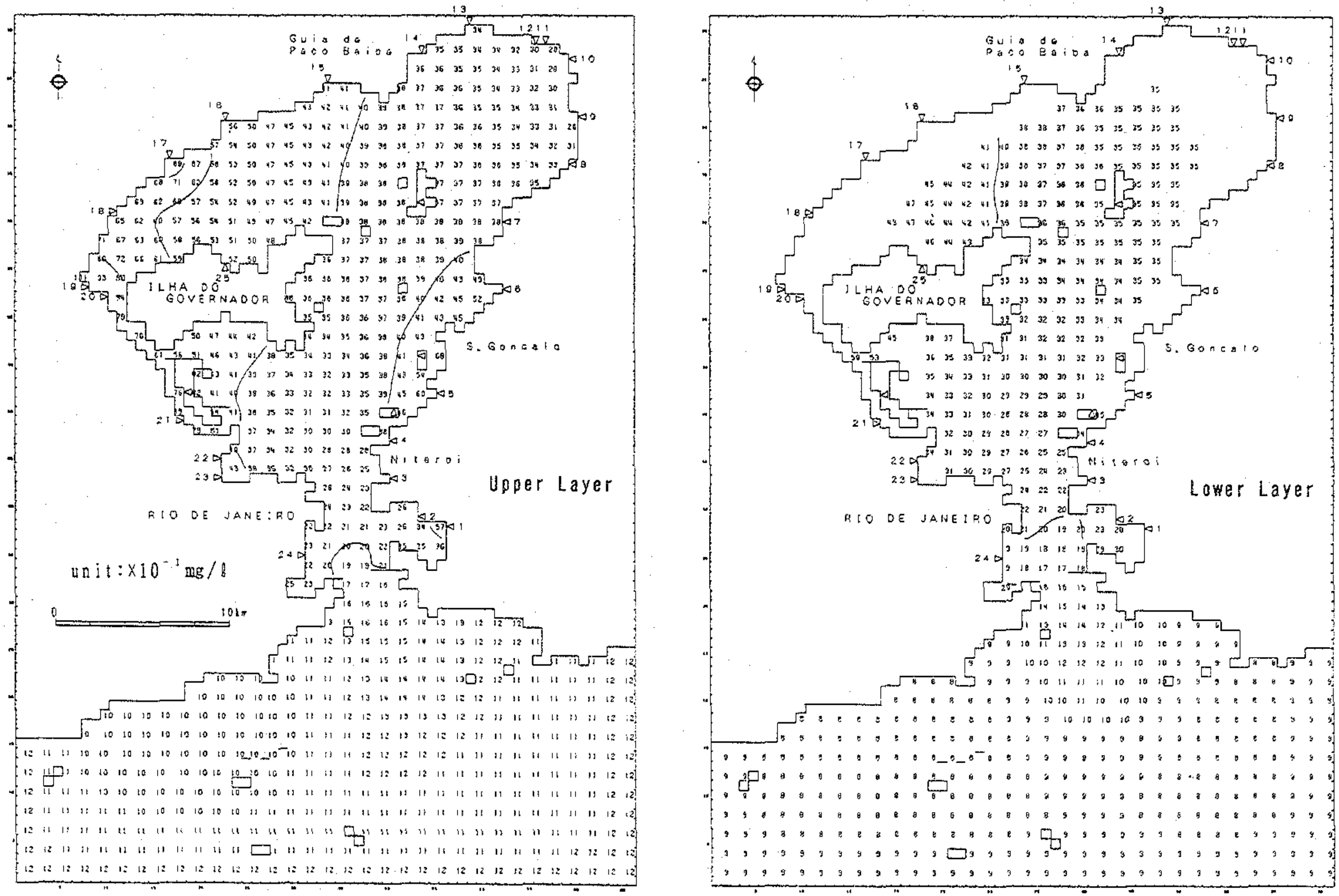


Fig. 3.4-2(2) Calculated BOD Distribution in the Hypothetical Case
(BOD Effluent Load from Northeastern Basin Group is Zero)

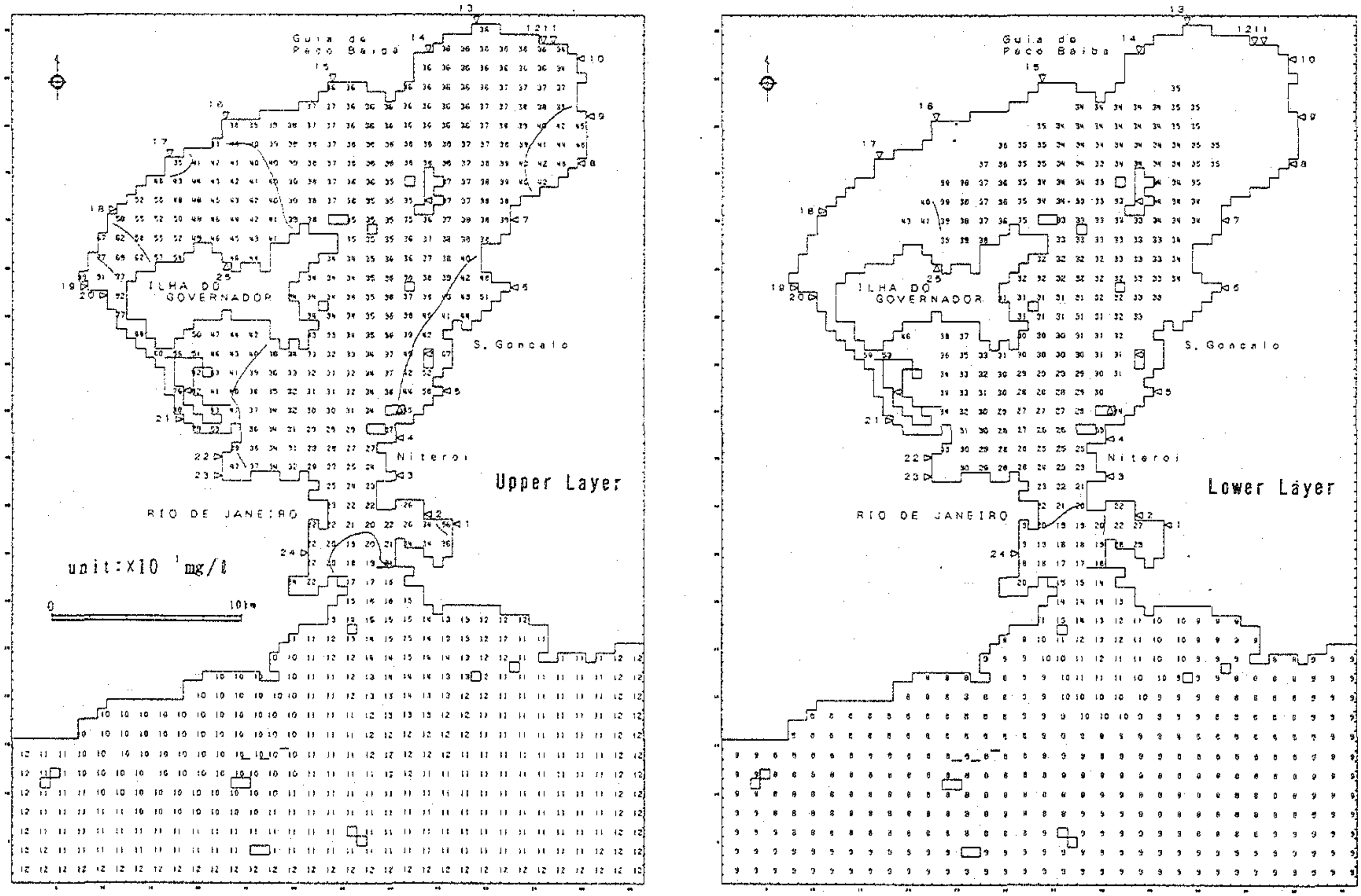


Fig. 3.4-2(3) Calculated BOD Distribution in the Hypothetical Case (BOD Effluent Load from Northwestern Basin Group is Zero)

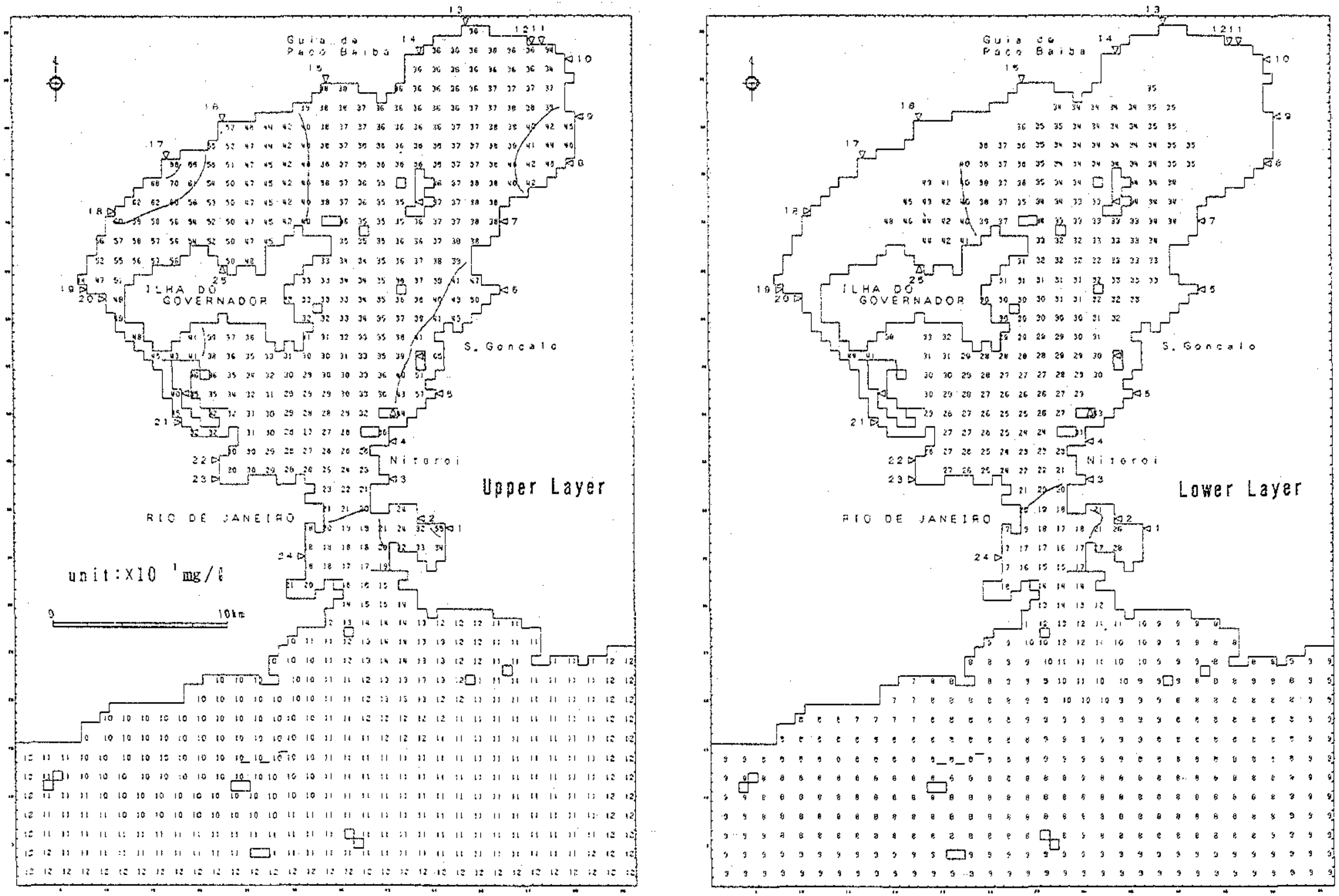


Fig. 3. 4-2(4) Calculated BOD Distribution in the Hypothetical Case
(BOD Effluent Load from Western Basin Group is Zero)

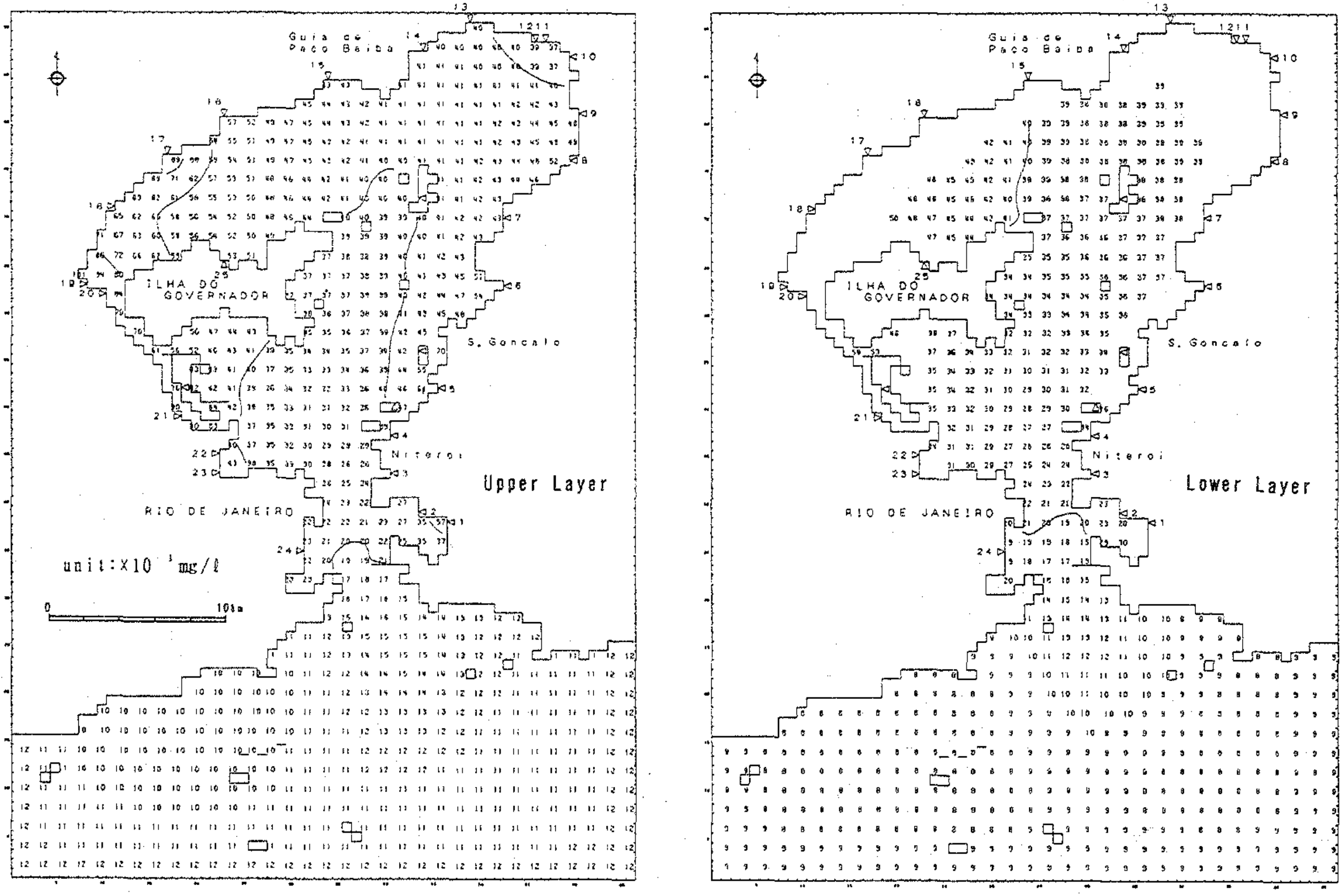


Fig. 3.4-3(1) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block A is Zero)

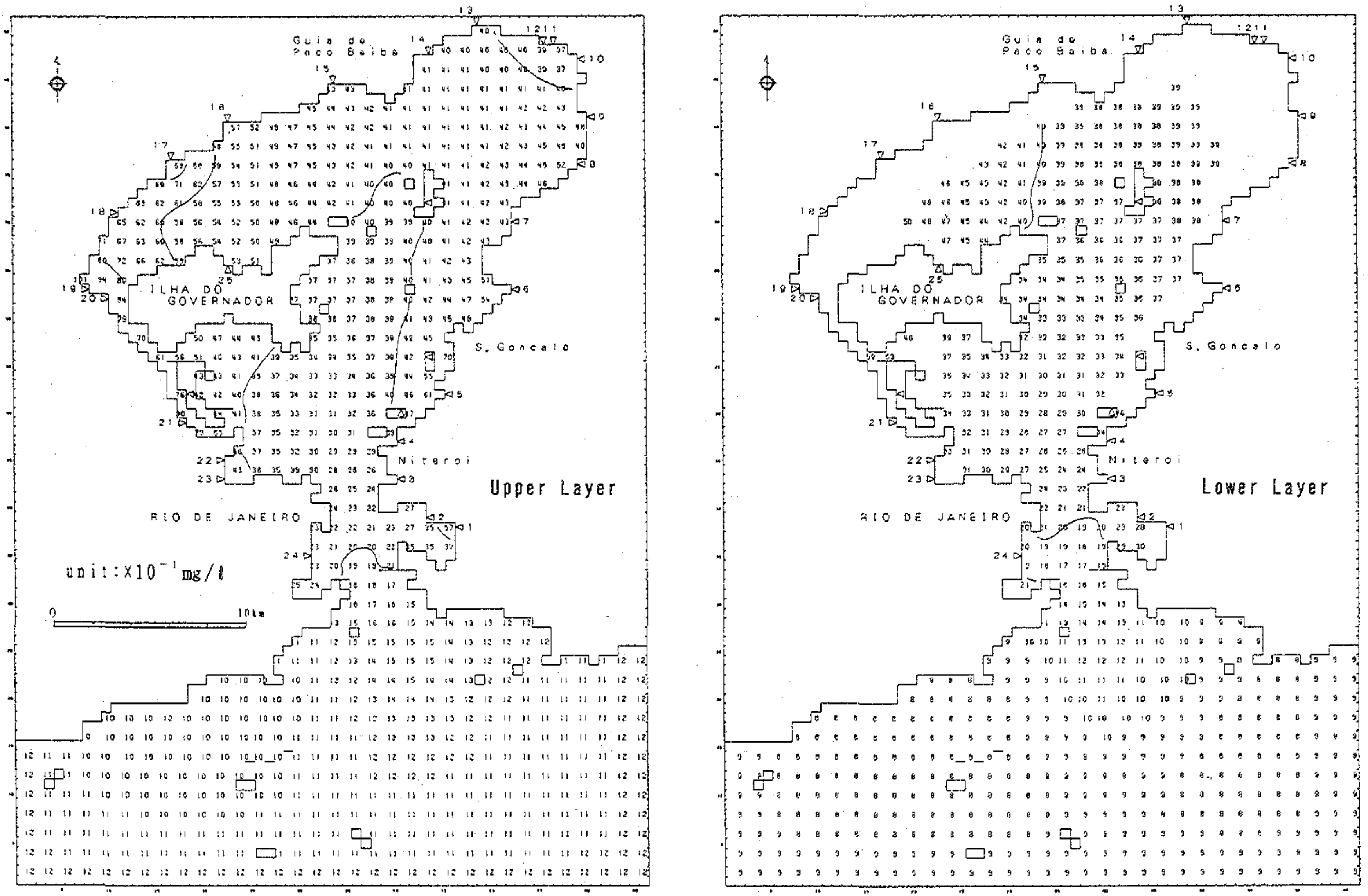


Fig. 3.4-3(2) Calculated BOD Distribution in the Hypothetical Case (BOD Release Load from Block B is Zero)

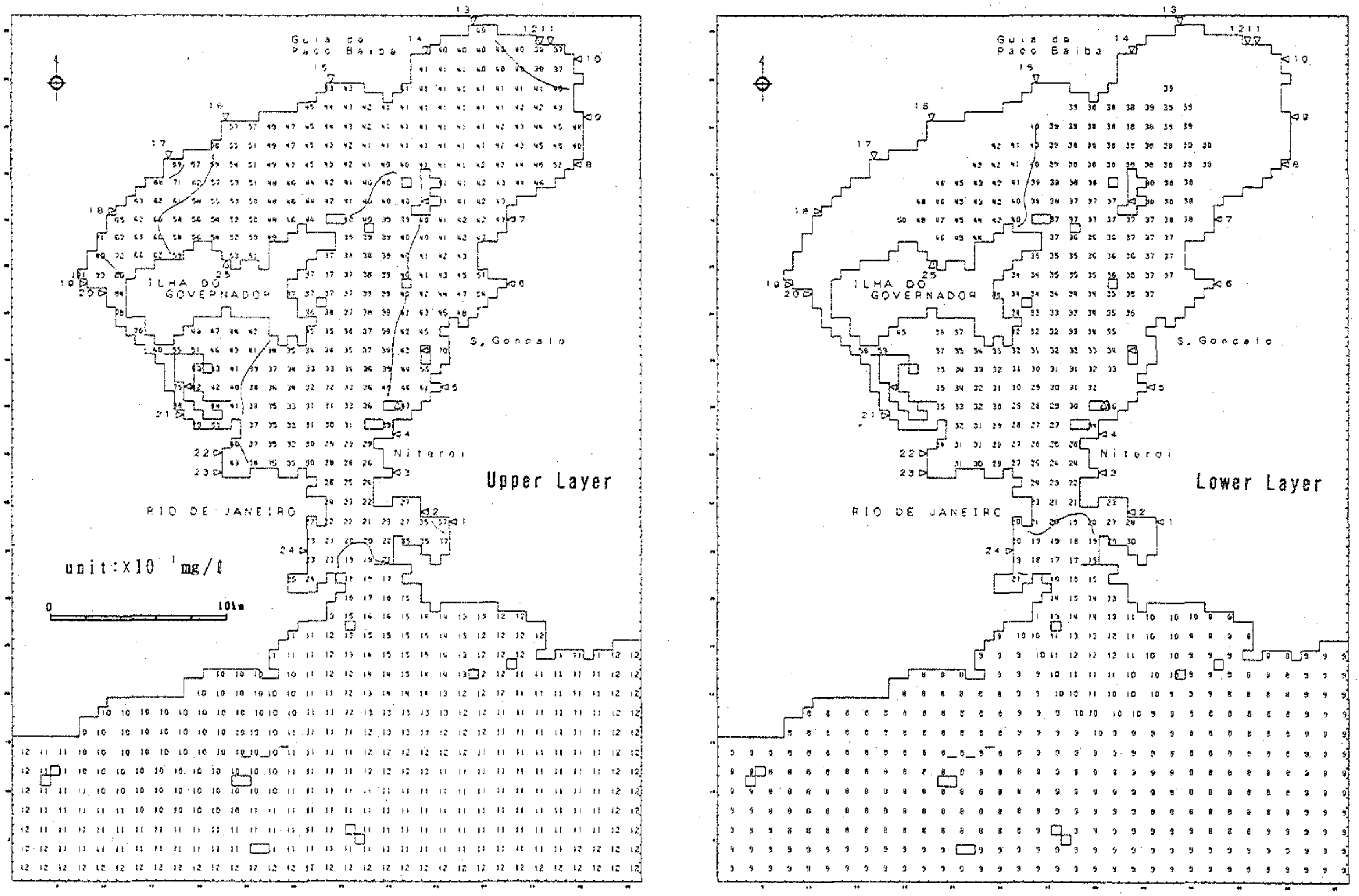


Fig. 3.4-3(3) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block C is Zero)

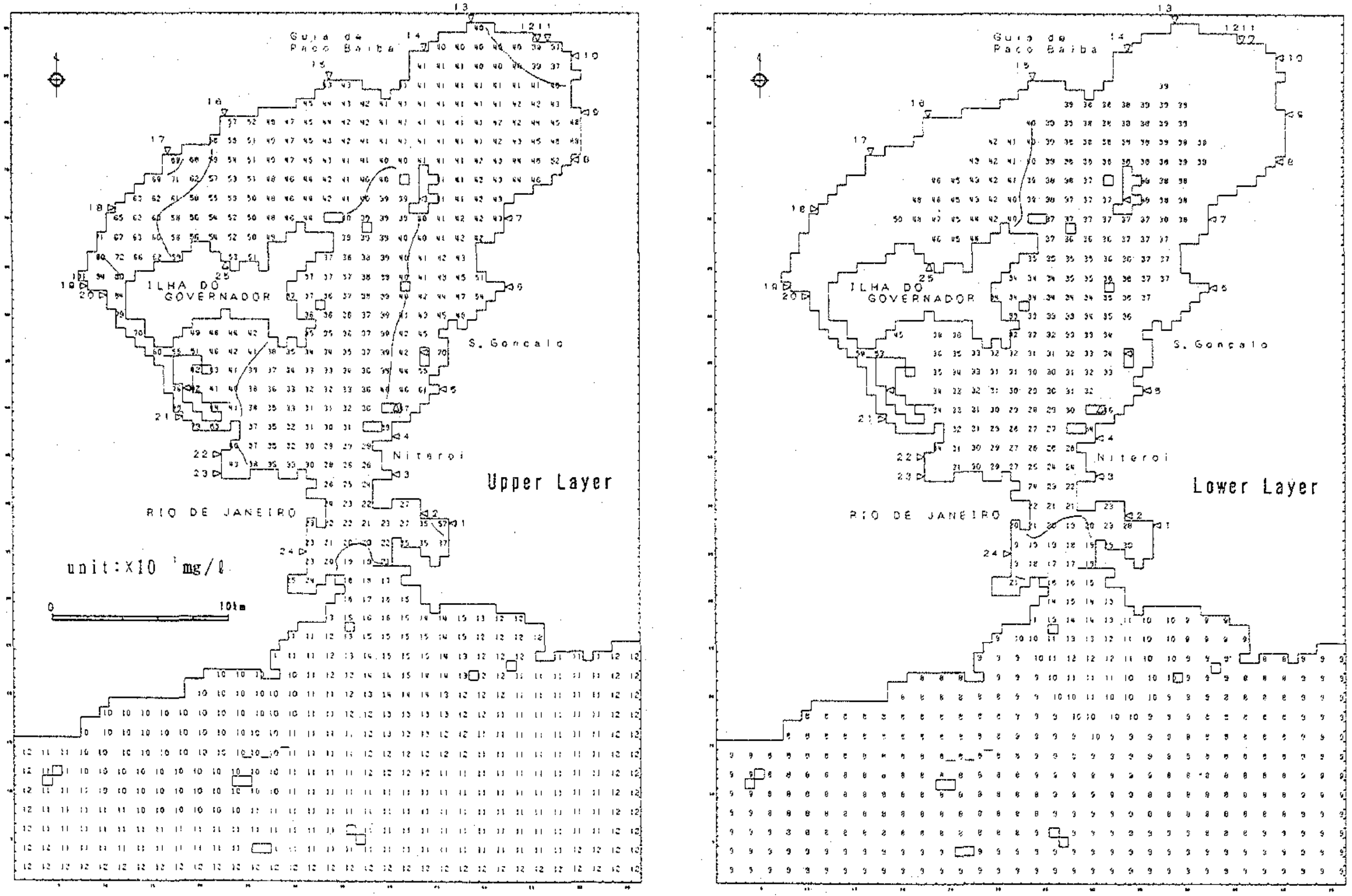


Fig. 3.4-3(4) Calculated BOD Distribution in the Hypothetical Case (BOD Release Load from Block D is Zero)

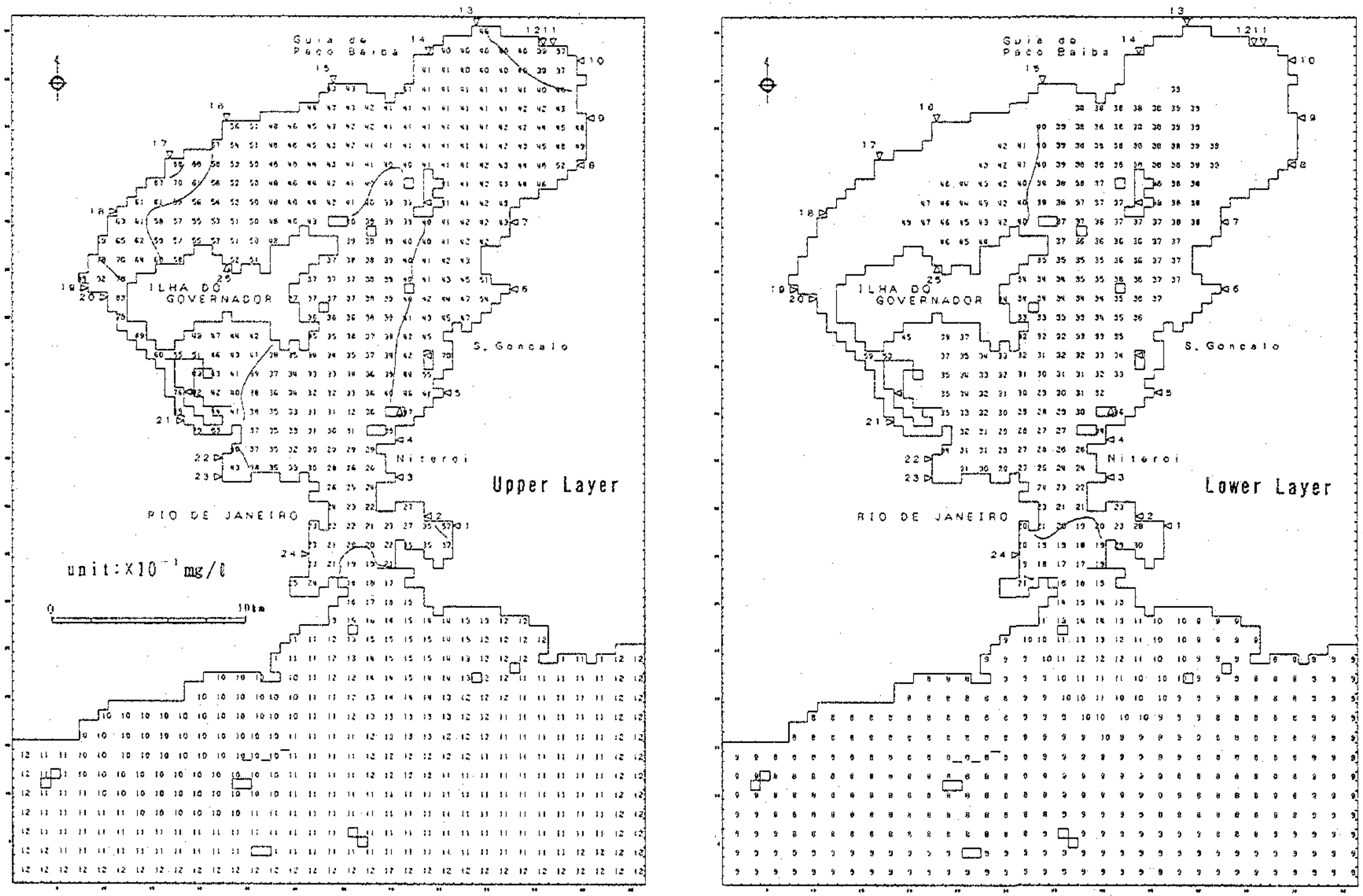


Fig. 3.4-3(5) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block E1 is Zero)

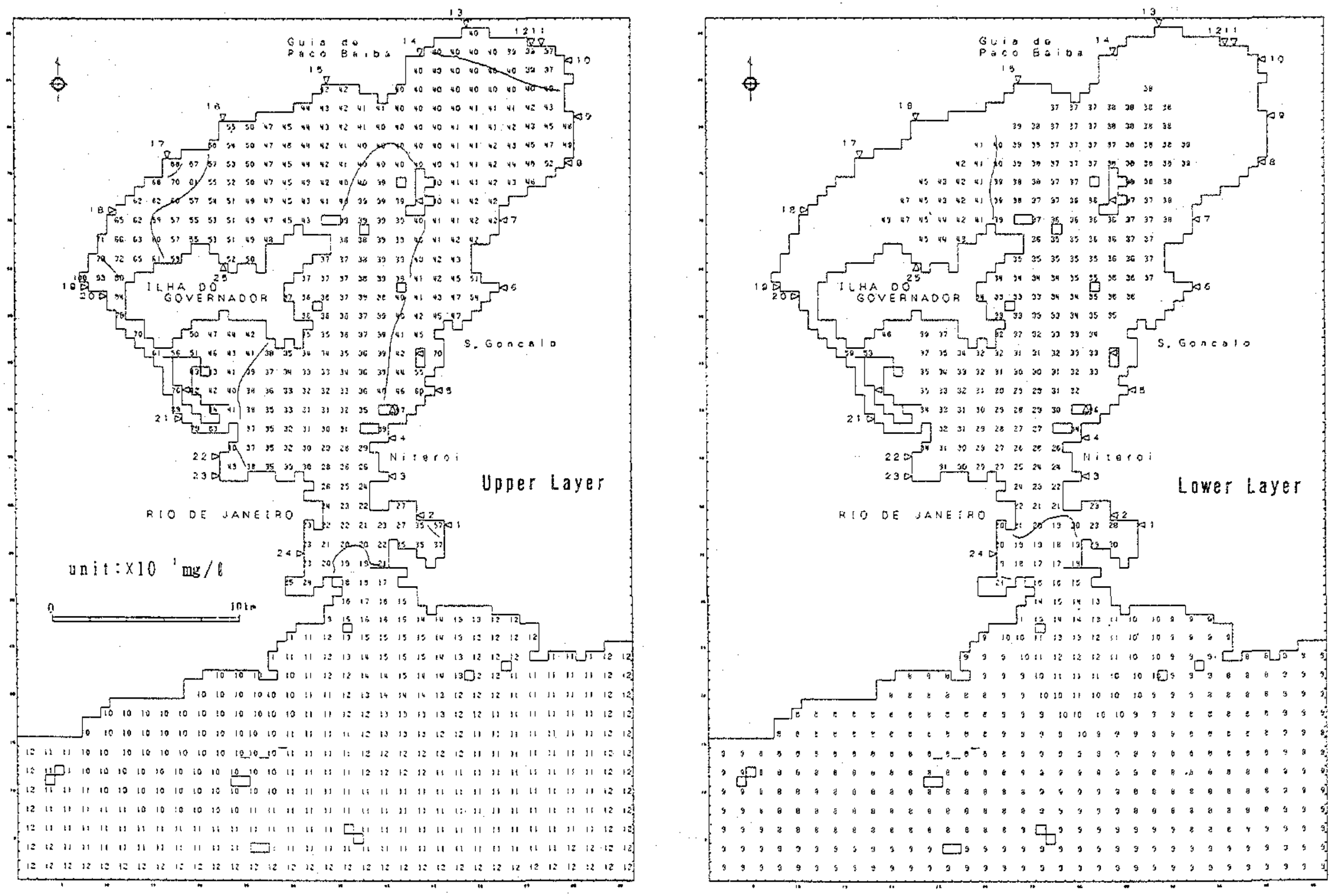


Fig. 3.4-3(6) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block E2 is Zero)

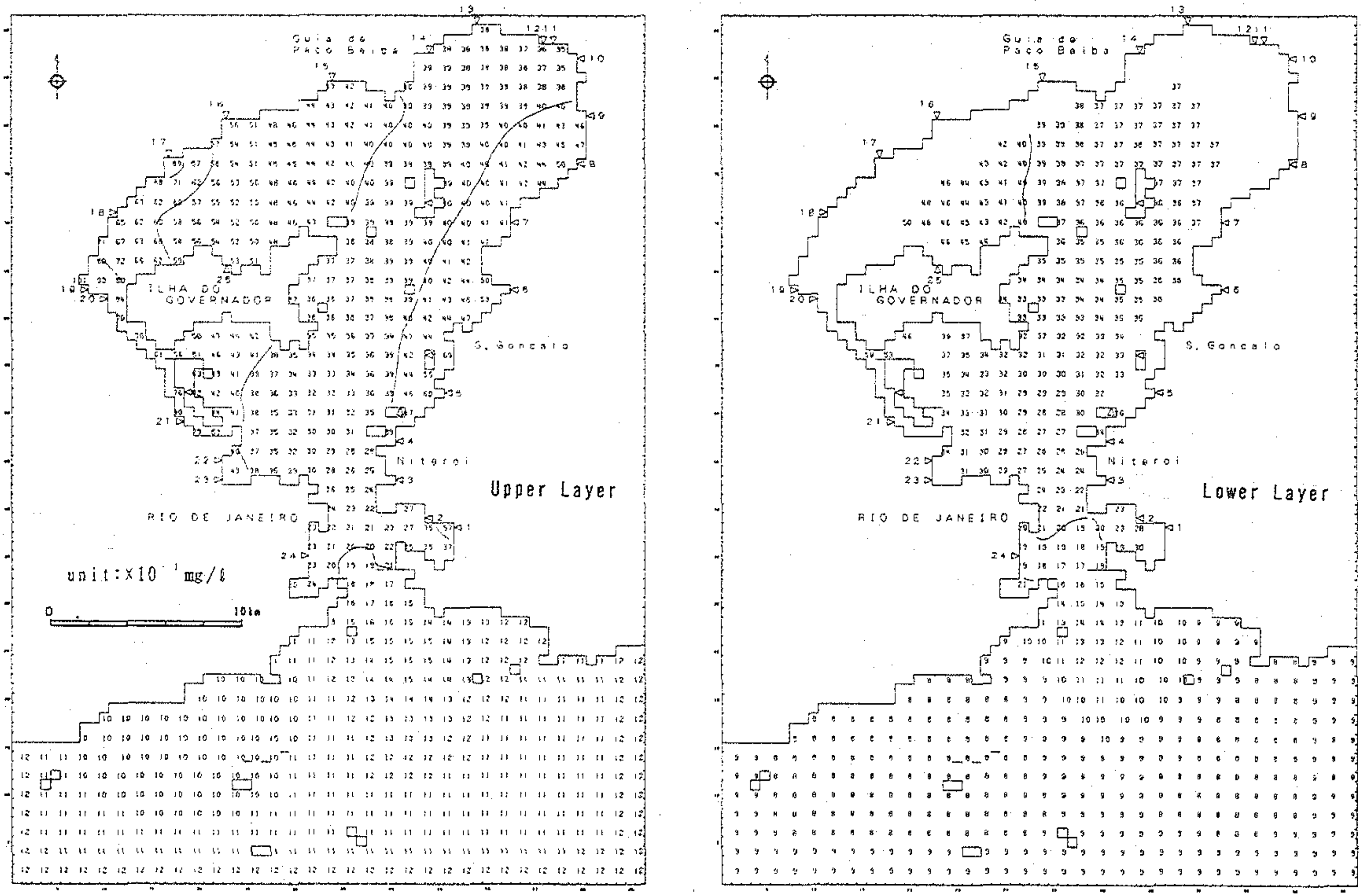


Fig. 3.4-3(7) Calculated BOD Distribution in the Hypothetical Case

(BOD Release Load from Block F is Zero)

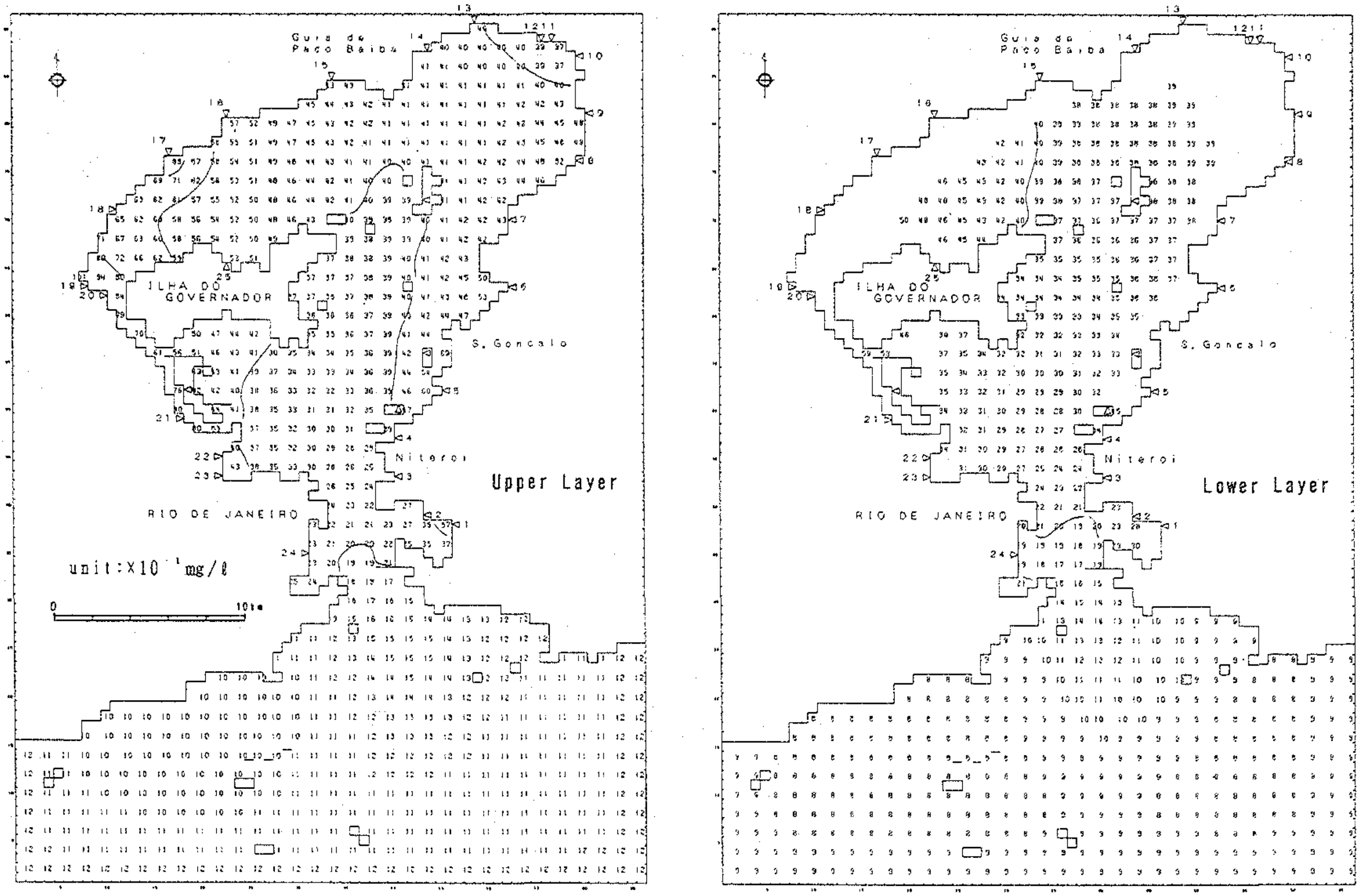


Fig. 3.4-3(8) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block G is Zero)

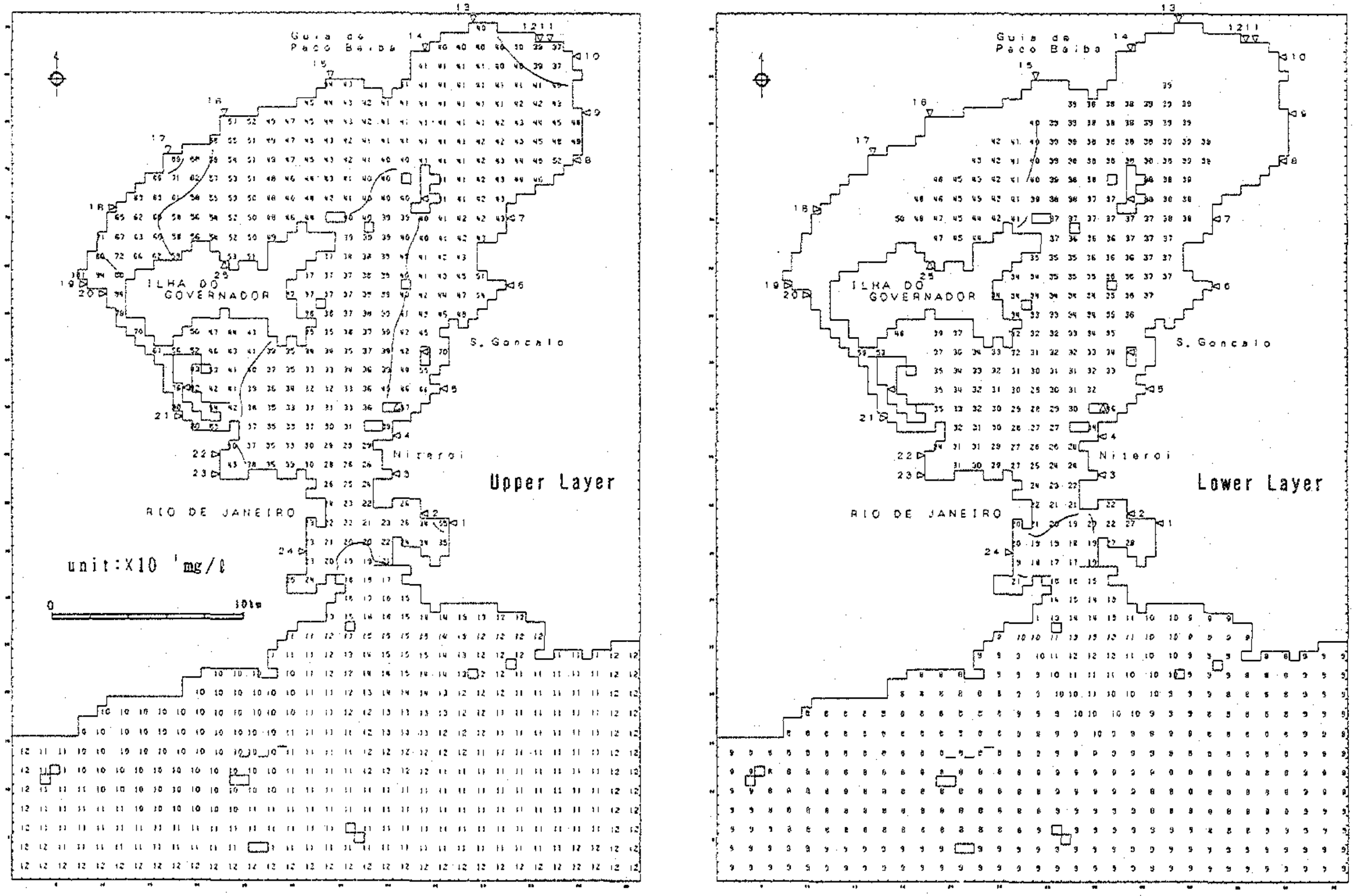


Fig. 3. 4-3(9) Calculated BOD Distribution in the Hypothetical Case
(BOD Release Load from Block H is Zero)

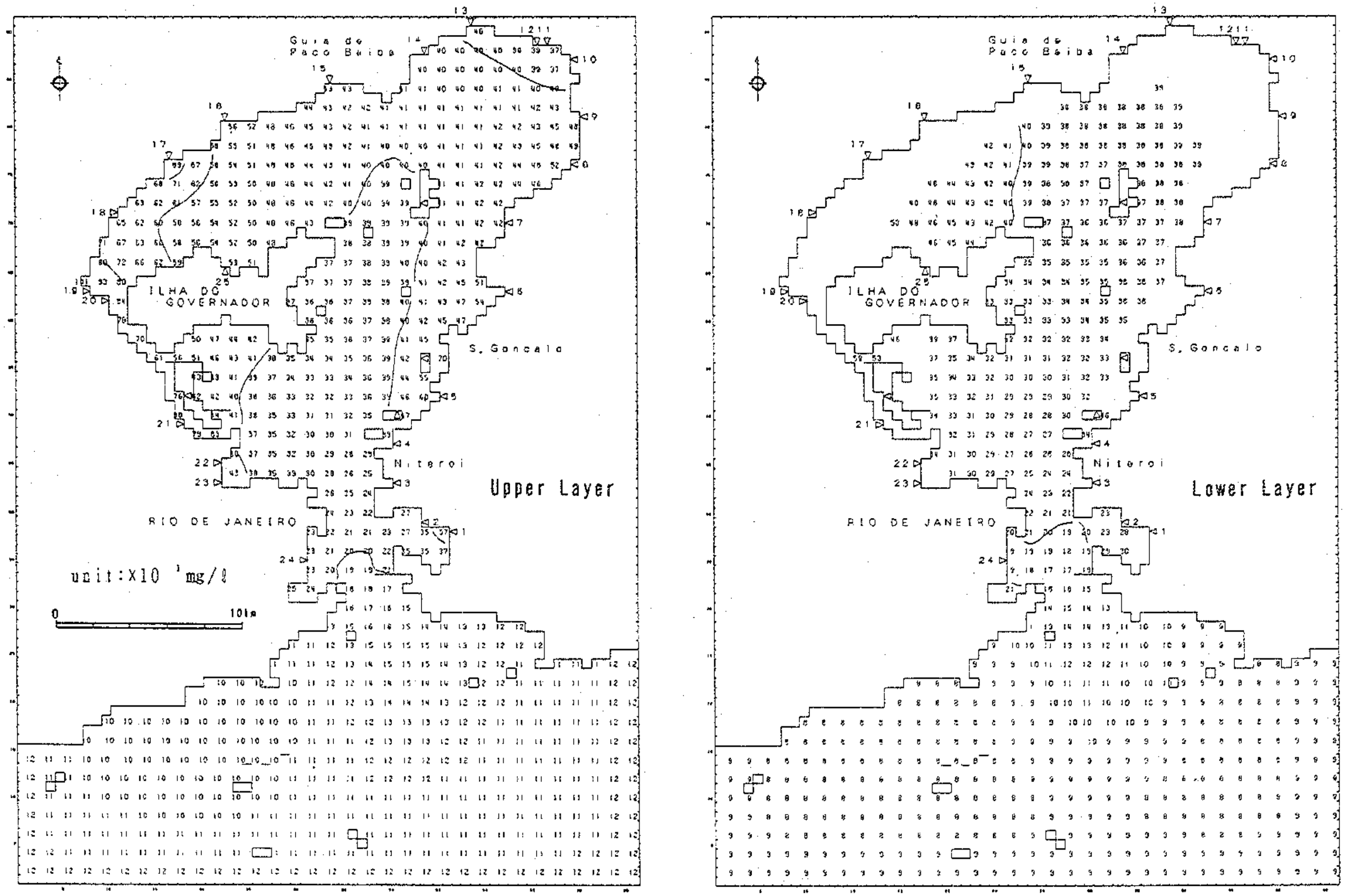


Fig. 3. 4-3(10) Calculated BOD Distribution in the Hypothetical Case

(BOD Release Load from Block I1 is Zero)

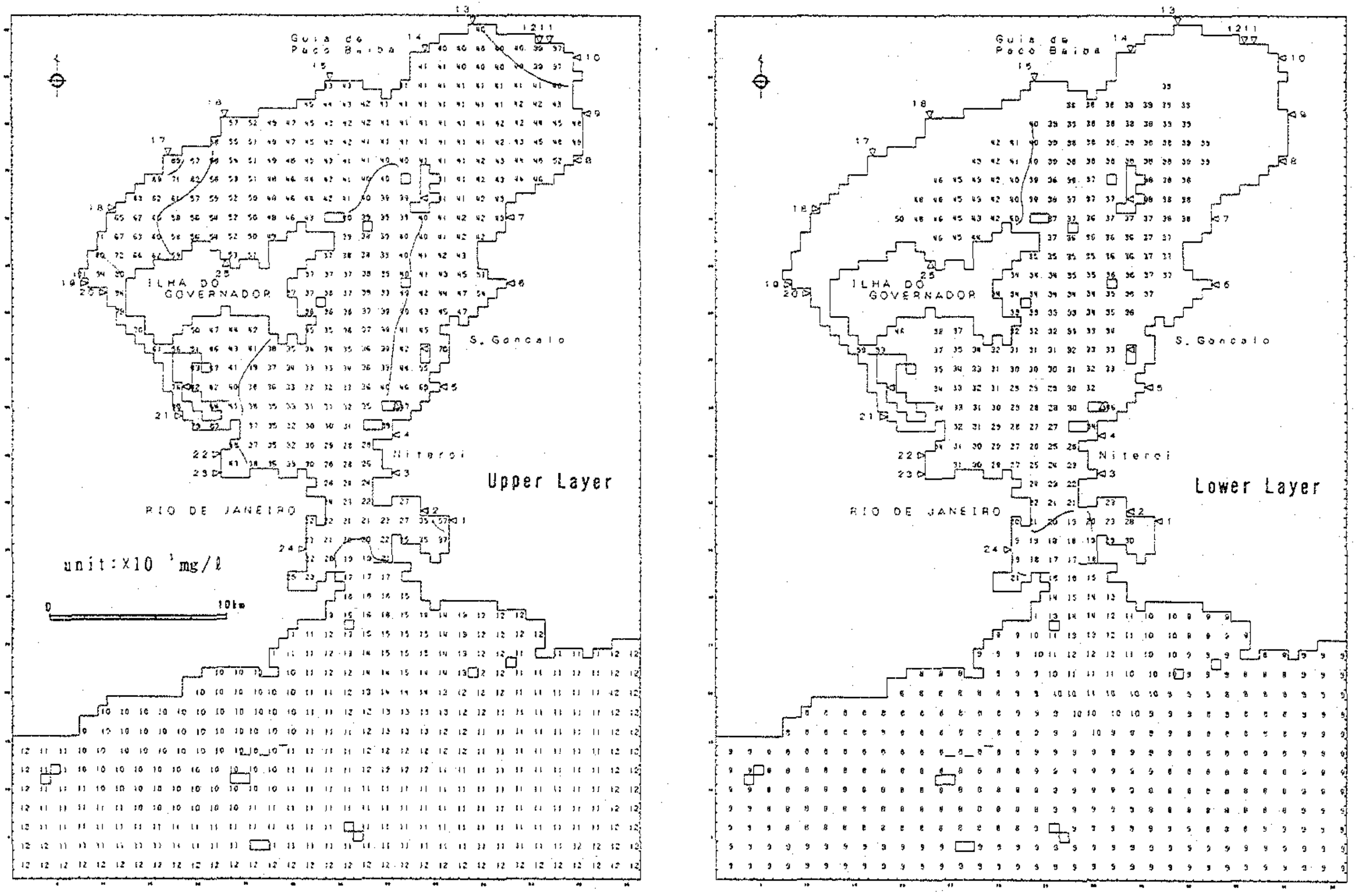
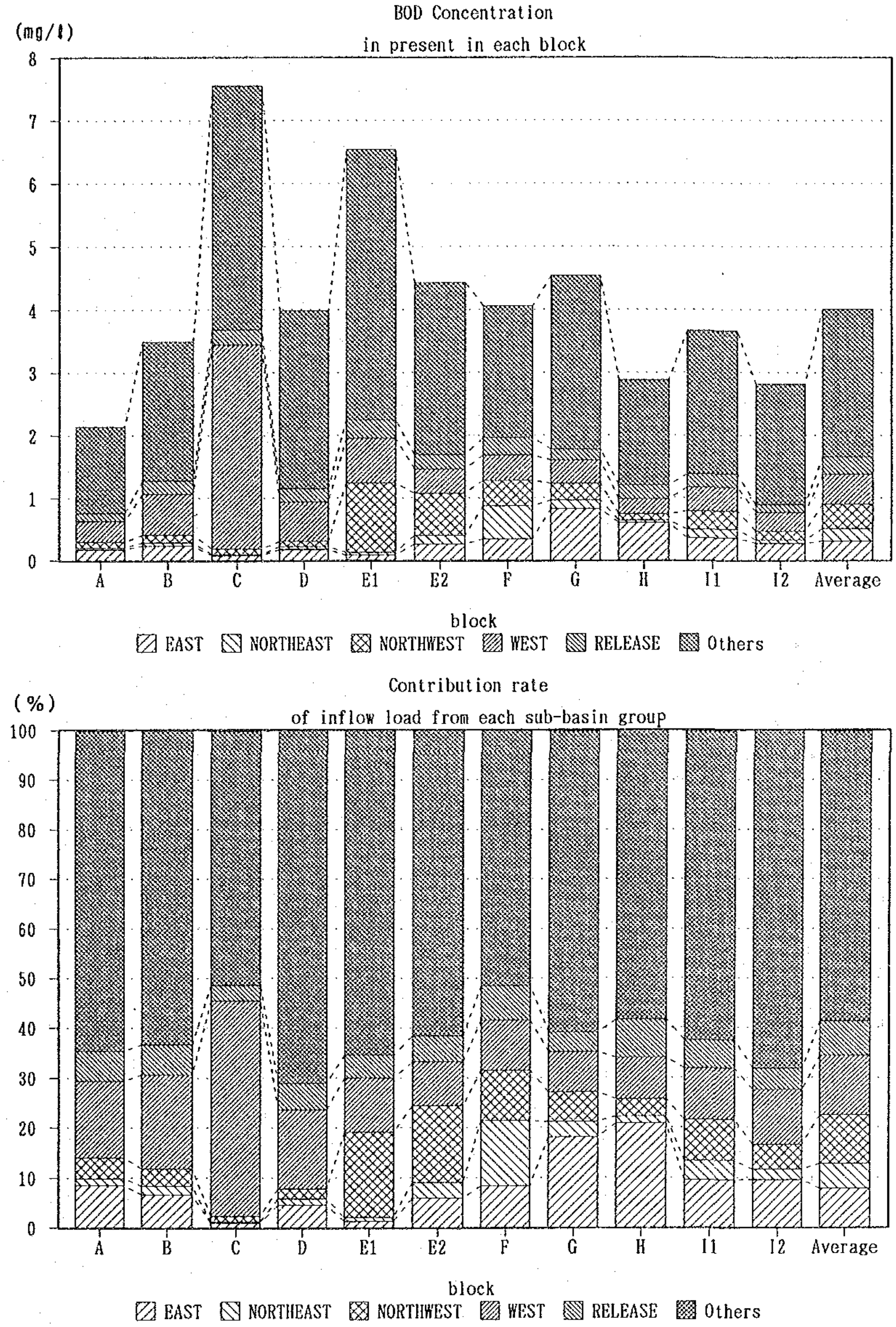


Fig. 3. 4-3(11) Calculated BOD Distribution in the Hypothetical Case (BOD Release Load from Block I2 is Zero)


BOD Concentration in present in each block

Contribution rate of inflow load from each sub-basin group

Fig. 3. 4-4 Contribution Rate of Each Sub-Basin Group to the Water Quality in the Bay

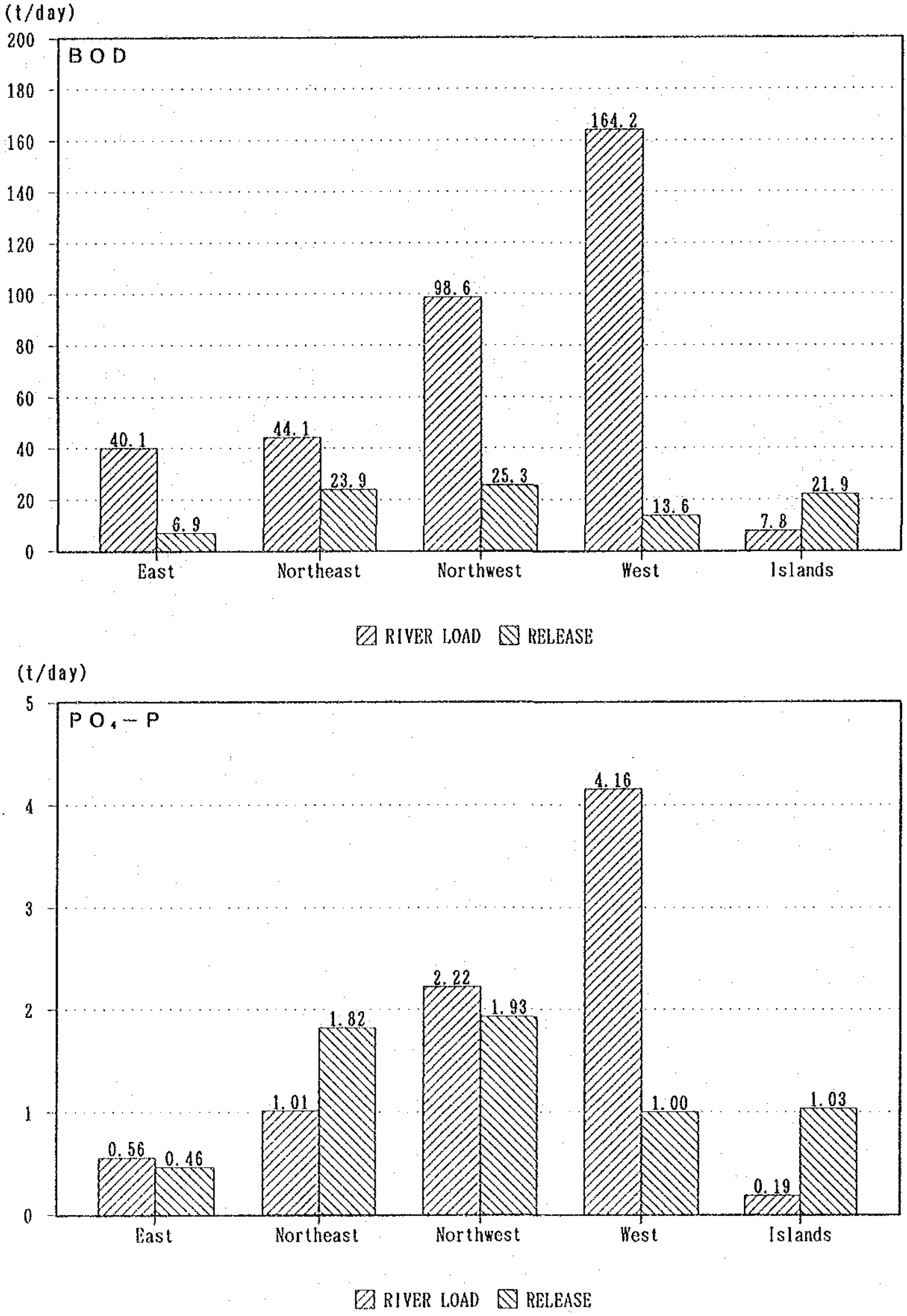


Fig. 3.4-5 Effluent Load from each Sub-Basin Group and Release Load from each Area

3.4.3 Target Reduction Load

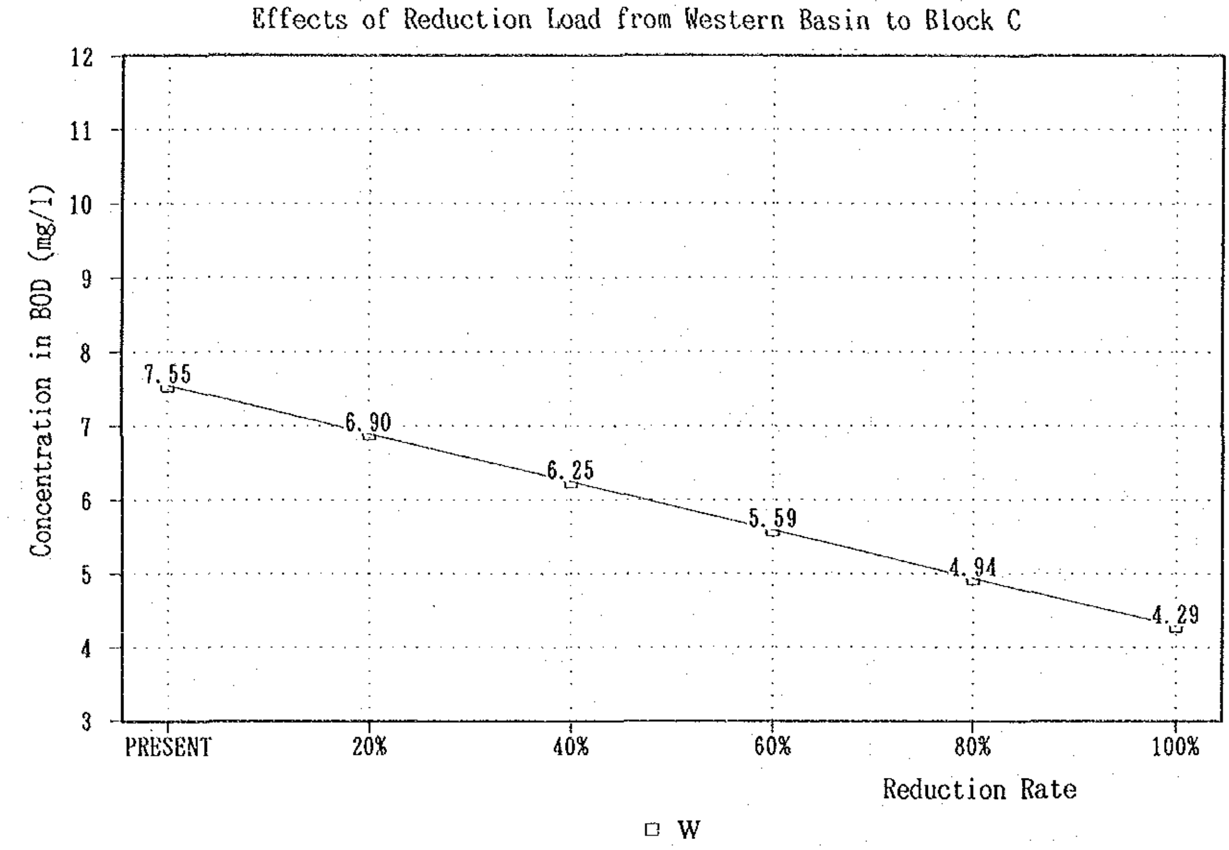
Seeing the distribution of the present water quality, the water areas of Block C, E1 and H do not meet the water quality standards. The influential basins to these water areas are the western, northwestern and eastern basins.

Therefore, we tried to know the effects of reducing loads from these basins. The results are shown in Fig.3.4-6. From this figure, we supposed 40% reduction of effluent loads from the western, northwestern and eastern basins.

Fig.3.4-7 and Fig.3.4-8 show the effects of the reduction for organic matters (BOD and O-P) and nutrient salts (PO_4-P), respectively. Namely,

Fig.3.4-7 (Case 1): 40% reduction of organic matters (BOD and O-P)
Fig.3.4-8 (Case 2): 40% reduction of nutrient salts (PO_4-P)

Moreover, Fig.3.4-9 and Fig.3.4-10 show the results of comparison between these cases and the present water quality.



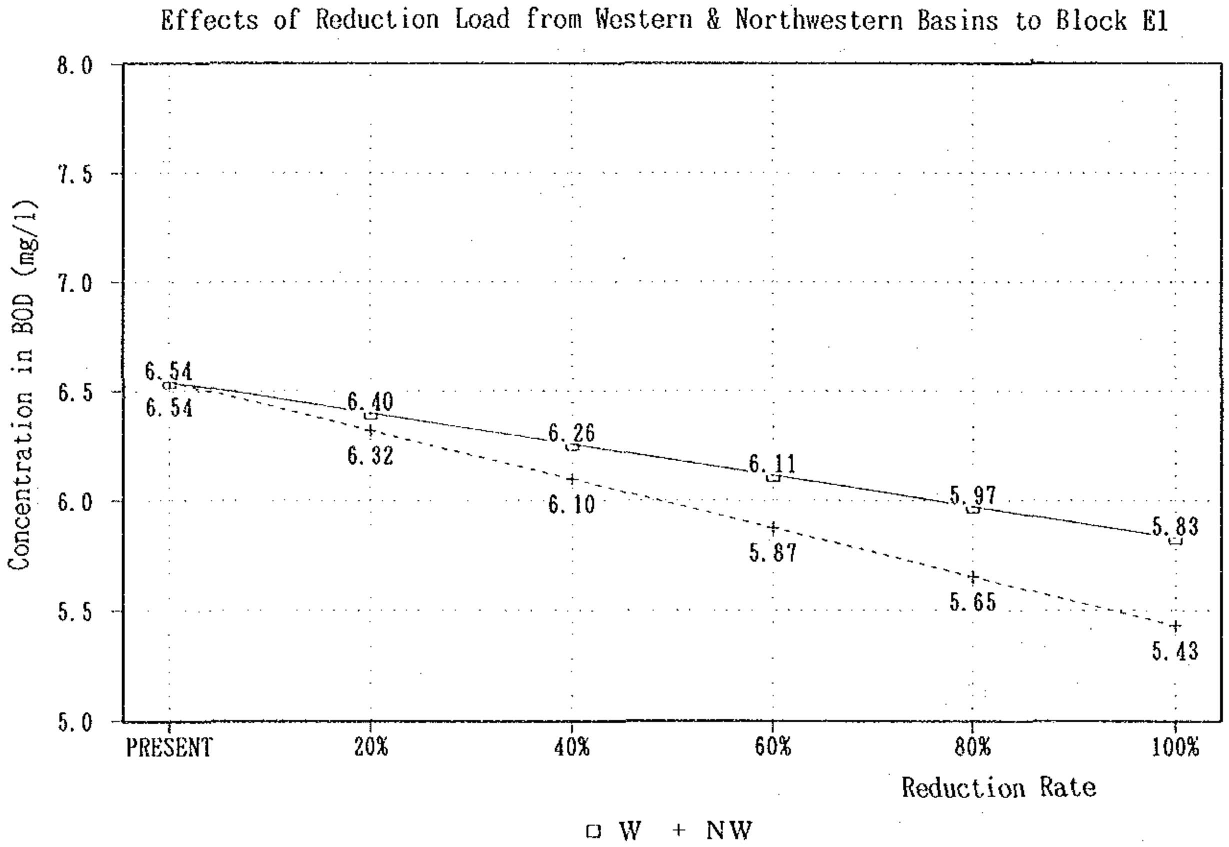


Fig. 3.4.6(1) Relation between Redusing Rate of Effluent Load and Water Quality Variation in BOD

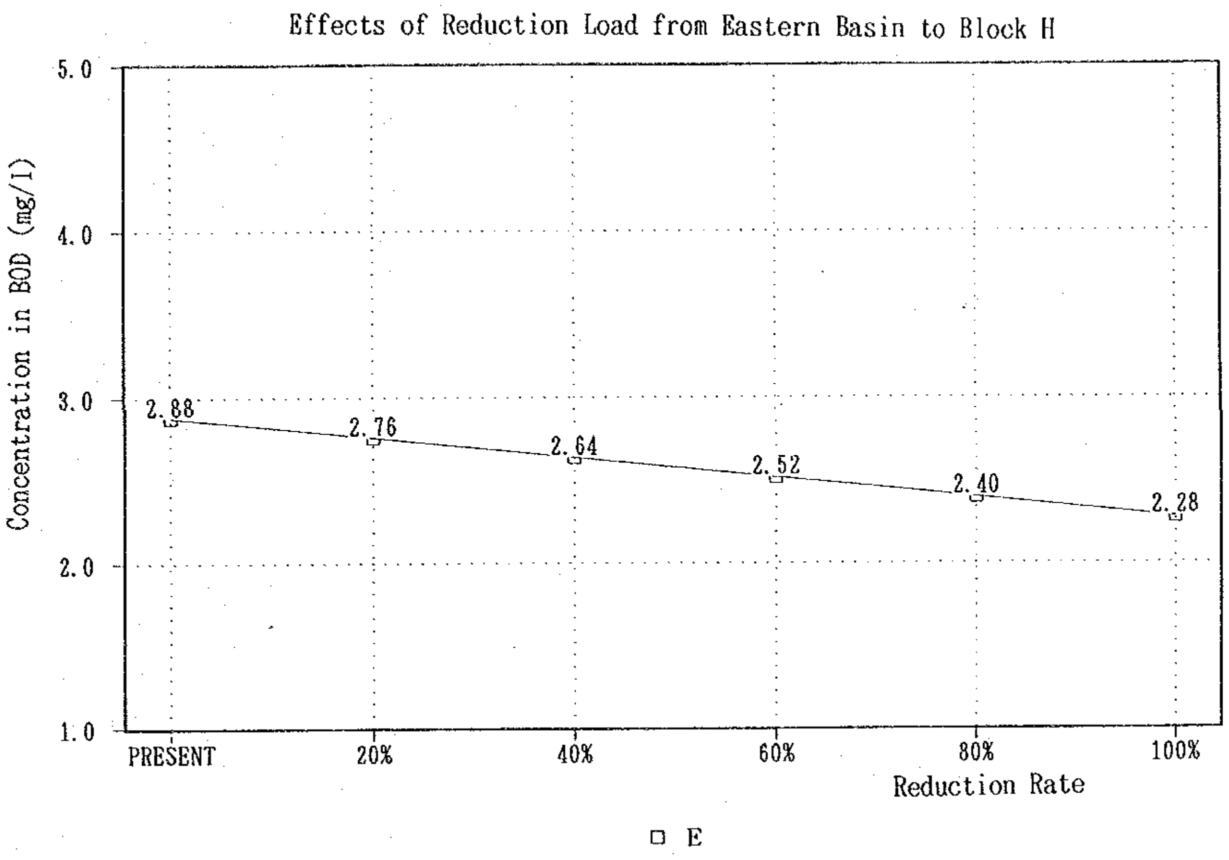


Fig. 3. 4. 6(2) Relation between Redusing Rate of Effluent Load and Water Quality Variation in BOD

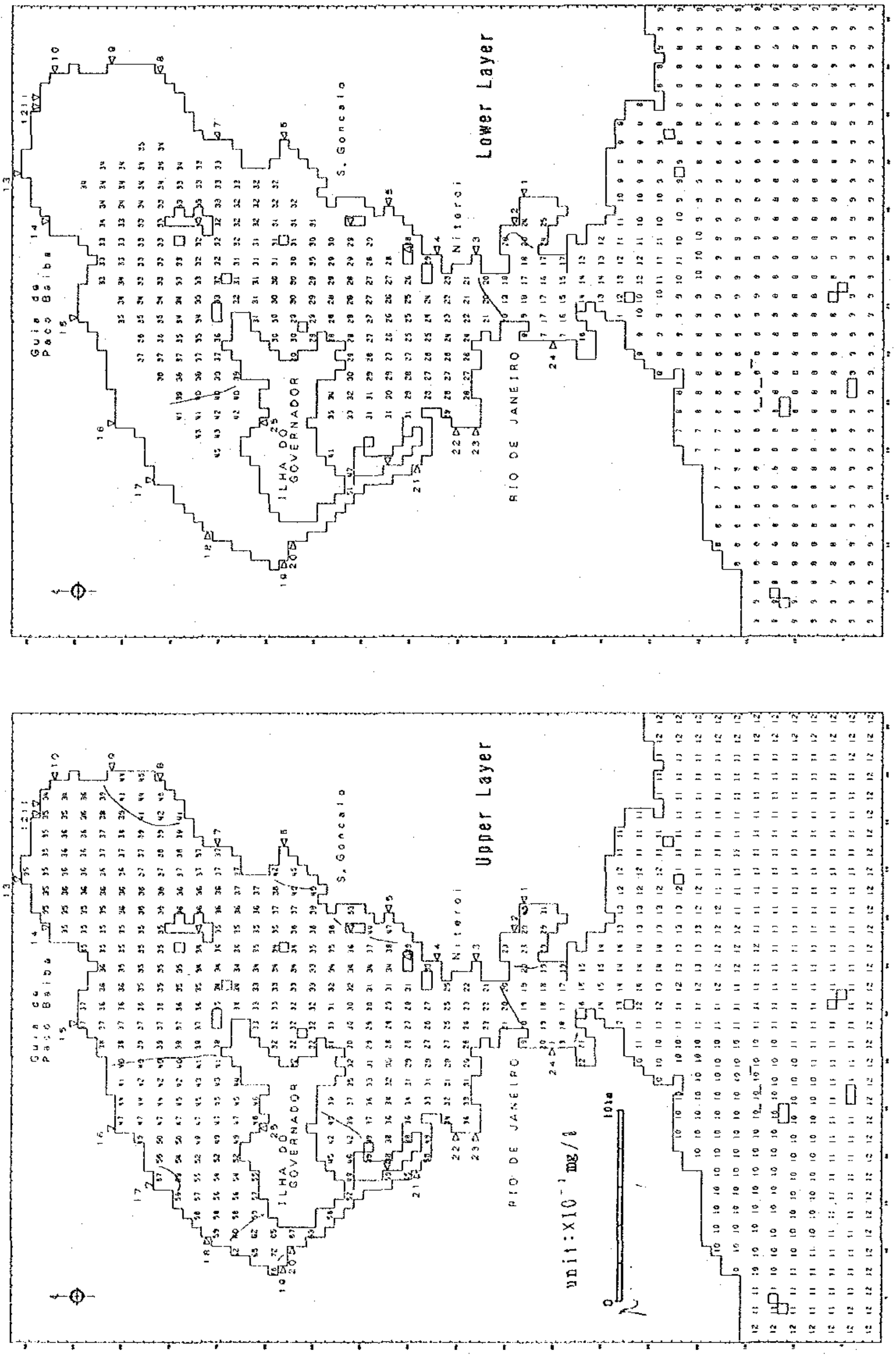


Fig. 3.4-7 Calculated BOD Distribution in the Hypothetical Case (Case 1)

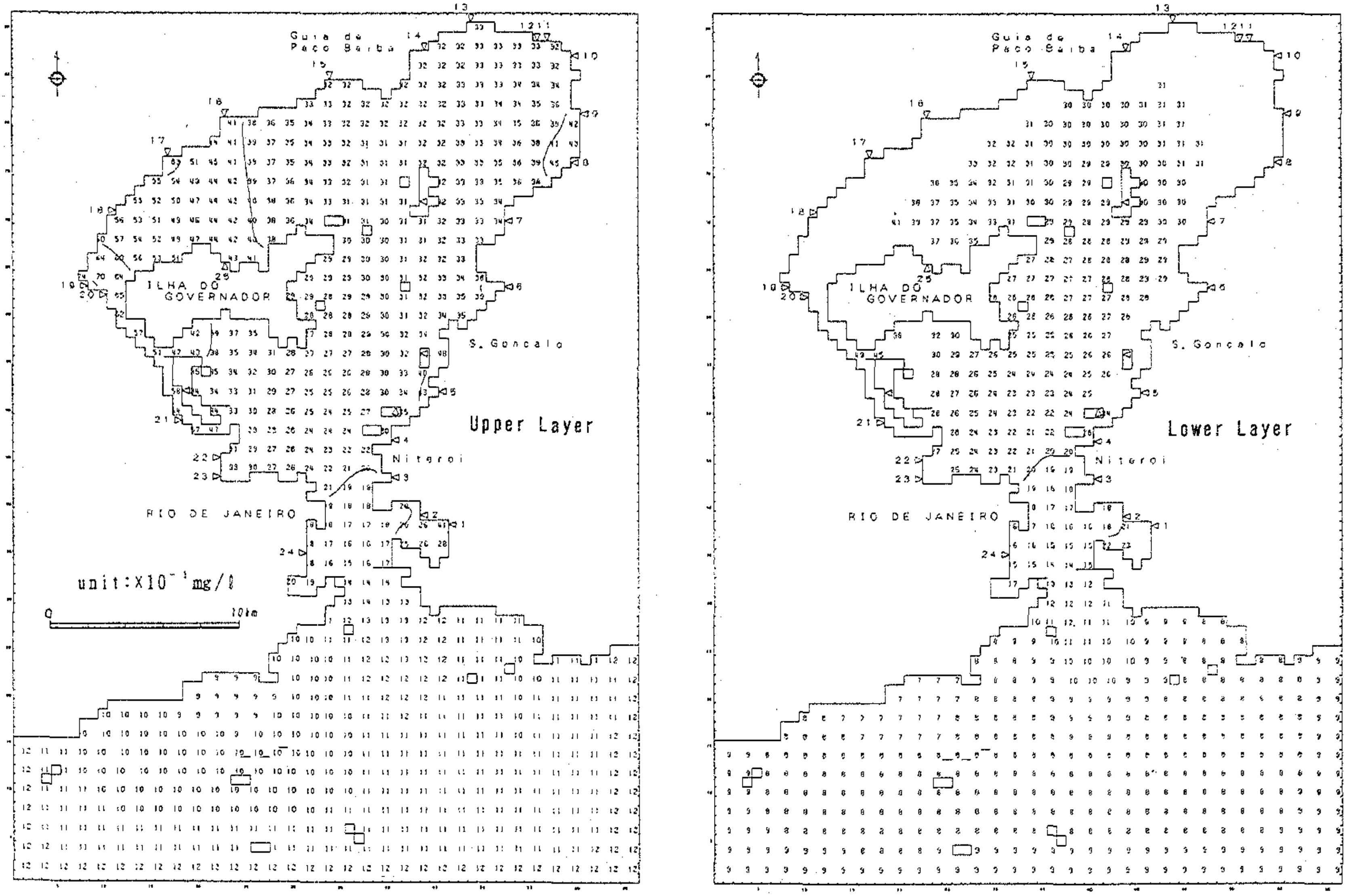


Fig. 3.4-8 Calculated BOD Distribution in the Hypothetical Case (Case 2)

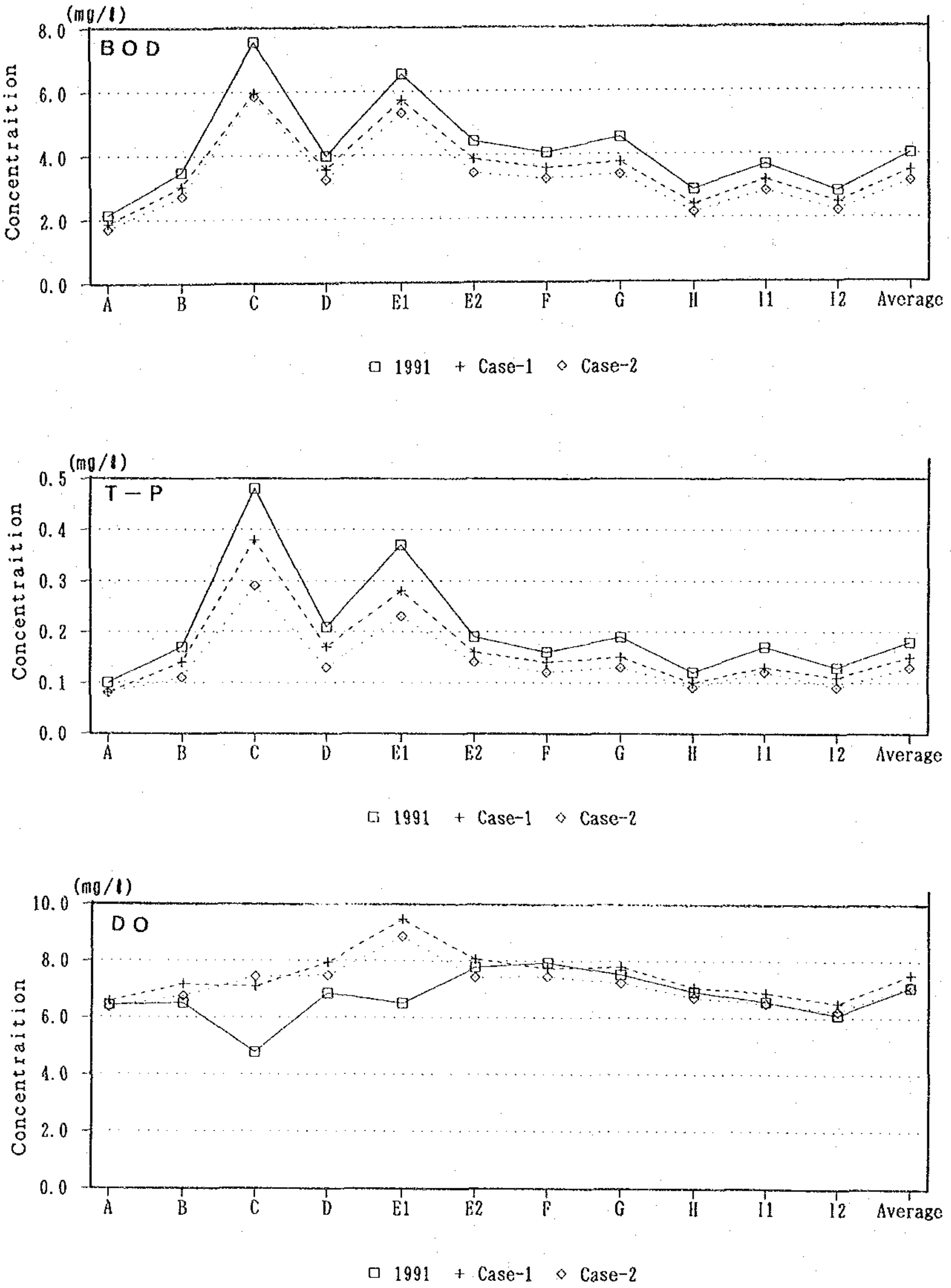


Fig. 3.4-9 Water Quality Change in each block

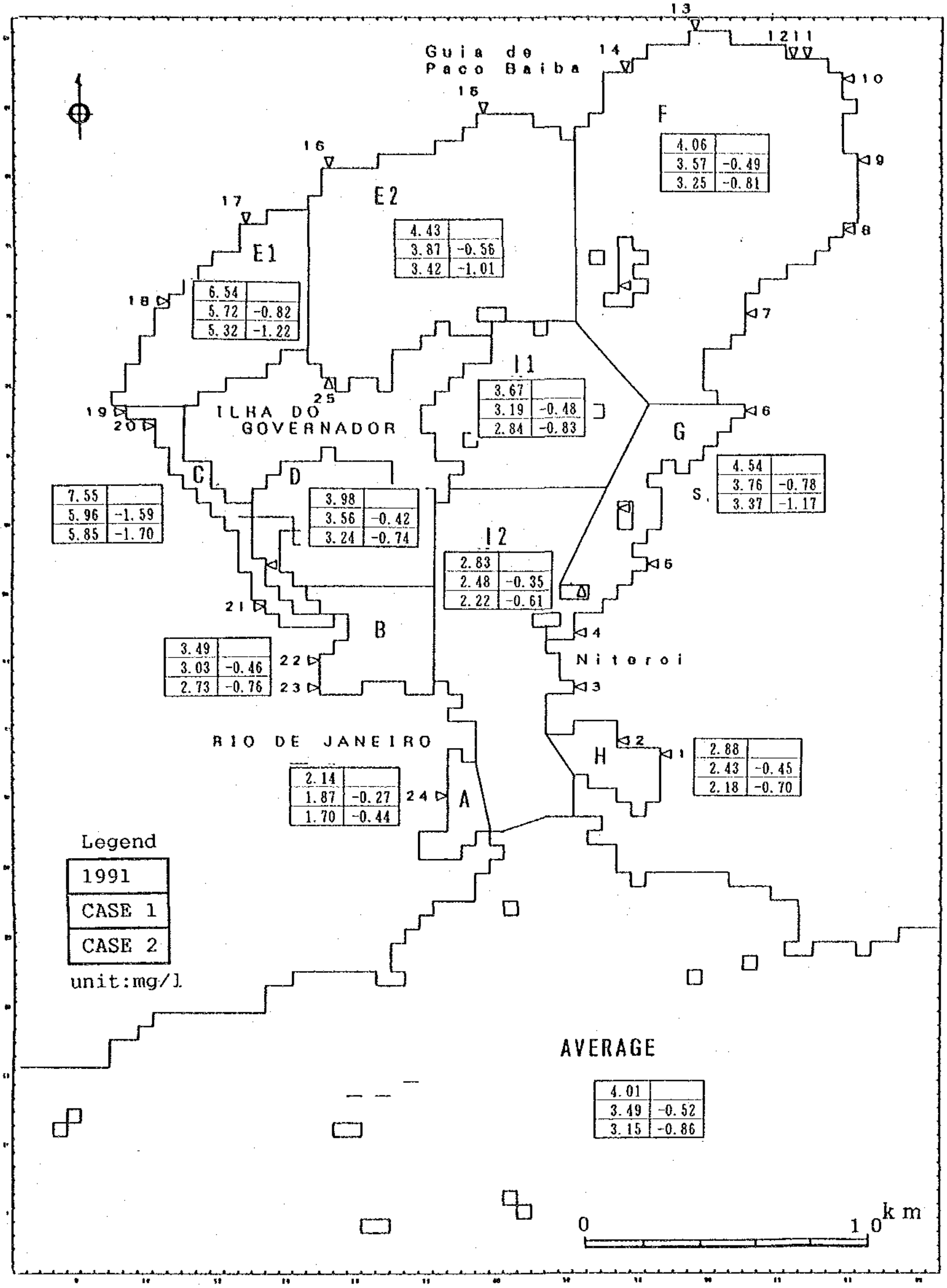


Fig. 3.4-10(1) BOD Concentration and Variation in each Block

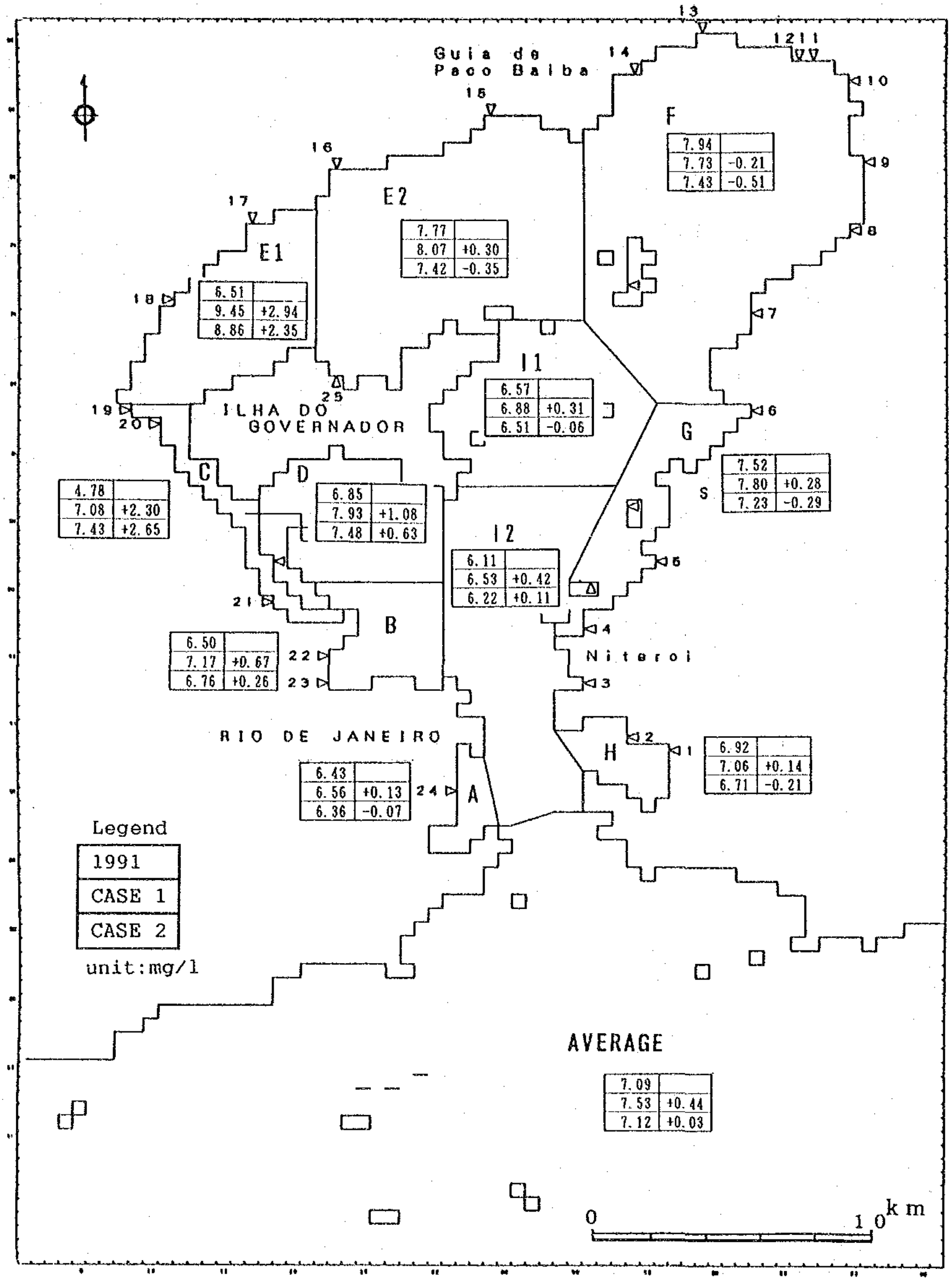


Fig. 3.4-10(2) DO Concentration and Variation in each Block

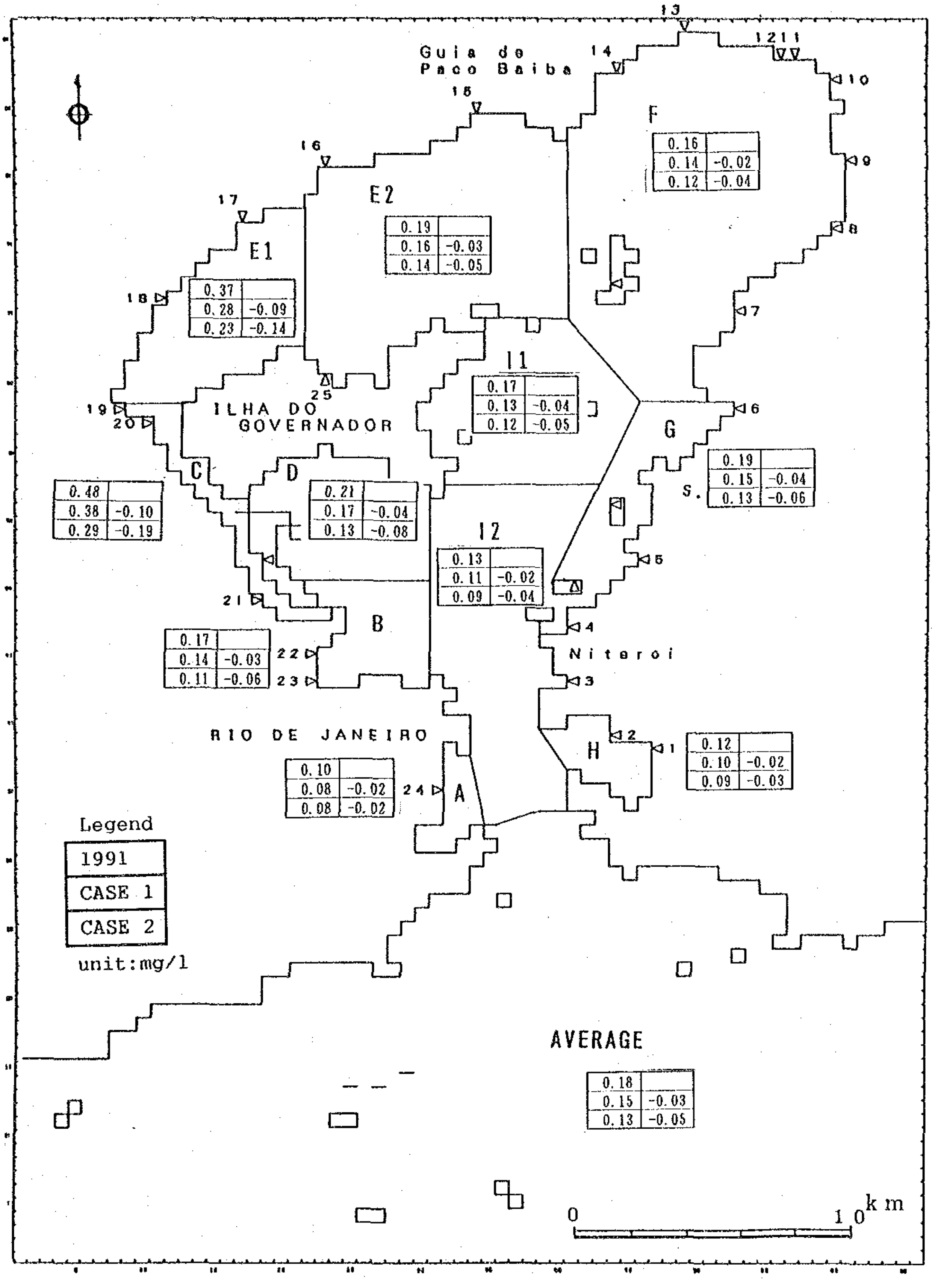


Fig. 3.4-10(3) T-P Concentration and Variation in each Block

3.5 Exchange of Bay Water by Simulation Models

3.5.1 Analysis by a Hydrodynamic Model

We divided the bay into four(4) blocks as shown in Fig.3.5-1 and analyzed the exchange of bay water by using the results of the tidal current simulation.

Fig.3.5-2 shows the amount of the water by advection between the blocks and the amount of river-flow into the bay for a day. The flow in the bay is governed by tidal motion, therefore there is a little difference of the amount between in the dry season and rainy season as we can see through the tidal current maps.

Fig.3.5-3 shows the difference of the amount of the water by advection between the blocks in Fig.3.5-2. The value in this figure means the amount of flow only caused by river-flow. Seeing the water flowed into the Block 1 from the rivers, 7.1m^3/day of fresh water flow into the Block 1, and 3.6m^3/day and 3.5m^3/day of water flow toward Block 2 and 3 respectively in dry season, and in the rainy season, 11.1m^3/day of fresh water flow into the Block 1, and 7.3m^3/day and 3.8m^3 day of water flow toward Block 2 and 3 respectively.

That is, the amount of water flowed toward Block 2 caused by the water flowed into Block 1 from the rivers is almost the same as toward Block 3 in dry season, but it is about two times larger than in rainy season.

These results are also summarized in Table 3.5-1 about the whole of the bay.

Now, if we suppose that the exchange of bay water is caused only by the river flows, it will take more than 90 days at least to exchange the bay water.

As the strong tidal currents, however, are seen at the baymouth, the bay water will be exchanged faster than 90 days.

Table 3.5-1 Relationship between Volume and the Amount of Flow

Item	Value	V/Q
Water Volume of the Bay(V)	2200.0*10^6m^3	
Amount of River-Flow (Q)		
Dry Season	15.4*10^6m^3/day	142.9days
Rainy Season	24.4*10^6m^3/day	90.2days
Amount of Outflow through the Baymouth (Q)		
Dry Season	804.4*10^6m^3/day	2.7days
Rainy Season	808.7*10^6m^3/day	2.7days

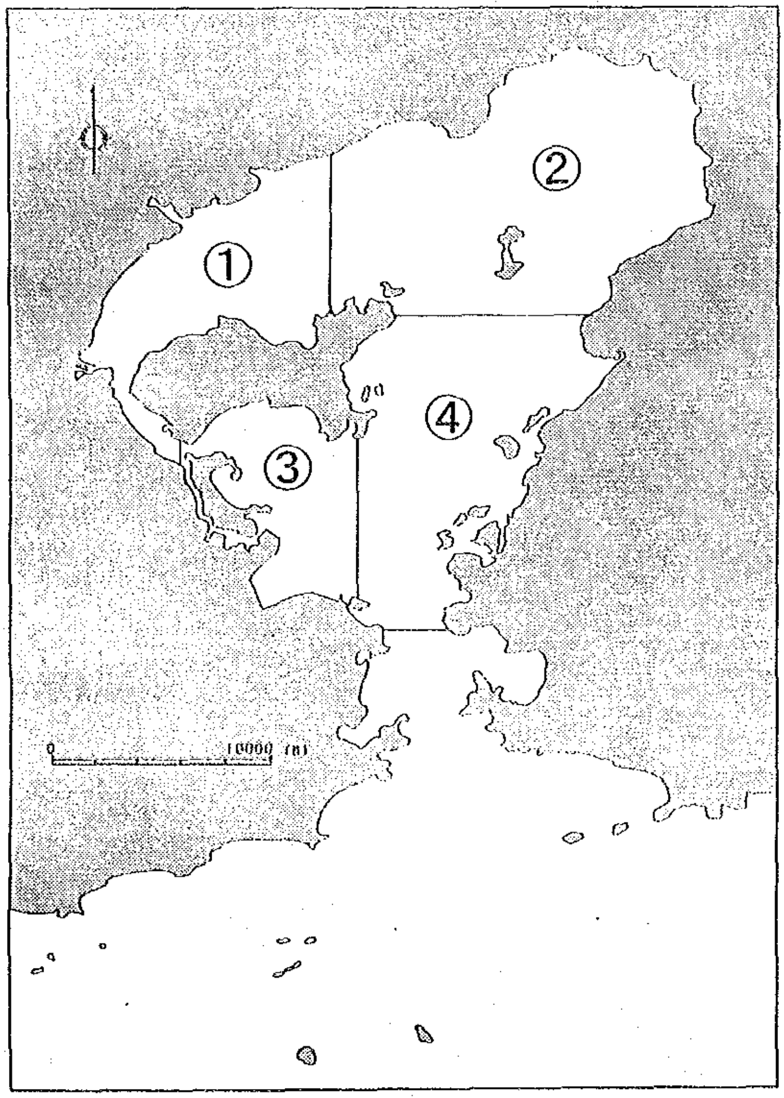


Fig.3.5-1 Block Division in the Bay for analyses of Bay Water

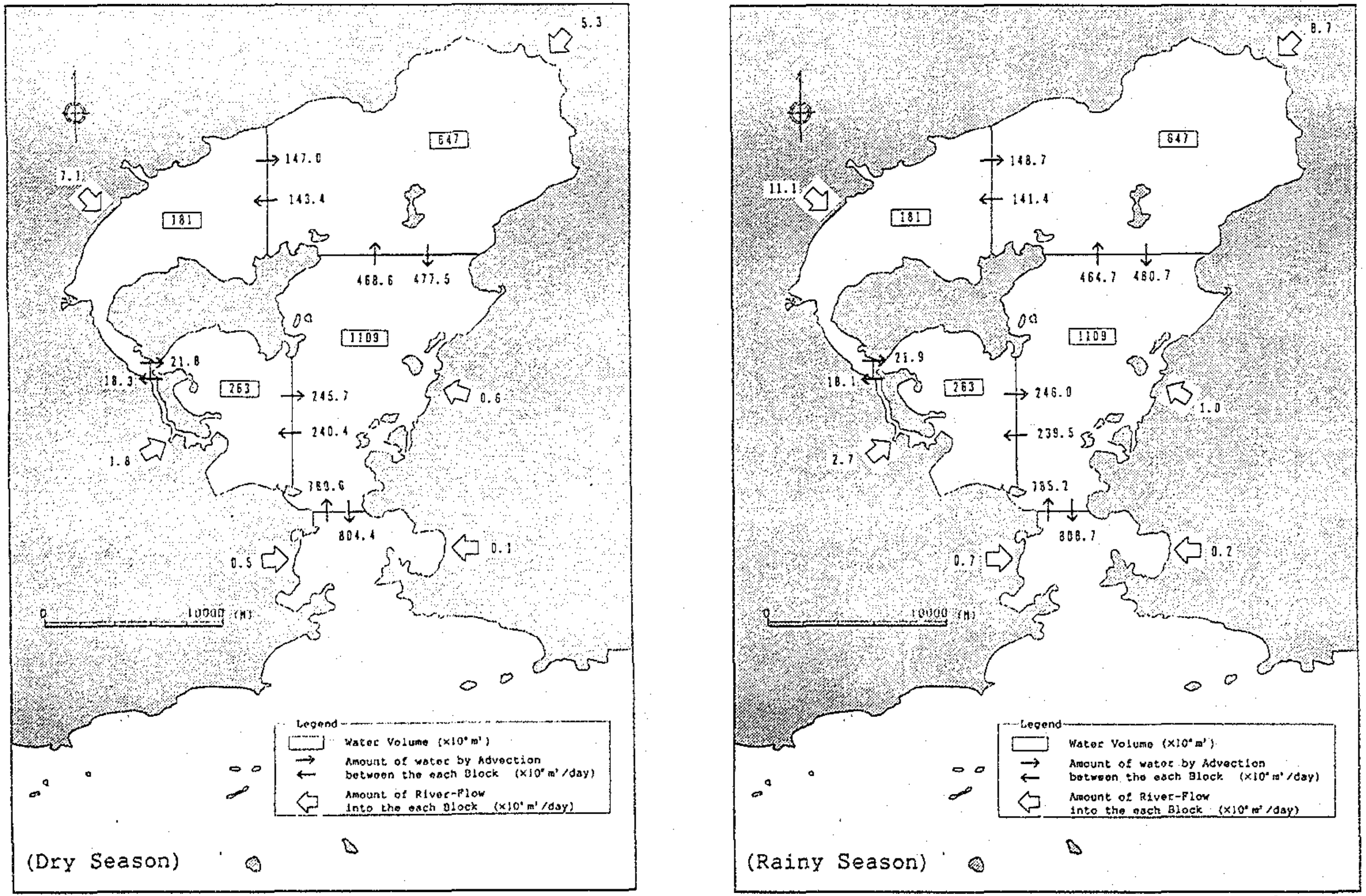
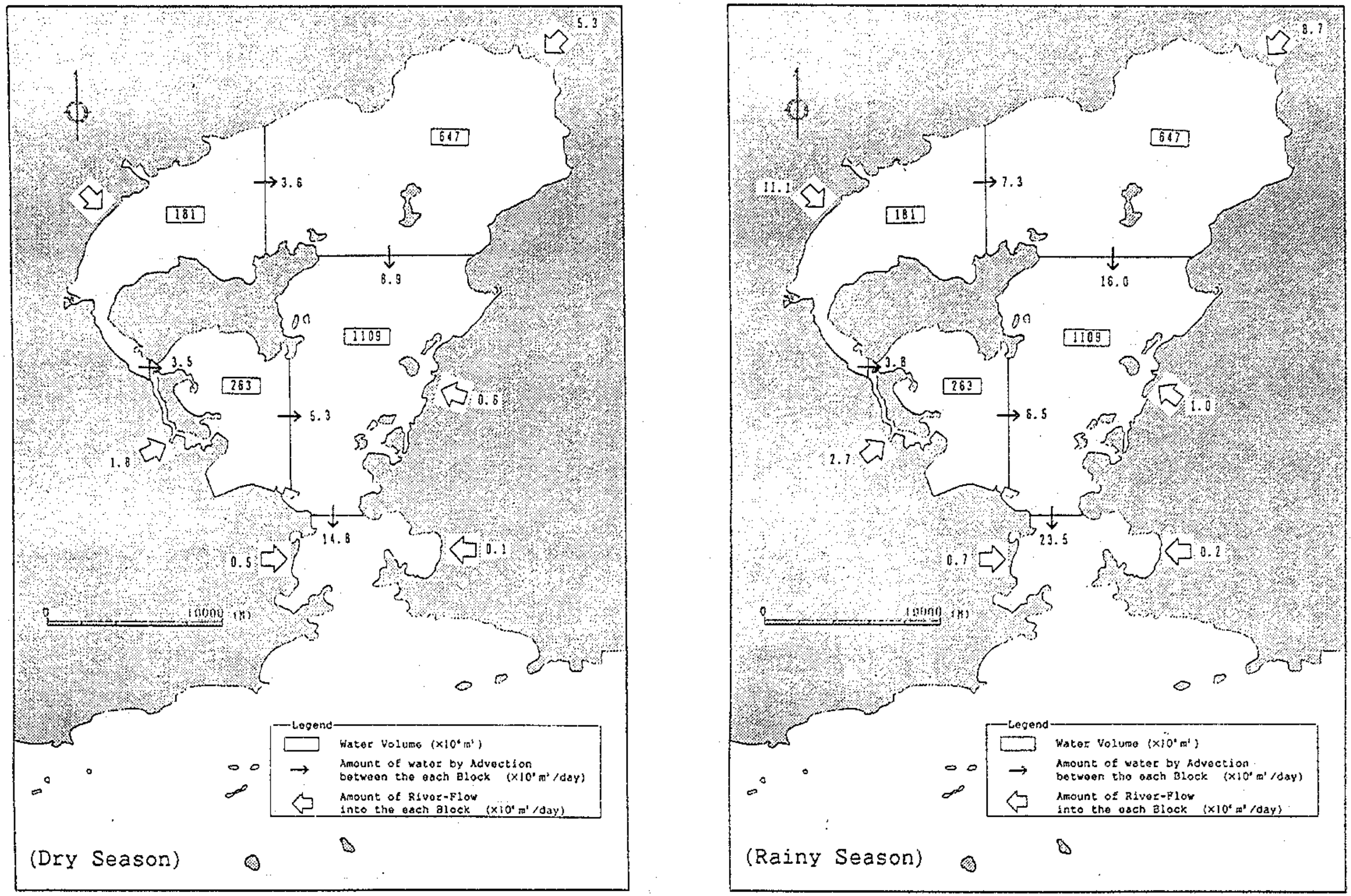


Fig .3.5-2 Exchange of Water calculated by the Tidal Current Simulation



(Dry Season)

(Rainy Season)

Fig.3.5-3 Exchange of Water only caused by River-Flow

3.5.2 Analysis by a Marker and Cell Method

Movement of the markers such as buoy with no weight was calculated by using the tidal current simulation (hydrodynamic model). Calculation cases are shown in Table 3.5-2.

Table 3.5-2 Calculation Cases for Markers

Case No.	Season	Initial Position of the Markers
1 (1)	Dry Season	Every meshes in the whole of the bay
1 (2)	Rainy Season	-- ditto --
2 (1)	Dry Season	Rivermouths of Meriti, Iguacu and Guapimirim
2 (2)	Rainy Season	-- ditto --

Fig.3.5-4 shows the difference of the distribution of markers between high tide and low tide in Case 1 of Table 3.5-2.

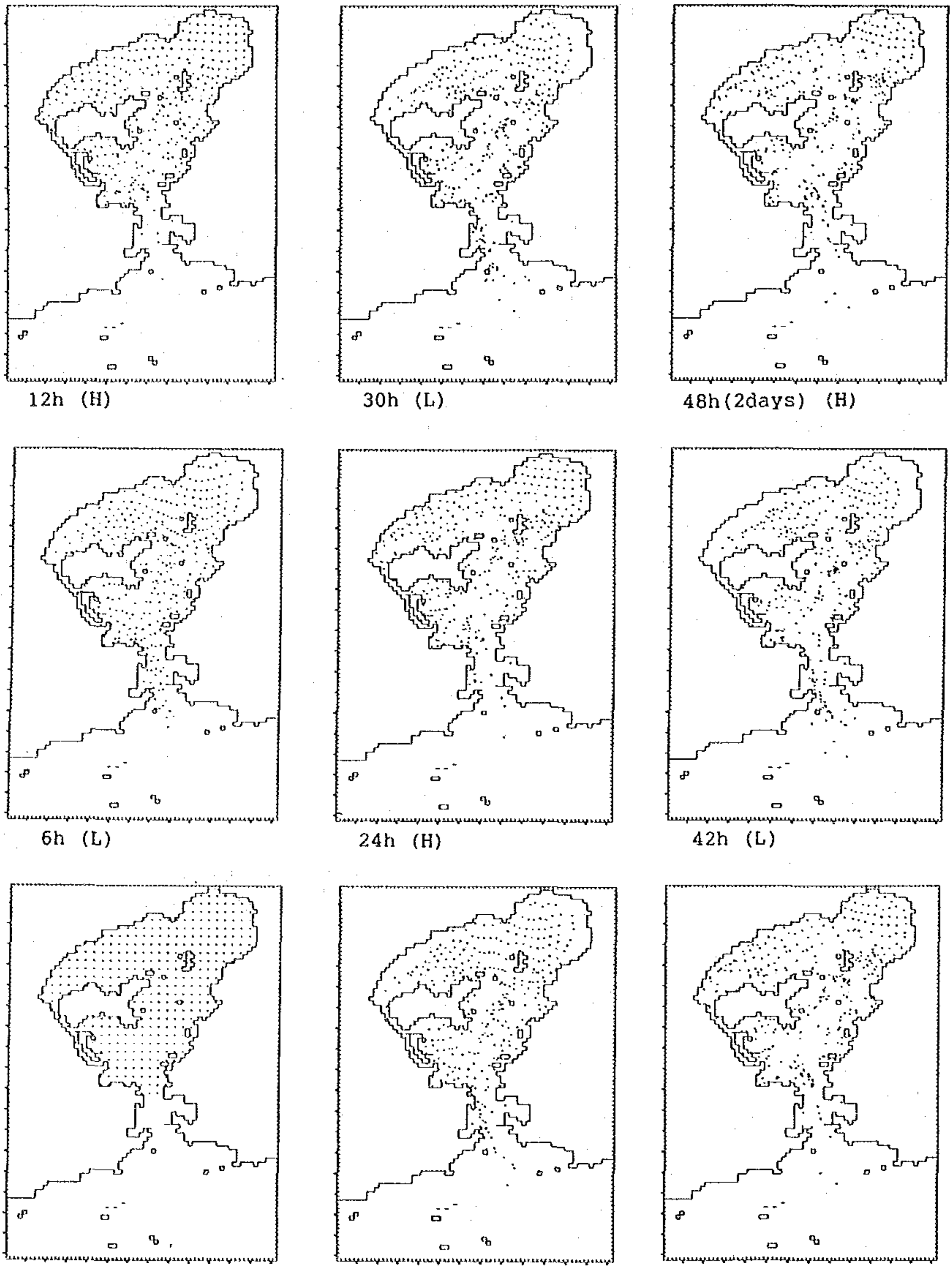
We can see that the markers move toward the baymouth during the ebb stream (from high tide to low tide) and toward the inner part of the bay during the flood stream (from low tide to high tide) on the flow of the tidal current. As the result, they are hard to go out of the bay.

Fig .3.5-5 shows the change of position of markers for 80 days in Case 2 of Table 3.5-2.

It is observed that the markers flowed toward the baymouth faster in the rainy season than in the dry season. But even in rainy season, it takes about 30 days for the some buoys flow out from the baymouth into the outer ocean and about 80 days for most of buoys to do. But the buoys still remain in the bay then and even if the buoys were outer ocean, they return at the next flood stream because of the slow velocity of tidal current in the outer ocean and the circulation at the just outer of the baymouth.

This is, however, only based on advection caused by tidal motion. In fact, the movement of buoy is influenced by other physical properties such as wind or ocean current in the outer ocean and we should consider the effect of diffusion for the analysis of exchange of bay water in the view of the water quality.

H : High Tide
L : Low Tide



12h (H)

30h (L)

48h(2days) (H)

6h (L)

24h (H)

42h (L)

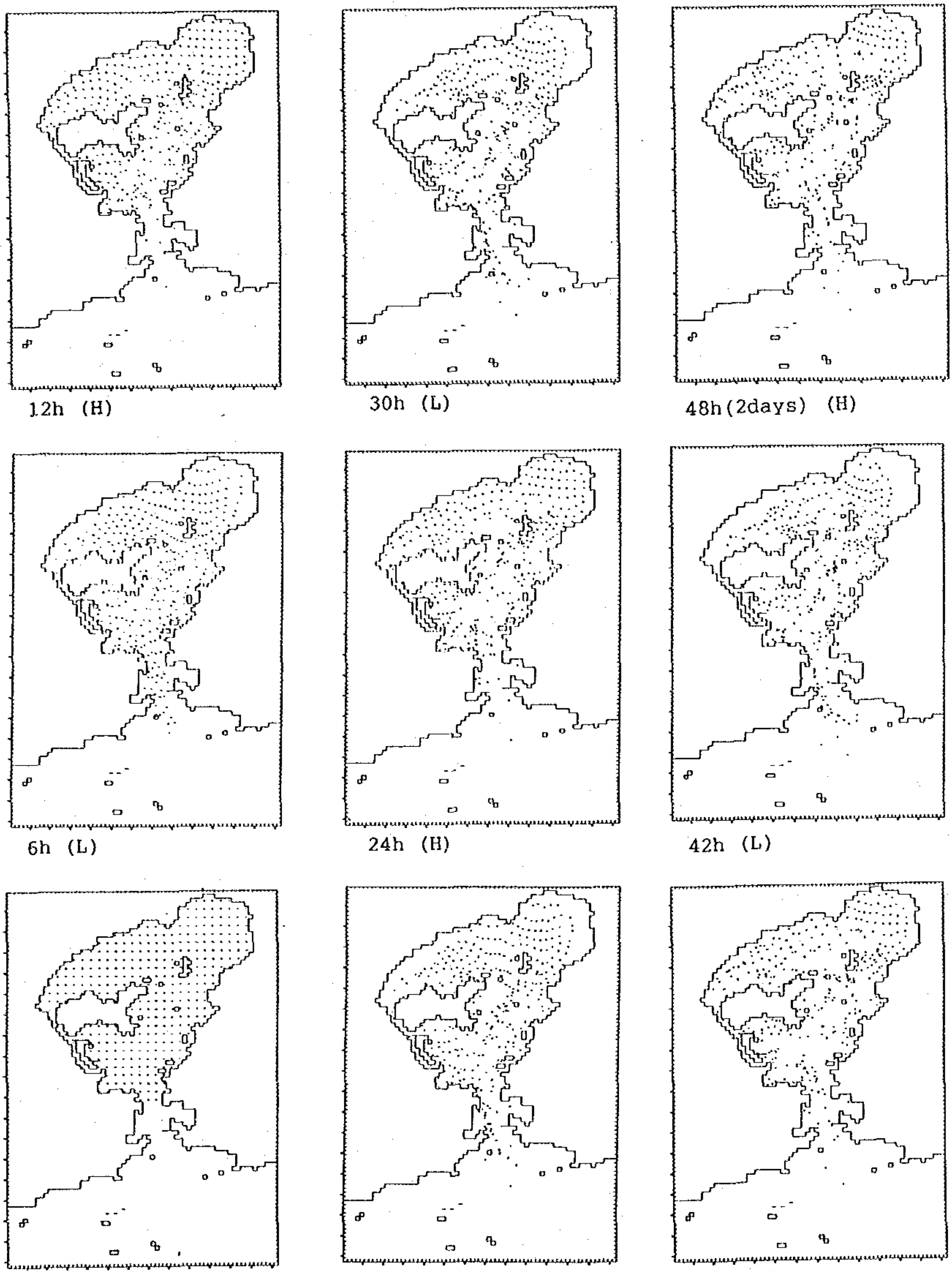
Start Time (H)

18h (L)

36h (H)

Fig.3.5-4(1) Distribution of Markers at High Tides and Low Tides (Case 1(1)) (Dry Season)

H : High Tide
L : Low Tide



12h (H)

30h (L)

48h(2days) (H)

6h (L)

24h (H)

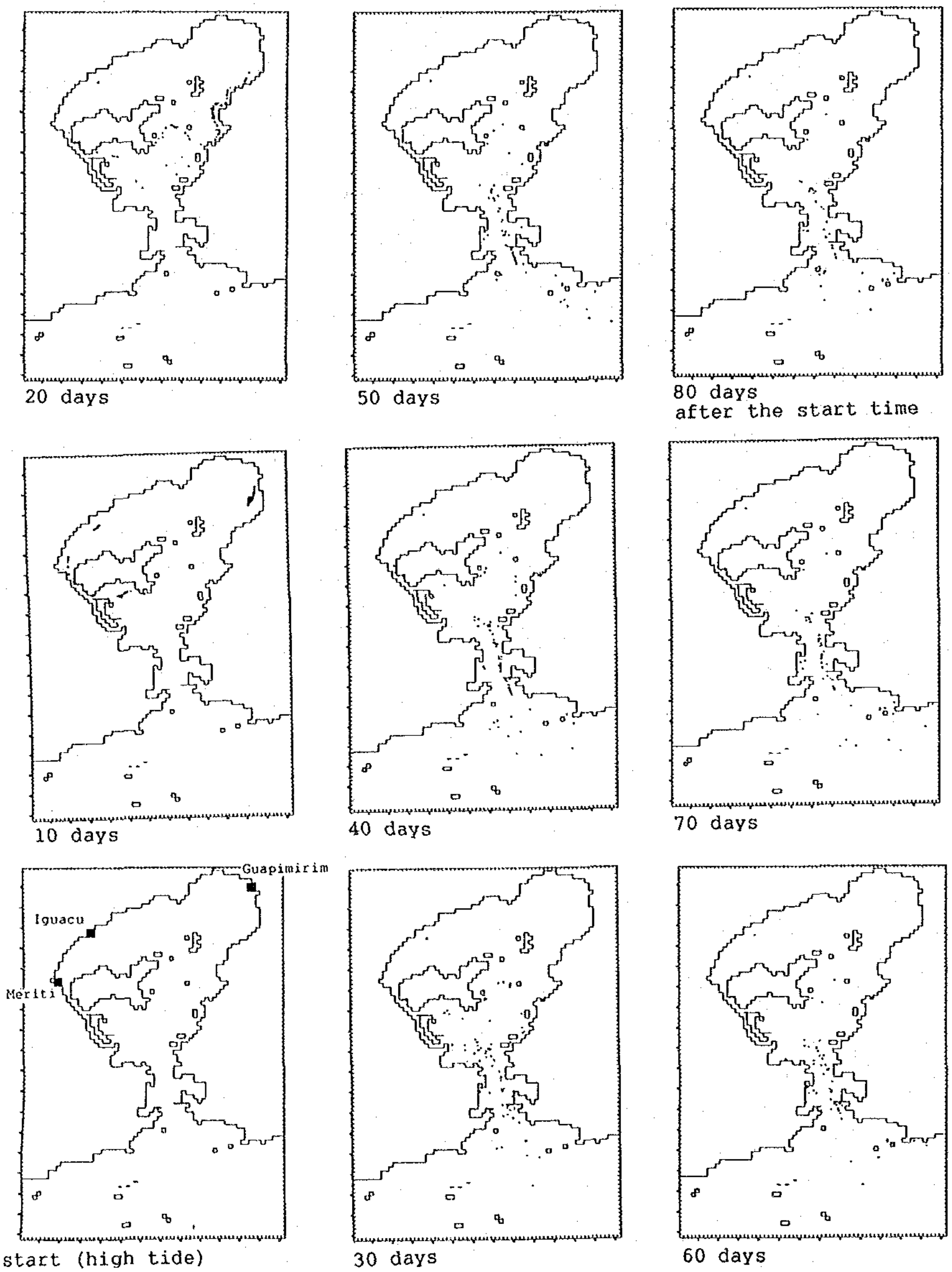
42h (L)

Start Time (H)

18h (L)

36h (H)

Fig.3.5-4(2) Distribution of markers at High Tides and Low Tides (Case 1(2)) (Rainy Season)



20 days

50 days

80 days
after the start time

10 days

40 days

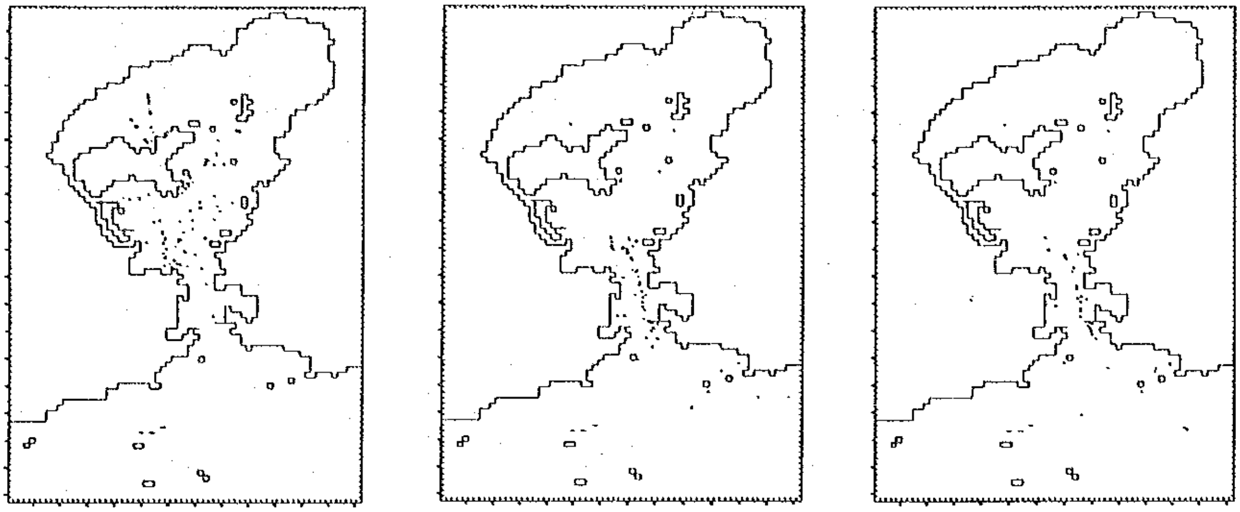
70 days

start (high tide)

30 days

60 days

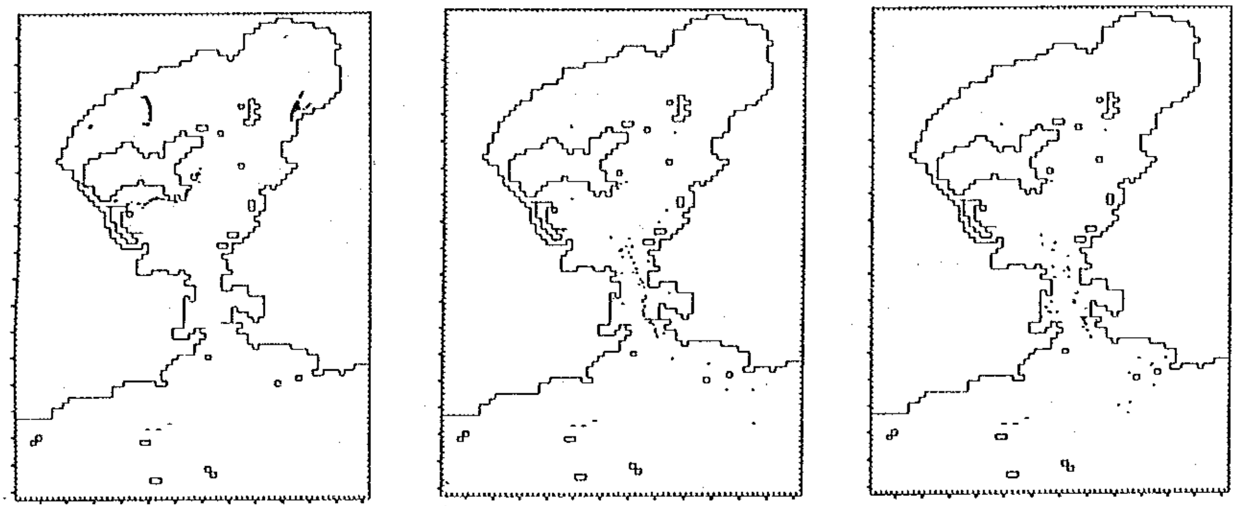
Fig.3.5-5(1) Distribution of markers from the Meriti, Iguacu and Guapimirim Rivers (Case 2(1)) (Dry Season)



20 days

50 days

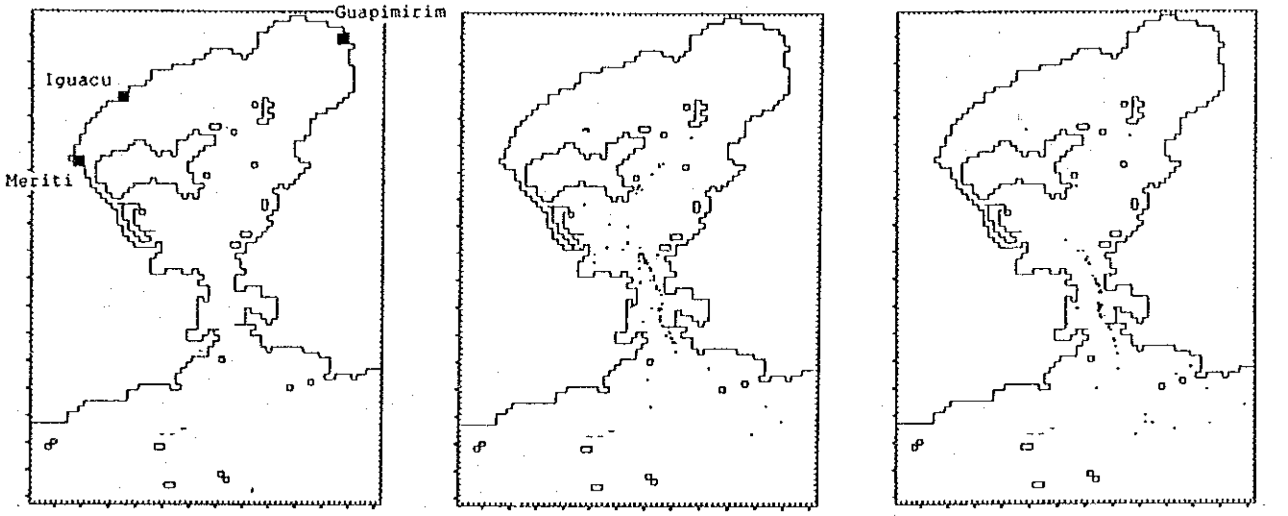
80 days
after the start time



10 days

40 days

70 days



start (high tide)

30 days

60 days

Fig.3.5-5(2) Distribution of Markers form the Meriti, Iguacu and Guapimirim Rivers (Case 2(2)) (Rainy Season)

3.5.3 Analysis by a Diffusion Simulation Model

We analyzed exchange of bay water by using the diffusion simulation model. The calculation cases are shown in Table 3.5-3 and the other calculation conditions except initial concentration are the same as those for salinity.

Table 3.5-3 Calculation Cases

Case No.	Initial Concentration		Season
1	Block 1	:10.0	Dry
	Other	: 0.0	Rainy
2	Block 2	:10.0	Dry
	Other	: 0.0	Rainy
3	Block 3	:10.0	Dry
	Other	: 0.0	Rainy
4	Block 4	:10.0	Dry
	Other	: 0.0	Rainy
5	Block 1,2,3,4	:10.0	Dry
	Outside of the bay	: 0.0	Rainy

In Case 1 to 4 of Table 3.5-3, we released conservative matters instantaneously into the each block respectively. Then the concentration change with time was calculated by a diffusion simulation model under the assumption of a perfect mixture in the bay in order to see the relation of the exchange of water between the blocks.

Fig.3.5-6 shows the variation of concentration (a relative concentration to the initial one C/C_0) in each block and the number of days becoming one tenth (1/10) of the initial concentration (C_0) for each block is as follows;

Block 1 : 30 tidal (about 15 days)
Block 2 : 70 tidal (about 35 days)
Block 3 : 10 tidal (about 5 days)
Block 4 : 80 tidal (about 40 days)

This means that the western part (Block 3) has the best water exchange (retention time is the shortest) and the west side of the inner part (Block 1) is in the second place. In contrast it, the eastern part (Block 2 and 4) shows a bad exchange (retention time is long).

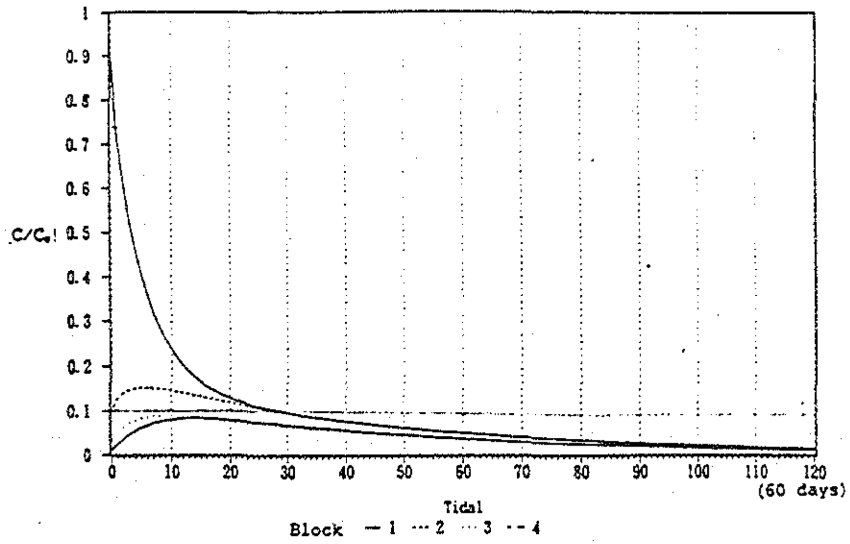
Regarding with the exchange of waters between the blocks, a good water exchange is seen between Block 1 and Block 2, and between Block 3 and Block 4.

Moreover, in case of releasing in Block 4 near the baymouth, it is seen that the concentration of Block 4 is higher than that of other blocks in the first stage, then the concentration of Block 3 in the west side of Block 4 soon becomes higher than that of Block 4 temporarily, and after one week the concentration of Block 1 and Block 2 situated in the inner part becomes higher than that of the releasing Block 4. This means that the inner part is strongly affected by the water quality in the baymouth area.

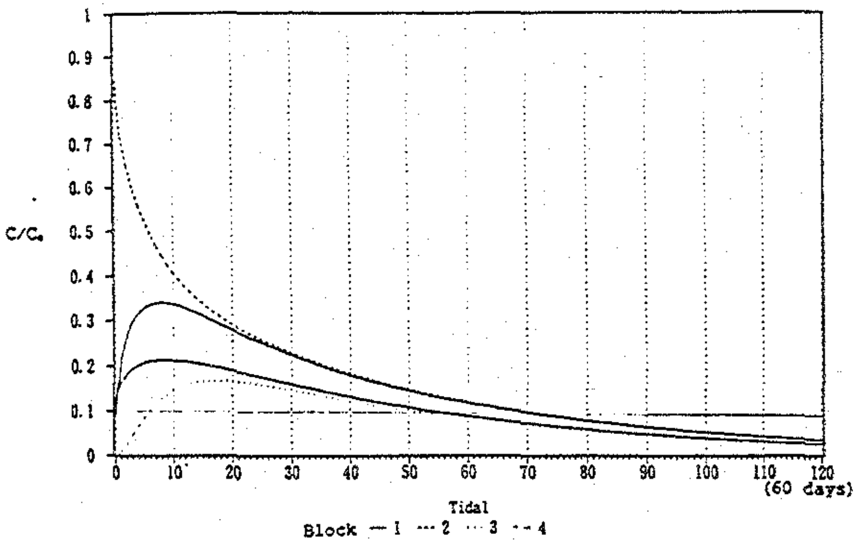
The results of the calculation in Case 5 that is the case of releasing conservative matters instantaneously in the whole bay area are shown in Fig 3.5-7.

Seeing the concentration change with time, it takes more than 60 days to become one tenth (1/10) of the initial concentration and the times in Block 3 and 4 are little shorter than those in Block 1 and 2.

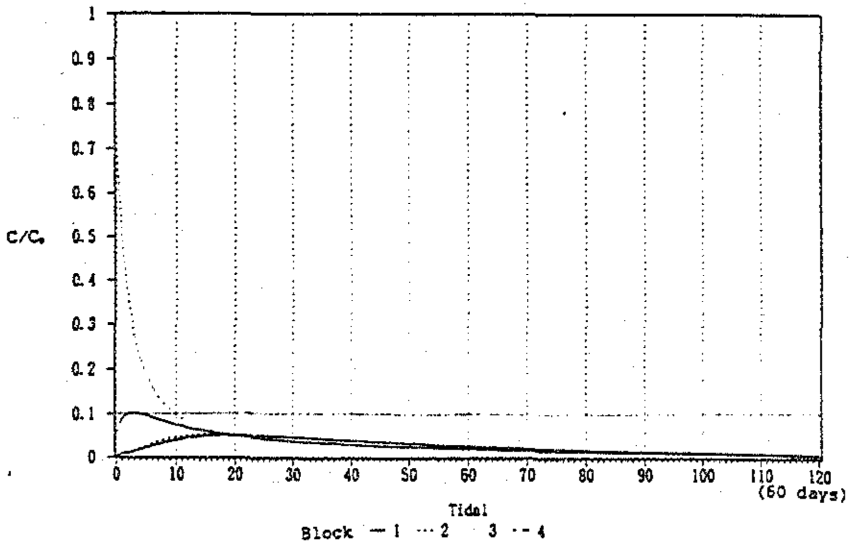
(1) In case of releasing in Block 1



(2) In case of releasing in Block 2



(3) In case of releasing in Block 3



(4) In case of releasing in Block 4

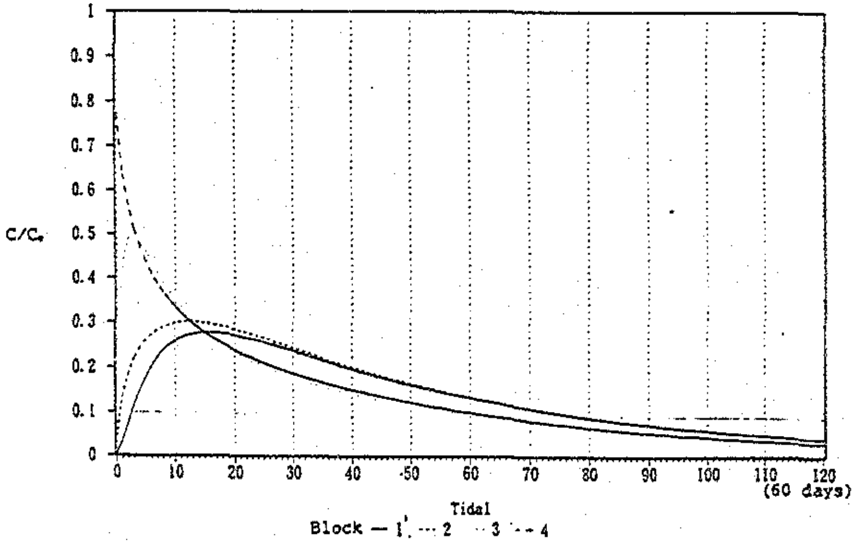
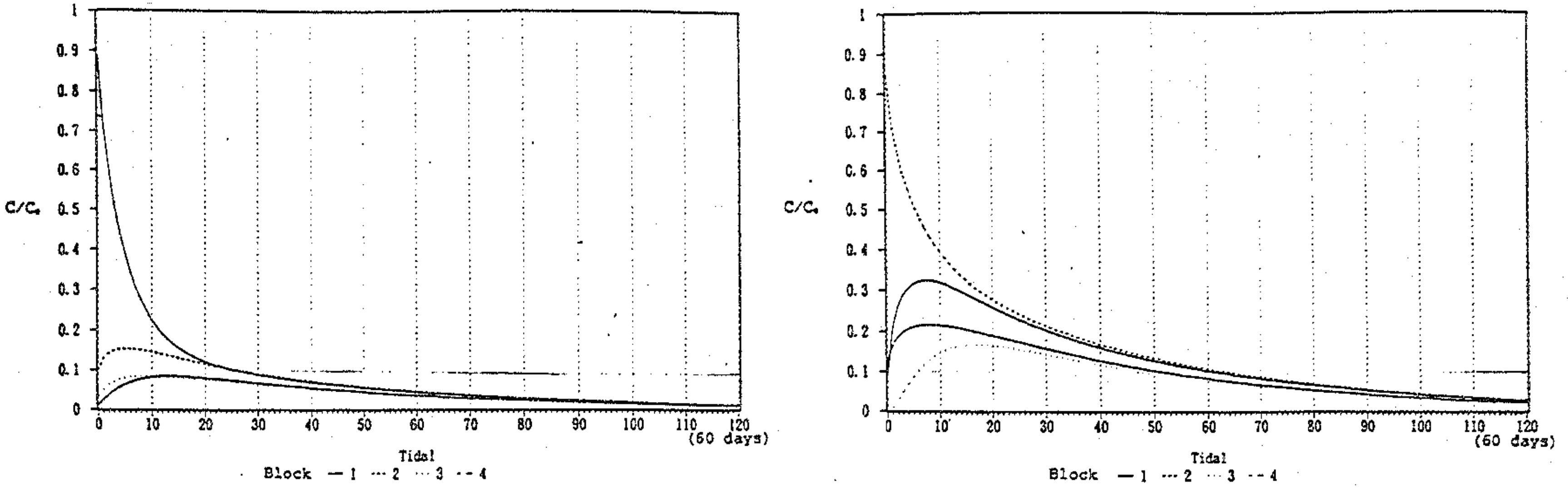


Fig. 3.5-6(1) Concentration Change of Conservative Matters Accompanied by Water Exchange in the Bay (Case1~4) (Dry Season)

(1) In case of releasing in Block 1

(2) In case of releasing in Block 2



(3) In case of releasing in Block 3

(4) In case of releasing in Block 4

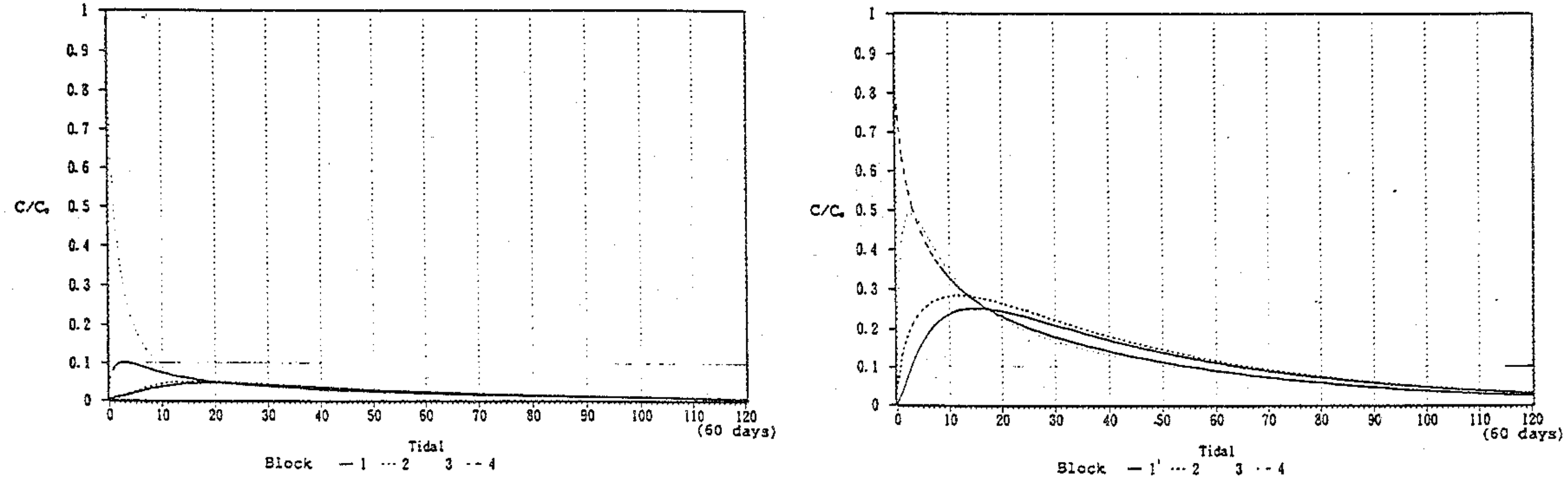
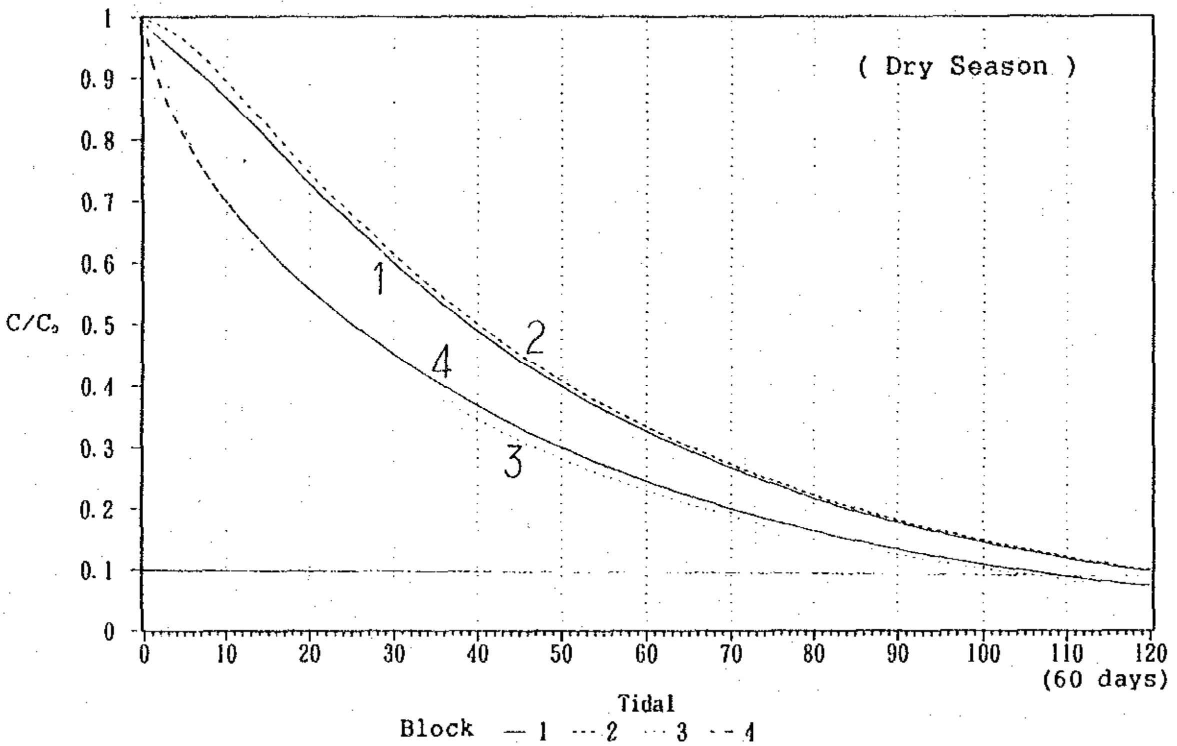


Fig. 3. 5-6(2) Concentration Change of Conservative Matters Accompanied by Water Exchange in the Bay (Case1~4) (Rainy Season)



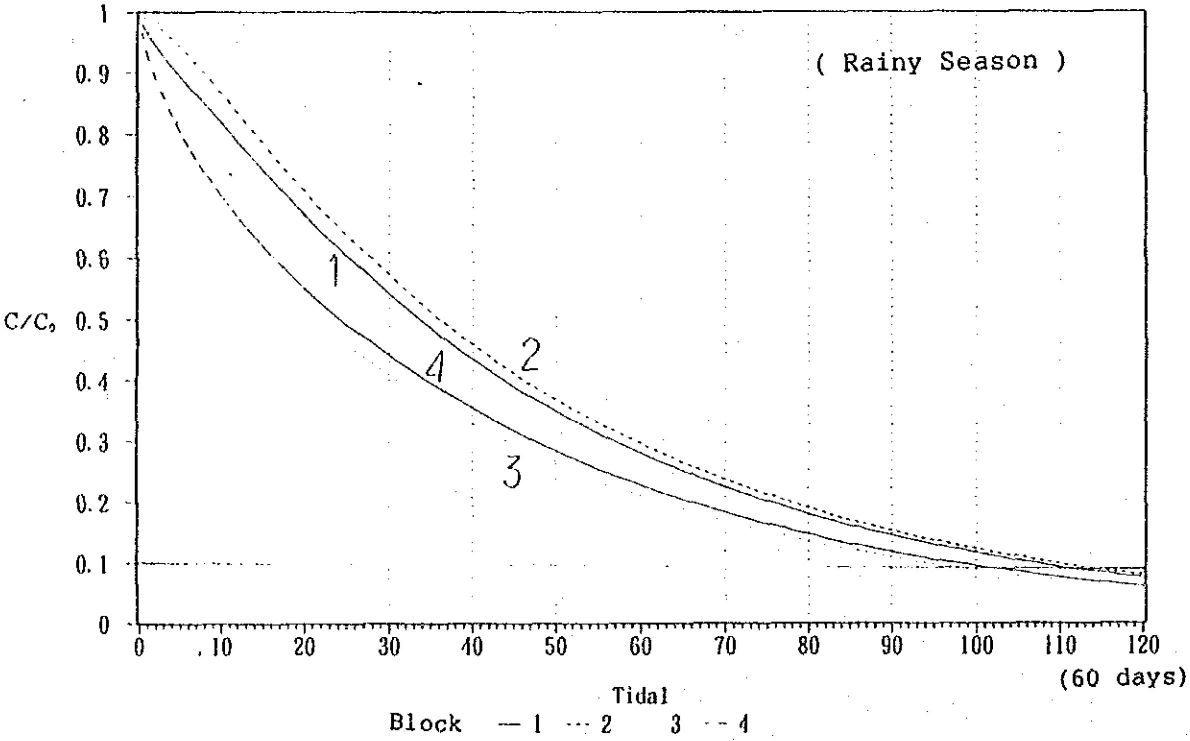


Fig. 3.5-7 Concentration Change of Conservative Matters by Water Exchange in the Bay (Case5)

3.5.4 Analysis by an Eutrophication Simulation Model

The balance, in other wards income/expenditure, of nutrient salts (O-P and PO_4-P), organic matters (COD and BOD) and dissolved oxygen (DO) is summarized in Table 3.5-4 on dry season, rainy season, and on annual mean for the present state.

Each term in this Table means below:

Existence : Amount of existing average for a day
Dispersion : Amount of inflow or outflow through the baymouth by dispersion an advection
External load : Amount of effluent load
Growth : Amount of growth
Decomposition : Amount of decomposition BOD, COD and O-P
Settling : Amount of setting in BOD, COD, O-P
Release : Amount of release by sediment in BOD, COD and PO_4-P
Exchange to Air: Amount of exchange to air in DO

From this table, we can know an outline of the amount of primary production, decomposition, release and so on, in other words, the sensitivity of the eutrophication model which we used for this study.

And if we regard COD, BOD and T-P as conservative matters, retention time in this model can be obtaind as the value of (Existence/Dispersion) in Table 3-5.4 and the values of them are 57 days, 59 days and 41 days respectively.

Table 3.5-4 Mass Balance in the Bay

		O-P	PO4-P	T-P	BOD	COD	DO
Dry Season							
		O-P	PO4-P	T-P	BOD	COD	DO
Existence	(t)	224.6	111.2	335.8	6091.2	4327.2	11605.4
Dipersion	(t/day)	-4.8	-3.7	-8.5	-100.6	-74.9	109.5
Existernal load	(t/day)	13.3	8.9	22.1	277.1	214.9	0.0
Growth	(t/day)	36.4	-36.4	0.0	932.1	597.1	5206.4
Decomposition	(t/day)	-25.3	25.3	0.0	-677.5	-446.0	-4064.8
Settling	(t/day)	-19.6	0.0	-19.6	-517.1	-345.9	0.0
Release	(t/day)	0.0	6.0	6.0	85.9	54.8	-279.8
Exchange to Air	(t/day)	0.0	0.0	0.0	0.0	0.0	-971.3
Wet Season							
		O-P	PO4-P	T-P	BOD	COD	DO
Existence	(t/day)	196.1	58.8	254.9	6245.3	4532.5	10894.2
Dipersion	(t/day)	-4.7	-1.3	-6.1	-105.3	-80.6	117.2
Exiternal load	(t/day)	9.6	6.4	16.0	387.1	314.1	0.0
Growth	(t/day)	31.8	-31.8	0.0	814.0	521.5	4546.9
Decomposition	(t/day)	-20.8	20.8	0.0	-666.2	-451.7	-3997.0
Settling	(t/day)	-15.9	0.0	-15.9	-515.5	-358.0	0.0
Release	(t/day)	0.0	6.0	6.0	85.9	54.8	-279.8
Exchange to Air	(t/day)	0.0	0.0	0.0	0.0	0.0	-387.3
Annual Mean							
		O-P	PO4-P	T-P	BOD	COD	DO
Existence	(t)	210.3	78.0	288.3	6214.2	4515.2	11272.9
Dipersion	(t/day)	-4.9	-2.1	-7.0	-105.2	-79.2	117.5
External load	(t/day)	11.4	7.6	19.0	332.1	264.5	0.0
Growth	(t/day)	34.9	-34.9	0.0	892.9	572.0	4987.8
Decomposition	(t/day)	-23.5	23.5	0.0	-683.0	-456.0	-4097.8
Settling	(t/day)	-18.0	0.0	-18.0	-522.7	-356.1	0.0
Release	(t/day)	0.0	6.0	6.0	85.9	54.8	-279.8
Exchange to Air	(t/day)	0.0	0.0	0.0	0.0	0.0	-727.7
Existence/Dispersion:				41	59	57	(days)

CHAPTER 4

PREDICTION OF FUTURE WATER QUALITY WITHOUT MEASURES

4.1 Case of Calculation

The prediction of future water quality without measures was performed about three cases shown in Table 4.1-1.

Table 4.1-1 Calculation Case without Measures

Case	Year
Case 1	2000
Case 2	2010 : scenario 1
Case 3	2010 : scenario 2

4.2 Conditions of Calculation

The inflowing loads and river discharges used for the numerical simulation are shown in Table 4.2-1 for each case.

For the estimation of PO_4-P and O-P loads, we assumed the same relation as the present. Namely,

$$(PO_4\text{-}P) / (T\text{-}P) = 0.4$$
$$O\text{-}P = (T\text{-}P) - (PO_4\text{-}P)$$

We also assumed that the release load from sediments and the direct loads in BOD do not change in the future.

We used the same values for other parameters as the present case.

Table 4.2-1(1) External Load used for simulation in 2000

NO	NAME	I	J	Discharge (m3/s)	BOD (t/day)	PO4-P (t/day)	O-P (t/day)
River load							
1	B.-CHARITAS	46	38	1.23	2.51	0.064	0.096
2	CANAL CANTO DO RIO	43	39	0.97	1.97	0.052	0.078
3	B.-CATEDRAR	40	43	0.90	1.77	0.044	0.066
4	B.-NORTE CENTRO	40	47	1.01	2.06	0.052	0.078
5	RIO BOMBA	45	52	4.48	9.96	0.256	0.384
6	RIO IMBOASSU	52	63	3.82	7.85	0.200	0.300
Eastern Sub Total				12.41	26.12	0.668	1.002
7	B.-ITAOCA	52	70	0.89	1.84	0.048	0.072
8	RIO ALCANTARA	59	76	13.41	25.33	0.612	0.918
9	RIO CACEREBU	60	81	29.54	19.46	0.420	0.630
10	RIO GUAPIMIRIN	59	87	32.76	5.22	0.116	0.174
11	CANAL DE MAGE	57	88	0.70	0.45	0.012	0.018
12	RIO RONCADOR	56	88	3.78	1.96	0.044	0.066
13	RIO IRIRI	49	90	1.00	0.58	0.012	0.018
14	RIO SURUI	44	87	2.15	0.74	0.016	0.024
Northeastern Sub Total				84.23	55.58	1.280	1.920
15	B.-MAUA	34	84	0.99	0.47	0.012	0.018
16	RIO ESTRELA	23	80	15.05	15.44	0.348	0.522
171	RIO IGUACU	17	76	29.35	38.30	0.868	1.302
172	RIO SARAPUI	17	76	22.87	49.56	1.220	1.830
18	B.-CABO DO BRITO	12	71	3.37	6.91	0.176	0.264
Northwestern Sub Total				71.63	110.68	2.624	3.936
19	RIO S.J.DE MERITI	9	63	30.19	69.56	1.740	2.610
20	RIO IRAJA	11	62	9.83	23.61	0.620	0.930
21	CANAL DO CUNHA	19	49	15.99	38.20	0.988	1.482
22	B.-S.CRISTOVAO	23	45	1.28	2.86	0.076	0.114
23	CANAL DO MANGUE	23	43	9.99	23.52	0.612	0.918
24	B.-BOTAFOGO	32	35	7.10	16.97	0.448	0.672
Western Sub Total				74.38	174.72	4.484	6.726
25	I.DO GAVANADOR	23	66	3.76	7.13	0.176	0.264
26	I.DO FUNDAO	18	52	0.26	0.25	0.008	0.012
27	I.DE PAQUETA	43	72	0.11	0.15	0.004	0.006
28	I.DO ENGENHO	43	56	0.25	0.53	0.016	0.024
29	I.DE S.CRUZ	41	51	0.13	0.23	0.008	0.012
Islands Sub Total				4.51	8.29	0.212	0.318
River load Total				247.16	375.39	9.268	13.902
Direct Load							
007		43	36	-	2.13	-	-
001		46	55	-	6.70	-	-
004		46	56	-	2.40	-	-
008		44	51	-	2.10	-	-
009		40	47	-	1.94	-	-
027		45	52	-	0.80	-	-
034		46	57	-	0.66	-	-
044		46	57	-	0.51	-	-
047		46	57	-	0.48	-	-
062		48	59	-	0.38	-	-
113		51	62	-	0.22	-	-
Eastern Sub Total				-	18.32	-	-
015		17	76	-	1.32	-	-
018		17	76	-	1.20	-	-
075		17	76	-	0.33	-	-
029		17	76	-	0.79	-	-
086		17	76	-	0.31	-	-
137		10	68	-	0.16	-	-
Northwestern Sub Total				-	4.11	-	-
030		11	62	-	0.72	-	-
042		11	62	-	0.52	-	-
051		32	36	-	0.45	-	-
Western Sub Total				-	1.69	-	-
Direct Load Sub Total				-	24.11	-	-
Total				247.16	399.50	9.268	13.902

Table 4.2-1(2) External Load used for simulation in 2010 (scenario-1)

NO	NAME	I	J	Discharge (m3/s)	BOD (t/day)	PO4-P (t/day)	O-P (t/day)
River load							
1	B.-CHARITAS	46	38	1.25	2.59	0.068	0.102
2	CANAL CANTO DO RIO	43	39	0.99	2.03	0.052	0.078
3	B.-CATEDRAR	40	43	0.92	1.82	0.048	0.072
4	B.-NORTE CENTRO	40	47	1.04	2.12	0.056	0.084
5	RIO BOMBA	45	52	4.97	11.26	0.292	0.438
6	RIO IMBOASSU	52	63	4.30	9.13	0.232	0.348
Eastern Sub Total				13.47	28.95	0.748	1.122
7	B.-ITAOCA	52	70	1.00	2.14	0.056	0.084
8	RIO ALCANTARA	59	76	14.68	28.79	0.700	1.050
9	RIO CACEREBU	60	81	30.89	22.90	0.500	0.750
10	RIO GUAPIMIRIN	59	87	33.25	5.97	0.132	0.198
11	CANAL DE MAGE	57	88	0.73	0.55	0.012	0.018
12	RIO RONCADOR	56	88	3.94	2.35	0.052	0.078
13	RIO IRIRI	49	90	1.05	0.69	0.016	0.024
14	RIO SURUI	44	87	2.21	0.88	0.020	0.030
Northeastern Sub Total				87.75	64.27	1.488	2.232
15	B.-MAUA	34	84	1.03	0.56	0.012	0.018
16	RIO ESTRELA	23	80	16.00	17.96	0.408	0.612
171	RIO IGUACU	17	76	31.11	43.06	0.980	1.470
172	RIO SARAPUI	17	76	24.49	53.97	1.336	2.004
18	B.-CABO DO BRITO	12	71	3.69	7.79	0.200	0.300
Northwestern Sub Total				76.32	123.34	2.936	4.404
19	RIO S.J.DE MERITI	9	63	31.15	72.17	1.808	2.712
20	RIO IRAJA	11	62	10.09	24.28	0.640	0.960
21	CANAL DO CUNHA	19	49	16.39	39.29	1.016	1.524
22	B.-S.CRISTOVAO	23	45	1.31	2.94	0.080	0.120
23	CANAL DO MANGUE	23	43	10.24	24.19	0.628	0.942
24	B.-BOTAFOGO	32	35	7.28	17.45	0.464	0.696
Western Sub Total				76.46	180.32	4.636	6.954
25	I.DO GAVANADOR	23	66	3.84	7.33	0.184	0.276
26	I.DO FUNDAO	18	52	0.26	0.26	0.008	0.012
27	I.DE PAQUETA	43	72	0.11	0.16	0.004	0.006
28	I.DO ENGENHO	43	56	0.25	0.55	0.016	0.024
29	I.DE S.CRUZ	41	51	0.14	0.24	0.008	0.012
Islands Sub Total				4.60	8.54	0.220	0.330
River load Total				258.60	405.42	10.028	15.042
Direct Load							
007		43	36	-	2.13	-	-
001		46	55	-	6.70	-	-
004		46	56	-	2.40	-	-
008		44	51	-	2.10	-	-
009		40	47	-	1.94	-	-
027		45	52	-	0.80	-	-
034		46	57	-	0.66	-	-
044		46	57	-	0.51	-	-
047		46	57	-	0.48	-	-
062		48	59	-	0.38	-	-
113		51	62	-	0.22	-	-
Eastern Sub Total				-	18.32	-	-
015		17	76	-	1.32	-	-
018		17	76	-	1.20	-	-
075		17	76	-	0.33	-	-
029		17	76	-	0.79	-	-
086		17	76	-	0.31	-	-
137		10	68	-	0.16	-	-
Northwestern Sub Total				-	4.11	-	-
030		11	62	-	0.72	-	-
042		11	62	-	0.52	-	-
051		32	36	-	0.45	-	-
Western Sub Total				-	1.69	-	-
Direct Load Sub Total				-	24.11	-	-
Total				258.60	429.53	10.028	15.042

Table 4.2-1(3) External Load used for simulation in 2010 (scenario-2)

NO	NAME	I	J	Discharge (m3/s)	BOD (t/day)	PO4-P (t/day)	O-P (t/day)
River load							
1	B.-CHARITAS	46	38	1.27	2.63	0.068	0.102
2	CANAL CANTO DO RIO	43	39	1.00	2.07	0.056	0.084
3	B.-CATEDRAR	40	43	0.93	1.85	0.048	0.072
4	B.-NORTE CENTRO	40	47	1.05	2.16	0.056	0.084
5	RIO BOMBA	45	52	5.00	11.34	0.296	0.444
6	RIO IMBOASSU	52	63	4.30	9.13	0.232	0.348
Eastern Sub Total				13.55	29.18	0.756	1.134
7	B.-ITAOCA	52	70	1.00	2.14	0.056	0.084
8	RIO ALCANTARA	59	76	14.75	28.99	0.704	1.056
9	RIO CACEREBU	60	81	30.89	22.90	0.500	0.751
10	RIO GUAPIMIRIN	59	87	33.25	5.97	0.132	0.198
11	CANAL DE MAGE	57	88	0.73	0.55	0.012	0.018
12	RIO RONCADOR	56	88	3.94	2.35	0.052	0.078
13	RIO IRIRI	49	90	1.05	0.69	0.016	0.024
14	RIO SURUI	44	87	2.21	0.88	0.020	0.031
Northeastern Sub Total				87.82	64.47	1.493	2.239
15	B.-MAUA	34	84	1.03	0.56	0.012	0.018
16	RIO ESTRELA	23	80	16.19	18.47	0.420	0.631
171	RIO IGUACU	17	76	31.93	45.29	1.032	1.548
172	RIO SARAPUI	17	76	25.30	56.17	1.392	2.088
18	B.-CABO DO BRITO	12	71	3.85	8.20	0.208	0.312
Northwestern Sub Total				78.30	128.69	3.064	4.597
19	RIO S.J.DE MERITI	9	63	31.88	74.14	1.860	2.791
20	RIO IRAJA	11	62	10.25	24.73	0.652	0.978
21	CANAL DO CUNHA	19	49	16.66	40.02	1.036	1.554
22	B.-S.CRISTOVAO	23	45	1.33	2.99	0.080	0.120
23	CANAL DO MANGUE	23	43	10.40	24.64	0.640	0.960
24	B.-BOTAFOGO	32	35	7.40	17.78	0.472	0.708
Western Sub Total				77.92	184.30	4.740	7.111
25	I.DO GAVANADOR	23	66	3.89	7.47	0.188	0.282
26	I.DO FUNDAO	18	52	0.26	0.26	0.008	0.012
27	I.DE PAQUETA	43	72	0.11	0.16	0.004	0.006
28	I.DO ENGENHO	43	56	0.25	0.56	0.016	0.024
29	I.DE S.CRUZ	41	51	0.14	0.24	0.008	0.012
Islands Sub Total				4.65	8.69	0.224	0.336
River load Total				262.24	415.33	10.278	15.416
Direct Load							
007		43	36	-	2.13	-	-
001		46	55	-	6.70	-	-
004		46	56	-	2.40	-	-
008		44	51	-	2.10	-	-
009		40	47	-	1.94	-	-
027		45	52	-	0.80	-	-
034		46	57	-	0.66	-	-
044		46	57	-	0.51	-	-
047		46	57	-	0.48	-	-
062		48	59	-	0.38	-	-
113		51	62	-	0.22	-	-
Eastern Sub Total				-	18.32	-	-
015		17	76	-	1.32	-	-
018		17	76	-	1.20	-	-
075		17	76	-	0.33	-	-
029		17	76	-	0.79	-	-
086		17	76	-	0.31	-	-
137		10	68	-	0.16	-	-
Northwestern Sub Total				-	4.11	-	-
030		11	62	-	0.72	-	-
042		11	62	-	0.52	-	-
051		32	36	-	0.45	-	-
Western Sub Total				-	1.69	-	-
Direct Load Sub Total				-	24.11	-	-
Total				262.24	439.44	10.278	15.416

4.3 results of Calculation

The calculation results for BOD, PO_4-P, O-P, T-P and DO are shown in Fig.4.3-1 to Fig.4.3-3 for Case 1 to Case 3, respectively.

Fig.4.3-4 to Fig.4.3-6 show the variation of BOD, T-P and DO values from the present case (1991).

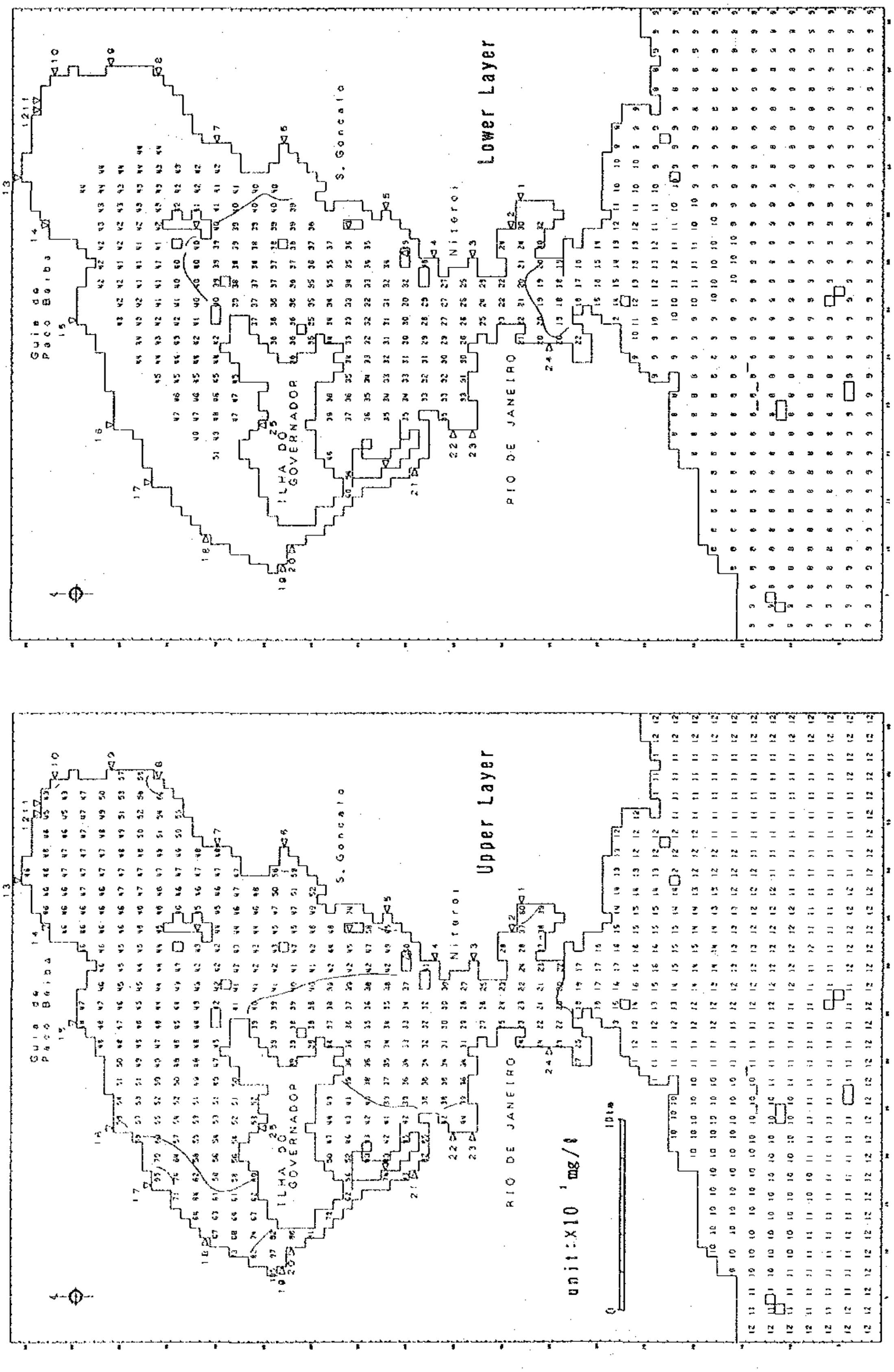


Fig. 4. 3-1(1) Calculated Water Quality in 2000 without Measure (BOD)

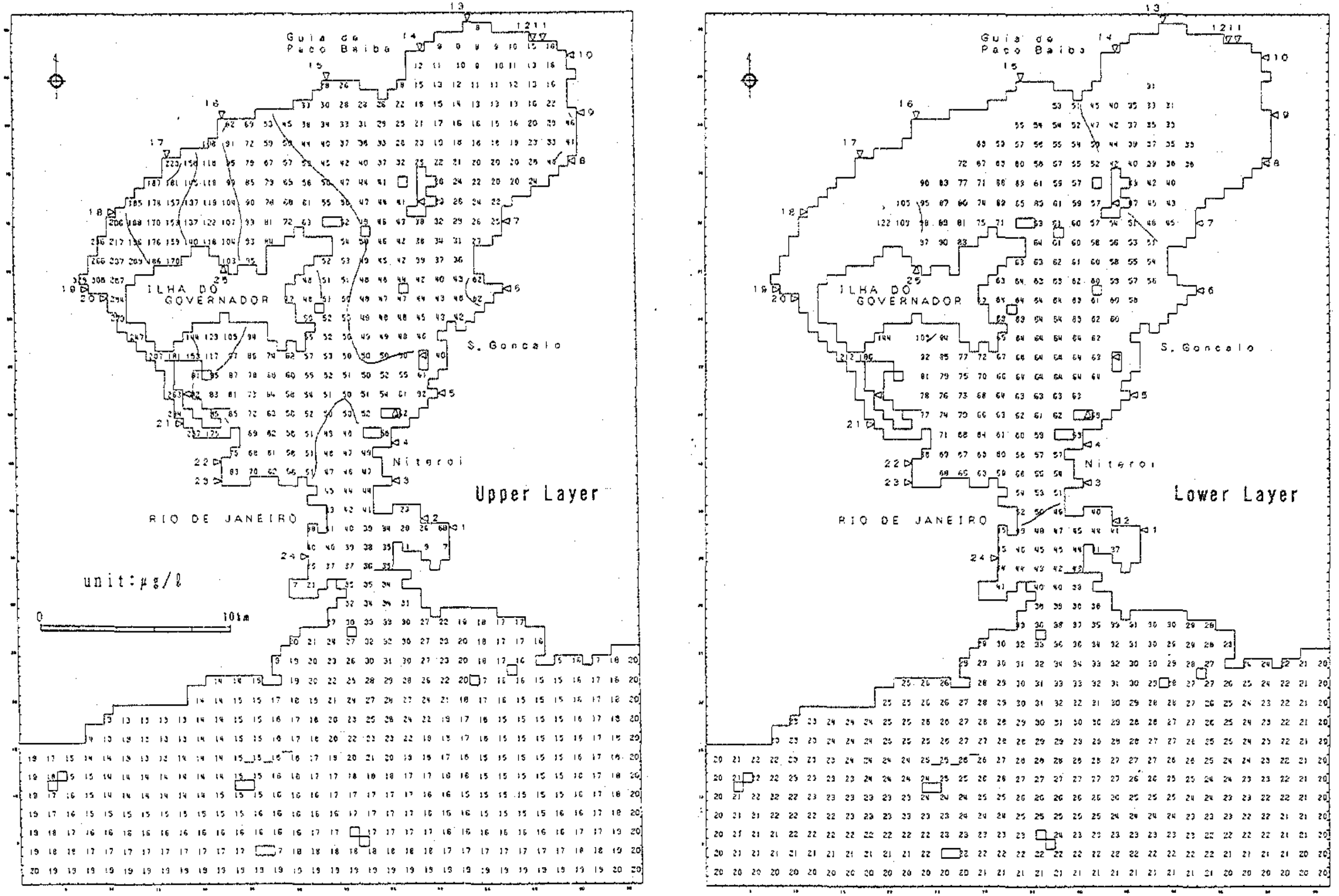


Fig. 4. 3-1(2) Calculated Water Quality in 2000 without Measure (PO_4-P)

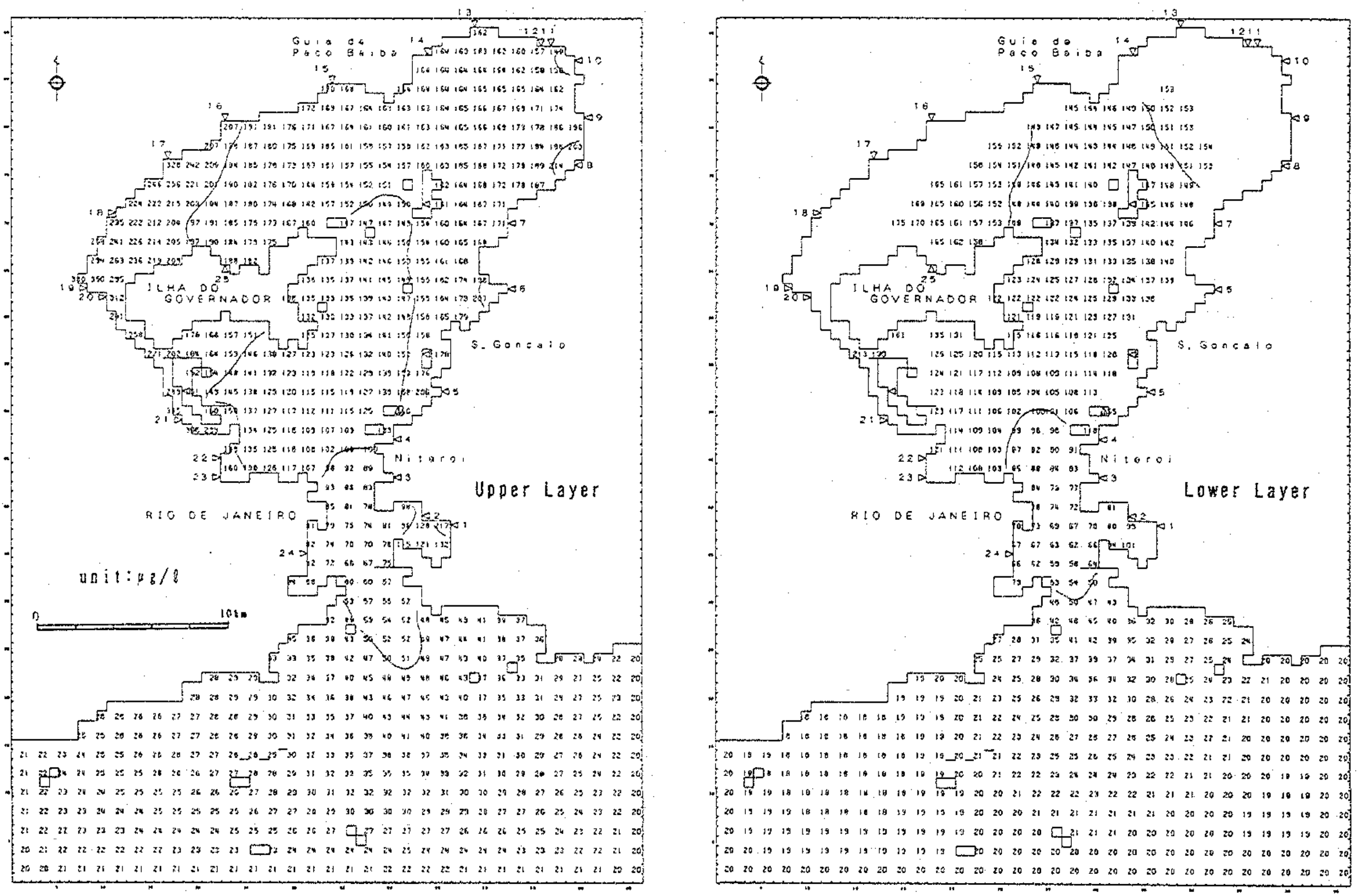


Fig. 4.3-1(3) Calculated Water Quality in 2000 without Measure (O-P)

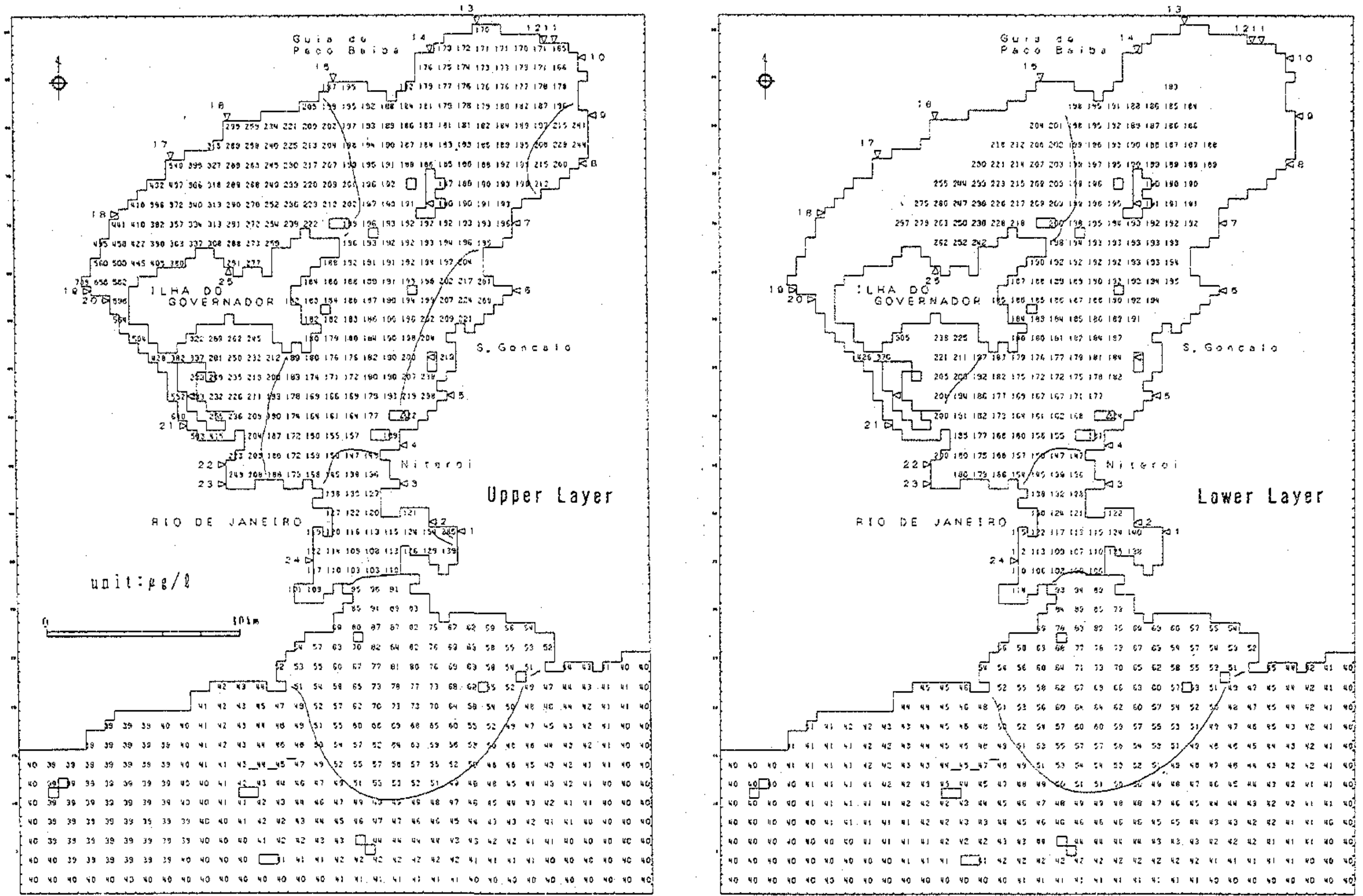


Fig. 4. 3-1(4) Calculated Water Quality in 2000 without Measure (T-P)

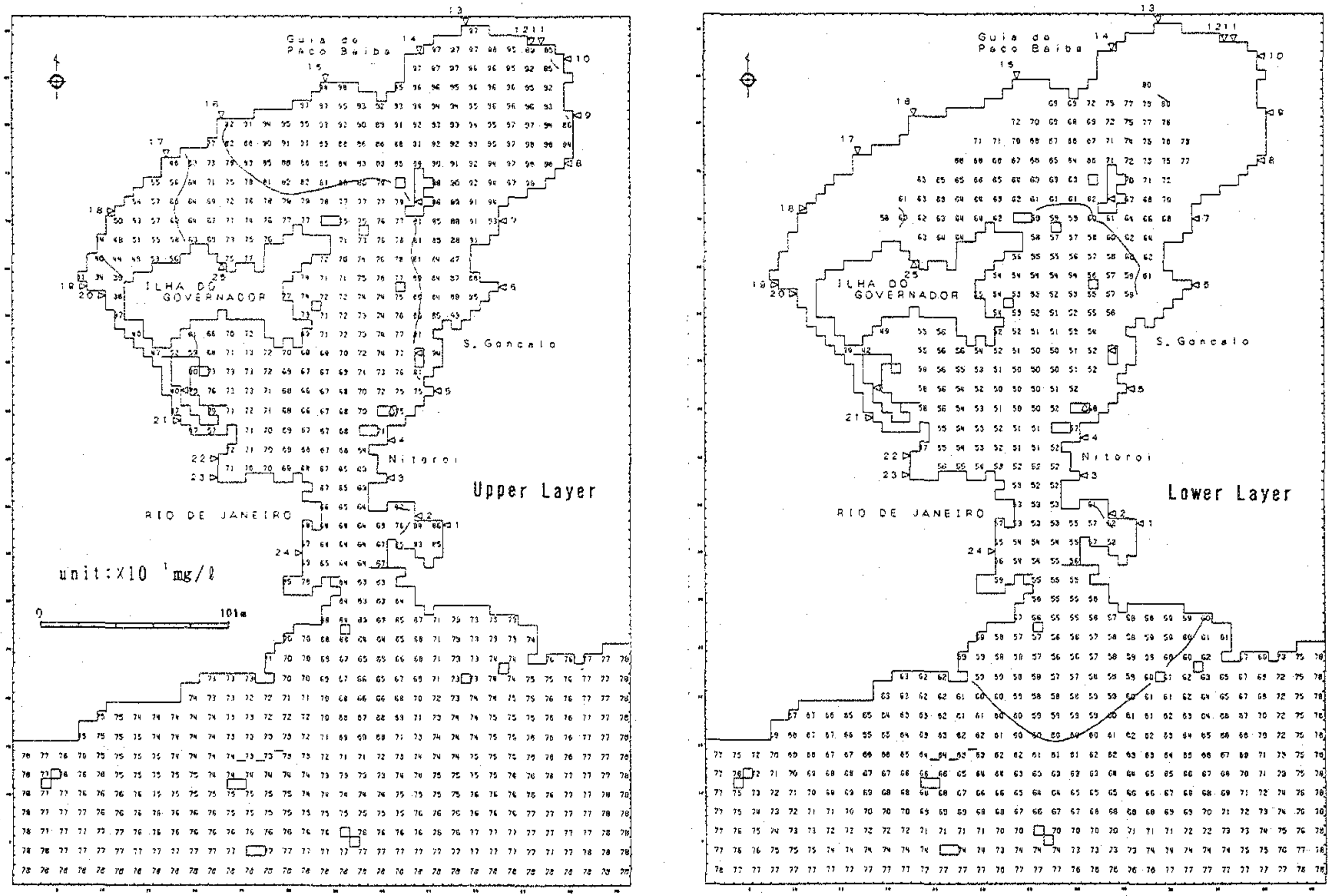


Fig. 4.3-1(5) Calculated Water Quality in 2000 without Measure (DO)

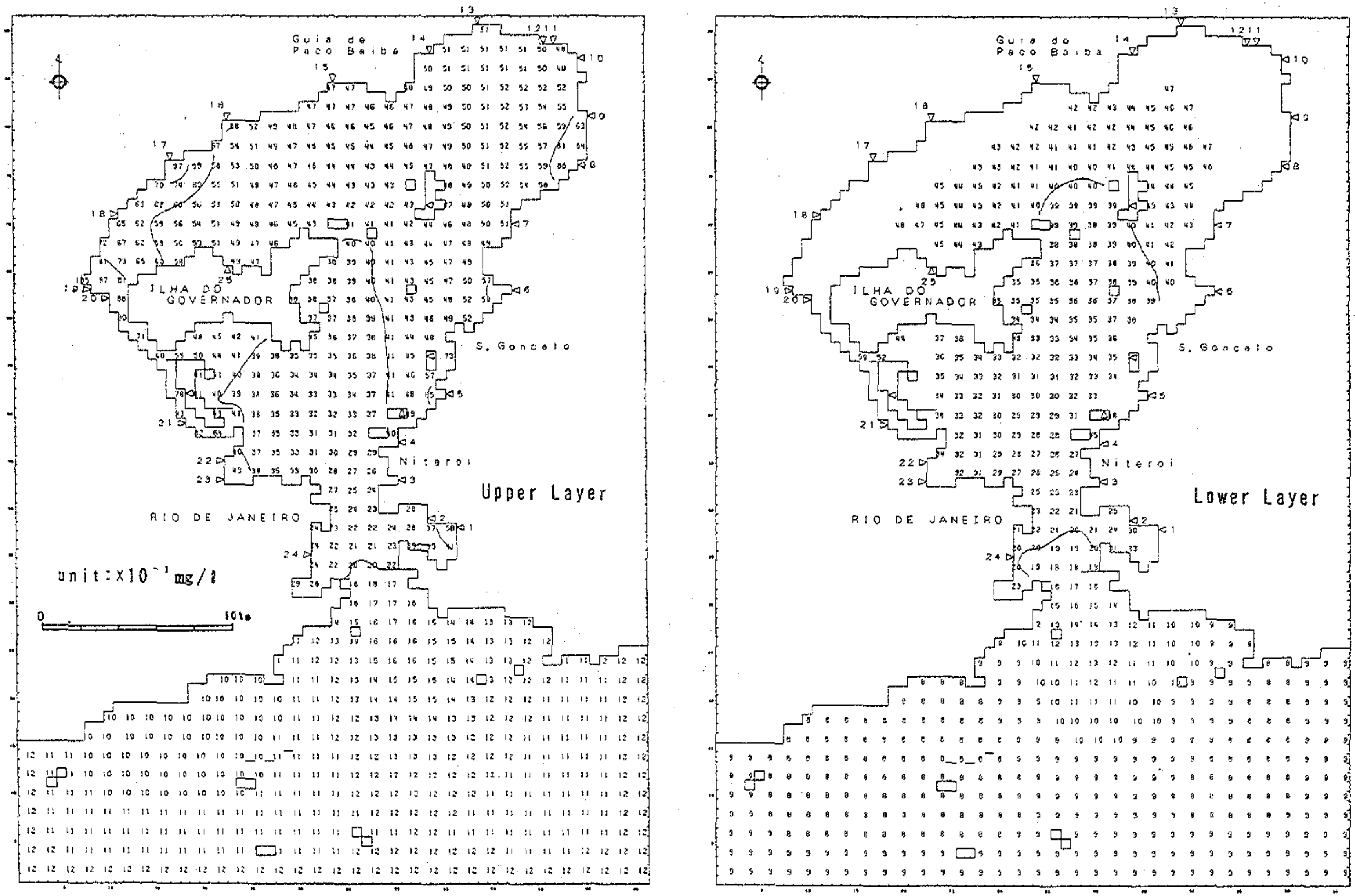


Fig. 4. 3-2(1) Calculated Water Quality in 2010 without Measure (sinario-1) (BOD)

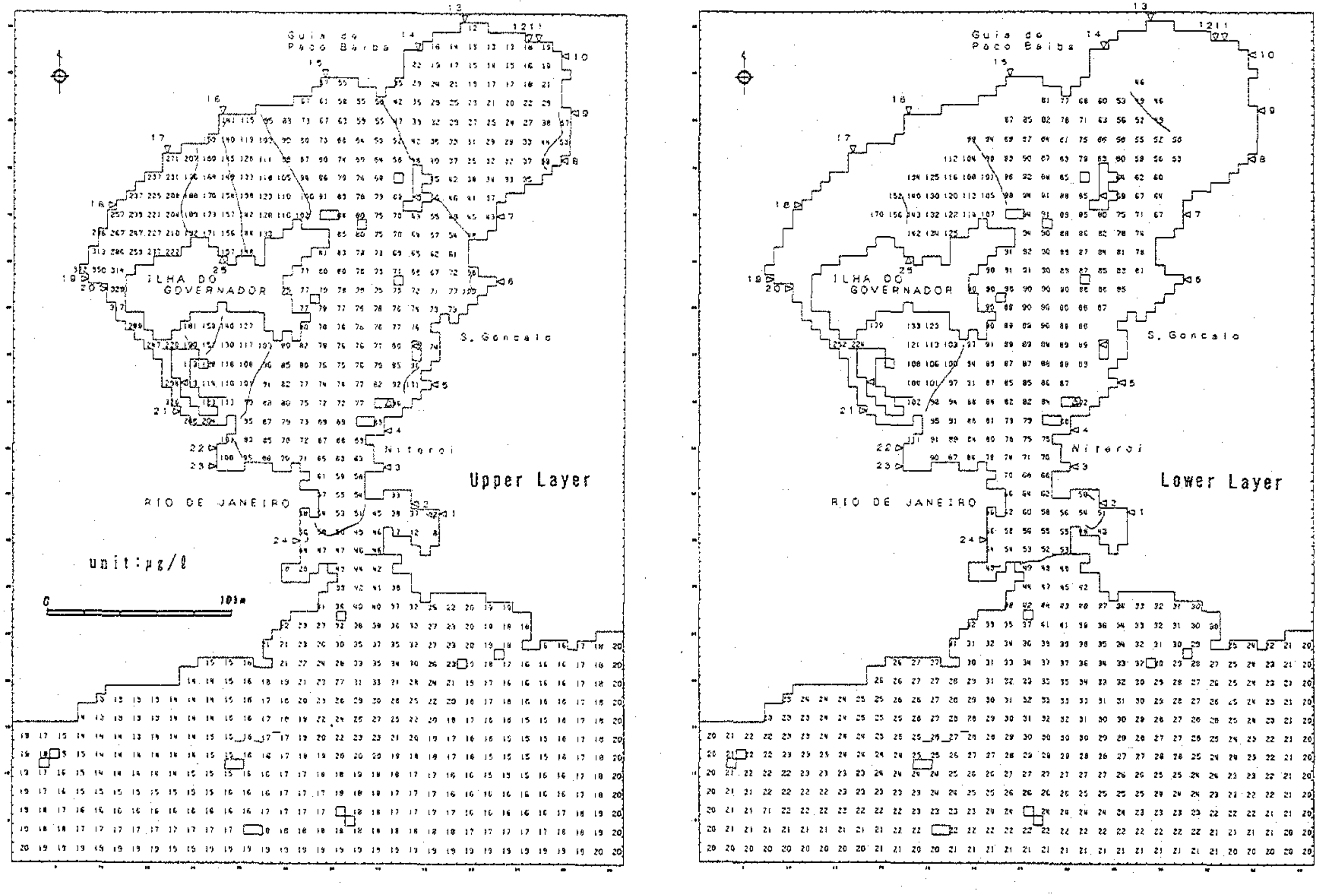


Fig. 4.3-2(2) Calculated Water Quality in 2010 without Measure (sinario-1) (PO_4-P)

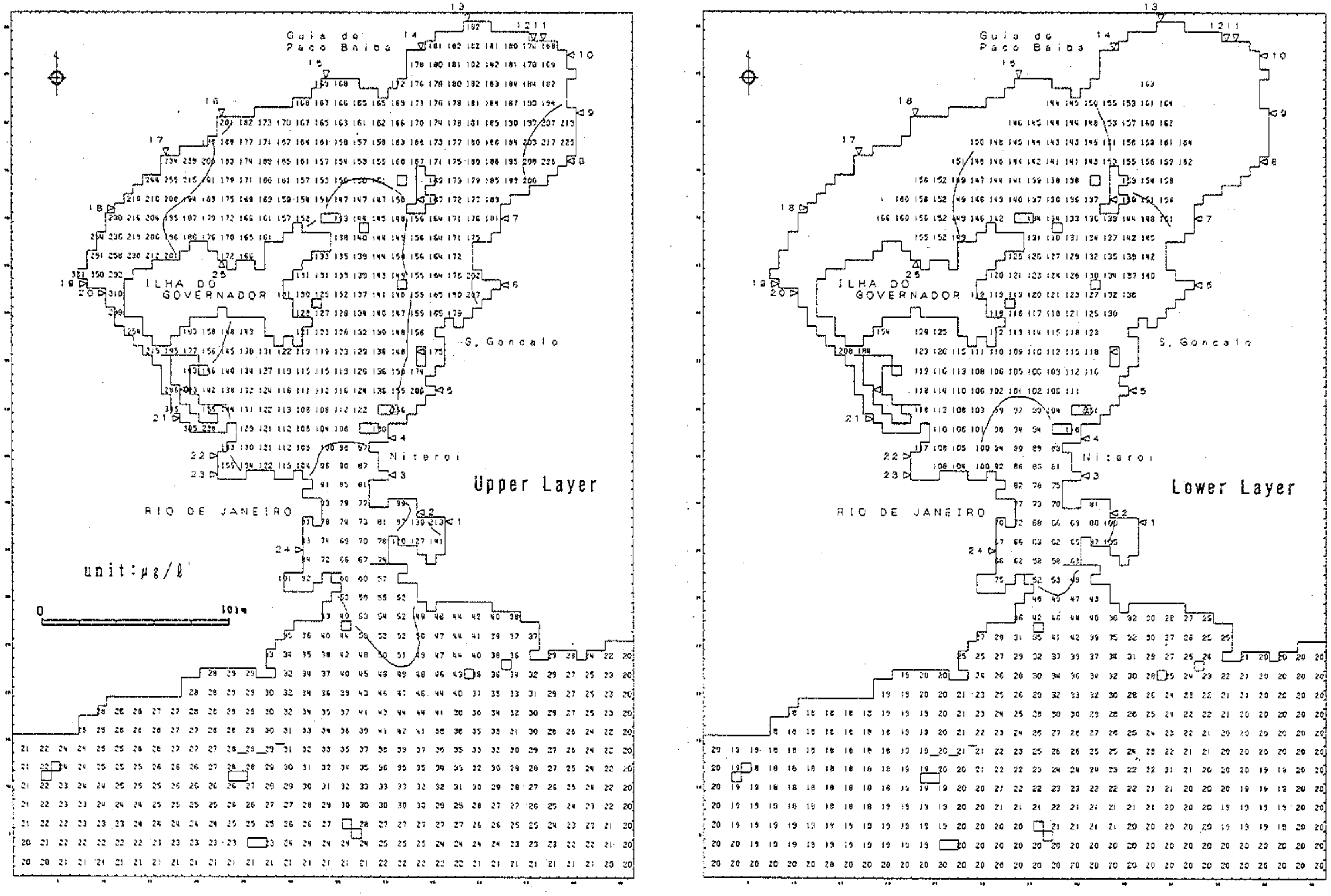


Fig. 4.3-2(3) Calculated Water Quality in 2010 without Measure (sinario-1) (O-P)

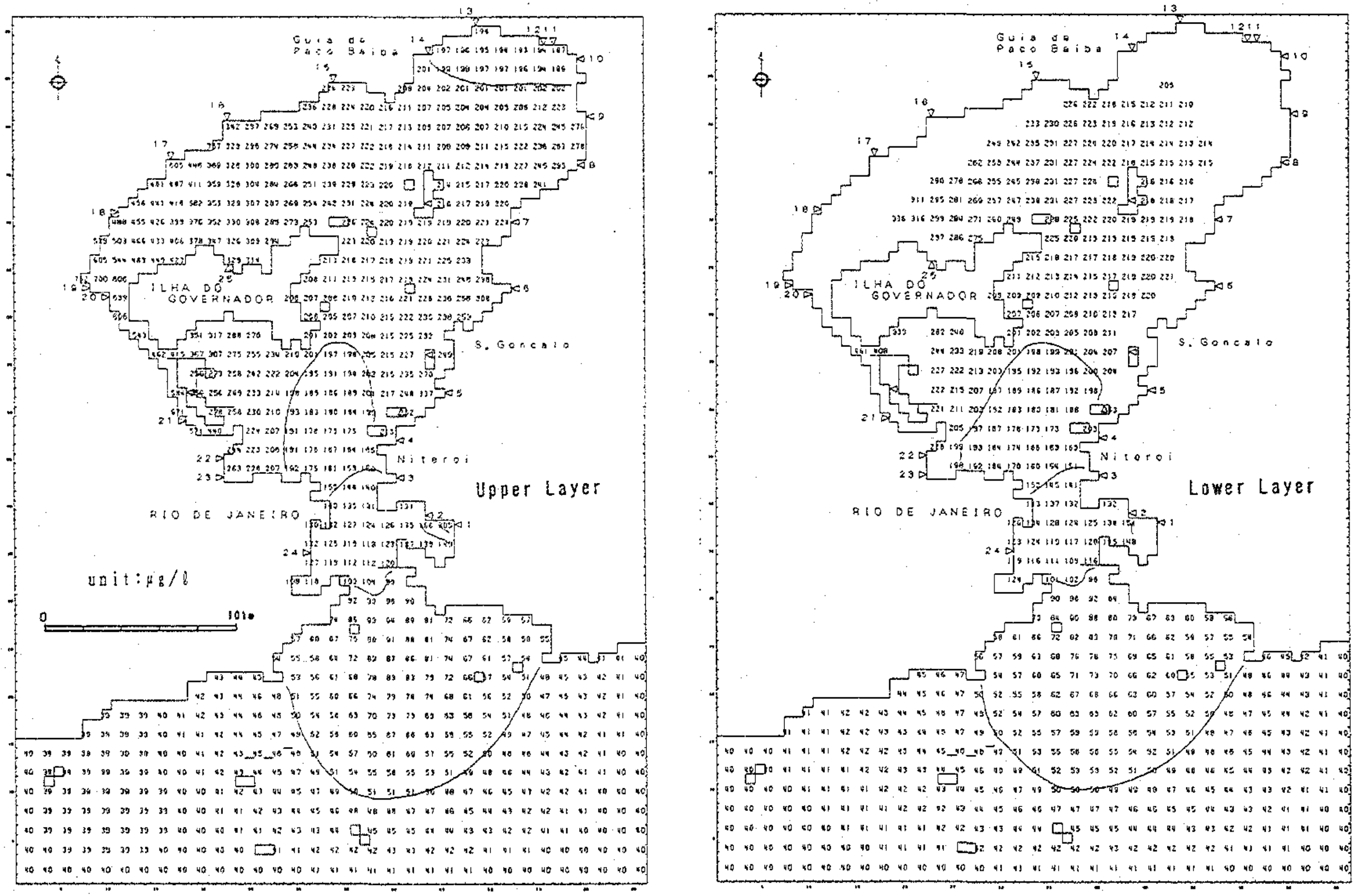


Fig. 4. 3-2(4) Calculated Water Quality in 2010 without Measure (sinario-1) (T-P)

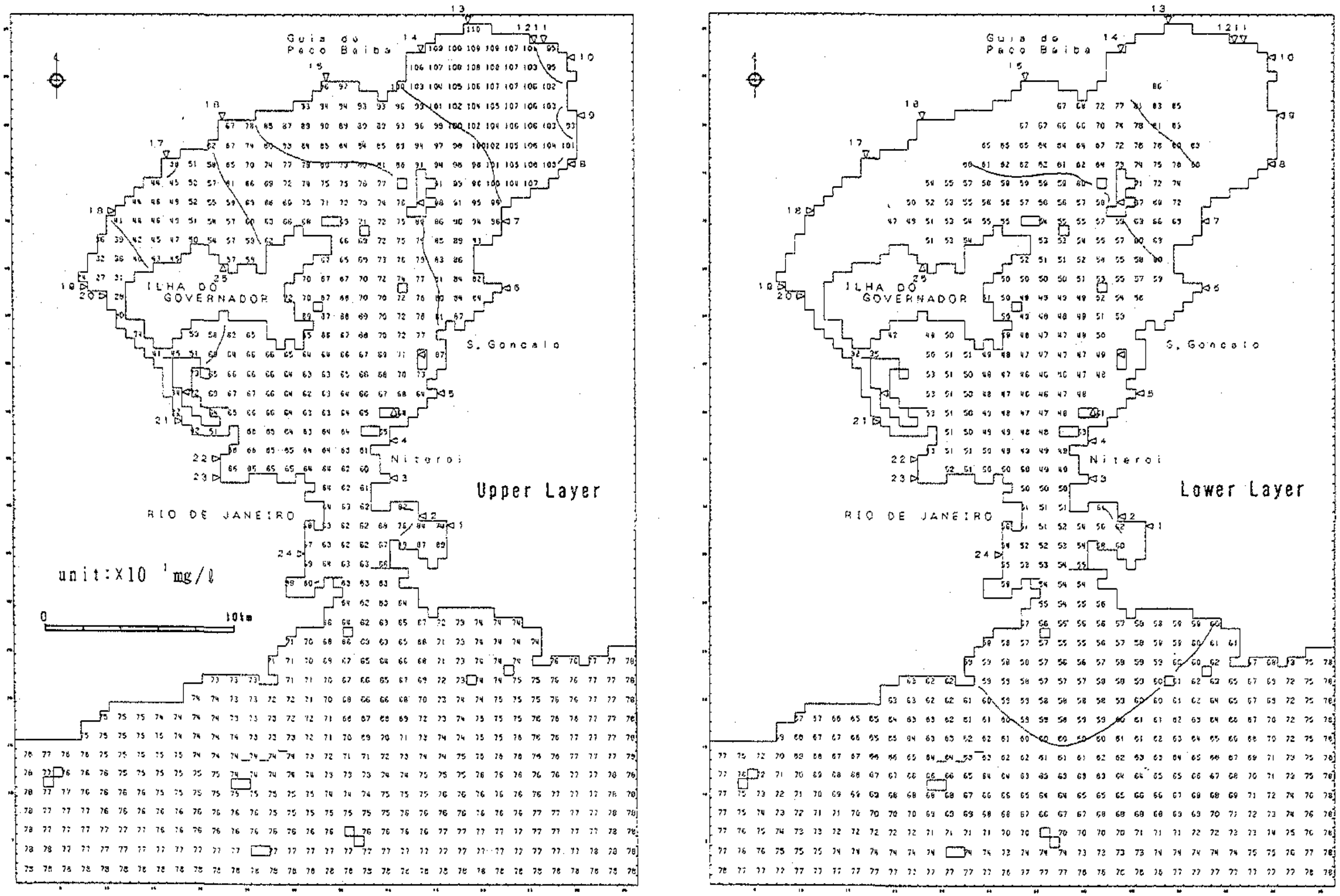


Fig. 4.3-2(5) Calculated Water Quality in 2010 without Measure (sinario-1) (DO)

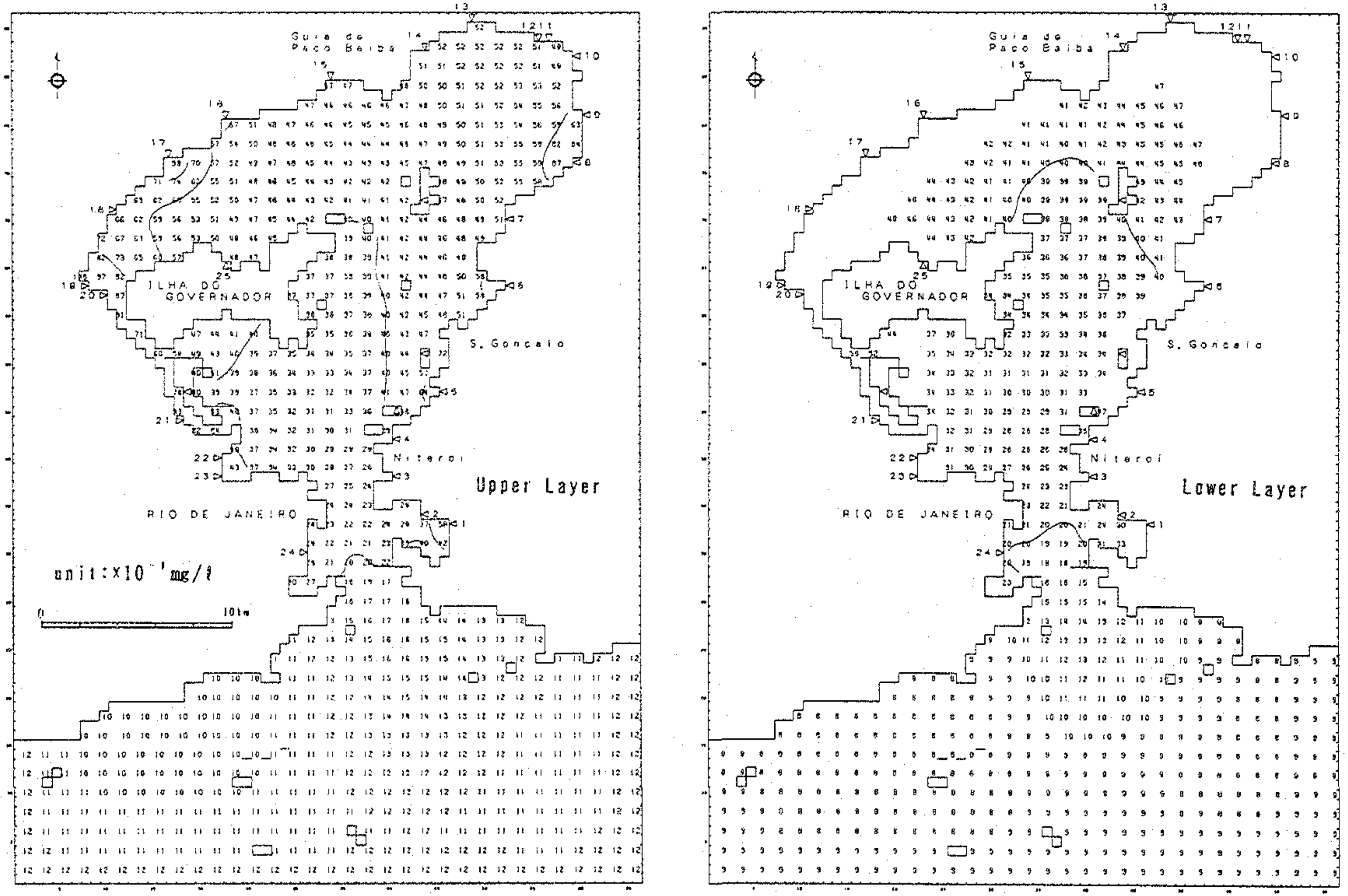


Fig. 4. 3-3(1) Calculated Water Quality in 2010 without Measure (sinario-2) (BOD)

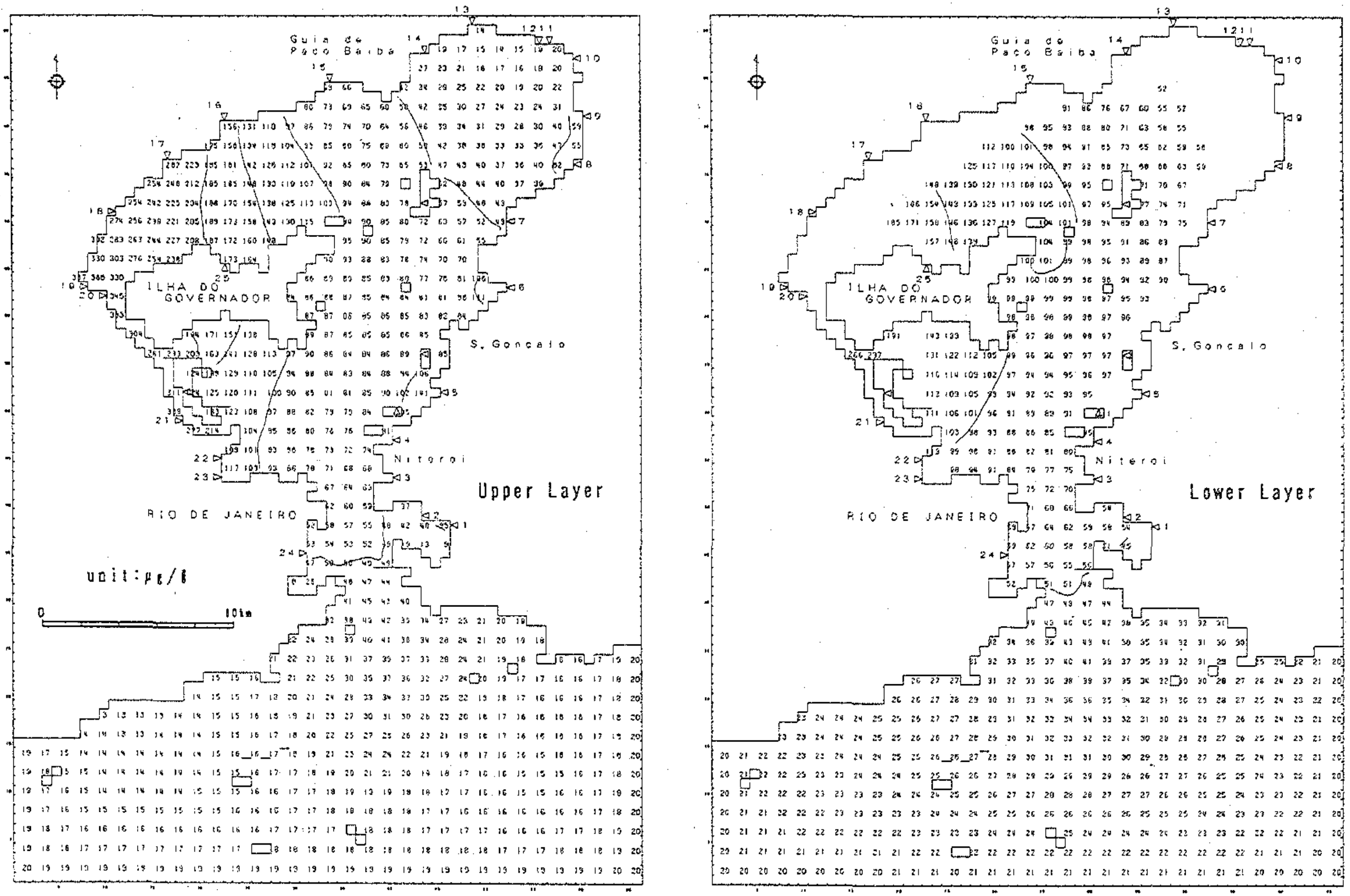


Fig. 4.3-3(2) Calculated Water Quality in 2010 without Measure (sinario-2) (PO_4-P)

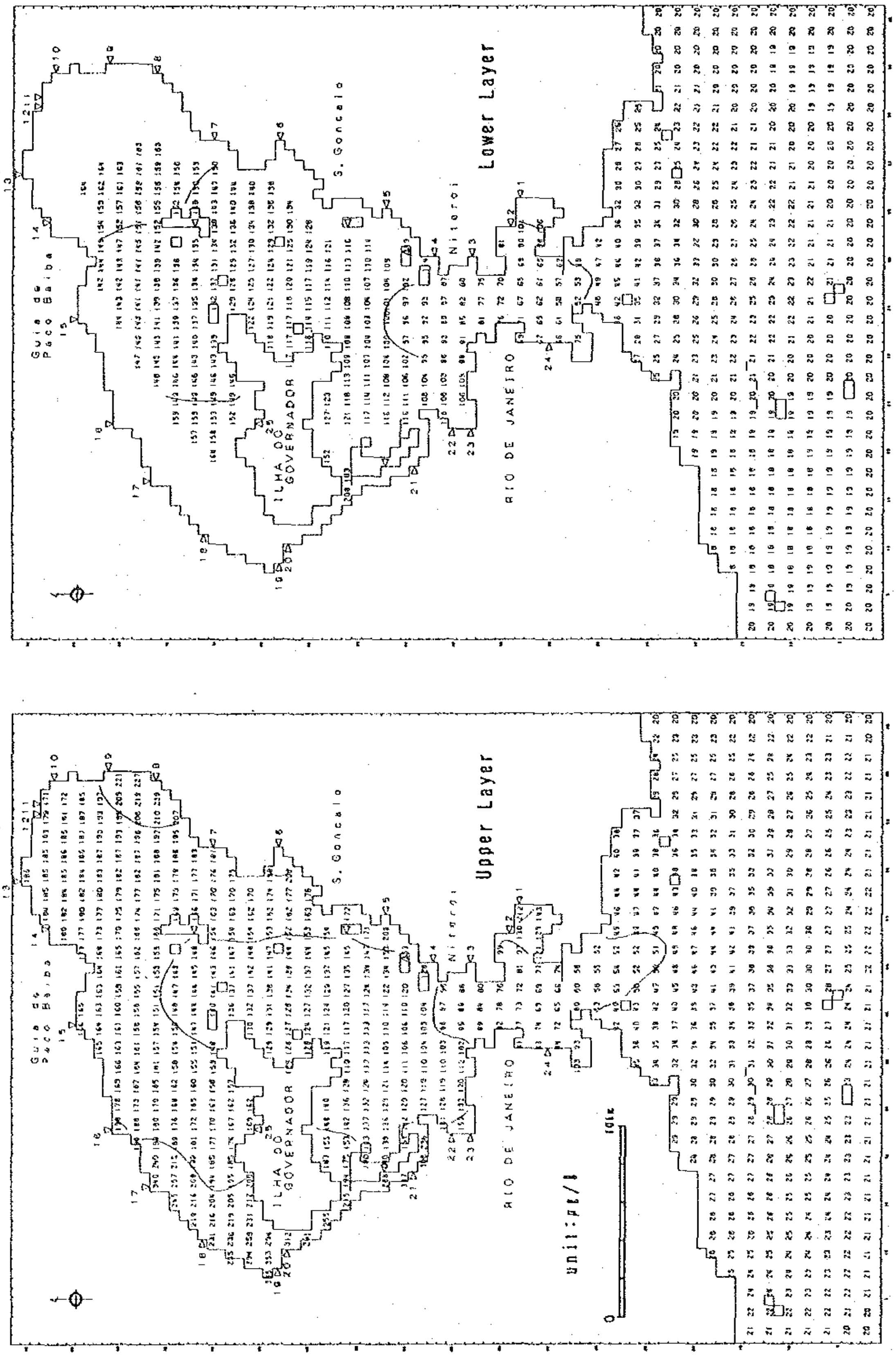


Fig. 4.3-3(3) Calculated Water Quality in 2010 without Measure (sinario-2) (O-P)

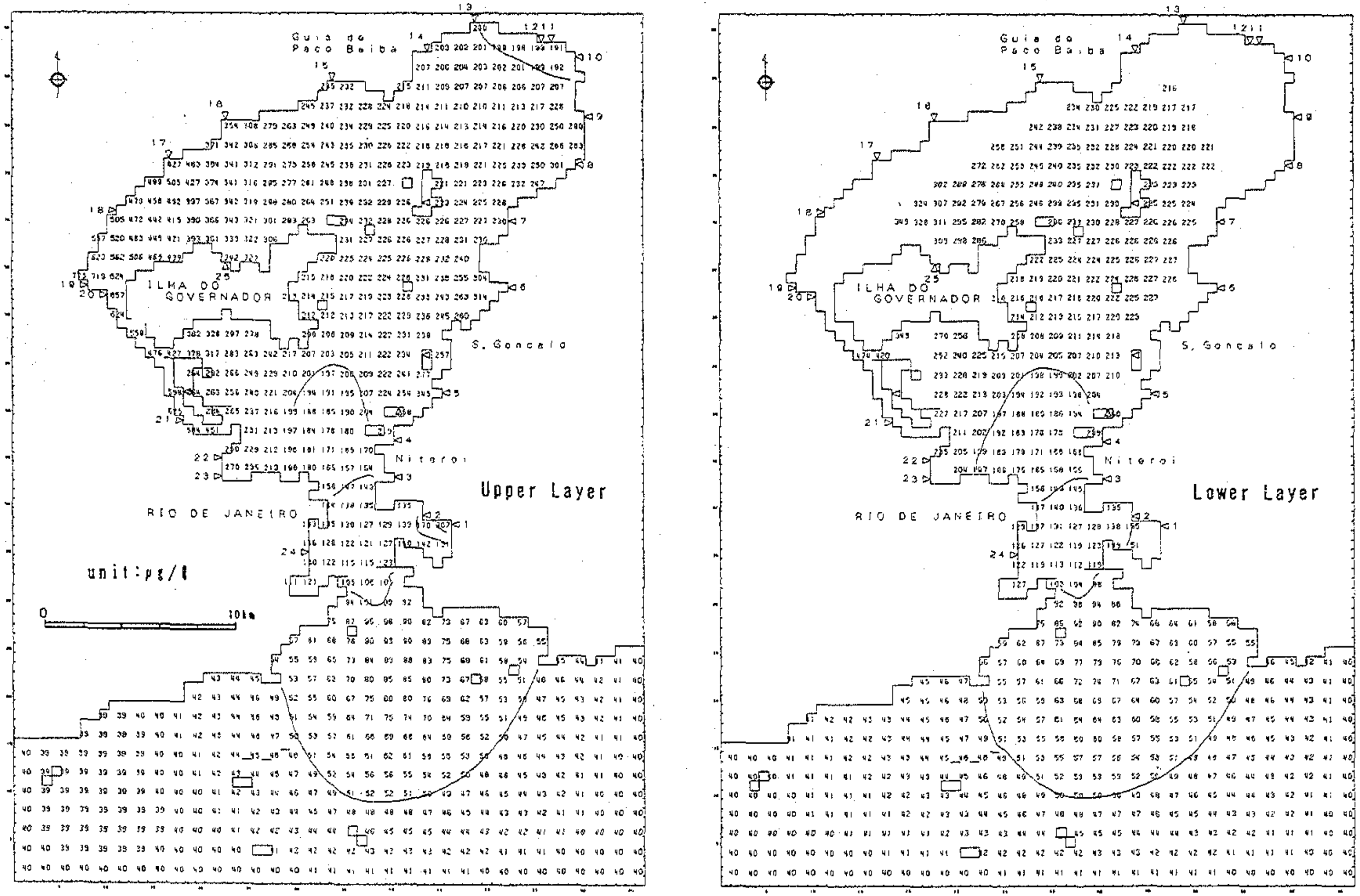


Fig. 4. 3-3(4) Calculated Water Quality in 2010 without Measure (sinario-2) (T-P)

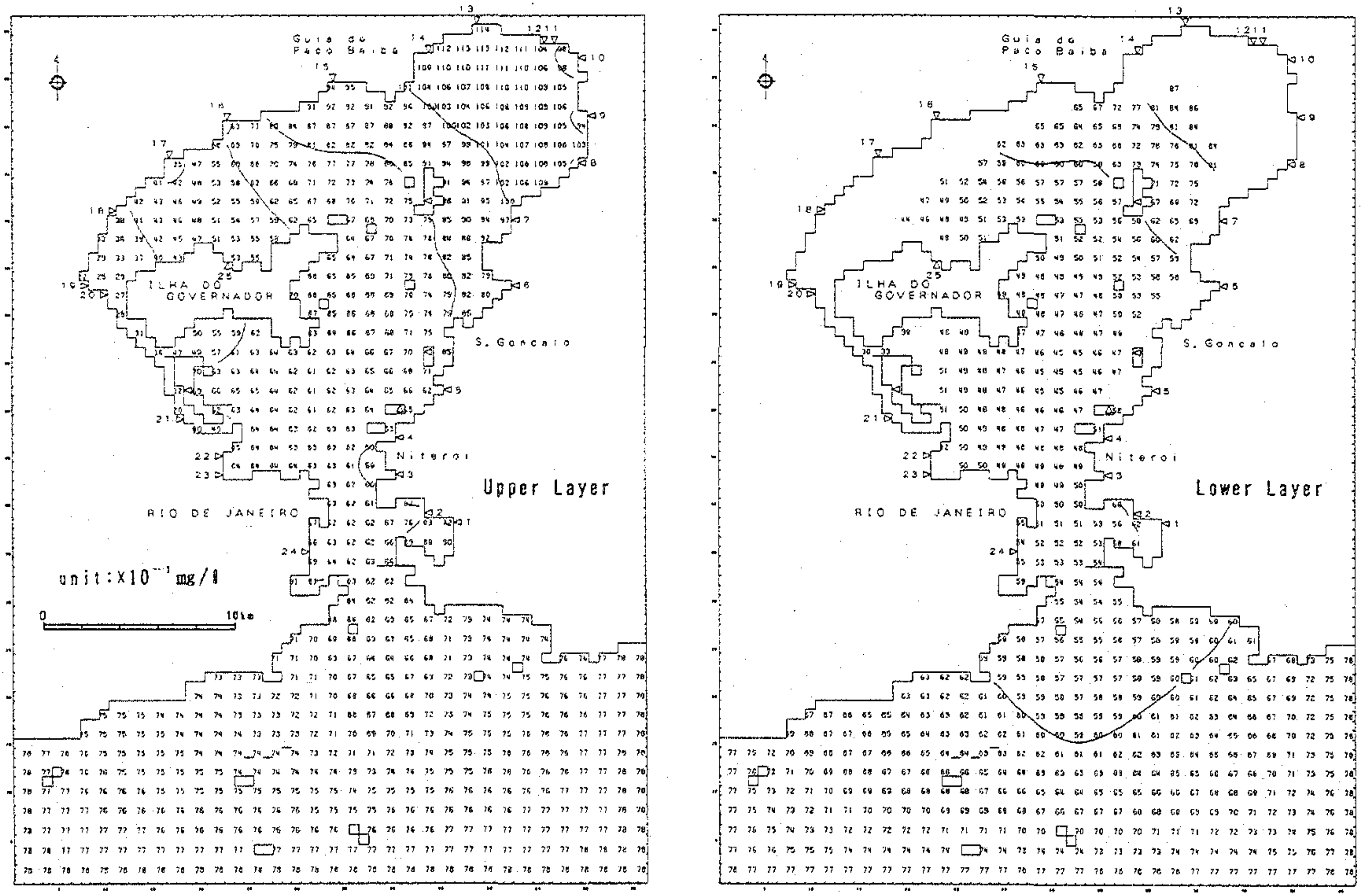


Fig. 4. 3-3(5) Calculated Water Quality in 2010 without Measure (sinario-2) (DO)