```
***MSA TOTAL Q MAP (X1000 cu.m)***
   **YEAR: 1981**

      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28
 1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    09999999999999999999999999999999999    1
 2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  099999    0    0   09999999999    2
 3    0    0    0    0    0    0    0    0    0    0    0    0    0   98 1066  209 1039  293  140    0    0  099999    0    0   09999999999    3
 4    0    0    0    0    0    0    0    0    0    0    0    0    0    0  366  455  323  399    0    0    0    0    0    0  0999999999999999    4
 5    0    0    0    0    0    0  233   84  136    0    0    0    0 1117  274 2525  175  434  134    0    0    0 2206    0  0999999999999999    5
 6    0    0    0    0    0    0    0   42   16   16 1319 2419 1552  345 3988 1124  245  333    0    0    0    0 1057    0  0999999999999999    6
 7    0    0    0    0    0    0    0  351  107   84  228 1955    0  134  446  428  302  219 1120    0    0  228  804  09999999999999999999    7
 8    0    0    0    9    0    0    0  903  779  641  254    0  623 1193   62  314  205  524  373  380  143  283 1644  09999999999999999999    8
999999    0    0    0    0    0   84 1424  624  450  482    0  618 4562  376  979  446  561  863  583  777  386  099999999999999999999999    9
109999999999    0    0    0    0   16 1256 2310 2209 1244 1238 5703  601  900  411  486  280  533   71  212  249  099999999999999999999999   10
119999999999    0    0    0    0    0  276  354    0 1517 2543 1188  959 1084    0  127   57  127  281  347 1411  099999999999999999999999   11
1299999999999999    0    0    0    0    0 1225  183   98  185  403  547  397  948    0  280  640  613 2806  131  099999999999999999999999   12
1399999999999999    0    0    0    0    0 1010  491    0  339  720  683  485  333  638  657  939  463  295  447 3319999999999999999999999999   13
14999999999999999999    0    0    0    0    0  511    0    0    0  457  751    0 1062    0 3415  944 1558 1327 7379999999999999999999999999   14
15999999999999999999    0    0    0    0   61  373  703    0  246  773  933  136  628  728 3100 1281  258  377 9059999999999999999999999999   15
1699999999999999999999999    0    0    0    0    0    0  134  362    0  745  462  500    0 1741 4900 4933 1306 2149999999999999999999999999   16
1799999999999999999999999    0    0    0    0  152  148  253  347    0  955 1395  746 1573 6039  232 4746 5817 2322999999999999999999999999   17
1899999999999999999999999    0    0    0    0  148  260    0  181 1671 2982  673  975 4237 1334  215    0    0 2011999999999999999999999999   18
1999999999999999999999999    0    0    0    0    0    0  522  889 5535  829  461  171  954  321 2104    0    0 1994 2556999999999999999999999   19
20999999999999999999    0    0    0    0    0    0    0  966  318 1560  286  853  222 1858  630  475  140    0  608  09999999999999999999   20
219999999999    0    0    0    0    0    0    0    0    0  397  974 1527  677  782    0 1908    0    0    0    0    0    0  0999999999999999   21
2299999    0    0    0    0    0    0    0    0    0    0  152 1328 2045 1030  175  311    0    0    0    0    0    0    0  0999999999999999   22
23    0    0    0    0    0    0    0    0    0    0    0  947  553  136  175 2671    0  433    0    0    0    0    0  09999999999999999999   23
24    0    0    0  666 1119  394    0    0    0    0    0  484  548  357 2191 2939 1177    0    0    0    0    0  099999999999999999999999   24
25    0    0    0 1536  457  787    0    0    0    0 1273  827  708  903 1285 9570 6695    0    0    0  09999999999999999999999999999999   25
26    0    0  957    0    0    0    0    0    0 2132  877  525 2858 1333 1134 3892 1119    0    0    0  09999999999999999999999999999999   26
27    0    0    0    0    0  471  573 5984  849 2160 2714 1495  945 1237 1913 7033  251    0    0  099999999999999999999999999999999999   27
28    0    0    0  775  258    0    0  710    0    0 2543 4917 1200 1314 1634 3403    0    0    0  099999999999999999999999999999999999   28
29    0    0 2066    0    0    0  549  746    0    0   45  900  780 1469 2846 3533    0    0    0  099999999999999999999999999999999999   29
30 1325    0    0    0    0    0    0  201  323    0    0  516    0  779  464 1307    0    0    0  099999999999999999999999999999999999   30
31 1762    0    0    0    0    0    0    0    0 1291  775    0    0  917  513  365    0    0    0  099999999999999999999999999999999999   31
32    0    0    0    0    0    0    0    0    0    0    0    0  272  481 1749 2748    0    0    0    0  09999999999999999999999999999999   32
33    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  0999999999999999999999999999   33
34    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  099999999999999999999999   34
35    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  09999999999999999999   35
      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28

                                                    TOTAL Q IN MODELED AREA =    333.130 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(1)

DISCHARGE MAP IN 1981

MSA TOTAL Q MAP (X1000 cu.m)*
YEAR: 1982

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	09999999999999999999999999999999999999999									1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	099999		0	0	09999999999			2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	98	1066	339	1039	293	182	0	0	099999		0	0	09999999999			3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	366	455	323	399	0	0	0	0	0	0	0999999999999999				4
5	0	0	0	0	0	0	233	84	136	0	0	0	0	1117	274	2525	172	434	129	0	0	0	2207	0	0999999999999999				5
6	0	0	0	0	0	0	0	42	16	16	1319	2435	1994	345	4059	950	222	312	0	0	0	0	1215	0	0999999999999999				6
7	0	0	0	0	0	0	0	351	107	84	216	1582	0	134	446	394	259	185	734	0	0	198	773	099999999999999999999					7
8	0	0	0	0	0	0	0	757	759	679	254	0	614	1291	26	314	176	430	226	219	96	197	1462	099999999999999999999					8
999999		0	0	0	0	0	44	949	488	445	568	0	597	3962	376	979	446	561	633	301	424	342	179999999999999999999999999						9
109999999999			0	0	0	0	11	1059	2524	2201	1260	1254	4638	400	660	411	496	280	445	49	157	205	09999999999999999999999999						10
119999999999			0	0	0	0	0	276	364	0	1488	2201	822	639	1094	0	127	57	121	264	285	958	09999999999999999999999999						11
12999999999999999				0	0	0	9	0	1313	183	98	130	271	482	397	948	0	280	640	593	2425	83	09999999999999999999999999						12
13999999999999999				0	0	0	0	0	1098	491	0	268	564	587	556	333	638	696	988	463	295	391	2739999999999999999999999999						13
1499999999999999999999					0	0	0	0	0	502	0	0	0	322	621	71	1062	0	3363	927	1685	1327	7379999999999999999999999999						14
1599999999999999999999					0	0	0	0	61	340	623	0	160	499	687	129	628	728	3100	1281	258	377	9059999999999999999999999999						15
169999999999999999999999999						0	0	0	0	0	0	120	220	0	600	455	500	0	1868	5028	4933	1528	21499999999999999999999999999						16
179999999999999999999999999						0	0	0	0	152	148	253	311	0	857	1302	746	1485	5995	232	4746	5635	22219999999999999999999999999						17
189999999999999999999999999						0	0	0	0	148	260	0	181	1401	2750	630	843	3570	1334	215	0	0	18199999999999999999999999999						18
199999999999999999999999999						0	0	0	0	0	0	522	1040	4939	821	461	168	954	321	2104	0	0	1994	25599999999999999999999					19
2099999999999999999999					0	0	0	0	0	0	0	966	318	1449	286	853	222	1789	512	475	140	0	608	099999999999999999999					20
219999999999			0	0	0	0	0	0	0	0	0	337	1360	1434	677	782	0	1884	0	0	0	0	0	0	0999999999999999				21
2299999		0	0	0	0	0	0	0	0	0	0	132	1506	2269	1030	175	486	0	0	0	0	0	0	0	0999999999999999				22
23	0	0	0	0	0	0	0	0	0	0	0	757	660	136	175	2678	0	433	0	0	0	0	0	099999999999999999999					23
24	0	0	0	661	935	354	0	0	0	0	0	419	548	357	2512	3097	1177	0	0	0	0	0	09999999999999999999999999						24
25	0	0	0	1513	443	787	0	0	0	0	1250	827	795	903	1285	9456	6410	0	0	0	099999999999999999999999999999999999								25
26	0	0	902	0	0	0	0	0	0	2161	646	525	2830	1506	1221	3905	862	0	0	0	099999999999999999999999999999999999								26
27	0	0	0	0	0	424	565	5787	1050	2160	2714	1495	945	1364	1975	7033	245	0	0	09999999999999999999999999999999999999999									27
28	0	0	0	775	258	0	0	710	0	0	2543	4917	1375	1314	1892	3539	0	0	0	09999999999999999999999999999999999999999									28
29	0	0	2066	0	0	0	684	654	0	0	46	900	780	1469	3021	3927	0	0	0	09999999999999999999999999999999999999999									29
30	1325	0	0	0	0	0	0	159	323	0	0	501	0	778	464	1230	0	0	0	09999999999999999999999999999999999999999									30
31	1762	0	0	0	0	0	0	0	0	1175	665	0	0	817	513	354	0	0	0	09999999999999999999999999999999999999999									31
32	0	0	0	0	0	0	0	0	0	0	0	0	272	617	2021	2666	0	0	0	0	099999999999999999999999999999999999								32
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0999999999999999999999999999999							33
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	09999999999999999999999999						34
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	099999999999999999999					35
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	

TOTAL Q IN MODELED AREA = 323.402 MCM/YEAR

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(2)

DISCHARGE MAP IN 1982

```
***MSA TOTAL Q MAP (X1000 cu.m)***
  **YEAR: 1983**

     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28
 1   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999999999999999999999999    1
 2   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   099999    0    0   09999999999    2
 3   0    0    0    0    0    0    0    0    0    0    0    0    0   98 1164  470 1169  391  182    0    0   099999    0    0   09999999999    3
 4   0    0    0    0    0    0    0    0    0    0    0    0    0    0  366  455  323  399    0    0    0    0    0    0   0999999999999999    4
 5   0    0    0    0    0    0  233   84  136    0    0    0    0 1311  274 2525  167  431  126    0    0    0 2216    0   0999999999999999    5
 6   0    0    0    0    0    0    0   42   16   16 1319 2435 2092  345 4101  804  201  295    0    0    0    0 1236    0   0999999999999999    6
 7   0    0    0    0    0    0    0  351  107   84  377 1271    0  134  446  363  223  157  474    0    0  172  714   09999999999999999999    7
 8   0    0    0    0    0    0    7  632  780  666  254    0  601 1291    9  314  193  352  135  107   65  146 1299   09999999999999999999    8
 999999   0    0    0    0    0   22  616  380  439  531    0  572 3422  376  979  446  561  461  150  280  305  1609999999999999999999999999    9
 109999999999  0    0    0    0    7  892 2531 2192 1652 1254 3779  262  569  411  557  280  370   33  115  168   0999999999999999999999999   10
 119999999999  0    0    0    0    0  275  364    0 1455 1869  560  451 1084    0  127   57  114  217  337  642   0999999999999999999999999   11
 1299999999999999    0    0    0    0    0 1411  183   98   95  179  423  397  948    0  280  640  575 1997   52   0999999999999999999999999   12
 1399999999999999    0    0    0    0    0 1098  491    0  208  437  503  556  333  638  571  983  463  295  450  2249999999999999999999999999   13
 14999999999999999999     0    0    0    0    0  494    0    0    0  224  504   71 1062    0 3473  914 1685 1327  7379999999999999999999999999   14
 15999999999999999999     0    0    0    0   61  309  550    0  102  317  503  123  628  728 3100 1573  258  377  9059999999999999999999999999   15
 1699999999999999999999999     0    0    0    0    0    0  106  130    0  569  448  500    0 1996 5028 4933 1533  2149999999999999999999999999   16
 1799999999999999999999999     0    0    0    0  152  148  253  277    0  767 1187  746 1401 6077  232 5262 5679 2415999999999999999999999999   17
 1899999999999999999999999     0    0    0    0  148  260    0  181 1221 2532  587  727 3001 1334  215    0    0 1950999999999999999999999999   18
 1999999999999999999999999     0    0    0    0    0    0  522 1135 4463  846  461  164  954  321 2104    0    0 1994 2556999999999999999999   19
 20999999999999999999     0    0    0    0    0    0    0  966  318 1453  286  853  222 1746  533  475  140    0  508   09999999999999999999   20
 219999999999    0    0    0    0    0    0    0    0    0  285 1429 1346  677  782    0 1784    0    0    0    0    0    0   0999999999999999   21
 2299999    0    0    0    0    0    0    0    0    0    0  114 1557 2705 1030  175  486    0    0    0    0    0    0    0   0999999999999999   22
23   0    0    0    0    0    0    0    0    0    0    0  729  767  136  175 3036    0  433    0    0    0    0    0   09999999999999999999   23
24   0    0    0  619  973  317    0    0    0    0    0  588  548  357 2512 3324 1177    0    0    0    0    0   0999999999999999999999999   24
25   0    0    0 1647  439  787    0    0    0    0 1181  827  795  903 1484 9859 5689    0    0    0   099999999999999999999999999999999999   25
26   0    0  872    0    0    0    0    0    0 2174  644  525 2867 1562 1380 3678  660    0    0    0   099999999999999999999999999999999999   26
27   0    0    0    0    0  440  553 5785 1086 2160 3035 1495  945 1553 2225 7033  240    0    0   09999999999999999999999999999999999999999   27
28   0    0    0  775  258    0    0  710    0    0 2543 4917 1375 1314 1892 3539    0    0    0   09999999999999999999999999999999999999999   28
29   0    0 2065    0    0    0  329  553    0    0   46  900  780 1469 3196 5006    0    0    0   09999999999999999999999999999999999999999   29
30 1325    0    0    0    0    0    0  125  323    0    0  485    0  778  464 1158    0    0    0   09999999999999999999999999999999999999999   30
31 1762    0    0    0    0    0    0    0    0 1068  573    0    0  817  513  345    0    0    0   09999999999999999999999999999999999999999   31
32   0    0    0    0    0    0    0    0    0    0    0    0  272  617 2157 2770    0    0    0    0   099999999999999999999999999999999999   32
33   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999999999999999   33
34   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   0999999999999999999999999999   34
35   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999999   35
     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28

                                                    TOTAL Q IN MODELED AREA =    319.181 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(3)

DISCHARGE MAP IN 1983

```
**MSA TOTAL Q MAP (X1000 cu.m)***
  **YEAR: 1984**

      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28
  1   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   099999999999999999999999999999999      1
  2   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   099999    0    0   09999999999   2
  3   0    0    0    0    0    0    0    0    0    0    0    0    0   98 1235  470 1169  391  182    0    0   099999    0    0   09999999999   3
  4   0    0    0    0    0    0    0    0    0    0    0    0    0    0  506  455  323  399    0    0    0    0    0    0   0999999999999999   4
  5   0    0    0    0    0    0  233   84  136    0    0    0    0 1311  274 2677  165  431  121    0    0    0 2351    0   0999999999999999   5
  6   0    0    0    0    0    0    0   42   16   16 1319 2435 2134  345 4244  658  182  277    0    0    0    0 1251    0   0999999999999999   6
  7   0    0    0    0    0    0    0  351  107   84  353 1009    0  134  446  334  504 1091  302    0    0  149  782   09999999999999999999   7
  8   0    0    0    0    0    0    9  525  756  679  254    0  585 1291    5  371  165  287   78   44   42  123 1152   09999999999999999999   8
 999999    0    0    0    0    0   11  386  293  432  520    0  546 2939  376  979  446  561  333   72  163  270   14299999999999999999999999   9
109999999999    0    0    0    0    4  748 2531 2184 1652 1254 3041  169  485  411  557  280  308   23   83  139   09999999999999999999999999   10
119999999999    0    0    0    0    0  276  364    0 1416 1649  375  292 1084    0  127   57  108   18  292  425   09999999999999999999999999   11
1299999999999999    0    0    0    0    0 1495  183   98  122  116  370  397  948    0  280  540  558 1641   32   09999999999999999999999999   12
1399999999999999    0    0    0    0    0 1186  491    0  162  337  429  556  333  638  550  939  463  295  391   27699999999999999999999999   13
14999999999999999999    0    0    0    0    0  485    0    0    0  154  407   71 1062    0 3465  905 1685 1327   73799999999999999999999999   14
15999999999999999999    0    0    0    0   61  282  485    0   64  197  364  116  628  728 3100 1681  256  377   90599999999999999999999999   15
169999999999999999999999    0    0    0    0    0    0   94   75    0  454  442  500    0 1996 5028 4933 1652   21499999999999999999999999   16
179999999999999999999999    0    0    0    0  152  148  253  246    0  685 1125  746 1321 6033  232 5262 5749 24239999999999999999999999   17
189999999999999999999999    0    0    0    0  148  260    0  181 1033 2275  549  625 2513 1334  215    0    0 21269999999999999999999999   18
199999999999999999999999    0    0    0    0    0    0  522 1135 4012  770  461  160  954  321 2104    0    0 1994 2556999999999999999999   19
20999999999999999999    0    0    0    0    0    0    0 1090  318 1347  286  853  222 1724  643  475  140    0  608   09999999999999999999   20
219999999999    0    0    0    0    0    0    0    0    0  241 1516 1264  677  782    0 1706    0    0    0    0    0    0   0999999999999999   21
2299999    0    0    0    0    0    0    0    0    0    0   99 1692 3345 1030  175  485    0    0    0    0    0    0    0   0999999999999999   22
 23   0    0    0    0    0    0    0    0    0    0    0  638  767  136  175 3042    0  433    0    0    0    0    0   09999999999999999999   23
 24   0    0    0  536  837  294    0    0    0    0    0  671  548  357 2600 3324 1177    0    0    0    0    0   099999999999999999999999   24
 25   0    0    0 1495  468  787    0    0    0    0 1187  827  795  903 1484 9986 5044    0    0    0   099999999999999999999999999999999   25
 26   0    0  926    0    0    0    0    0    0 2154  645  525 2897 1947 1380 3391  502    0    0    0   099999999999999999999999999999999   26
 27   0    0    0    0    0  411  659 5950 1015 2160 3035 1753  945 1625 2312 7096  392    0    0   0999999999999999999999999999999999999   27
 28   0    0    0  775  256    0    0  710    0    0 2543 5238 1375 1314 2106 3990    0    0    0   0999999999999999999999999999999999999   28
 29   0    0 2066    0    0    0  385  511    0    0   46  900  780 1469 3195 6101    0    0    0   0999999999999999999999999999999999999   29
 30 1325    0    0    0    0    0    0   98  323    0    0  470    0  778  464 1089    0    0    0   0999999999999999999999999999999999999   30
 31 1762    0    0    0    0    0    0    0    0  971  490    0    0  817  771  358    0    0    0   0999999999999999999999999999999999999   31
 32   0    0    0    0    0    0    0    0    0    0    0    0  272  617 2157 2992    0    0    0    0   09999999999999999999999999999999   32
 33   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  318    0    0    0    0    0   0999999999999999999999999999   33
 34   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   099999999999999999999999   34
 35   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999   35
      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28

                                                          TOTAL Q IN MODELED AREA =    317.041 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(4)

DISCHARGE MAP IN 1984

```
***NSA TOTAL Q MAP (X1000 cu.m)***
   **YEAR: 1985**

     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28
1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999999999999999999999999   1
2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   099999    0    0   09999999999   2
3    0    0    0    0    0    0    0    0    0    0    0    0    0   98 1235  470 1169  489  182    0    0   099999    0    0   09999999999   3
4    0    0    0    0    0    0    0    0    0    0    0    0    0    0  506  455  323  557    0    0    0    0    0    0   0999999999999999   4
5    0    0    0    0    0    0  233   84  136    0    0    0    0 1311  274 2677  160  431  117    0    0    0 2508  263   0999999999999999   5
6    0    0    0    0    0    0    0   42   16   16 1319 2435 2218  497 4286  548  165  261    0    0    0    0 1201    0   0999999999999999   6
7    0    0    0    0    0    0    0  351  107   84  329  793    0  134  446  357  648 1349  188    0    0  128  964   09999999999999999999   7
8    0    0    0    0    0    0   14  433  733  568  349    0  568 1291    0  371  141  233   44   22   27  125 1022   09999999999999999999   8
999999    0    0    0    0    0   10  243  225  424  180    0  513 2507  376  979  446  561  262   32  109  239 1269999999999999999999999999   9
109999999999    0    0    0    0    3  626 2524 2176 1652 1254 2380  107  415  411  557  280  255   15   60  113   0999999999999999999999999   10
119999999999    0    0    0    0    0  276  364    0 1374 1383  246  185 1084    0  127   57  103    0  223  277   0999999999999999999999999   11
1299999999999999    0    0    0    0    0 1517  183   98   89   74  375  397  948    0  280  640  540 1344   19   0999999999999999999999999   12
1399999999999999    0    0    0    0    0 1186  491    0  125  256  354  555  333  638  597  926  463  295  505 2259999999999999999999999999   13
1499999999999999999999    0    0    0    0    0  478    0    0    0  104  328   71 1062    0 3294  839 1685 1523 7379999999999999999999999999   14
1599999999999999999999    0    0    0    0   61  256  427    0   39  120  262  111  628  728 3100 1808  258  377 9059999999999999999999999999   15
1699999999999999999999999999    0    0    0    0    0    0   83   42    0  361  435  600    0 1996 5029 4933 1686 2149999999999999999999999999   16
1799999999999999999999999999    0    0    0    0  152  148  253  218    0  611 1050  746 1244 5988  232 5262 6037 2358999999999999999999999999   17
1899999999999999999999999999    0    0    0    0  148  260    0  181  846 1929  512  536 2097 1334  215    0  265 2628999999999999999999999999   18
1999999999999999999999999999    0    0    0    0    0    0  522 1135 3223  750  461  157  954  321 2104    0    0 1994 2556999999999999999999   19
2099999999999999999999    0    0    0    0    0    0    0 1090  318 1279  265  853  222 1698  527  475  140    0  608   09999999999999999999   20
219999999999    0    0    0    0    0    0    0    0    0  203 1481 1185  677  782    0 1505    0    0    0    0    0    0   0999999999999999   21
2299999    0    0    0    0    0    0    0    0    0    0   85 1914 3450 1030  175  486    0    0    0    0    0    0    0   0999999999999999   22
23    0    0    0    0    0    0    0    0    0    0    0  574  767  136  175 3111    0  433    0    0    0    0    0   09999999999999999999   23
24    0    0    0  395  723  254    0    0    0    0    0  652  548  357 2600 3402 1177    0    0    0    0    0   0999999999999999999999999   24
25    0    0    0 1355  364  787    0    0    0    0 1083  827  795  903 1660 9853 4664    0    0    0   0999999999999999999999999999999999   25
26    0    0  875    0    0    0    0    0    0 2040  587  525 2882 1932 1380 3168  381    0    0    0   0999999999999999999999999999999999   26
27    0    0    0    0    0  381  819 5968  950 2160 3035 1753  945 1625 2312 7096  497    0    0   09999999999999999999999999999999999999   27
28    0    0    0  833  262    0    0  710    0    0 2543 5558 1375 1314 2106 4126    0    0    0   09999999999999999999999999999999999999   28
29    0    0 2236    0    0    0  230  495    0    0   46  900  780 1469 3196 6456    0    0    0   09999999999999999999999999999999999999   29
30 1325    0    0    0    0    0    0   77  323    0    0  456    0  778  464 1423    0    0    0   09999999999999999999999999999999999999   30
31 1762    0    0    0    0    0    0    0    0  881  420    0    0  817  771  847    0    0    0   09999999999999999999999999999999999999   31
32    0    0    0    0    0    0    0    0    0    0    0    0  272  617 2157 3007    0    0    0    0   0999999999999999999999999999999999   32
33    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0  460    0    0    0    0   0999999999999999999999999999999   33
34    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   0999999999999999999999999   34
35    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0   09999999999999999999   35
     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24   25   26   27   28

                                                  TOTAL Q IN MODELED AREA =    312.599 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(5)

DISCHARGE MAP IN 1985

MSA TOTAL Q MAP (X1000 cu.m)
YEAR: 1986

```
     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28
 1   0   0   0   0   0   0   0   0   0   0   0   0`  0   0   0   0   0   0   0   0999999999999999999999999999999999999   1
 2   0   0   0   0   0   0   0   0   0   0`  0   0   0   0   0   0   0   0   0   0   0   099999   0   0   09999999999   2
 3   0   0   0   0   0   0   0   0   0   0   0   0   0  98 1235 470 1169 489 182   0   0   099999   0   0   09999999999   3
 4   0   0   0   0   0   0   0   0   0   0   0   0   0   0 506 455 323 557   0   0   0   0   0   0   0999999999999999   4
 5   0   0   0   0   0   0 233  84 136   0   0   0   0 1395 274 2677 158 865 112  0   0   0 2490 310   0999999999999999   5
 6   0   0   0   0   0   0   0  42 212  16 1319 2650 2417 497 4328 455 148 396  0   0   0   0 1226  0   0999999999999999   6
 7   0   0   0   0   0   0   0 351 107  84 303 675   0 134 446 328 604 1102 116   0   0 111 806   09999999999999999999   7
 8   0   0   0   0   0   0  10 356 707 656 406   0 545 1291   0 371 120 189  24   9  18 140 905   09999999999999999999   8
999999   0   0   0   0   0   5 147 171 415 136   0 479 2122 376 979 446 561 186  14  57 212 1129999999999999999999999999   9
109999999999   0   0   0   0   1 523 2508 2157 1552 1453 1826 66 353 411 557 280 211   9  43  92   0999999999999999999999999   10
119999999999   0   0   0   0   0 364 364   0 1325 1139 157 115 1084   0 127  57  98   0 178 179   0999999999999999999999999   11
1299999999999999   0   0   0   0   0 1517 183  98  56  46 324 397 948   0 280 640 524 1098  12   0999999999999999999999999   12
1399999999999999   0   0   0   0   0 1186 491   0  95 193 308 556 333 638 488 926 463 295 420 2319999999999999999999999999   13
14999999999999999999   0   0   0   0   0 469   0   0   0  70 264  71 1062   0 3112 827 1685 1523 7379999999999999999999999999   14
15999999999999999999   0   0   0   0  61 233 375   0  23  71 186 105 628 728 3100 1808 258 377 9059999999999999999999999999   15
169999999999999999999999   0   0   0   0   0   0  73  23   0 285 429 500   0 1996 5029 4933 1710 2149999999999999999999999999   16
179999999999999999999999   0   0   0   0 152 148 253 193   0 544 1002 746 1170 5944 232 5262 6058 2419999999999999999999999999   17
189999999999999999999999   0   0   0   0 148 260   0 181 712 1794 477 459 1743 1334 215   0 565 2874999999999999999999999999   18
199999999999999999999999   0   0   0   0   0   0 522 1135 2732 729 461 153 954 321 2104   0   0 1994 2556999999999999999999999   19
20999999999999999999   0   0   0   0   0   0   0 1090 318 1199 461 853 222 1608 258 475 140   0 608   0999999999999999999999   20
219999999999   0   0   0   0   0   0   0   0   0 170 1680 1163 677 782   0 836   0   0   0   0   0   0   0999999999999999   21
2299999   0   0   0   0   0   0   0   0   0   0  73 1935 3252 1030 175 486   0   0   0   0   0   0   0   0999999999999999   22
23   0   0   0   0   0   0   0   0   0   0   0 540 767 136 175 3100   0 433   0   0   0   0   0   09999999999999999999   23
24   0   0   0 333 602 227   0   0   0   0   0 630 548 357 2600 3402 1177   0   0   0   0   0   0999999999999999999999999   24
25   0   0   0 1471 335 787   0   0   0   0 1121 1041 795 903 1746 9717 4297   0   0   0   099999999999999999999999999999999   25
26   0   0 708   0   0   0   0   0   0 2011 518 525 2752 1689 1467 3129 286   0   0   0   099999999999999999999999999999999   26
27   0   0   0   0   0 422 948 5947 905 2160 3371 2332 945 1625 2312 7096 528   0   0   09999999999999999999999999999999999999   27
28   0   0   0 1229 934   0   0 710   0   0 2543 5558 1686 1314 2106 4125   0   0   0   0999999999999999999999999999999999999   28
29   0   0 2400   0   0   0 257 553   0   0  46 900 780 1469 3196 6556   0   0   0   0999999999999999999999999999999999999   29
30 1325   0   0   0   0   0   0  59 323   0   0 442   0 778 464 1277   0   0   0   0999999999999999999999999999999999999   30
31 1762   0   0   0   0   0   0   0   0 799 359   0   0 817 771 796   0   0   0   0999999999999999999999999999999999999   31
32   0   0   0   0   0   0   0   0   0   0   0   0 272 617 2157 3061   0   0   0   0   099999999999999999999999999999999   32
33   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 412   0   0   0   0   0999999999999999999999999999999   33
34   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   09999999999999999999999999   34
35   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0999999999999999999999   35
     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28
```

TOTAL Q IN MODELED AREA =   309.028 MCM/YEAR

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.16(6) DISCHARGE MAP IN 1986
JAPAN INTERNATIONAL COOPERATION AGENCY	

```
***MSA TOTAL Q MAP (X1000 cu.m)***
   **YEAR: 1987**

      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28
  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   09999999999999999999999999999999999999   1
  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   099999   0   0   09999999999   2
  3   0   0   0   0   0   0   0   0   0   0   0   0   0  98 1235 470 1169 489 182   0   0   099999   0   0   09999999999   3
  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0 548 455 323 557   0   0   0   0   0   0   0999999999999999   4
  5   0   0   0   0   0   0 233  84 136   0   0   0  98 1395 274 2677 155 748 110   0   0   0 2530 178   0999999999999999   5
  6   0   0   0   0   0   0   0  42 212  16 1319 2861 2578 497 4328 376 134 371   0   0   0   0 1497   0   0999999999999999   6
  7   0   0   0   0   0   0   0 351 141  84 554 606   0 134 446 301 338 842  69   0   0  95 705   0999999999999999999   7
  8   0   0   0   0   0   0   7 290 680 822 377   0 519 1291   0 371 102 153  13   3  11 164 800   0999999999999999999   8
999999   0   0   0   0   0   2  81 129 405 136   0 439 1778 376 979 446 561 130   6  33 187 1009999999999999999999999   9
1099999999   0   0   0   0   1 435 2475 2159 1652 1453 1367  40 301 411 557 280 173   6  30  75   0999999999999999999999   10
1199999999   0   0   0   0   0 364 364   0 1270 915  97  70 1084   0 127  57  93   0 147 113   0999999999999999999999   11
1299999999999999   0   0   0   0   0 1487 183  98  39  28 281 397 948   0 280 640 507 893   7   0999999999999999999999   12
1399999999999999   0   0   0   0   0 1186 491   0  72 143 259 556 333 638 361 926 463 295 380 1889999999999999999999999   13
14999999999999999999   0   0   0   0   0 461   0   0   0  46 210  71 1062   0 3112 827 1685 1523 7379999999999999999999999   14
15999999999999999999   0   0   0   0  61 211 373   0  14  41 131  99 628 728 3100 1808 258 377 9059999999999999999999999   15
1699999999999999999999999   0   0   0   0   0   0  63  12   0 224 422 500   0 1996 5028 4933 1693 2149999999999999999999999   16
1799999999999999999999999   0   0   0   0 152 148 253 170   0 483 968 746 1101 5900 232 5262 5868 2475999999999999999999999999   17
1899999999999999999999999   0   0   0   0 148 260   0 181 572 1632 444 392 1444 1334 215   0 431 2575999999999999999999999999   18
1999999999999999999999999   0   0   0   0   0   0 522 1135 2364 708 461 150 954 321 2104   0   0 1994 2556999999999999999999   19
20999999999999999999   0   0   0   0   0   0   0 1090 318 1115 442 853 222 1608 258 475 140   0 608   099999999999999999   20
2199999999   0   0   0   0   0   0   0   0   0 143 1694 1090 677 782   0 836   0   0   0   0   0   0   09999999999999   21
2299999   0   0   0   0   0   0   0   0   0   0  63 1588 3601 1030 175 486   0   0   0   0   0   0   0   09999999999999   22
 23   0   0   0   0   0   0   0   0   0   0   0 429 767 136 175 3368   0 433   0   0   0   0   0   099999999999999999   23
 24   0   0   0 283 504 203   0   0   0   0   0 543 548 357 2600 3480 1177   0   0   0   0   0   09999999999999999999999   24
 25   0   0   0 1288 324 787   0   0   0   0 1093 1041 795 903 2055 9580 4002   0   0   0   0999999999999999999999999999999   25
 26   0   0 746   0   0   0   0   0   0 2116 507 525 2703 1813 1467 3153 214   0   0   0   0999999999999999999999999999999   26
 27   0   0   0   0   0 378 1142 5735 885 2160 3371 2332 945 1790 2312 7183 648   0   0   09999999999999999999999999999999999   27
 28   0   0   0 1284 1218   0   0 710   0   0 2543 5558 1686 1314 2451 4125   0   0   0   099999999999999999999999999999999   28
 29   0   0 2460   0   0   0 240 540   0   0  46 900 780 1469 3196 6309   0   0   0   099999999999999999999999999999999   29
 30 1537   0   0   0   0   0   0  46 323   0   0 429   0 778 464 1154   0   0   0   0999999999999999999999999999999999   30
 31 1762   0   0   0   0   0   0   0   0 725 306   0   0 817 771 857   0   0   0   0999999999999999999999999999999999   31
 32   0   0   0   0   0   0   0   0   0   0   0   0 272 617 2157 2994   0   0   0   0   0999999999999999999999999999999   32
 33   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 366   0   0   0   0   099999999999999999999999999   33
 34   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   09999999999999999999999   34
 35   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0999999999999999999   35
      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28

                                                        TOTAL Q IN MODELED AREA =    304.330 MCM/YEAR
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STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(7)

DISCHARGE MAP IN 1987

```
***NGA TOTAL Q MAP (X1000 cu.m)***
  **YEAR: 1988**

      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28
  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   099999999999999999999999999999999999   1
  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  099999   0   0  09999999999   2
  3   0   0   0   0   0   0   0   0   0   0   0   0   0  98 1235 470 1169 489 182   0   0  099999   0   0  09999999999   3
  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0 589 455 323 557   0   0   0   0   0   0 0999999999999999   4
  5   0   0   0   0   0   0 233  84 136   0   0   0  98 1474 345 2764 262 748 105   0   0   0 2532  91 0999999999999999   5
  6   0   0   0   0   0   0   0  42 212 212 1319 3131 2754 555 4416 311 121 472   0   0   0   0 1767   0 0999999999999999   6
  7   0   0   0   0   0   0   9 394 173  84 617 505   0 134 446 276 418 641  44   0   0  82 671 099999999999999999999999   7
  8   0   0   0   0   0   0   4 235 650 973 560   0 488 1291   0 371  87 122   7   1   7 119 707 099999999999999999999999   8
999999   0   0   0   0   0   1  49  96 736 135   0 452 1475 376 979 446 561  91   2  21 165 899999999999999999999999   9
109999999999   0   0   0   0   1 361 2457 2151 1848 1453 987  23 254 411 557 280 143   4  22  61 099999999999999999999999   10
119999999999   0   0   0   0   0 364 364   0 1210 674  58  42 1084   0 127  57  88   0 110  70 099999999999999999999999   11
12999999999999999   0   0   0   0   0 1478 225  98  14  16 241 397 948   0 280 640 491 725   4 099999999999999999999999   12
13999999999999999   0   0   0   0   0 1186 491   0  54 105 217 556 333 638 560 926 463 295 308 151999999999999999999999   13
1499999999999999999999   0   0   0   0   0 453   0   0   0  29 167  71 1062   0 3206 827 1685 1523 737999999999999999999999   14
1599999999999999999999   0   0   0   0  61 192 326   0   8  23 100  95 628 728 3100 1916 258 377 905999999999999999999999   15
16999999999999999999999999   0   0   0   0   0   0  55   6   0 174 415 500   0 1996 5029 4933 1672 214999999999999999999999   16
17999999999999999999999999   0   0   0   0 152 148 341 149   0 427 934 746 1228 5856 232 5262 6125 233599999999999999999999   17
18999999999999999999999999   0   0   0   0 148 260   0 181 445 1460 413 332 1190 1334 215   0 322 295299999999999999999999   18
19999999999999999999999999   0   0   0   0   0   0 522 1135 2128 703 465 146 954 321 2104   0   0 1994 255699999999999999999999   19
2099999999999999999999   0   0   0   0   0   0   0 1090 318 987 604 1097 222 1608 258 475 140   0 608 09999999999999999999   20
219999999999   0   0   0   0   0   0   0   0   0 119 1748 1021 960 782   0 836   0   0   0   0   0   0 0999999999999999   21
2299999   0   0   0   0   0   0   0   0   0   0  54 1508 3721 1030 175 486   0   0   0   0   0   0 0999999999999999   22
 23   0   0   0   0   0   0   0   0   0   0   0 410 767 136 175 3374   0 433   0   0   0   0   0 09999999999999999999   23
 24   0   0   0 232 455 180   0   0   0   0   0 603 548 357 2600 3819 1177   0   0   0   0   0 099999999999999999999999   24
 25   0   0   0 1337 312 787   0   0   0   0 1018 1041 795 903 2055 9594 3527   0   0   0 09999999999999999999999999999999   25
 26   0   0 598   0   0   0   0   0   0 2099 752 525 3111 1997 1538 2898 159   0   0   0 09999999999999999999999999999999   26
 27   0   0   0   0   0 372 1102 5983 885 2160 3495 2332 945 1790 2651 7246 496   0   0 099999999999999999999999999999999999   27
 28   0   0   0 1457 1111   0   0 710   0   0 2543 5558 1686 1314 2451 4126   0   0   0 099999999999999999999999999999999999   28
 29   0   0 2595   0   0   0 314 556   0   0  46 900 780 1469 3196 6374   0   0   0 099999999999999999999999999999999999   29
 30 1600   0   0   0   0   0   0  35 323   0   0 415   0 778 464 1064   0   0   0 099999999999999999999999999999999999   30
 31 1762   0   0   0   0   0   0   0   0 657 260   0   0 817 771 919   0   0   0 099999999999999999999999999999999999   31
 32   0   0   0   0   0   0   0   0   0   0   0   0 272 617 2293 3213   0   0   0   0 09999999999999999999999999999999   32
 33   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 280   0   0   0   0 0999999999999999999999999999   33
 34   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 099999999999999999999999   34
 35   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 09999999999999999999   35
      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28

                                              TOTAL Q IN MODELED AREA =    305.976 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(8)

DISCHARGE MAP IN 1988

```
**MGA TOTAL Q MAP (X1000 cu.m)***
  **YEAR: 1989**

     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28
 1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  099999999999999999999999999999999999  1
 2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  099999   0   0  09999999999  2
 3   0   0   0   0   0   0   0   0   0   0   0   0   0  99 1235 470 1169 499 182  0   0  099999   0   0  09999999999  3
 4   0   0   0   0   0   0   0   0   0   0   0   0   0   0 569 455 323 567   0   0   0   0   0   0  0999999999999999  4
 5   0   0   0   0   0   0 233  84 135   0 271   0  99 1567 345 2764 256 683 101  0   0   0 2479 221  0999999999999999  5
 6   0   0   0   0   0   0   0  42 212 212 1319 3539 2885 742 4631 256 109 419  0   0   0   0 1957  0  0999999999999999  6
 7   0   0   0   0   0   0   8 430 192  84 984 458   0 134 446 253 348 545  25   0   0  71 576  09999999999999999999  7
 8   0   0   0   0   0   0   2 188 677 941 564   0 453 1291  0 371  74  98   3   0   4 143 623  09999999999999999999  8
999999   0   0   0   0   0   0  28  72 711 135   0 397 1205 376 979 446 561  62   1  11 145  7899999999999999999999999999  9
109999999999   0   0   0   0   0 298 2380 2143 1848 1453 675  13 215 411 557 280 116   3  15  49  0999999999999999999999999999  10
119999999999   0   0   0   0   0 364 364   0 1143 494  32  24 1084   0 127  57  83   0  90  43  0999999999999999999999999999  11
1299999999999999   0   0   0   0   0 1472 225  98   5   9 207 397 948   0 280 640 476 586   2  0999999999999999999999999999  12
1399999999999999   0   0   0   0   0 1186 491   0  40  75 180 556 333 638 534 926 463 295 263  1239999999999999999999999999  13
14999999999999999999   0   0   0   0   0 445   0   0   0  18 132  71 1062   0 3206 827 1685 1523  7379999999999999999999999999  14
15999999999999999999   0   0   0   0  61 173 284   0   4  12  68  89 628 986 3100 2024 258 377  9059999999999999999999999999  15
169999999999999999999999   0   0   0   0   0   0  47   3   0 135 407 500   0 2103 5028 4933 1667  2149999999999999999999999999  16
179999999999999999999999   0   0   0   0 152 148 341 130   0 379 901 746 971 5310 232 5262 6229 2106999999999999999999999999  17
189999999999999999999999   0   0   0   0 148 260   0 181 372 1278 383 281 976 1334 215   0 480 2635999999999999999999999999  18
199999999999999999999999   0   0   0   0   0   0 522 1135 1630 666 461 142 954 321 2104   0   0 1954 2705999999999999999999999  19
2099999999999999999999   0   0   0   0   0   0   0 1090 318 915 767 1256 222 1608 258 475 140   0 608  09999999999999999999  20
219999999999   0   0   0   0   0   0   0   0   0 100 1909 956 677 782   0 836   0   0   0   0   0   0  0999999999999999  21
2299999   0   0   0   0   0   0   0   0   0   0  46 1527 3524 1030 175 466   0   0   0   0   0   0  0999999999999999  22
23   0   0   0   0   0   0   0   0   0   0   0 362 767 135 175 3355   5 433   0   0   0   0   0  09999999999999999999  23
24   0   0   0 183 368 161   0   0   0   0   0 603 548 357 2600 3819 1177  0   0   0   0   0  0999999999999999999999999  24
25   0   0   0 1318 296 737   0   0   0   0 632 1498 795 990 2055 9681 3198  0   0   0  099999999999999999999999999999999999  25
26   0   0 566   0   0   0   0   0   0 2112 764 525 3502 1984 1538 2560 118   0   0   0  099999999999999999999999999999999999  26
27   0   0   0   0   0 357 1083 6753 1018 2160 4535 2332 1261 1790 2651 7373 381   0   0  0999999999999999999999999999999999999999  27
28   0   0   0 1379 998   0   0 710   0   0 2879 6250 2139 1401 2451 4126   0   0   0  0999999999999999999999999999999999999999  28
29   0   0 3075   0   0   0 356 488   0   0  46 900 780 1469 3196 6546   0   0   0  0999999999999999999999999999999999999999  29
30 1574   0   0   0   0   0   0  27 323   0   0 402   0 778 639 926   0   0   0  0999999999999999999999999999999999999999  30
31 1762   0   0   0   0   0   0   0   0 594 220   0   0 817 771 1030   0   0   0  0999999999999999999999999999999999999999  31
32   0   0   0   0   0   0   0   0   0   0   0   0 272 617 2293 3568   0   0   0   0  099999999999999999999999999999999999  32
33   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 334   0   0   0   0  0999999999999999999999999999999999  33
34   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  0999999999999999999999999999  34
35   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  099999999999999999999  35
     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28

                                                  TOTAL Q IN MODELED AREA =   309.901 MCM/YEAR
```

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(9)

DISCHARGE MAP IN 1989

MSA TOTAL Q MAP (X1000 cu.m)
YEAR: 1990

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99999	0	0	0	99999	99999	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	98	1235	600	1169	489	182	0	0	0	99999	0	0	0	99999	99999	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	589	455	323	557	0	0	0	0	0	0	0	99999	99999	99999	4
5	0	0	0	0	0	0	233	84	136	0	271	0	98	1667	345	2764	251	659	98	0	0	0	2420	274	0	99999	99999	99999	5
6	0	0	0	0	0	0	0	42	212	408	1319	3539	2885	742	4631	210	300	387	0	0	0	0	1814	0	0	99999	99999	99999	6
7	0	0	0	0	0	0	8	437	168	84	862	337	0	134	446	232	238	465	15	0	0	60	526	0	99999	99999	99999	99999	7
8	0	0	0	0	0	0	1	149	641	904	553	0	414	1291	0	371	62	78	2	0	3	99	593	0	99999	99999	99999	99999	8
9	99999	0	0	0	0	0	0	15	52	685	136	0	337	969	376	979	446	561	42	0	4	128	65	99999	99999	99999	99999	99999	9
10	99999	99999	0	0	0	0	0	246	2272	2135	1848	1453	422	7	181	411	557	280	95	1	11	39	0	99999	99999	99999	99999	99999	10
11	99999	99999	0	0	0	0	0	364	364	0	1069	360	16	13	1084	0	127	57	79	0	73	25	0	99999	99999	99999	99999	99999	11
12	99999	99999	99999	0	0	0	0	0	1401	225	98	4	5	174	397	948	0	280	675	461	473	1	0	99999	99999	99999	99999	99999	12
13	99999	99999	99999	0	0	0	0	0	1186	491	0	29	52	148	556	333	638	558	926	463	295	241	98	99999	99999	99999	99999	99999	13
14	99999	99999	99999	99999	0	0	0	0	0	437	0	0	0	15	104	71	1062	0	3206	327	1685	1523	737	99999	99999	99999	99999	99999	14
15	99999	99999	99999	99999	0	0	0	0	61	156	247	0	2	6	46	84	628	1531	3100	2239	259	317	905	99999	99999	99999	99999	99999	15
16	99999	99999	99999	99999	99999	0	0	0	0	0	0	40	1	0	103	400	500	0	2103	5028	4933	1683	214	99999	99999	99999	99999	99999	16
17	99999	99999	99999	99999	99999	0	0	0	0	152	148	341	112	0	333	869	746	910	5765	232	5262	6124	2247	99999	99999	99999	99999	99999	17
18	99999	99999	99999	99999	99999	0	0	0	0	148	260	0	181	310	1117	355	338	798	1334	215	0	439	2632	99999	99999	99999	99999	99999	18
19	99999	99999	99999	99999	99999	0	0	0	0	0	0	522	1135	1594	876	461	138	954	321	2104	0	0	1994	3190	99999	99999	99999	99999	19
20	99999	99999	99999	99999	0	0	0	0	0	0	0	1198	318	840	787	1185	222	1608	258	541	140	0	608	0	99999	99999	99999	99999	20
21	99999	99999	0	0	0	0	0	0	0	0	0	83	1832	895	777	782	0	836	0	0	0	0	0	0	0	99999	99999	99999	21
22	99999	0	0	0	0	0	0	0	0	0	0	40	1483	3635	1030	175	486	0	0	0	0	0	0	0	0	99999	99999	99999	22
23	0	0	0	0	0	0	0	0	0	0	0	331	767	223	175	3349	172	433	0	0	0	0	0	0	99999	99999	99999	99999	23
24	0	0	0	142	307	142	0	0	0	0	0	603	548	357	2600	3905	1177	0	0	0	0	0	0	99999	99999	99999	99999	99999	24
25	0	0	0	1201	304	1045	0	0	0	0	832	1623	795	990	2055	9529	2809	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	25
26	0	0	556	0	0	0	0	0	0	2120	677	525	3574	1979	1538	2541	86	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	26
27	0	0	0	0	0	347	1572	6758	855	2160	4535	2332	1333	1790	2722	7373	407	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	27
28	0	0	0	1894	986	0	0	710	0	0	2879	6250	2575	1544	2451	4126	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	28
29	0	0	2806	0	0	0	305	484	0	0	46	900	780	1469	3196	6862	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	29
30	2344	1044	668	0	0	0	0	20	323	0	0	390	0	778	639	864	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	30
31	1762	0	0	0	0	0	0	0	0	538	187	0	0	817	771	932	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	99999	31
32	0	0	0	0	0	0	0	0	0	0	0	0	272	617	2293	3539	0	0	0	0	0	99999	99999	99999	99999	99999	99999	99999	32
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	308	0	0	0	0	0	99999	99999	99999	99999	99999	99999	33
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99999	99999	99999	99999	99999	34
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99999	99999	99999	99999	35
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	

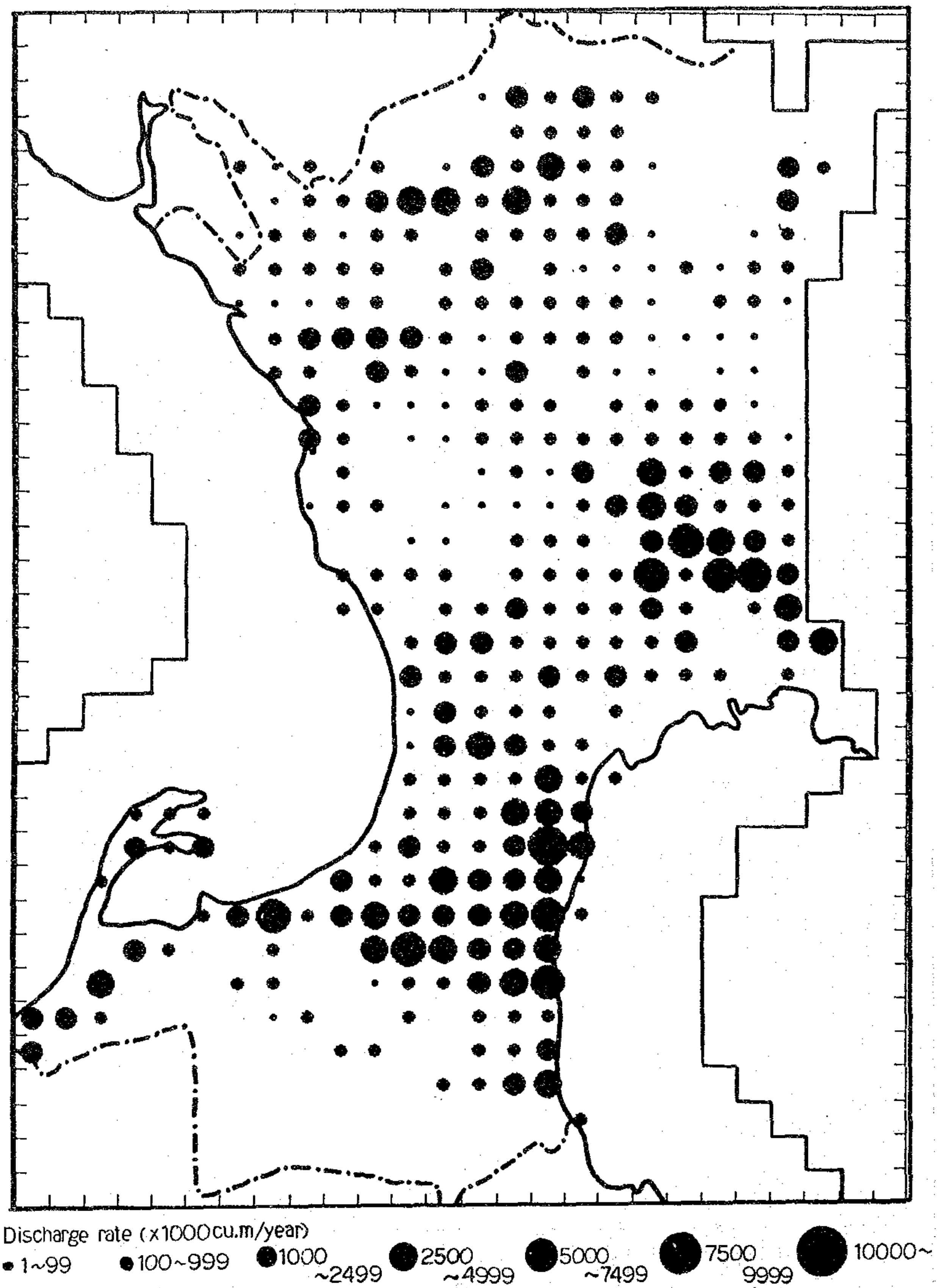
TOTAL Q IN MODELED AREA = 310.525 MCM/YEAR

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.16(10)

DISCHARGE MAP IN 1990

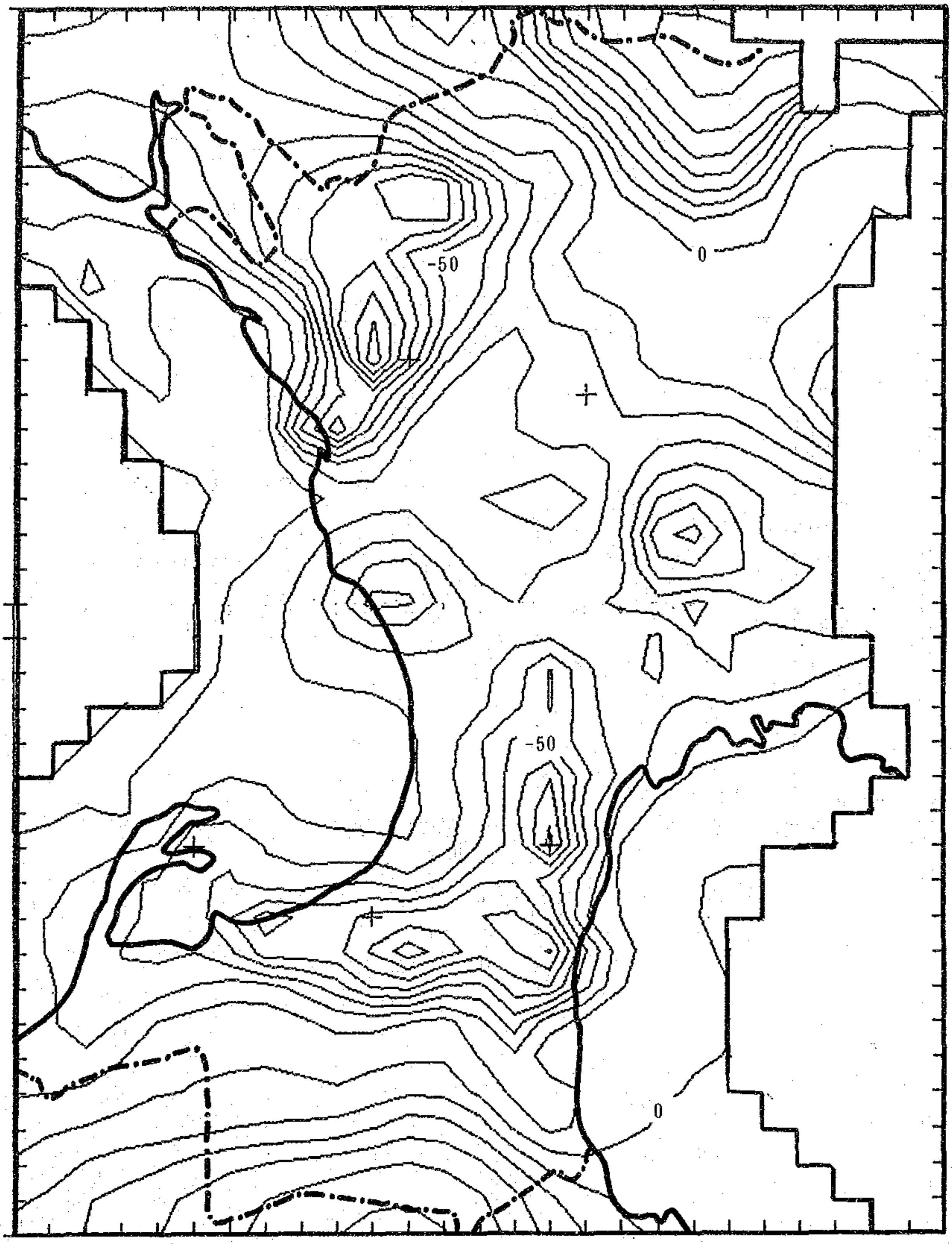


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

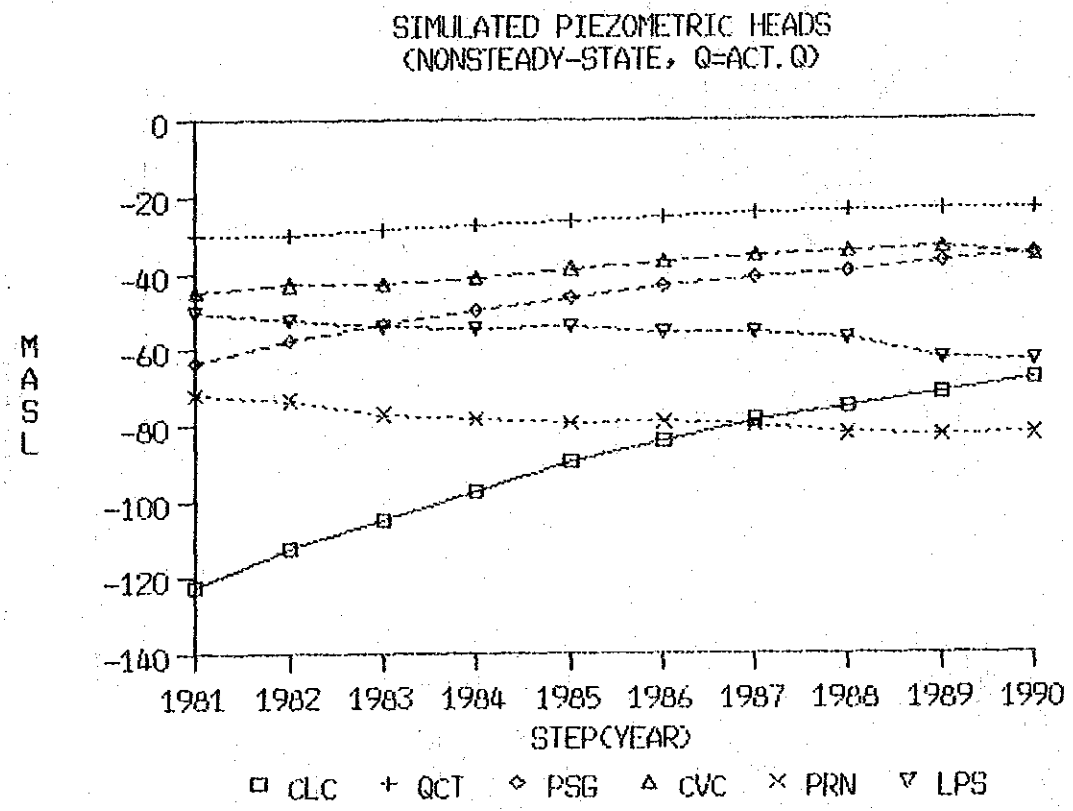
FIGURE 8.5.17

DISCHARGE DISTRIBUTION IN 1990

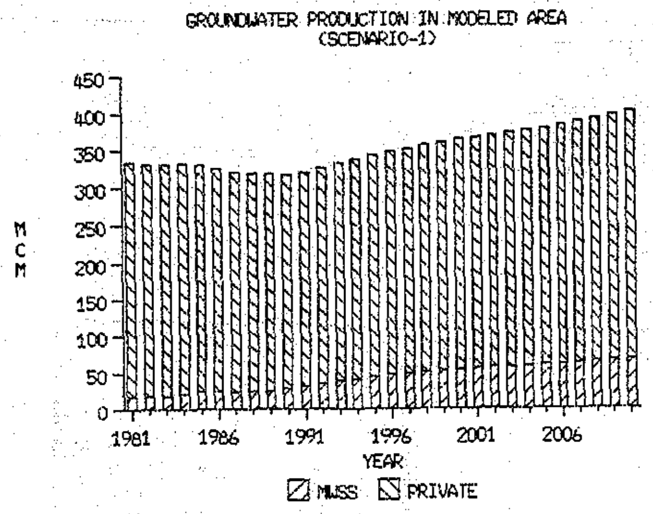


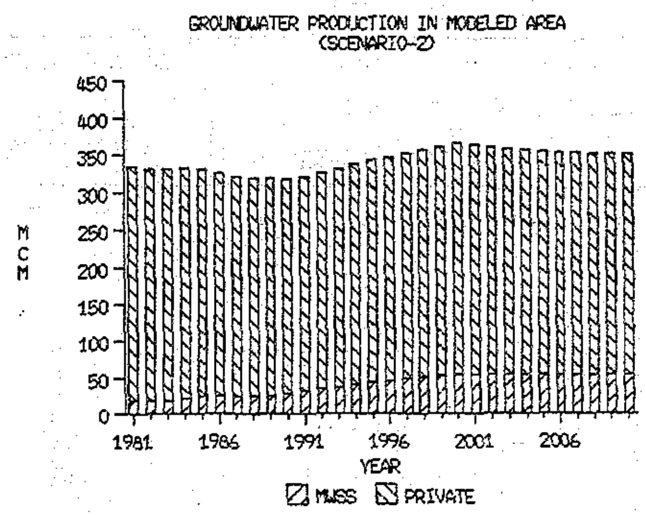
(Contour Interval: 10m, Unit: masl)

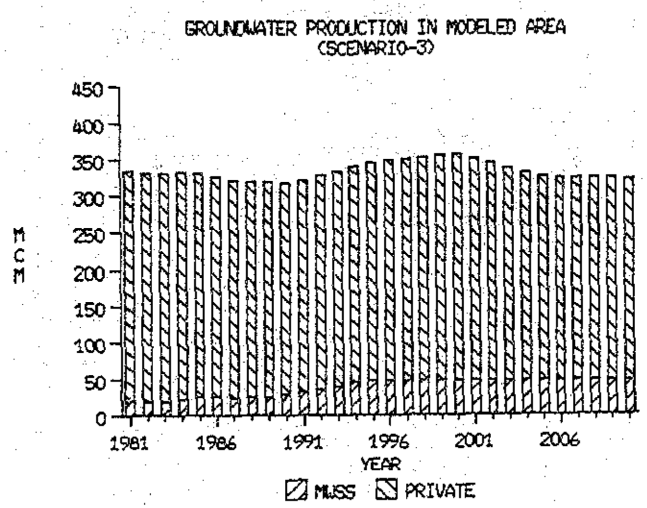
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA JAPAN INTERNATIONAL COOPERATION AGENCY	FIGURE 8.5.188 SIMULATED PIEZOMETRIC HEADS IN 1990

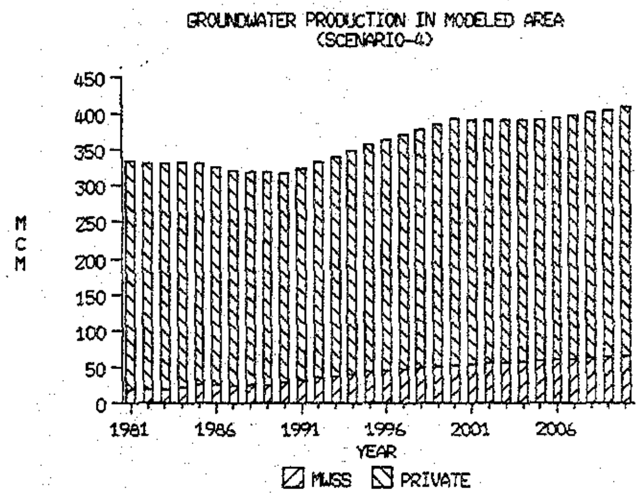


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.19 SIMULATED PIEZOMETRIC HEADS BY NONSTEADY-STATE CALCULATION
JAPAN INTERNATIONAL COOPERATION AGENCY	







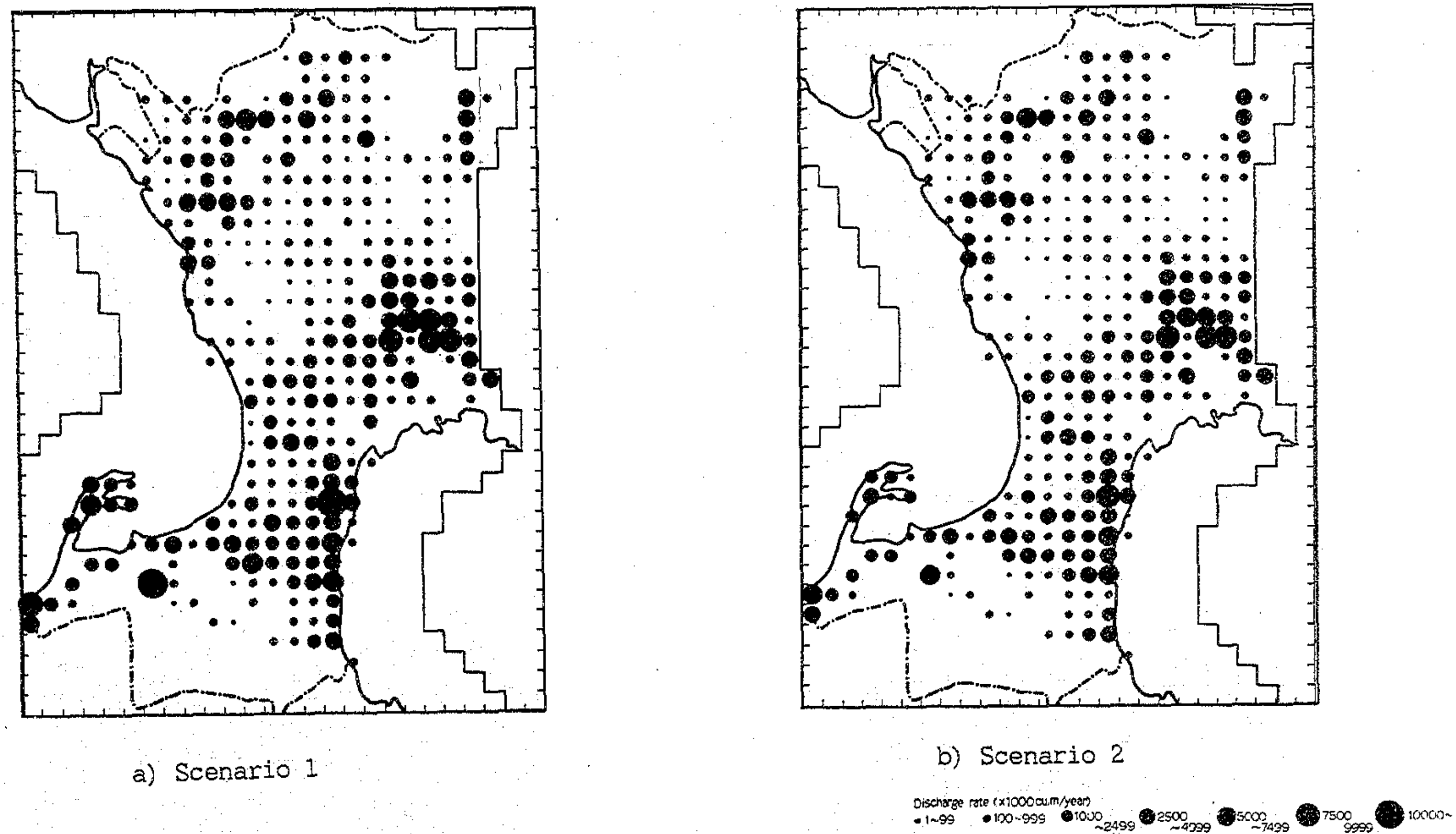


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

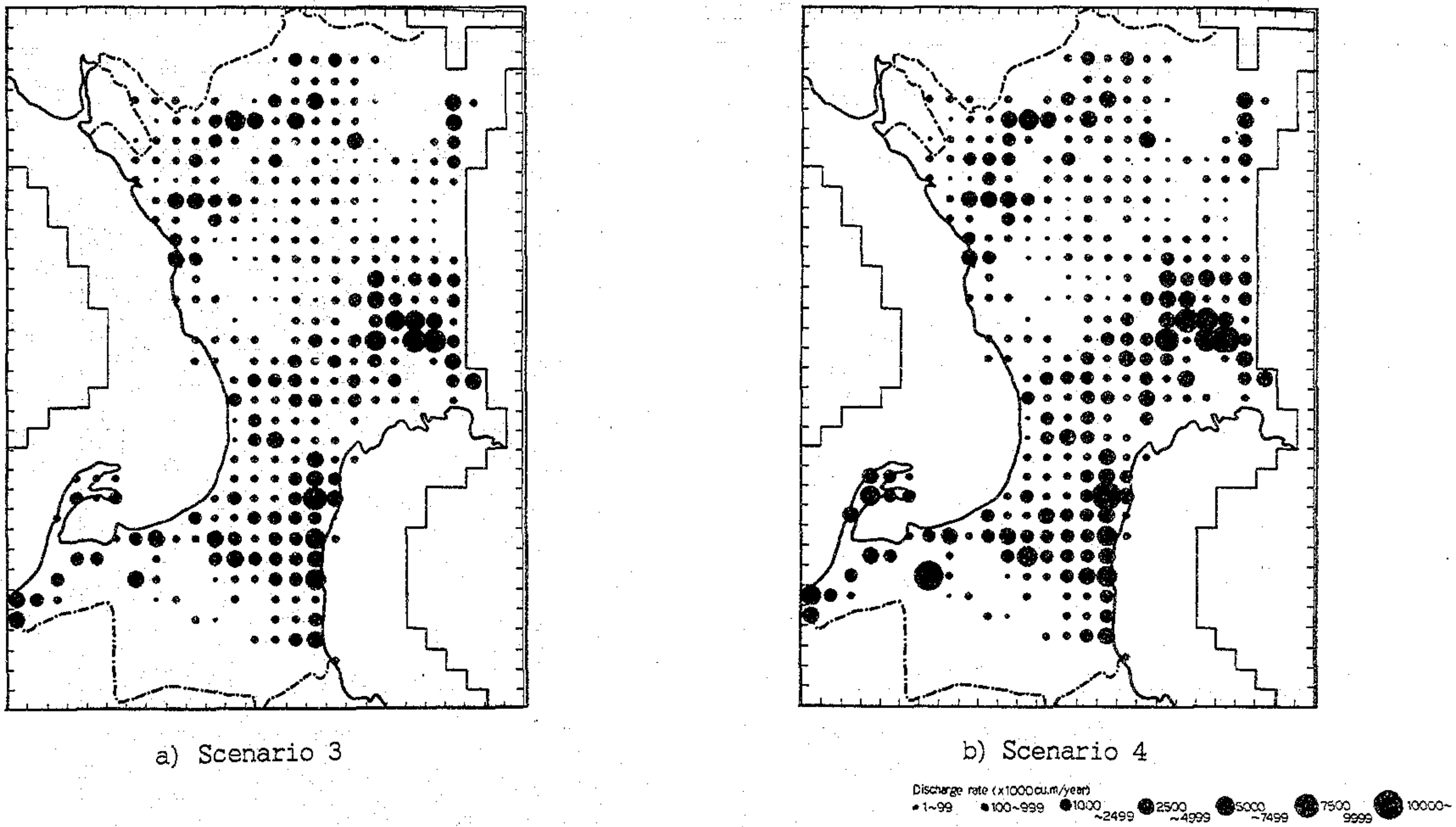
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.20

GROUNDWATER PRODUCTION OF EACH SCENARIO



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.21
JAPAN INTERNATIONAL COOPERATION AGENCY	DISCHARGE DISTRIBUTION IN 2010 (Scenario 1, Scenario 2)

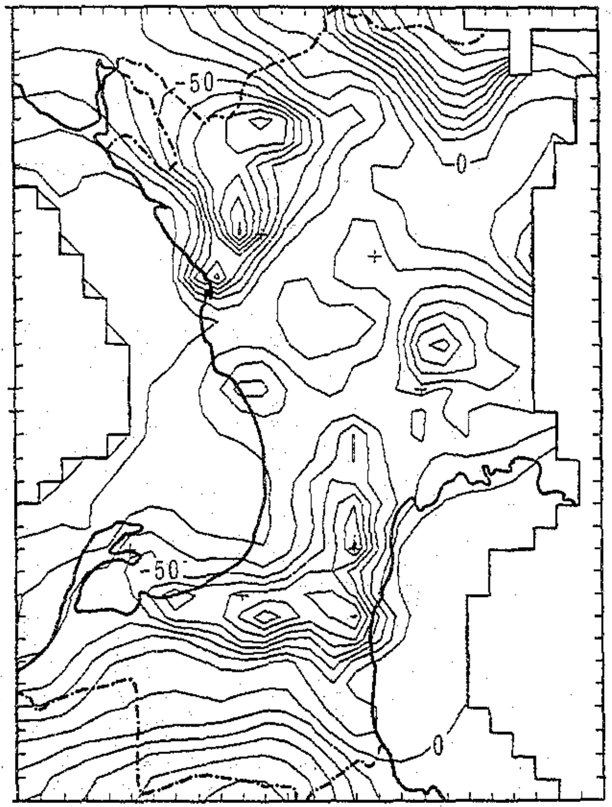


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

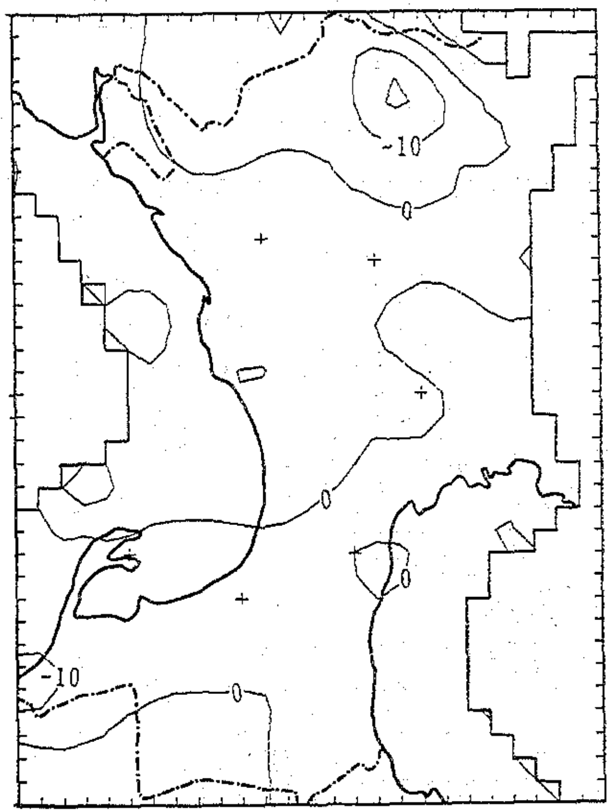
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.222

DISCHARGE DISTRIBUTION IN 2010
(Scenario 3, Scenario 4)

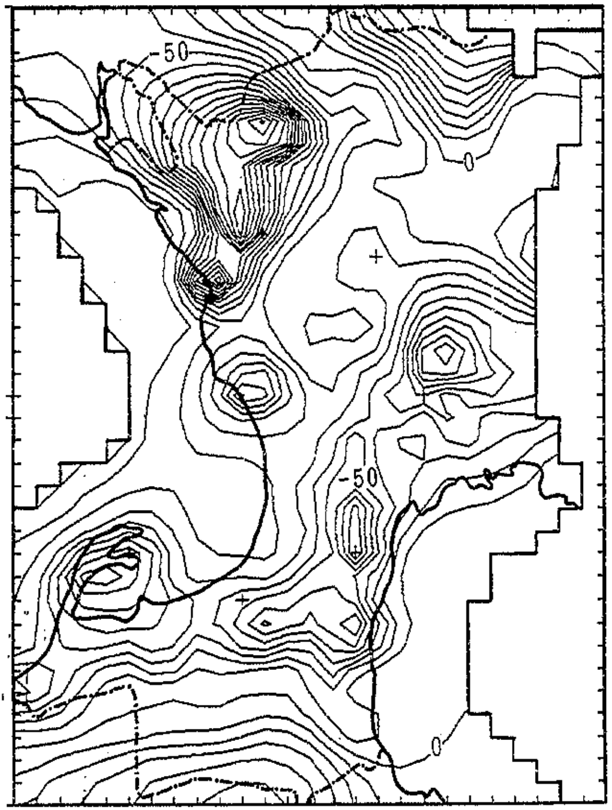


a) Simulated Piezometric Heads in 2010
(Contour Interval: 10m, Unit: masl)



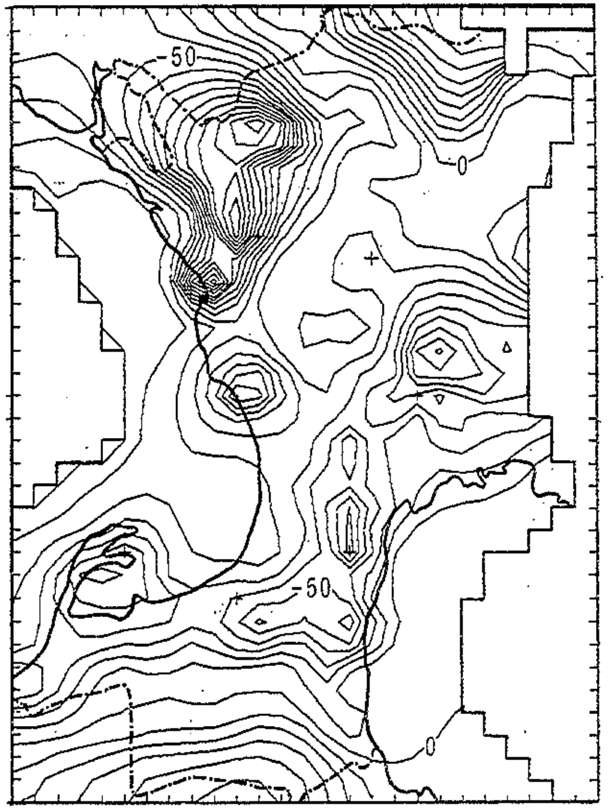
b) Simulated Piezometric Changes from 1991 to 2010
(Contour Interval: 10m, Unit: m)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.23
JAPAN INTERNATIONAL COOPERATION AGENCY	SIMULATED PIEZOMETRIC HEADS AND CHANGES



a) Scenario 1

(Contour Interval: 10m, Unit: masl)



b) Scenario 2

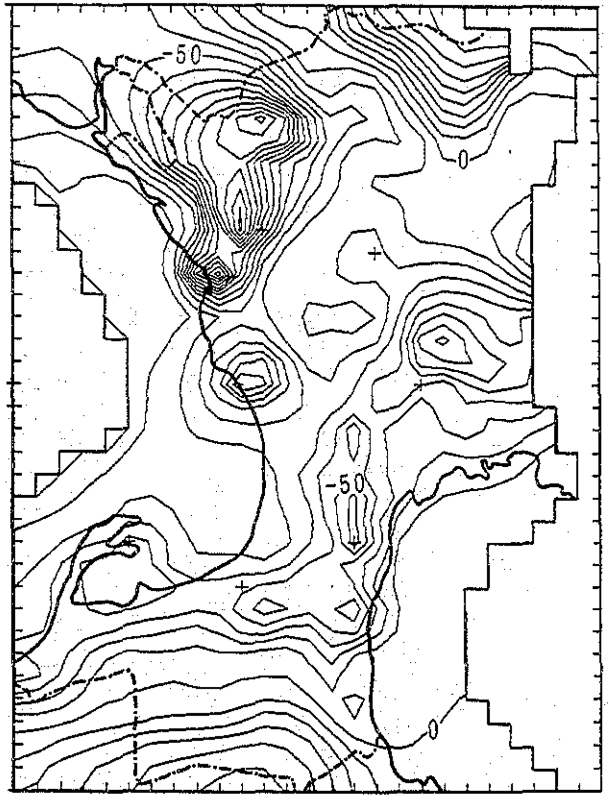
(Contour Interval: 10m, Unit: masl)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

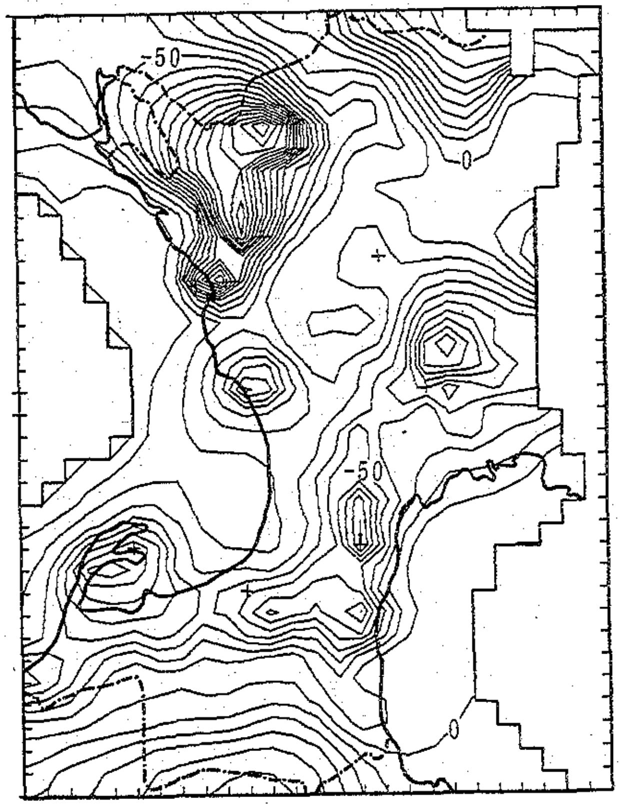
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.24

SIMULATED PIEZOMETRIC HEADS IN 2010
(Scenario 1, Scenario 2)



a) Scenario 3
(Contour Interval: 10m, Unit: masl)



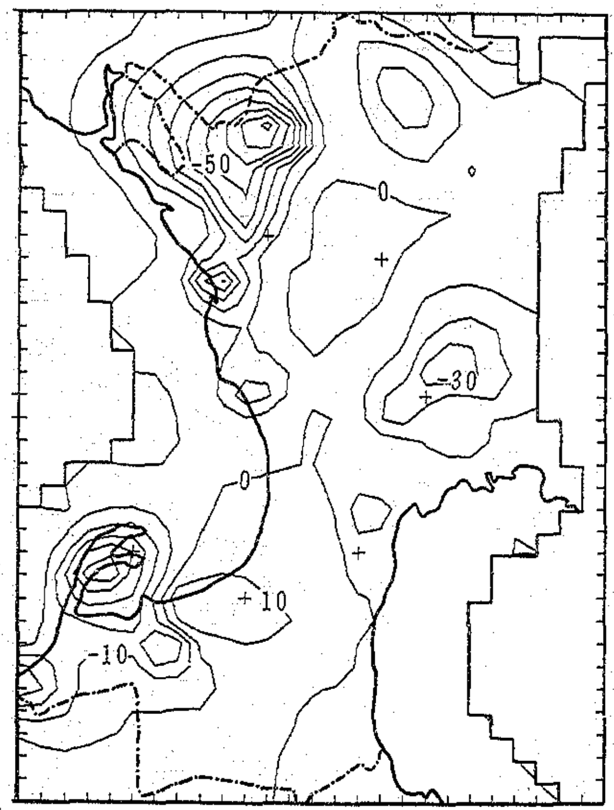
b) Scenario 4
(Contour Interval: 10m, Unit: masl)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

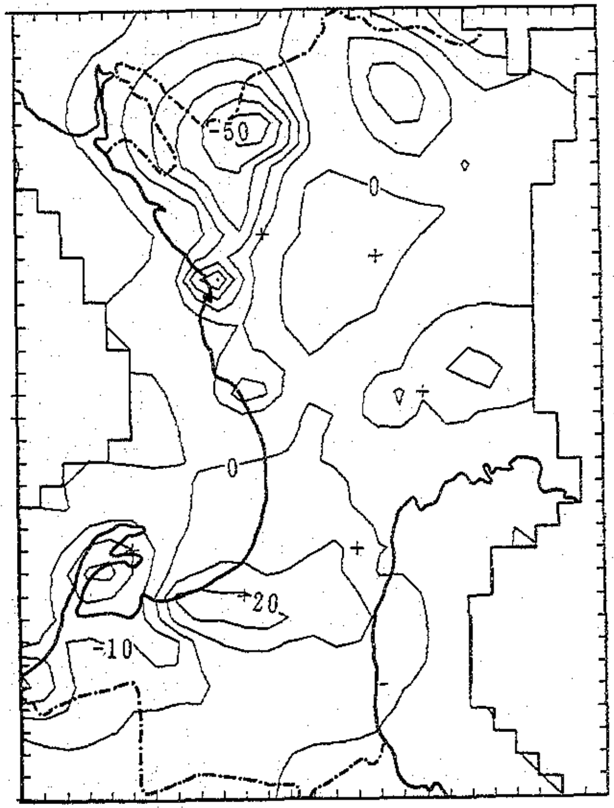
FIGURE 8.5.255

SIMULATED PIEZOMETRIC HEADS IN 2010
(Scenario 3, Scenario 4)



a) Scenario 1

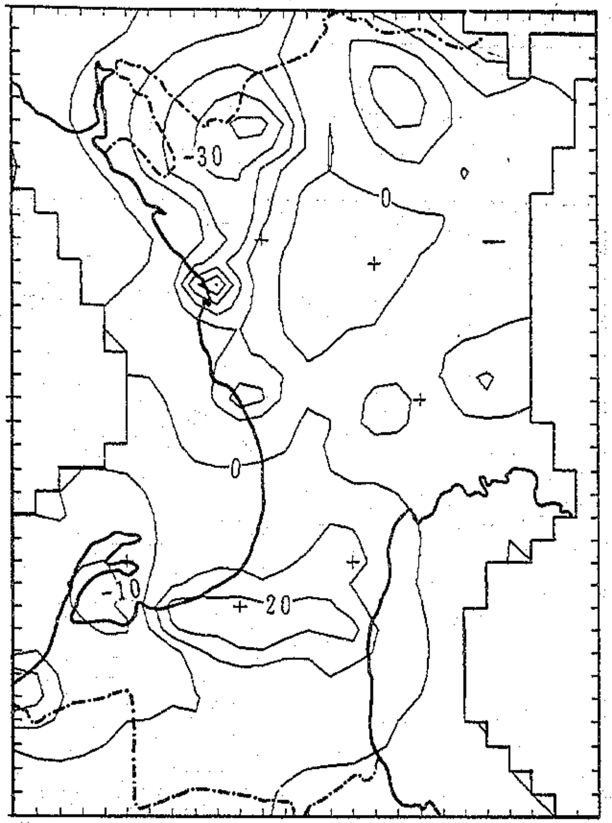
(Contour Interval: 10m, Unit: m)



b) Scenario 2

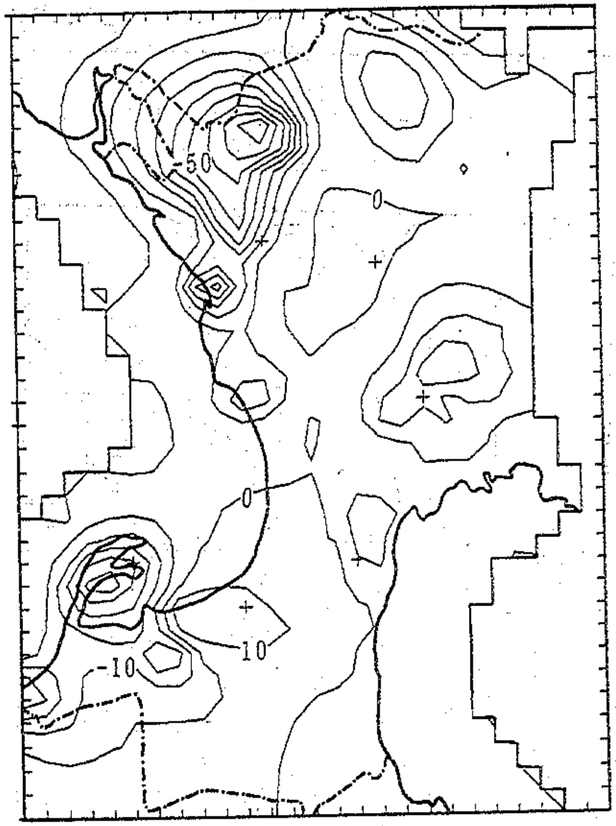
(Contour Interval: 10m, Unit: m)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.26 SIMULATED PIEZOMETRIC CHANGES FROM 1991 TO 2010 (Scenario 1, Scenario 2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



a) Scenario 3

(Contour Interval: 10m, Unit: m)



b) Scenario 4

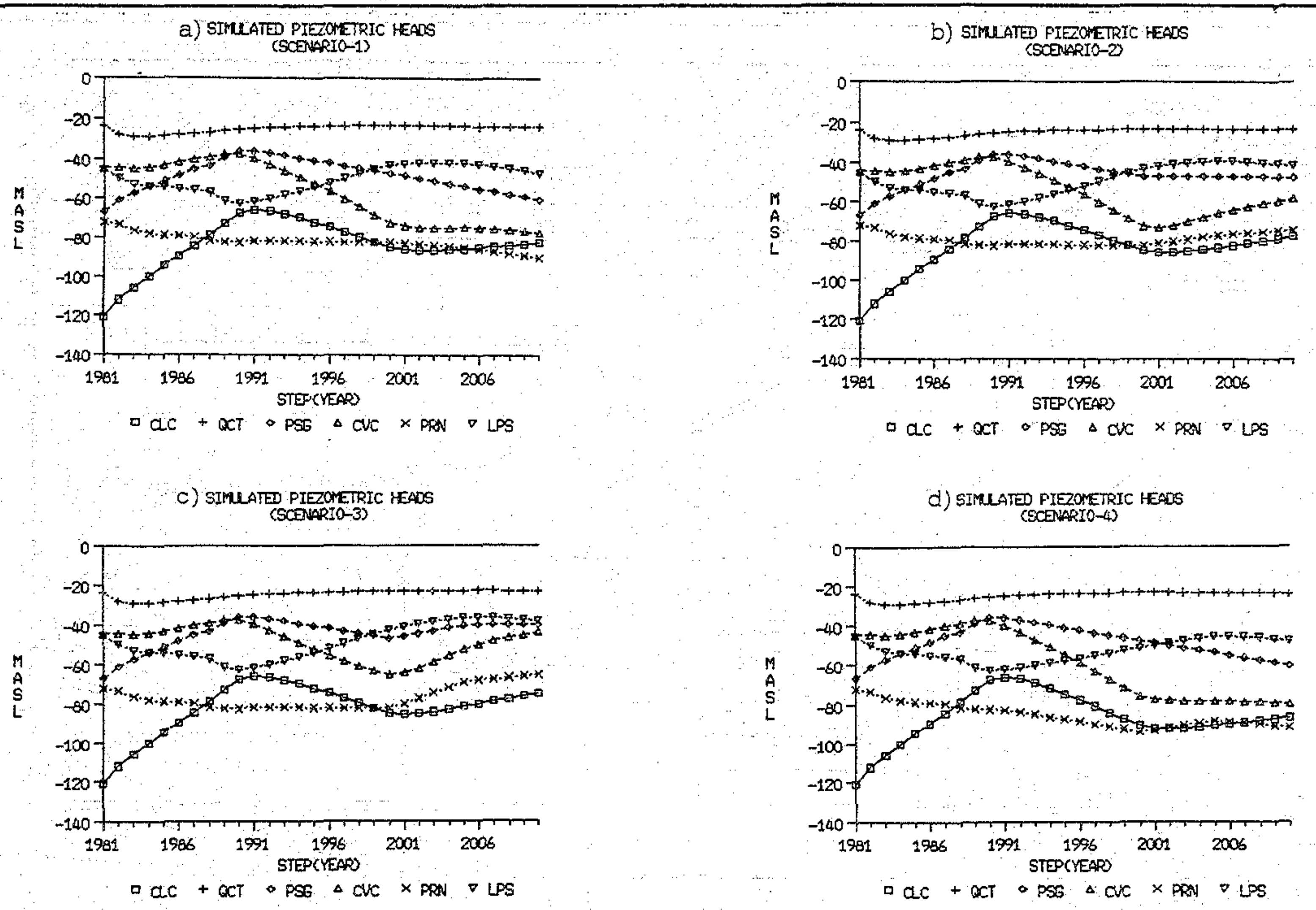
(Contour Interval: 10m, Unit: m)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.27

SIMULATED PIEZOMETRIC CHANGES FROM 1991 TO 2010
(Scenario 3, Scenario 4)

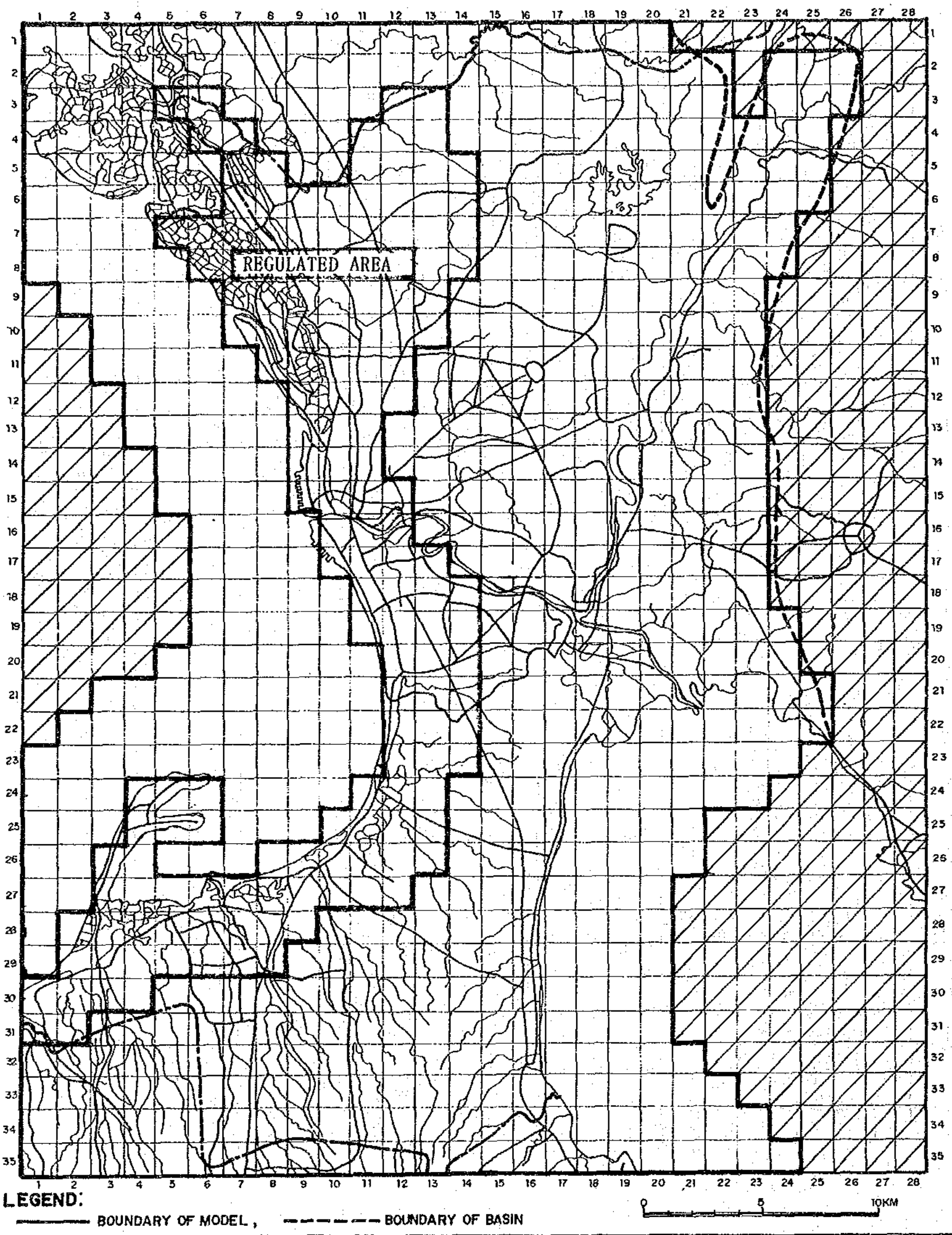


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.288

SIMULATED PIEZOMETRIC CHANGES IN THE SCENARIOS

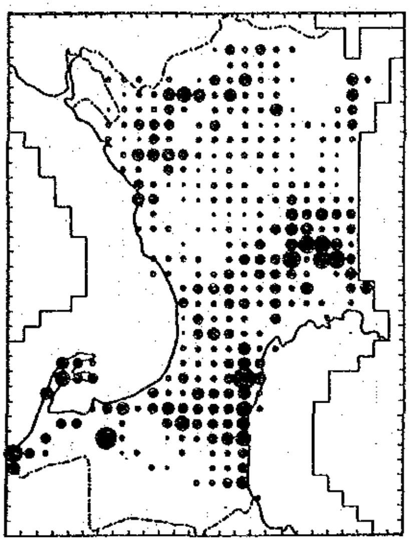


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

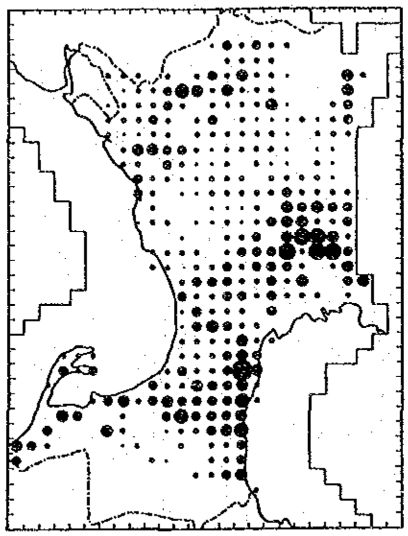
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.29

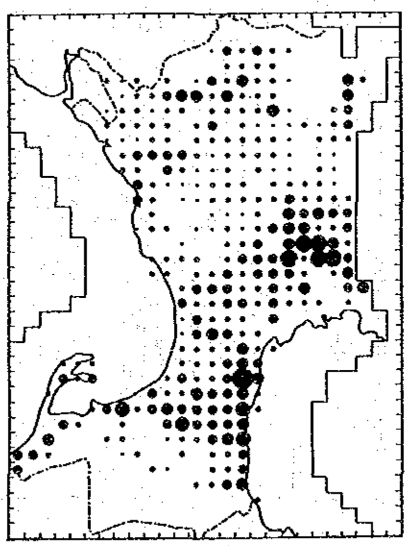
REGULATED AREA FOR GROUNDWATER PUMPAGE



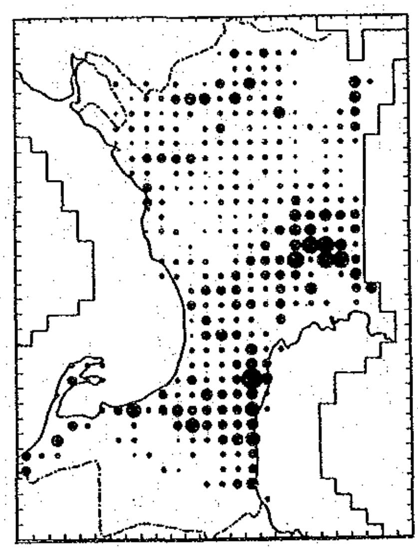
Scenario 1



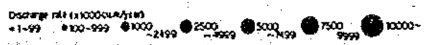
Plan(a)



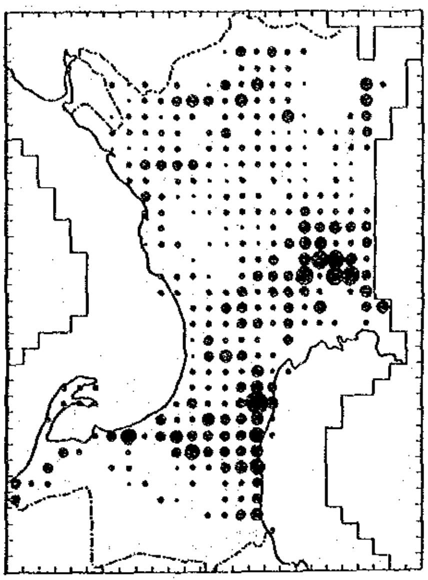
Plan(b)



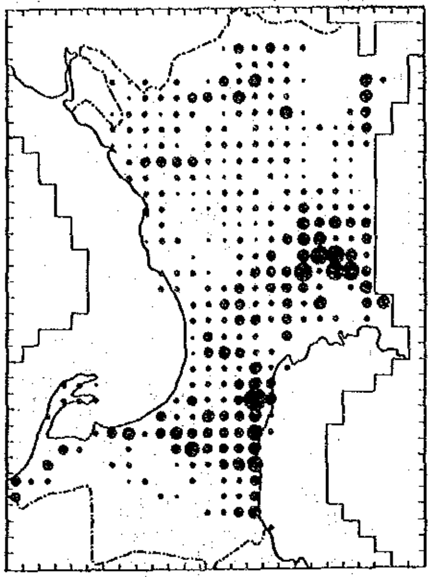
Plan(c)



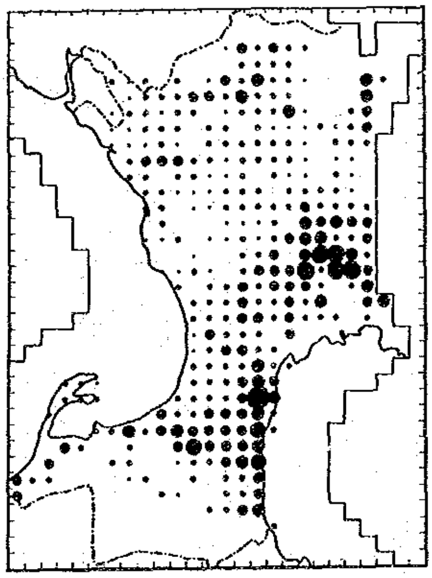
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.30
JAPAN INTERNATIONAL COOPERATION AGENCY	DISCHARGE DISTRIBUTION OF FUTURE PLANS IN 2010 (1)



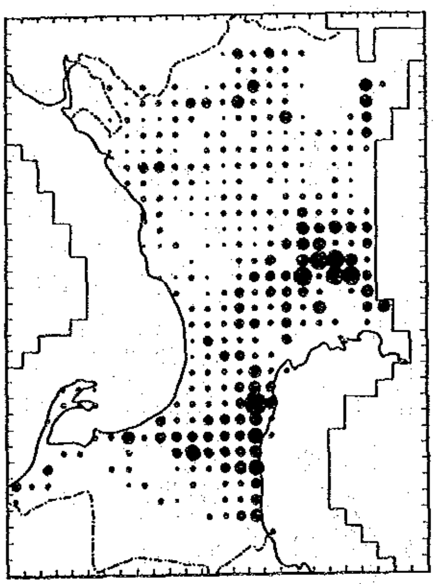
Plan(d)



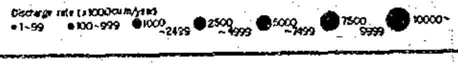
Plan(e)



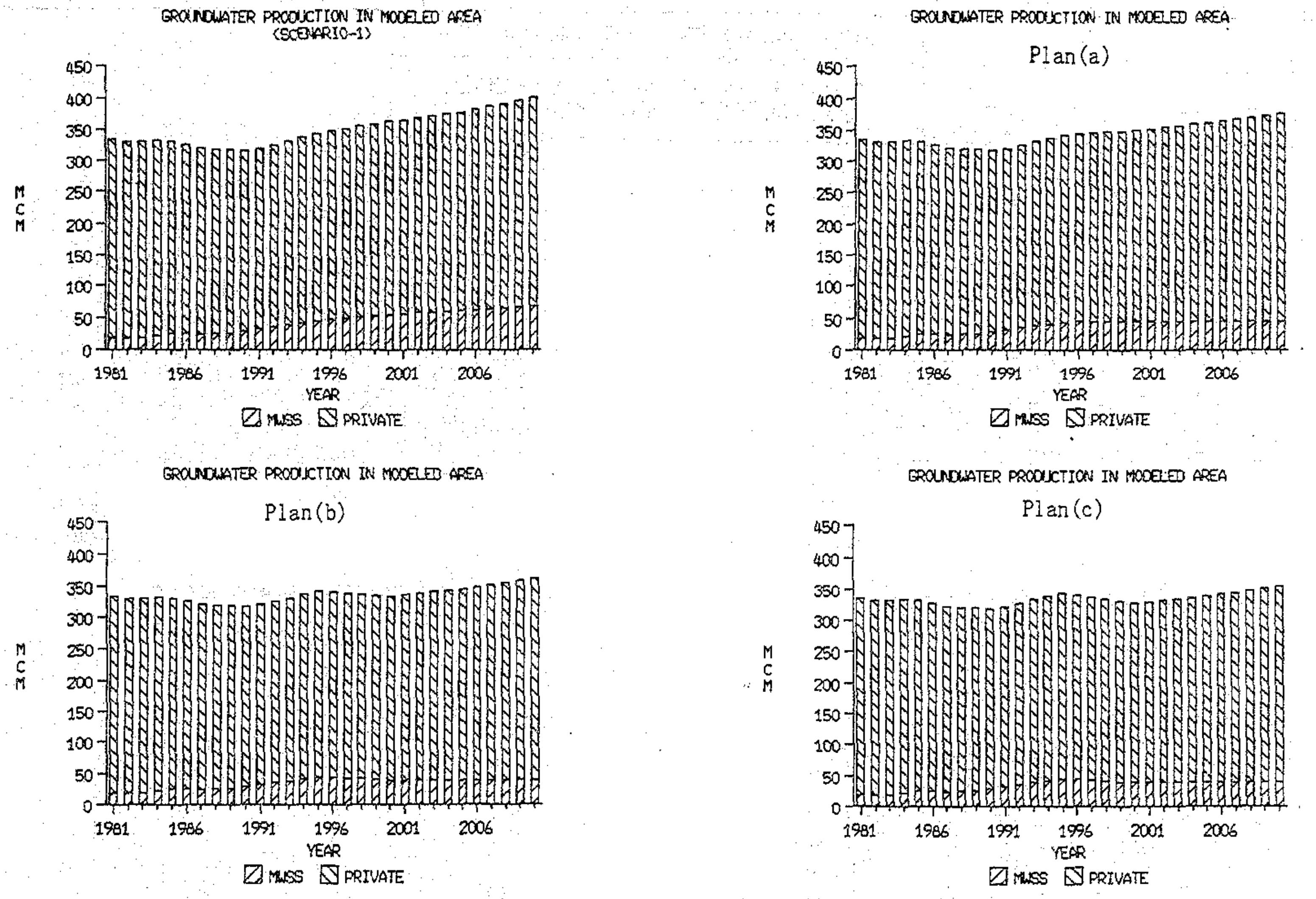
Plan(f)



Plan(g)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.31
JAPAN INTERNATIONAL COOPERATION AGENCY	DISCHARGE DISTRIBUTION OF FUTURE PLANS IN 2010 (2)

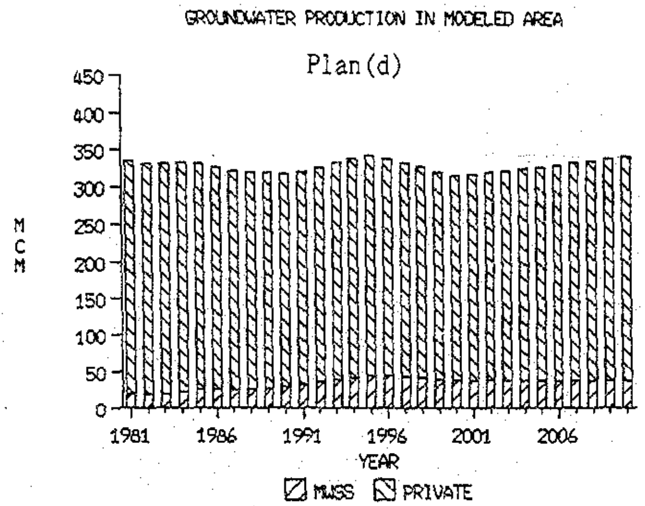


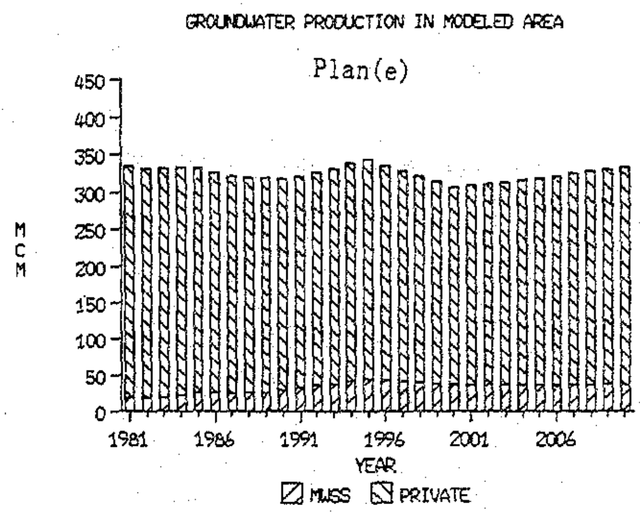
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

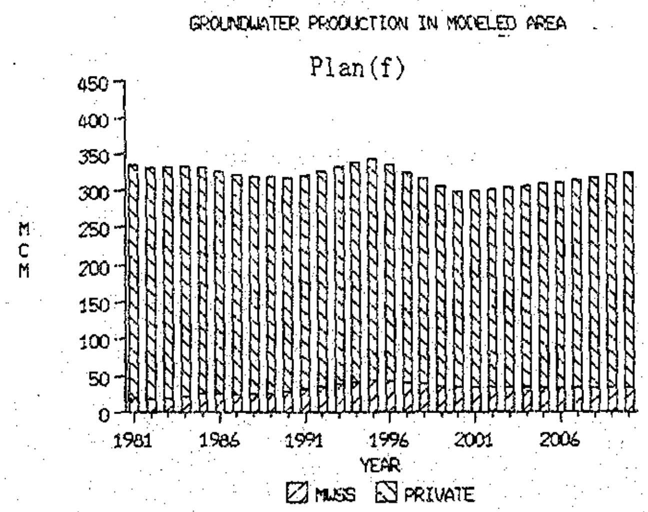
JAPAN INTERNATIONAL COOPERATION AGENCY

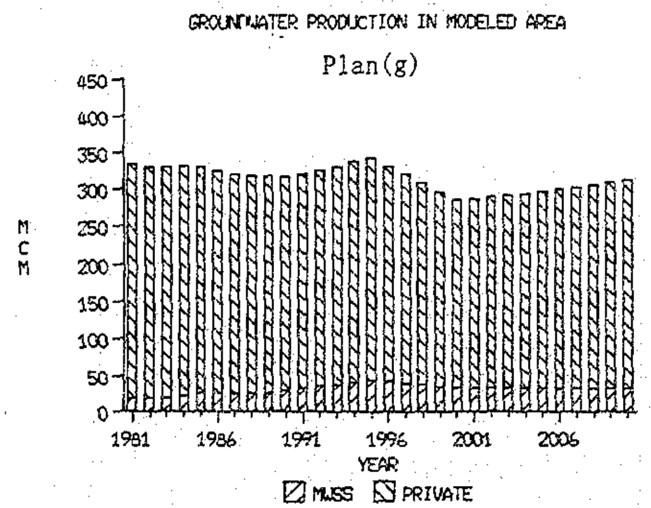
FIGURE 8.5.32

YEARLY DISCHARGE OF FUTURE PLANS (1)

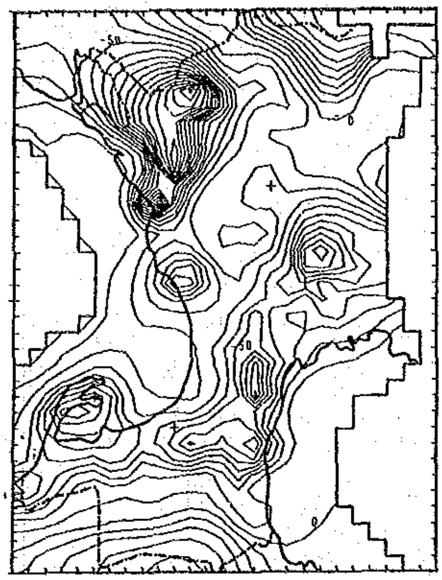




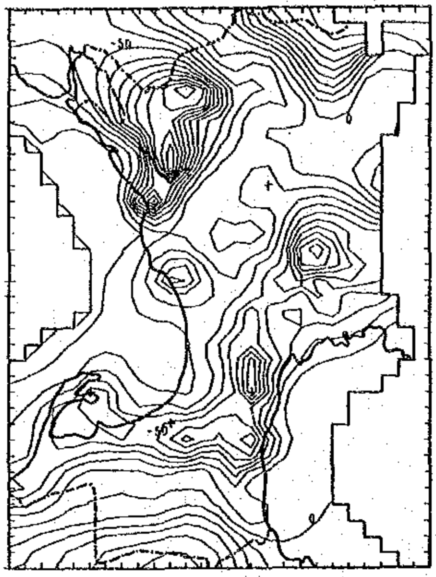




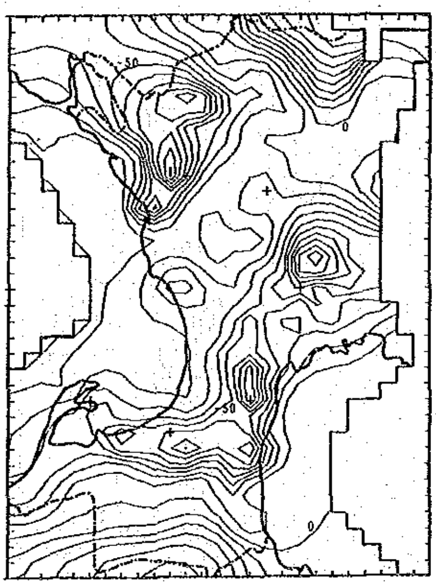
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.33
JAPAN INTERNATIONAL COOPERATION AGENCY	YEARLY DISCHARGE OF FUTURE PLANS (2)



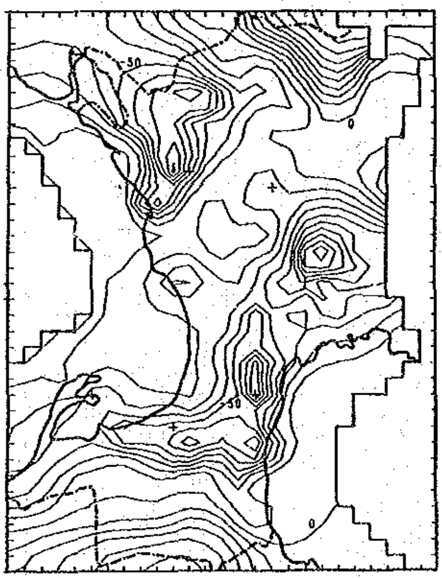
Scenario 1



Plan(a)



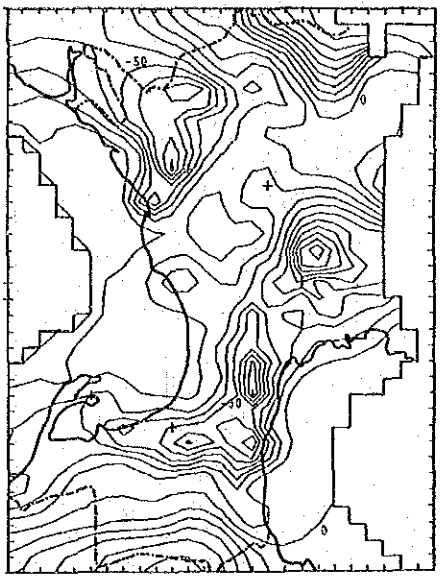
Plan(b)



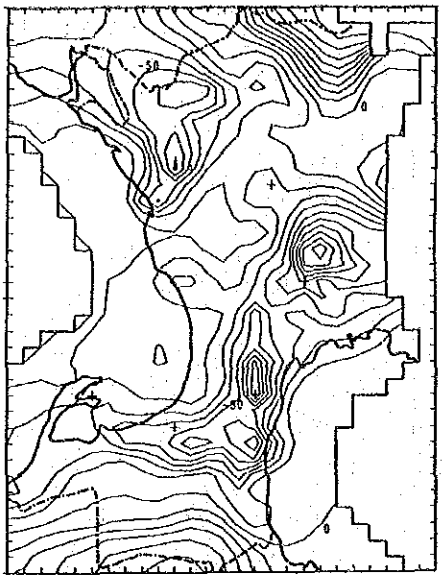
Plan(c)

(Contour Interval: 10m, Unit: masl)

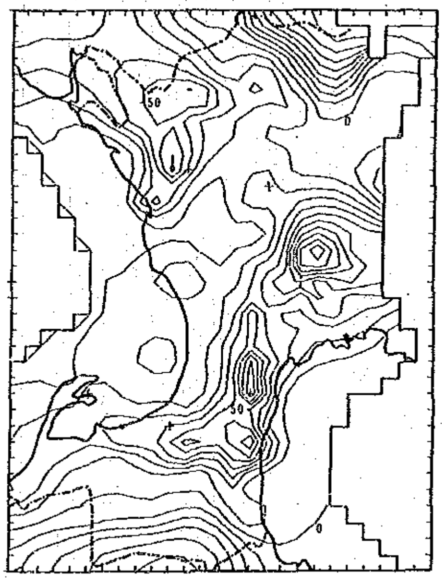
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.34
JAPAN INTERNATIONAL COOPERATION AGENCY	SIMULATED PIEZOMETRIC HEADS IN 2010 BY THE FUTURE DISCHARGE PLANS (1)



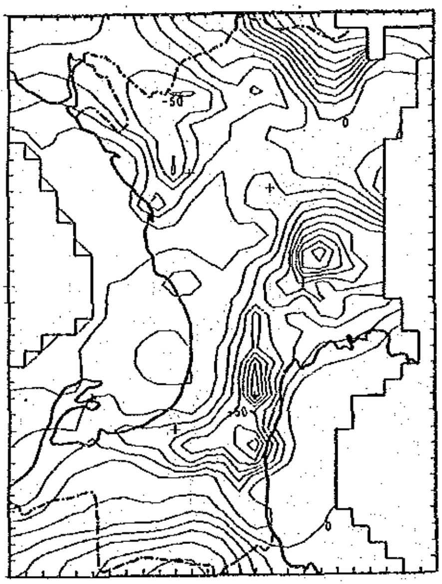
Plan(d)



Plan(e)



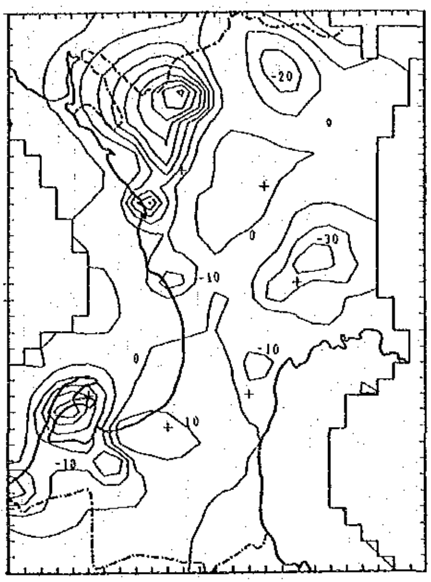
Plan(f)



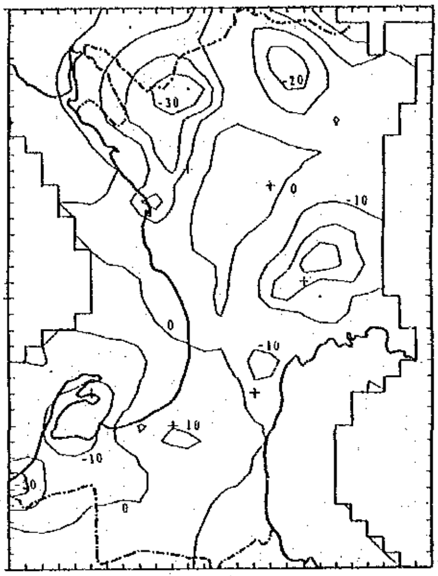
Plan(g)

(Contour Interval: 10m, Unit: masl)

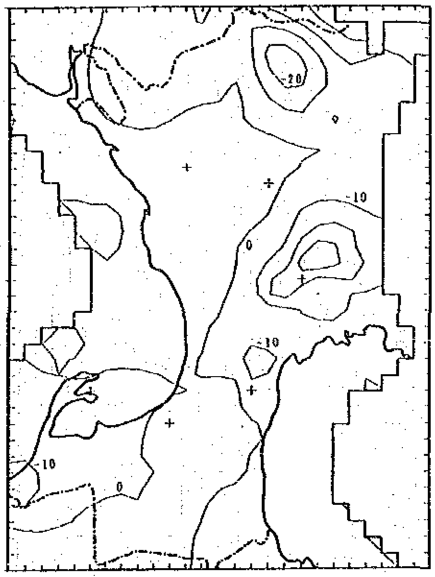
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.35
JAPAN INTERNATIONAL COOPERATION AGENCY	SIMULATED PIEZOMETRIC HEADS IN 2010 BY THE FUTURE DISCHARGE PLANS (2)



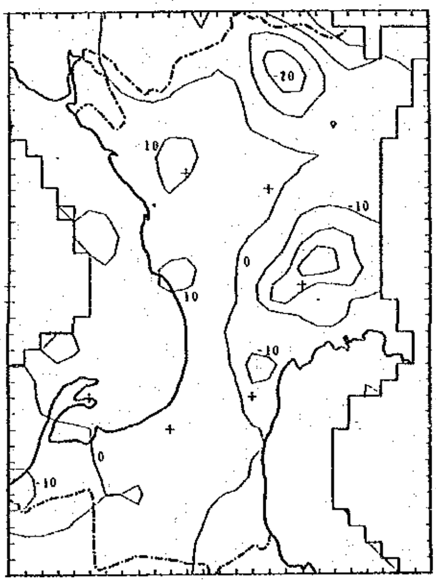
Scenario 1



Plan(a)



Plan(b)



Plan(c)

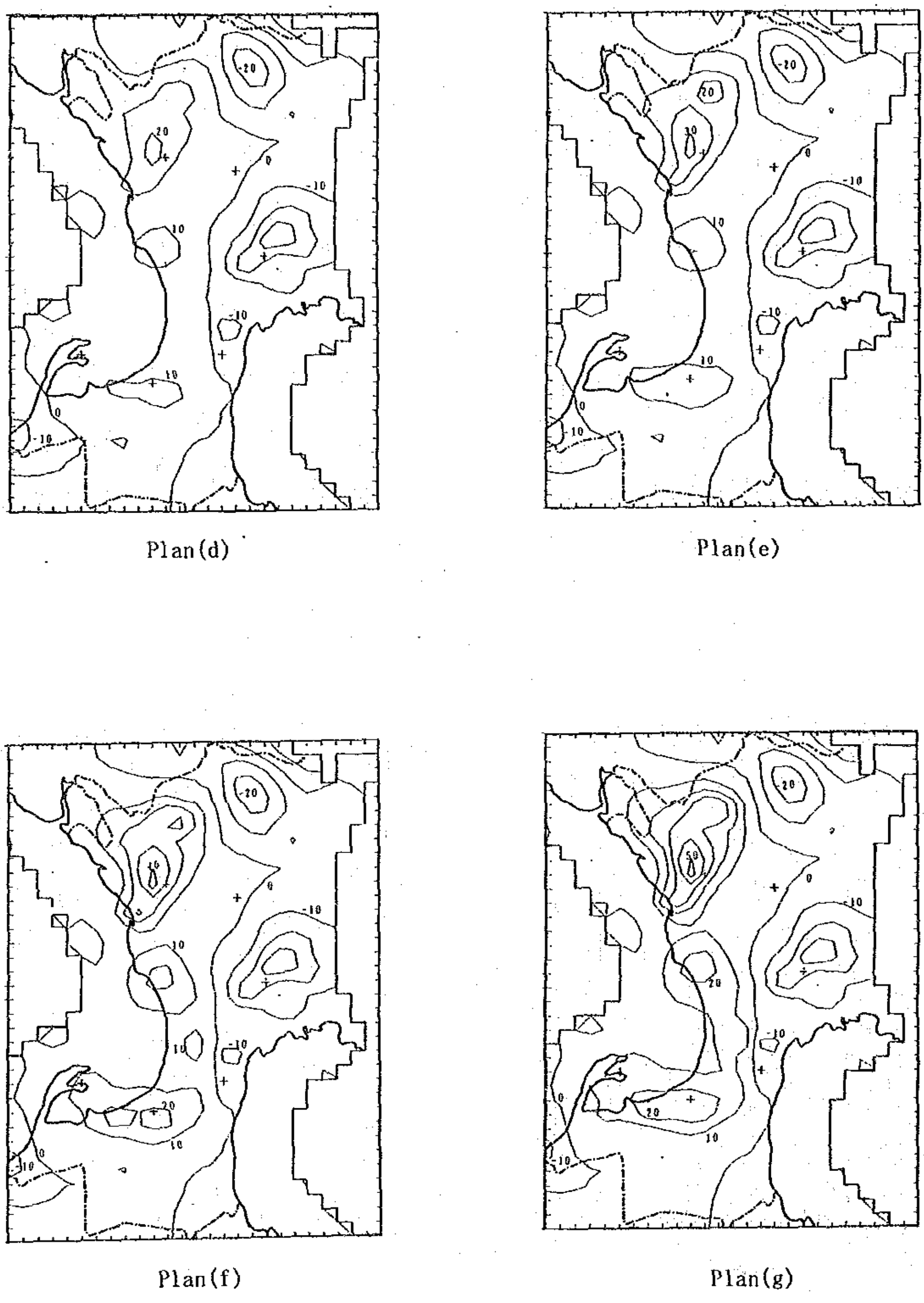
(Contour Interval: 10m, Unit: m)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

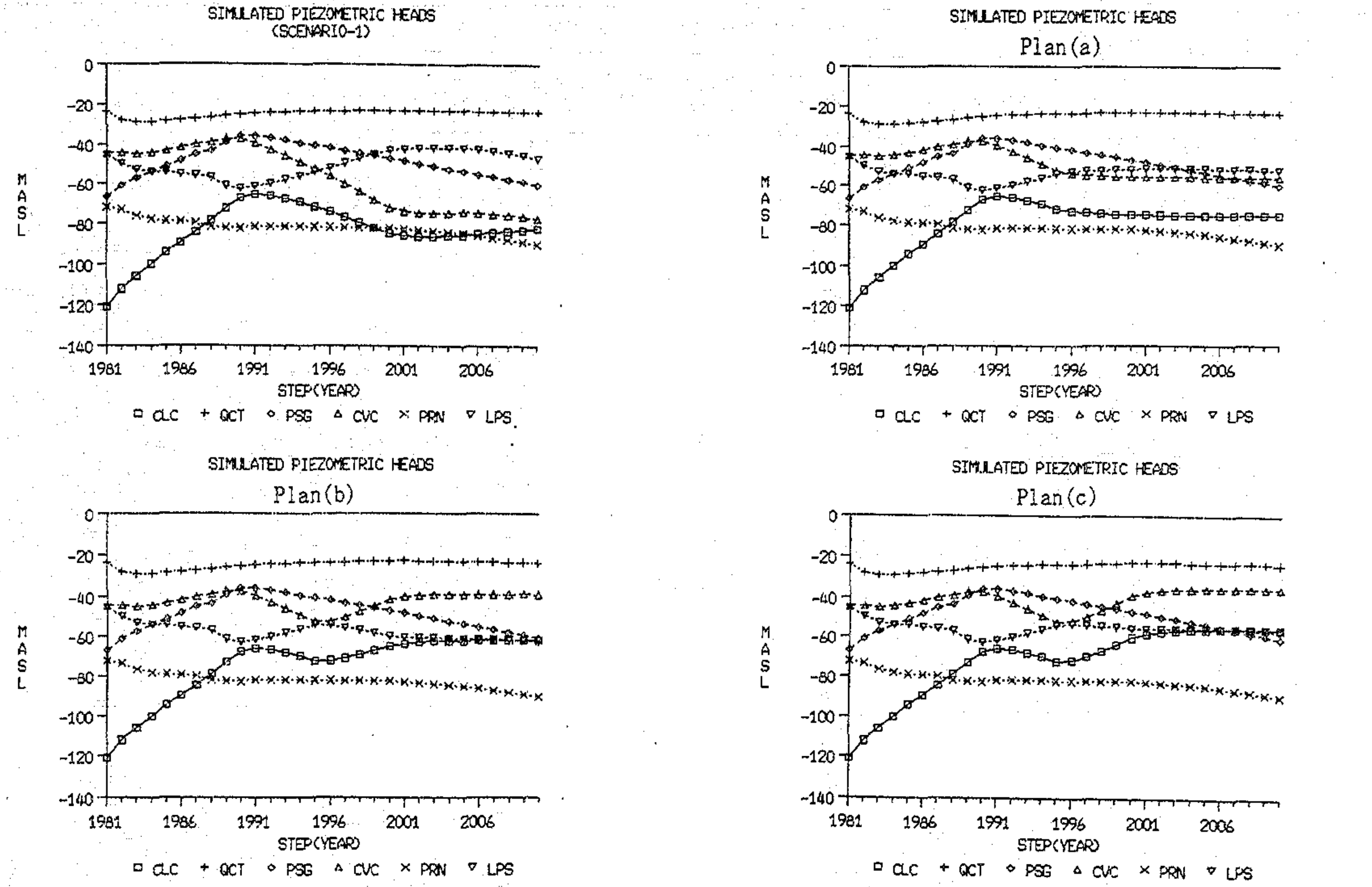
FIGURE 8.5.36

SIMULATED PIEZOMETRIC CHANGES FROM 1991 TO 2010 BY THE FUTURE DISCHARGE PLANS (1)



(Contour Interval: 10m, Unit: m)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.5.37
JAPAN INTERNATIONAL COOPERATION AGENCY	SIMULATED PIEZOMETRIC CHANGES FROM 1991 TO 2010 BY THE FUTURE DISCHARGE PLANS (2)

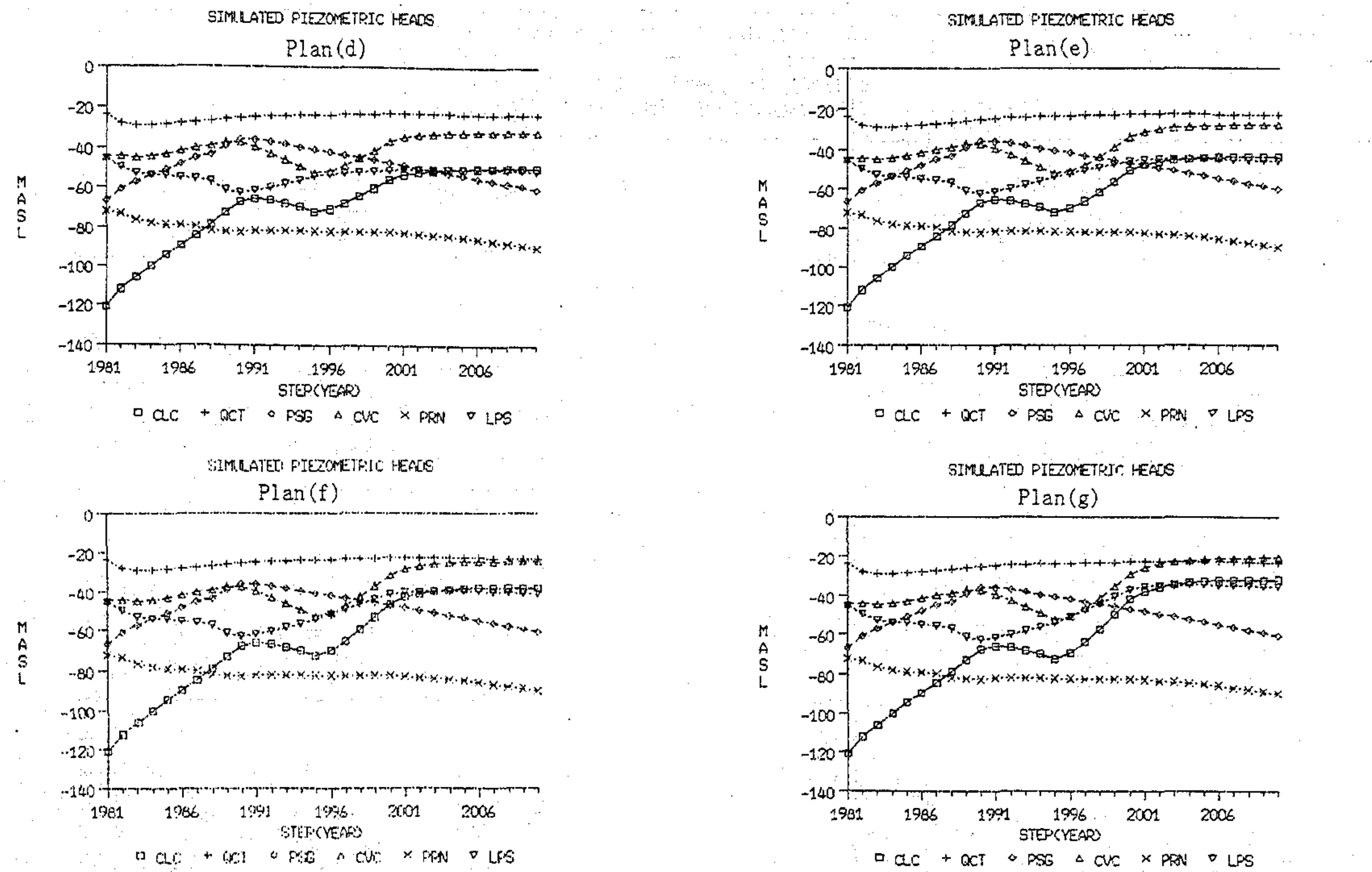


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.38

SIMULATED PIEZOMETRIC CHANGES BY THE FUTURE DISCHARGE PLANS (1)

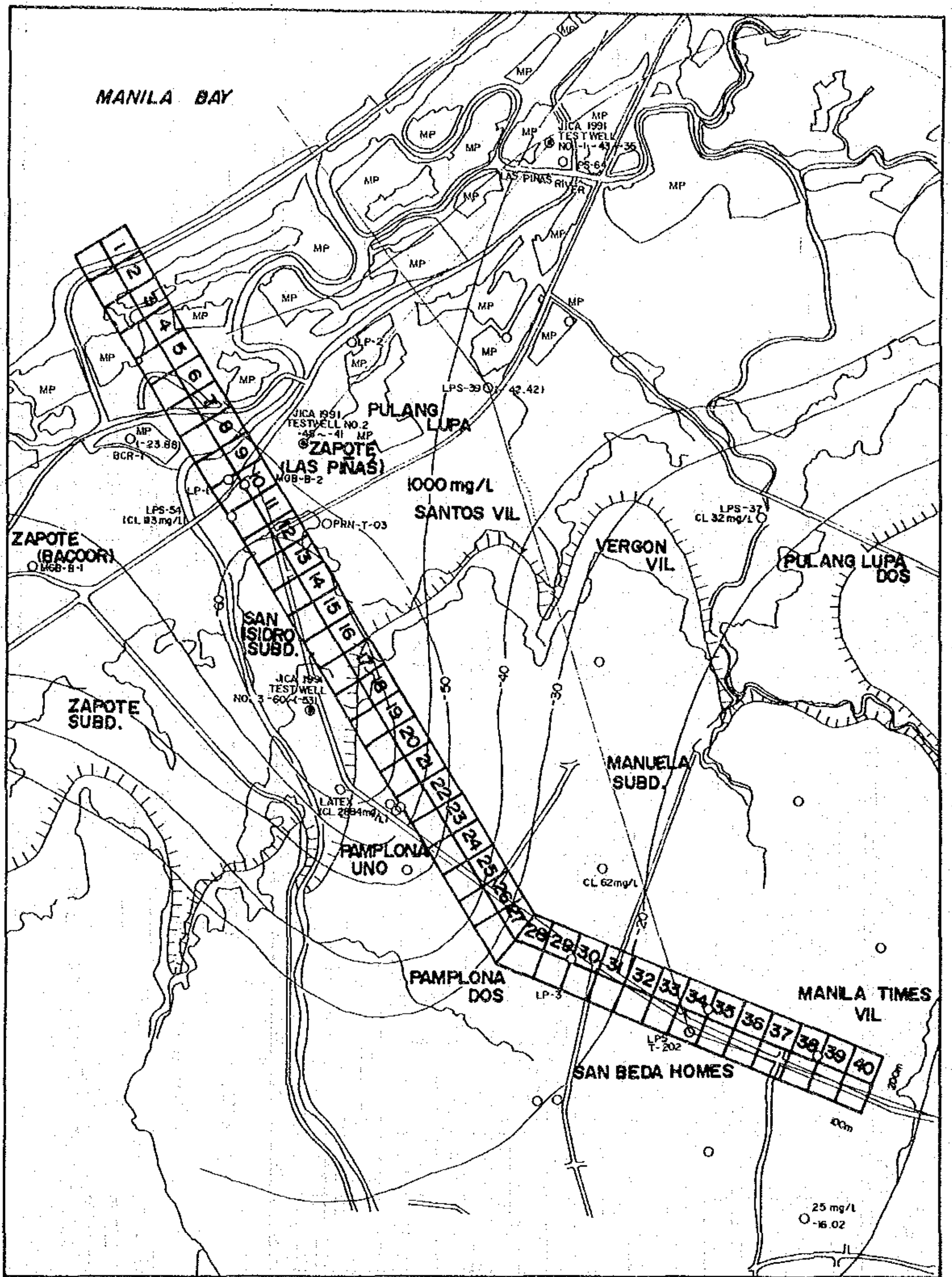


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

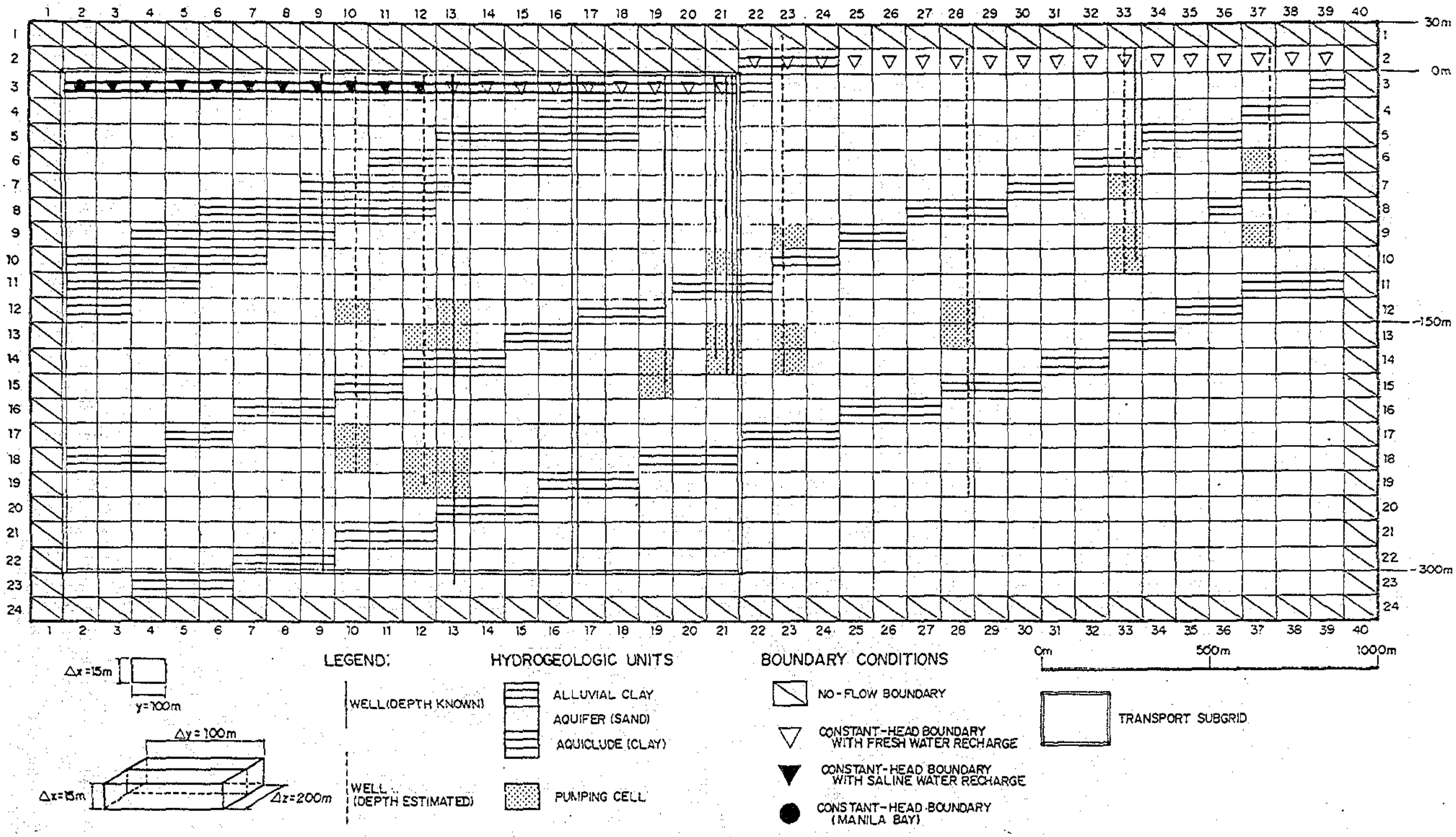
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.5.39

SIMULATED PIEZOMETRIC CHANGES BY THE FUTURE DISCHARGE PLANS (2)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.6.1 **LOCATION OF VERTICAL TWO-DIMENSIONAL MODEL FOR SALTWATER INTRUSION ANALYSIS**
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.6.2
VERTICAL TWO-DIMENSIONAL GRID FOR THE SOLUTE TRANSPORT AND DISPERSION MODEL IN LAS PIÑAS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
1	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	1
2	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	NF	2
3	NF	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	NF	3
4	NF	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	NF	4
5	NF	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	F	F	F	NF	5
6	NF	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	E	NF	6
7	NF	B	B	B	B	B	B	B	C	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	E	E	F	NF	7
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9	NF	B	B	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	NF	9
10	NF	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	NF	10
11	NF	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	NF	11
12	NF	C	C	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	H	H	H	NF	12
13	NF	D	D	D	D	D	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	H	H	H	H	H	NF	13
14	NF	D	D	D	D	D	D	D	D	D	D	E	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	H	H	H	H	H	H	H	NF	14
15	NF	D	D	D	D	D	D	D	D	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	H	H	H	H	H	H	H	H	H	NF	15
16	NF	D	D	D	D	D	E	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	H	H	H	H	H	H	H	H	H	H	H	H	NF	16
17	NF	D	D	D	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	NF	17
18	NF	E	E	E	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	NF	18
19	NF	F	F	F	F	F	F	F	F	F	F	F	F	F	F	G	G	G	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	NF	19
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23	NF	F	F	G	G	G	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	NF	23
24	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	24
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	

Label	Hydrogeologic Unit
A	Alluvium
B	Aquifer-1
C	Aquiclude-1
D	Aquifer-2
E	Aquiclude-2
F	Aquifer-3
G	Aquiclude-3
H	Aquifer-4
NF	No-Flow Boundary

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 8.6.3 MODELED HYDROGEOLOGIC UNIT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	0	2
3	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	0	3
4	0	182	182	182	182	182	182	182	182	182	182	182	182	182	182	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	28	0	4
5	0	182	182	182	182	182	182	182	182	182	182	182	4	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	2	28	28	28	0	5
6	0	182	182	182	182	182	182	182	182	182	4	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	28	28	28	28	28	2	0	6
7	0	182	182	182	182	182	182	182	4	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	28	28	28	28	28	2	2	28	0	7
8	0	182	182	182	182	4	4	4	4	4	4	4	51	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	2	28	28	28	28	28	28	2	28	28	28	0	8
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13	0	51	51	51	51	51	51	51	51	51	51	51	51	51	2	2	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	25	25	25	25	25	0	13
14	0	51	51	51	51	51	51	51	51	51	51	2	2	2	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	25	25	25	25	25	25	25	0	14
15	0	51	51	51	51	51	51	51	51	2	2	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	0	15
16	0	51	51	51	51	51	2	2	2	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	0	16
17	0	51	51	51	2	2	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0	17
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19	0	28	28	28	28	28	28	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0	19
20	0	28	28	28	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0	20
21	0	28	28	28	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0	21
22	0	28	28	28	28	28	2	2	2	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	0	22
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24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	

(UNIT : ft^2/s)

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FIGURE 8.6.4

TRANSMISSIVITY MAP OF LAS PIÑAS MODEL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	6
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	7
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	112	0	0	0	0	0	0	0	0	0	28	0	0	0	14	0	0	0	9
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	276	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	10
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	12
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	276	0	112	0	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	13
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	0	276	0	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	

(UNIT : ft/s)

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FIGURE 8.6.5

DISCHARGE MAP OF LAS PIÑAS MODEL

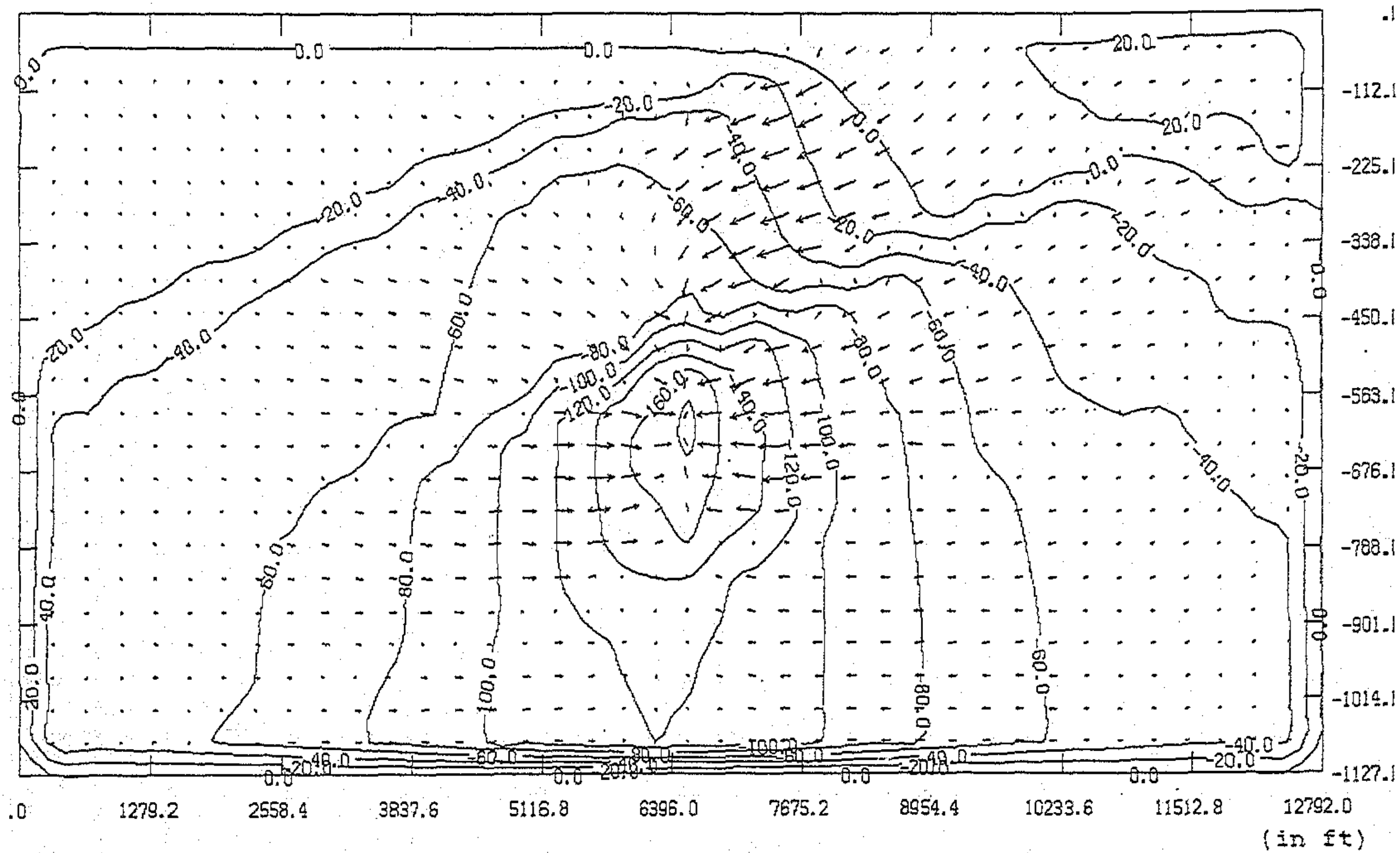

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FIGURE 8.6.6
SIMULATED PIEZOMETRIC HEADS
IN STEADY-STATE CONDITION

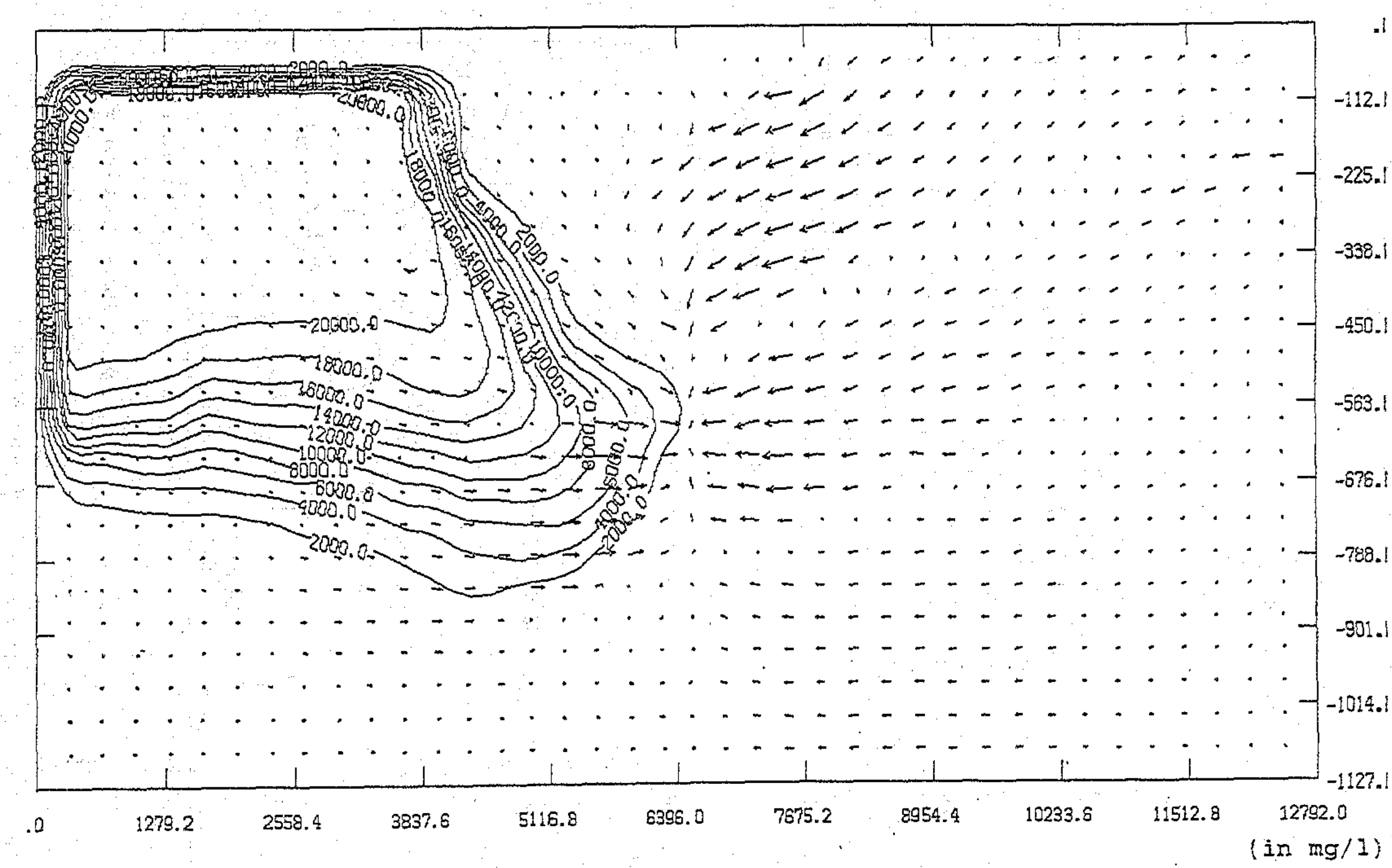

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FIGURE 8.6.7
COMPUTED CHLORIDE CONCENTRATIONn
AFTER 10 YEARS SIMULATION

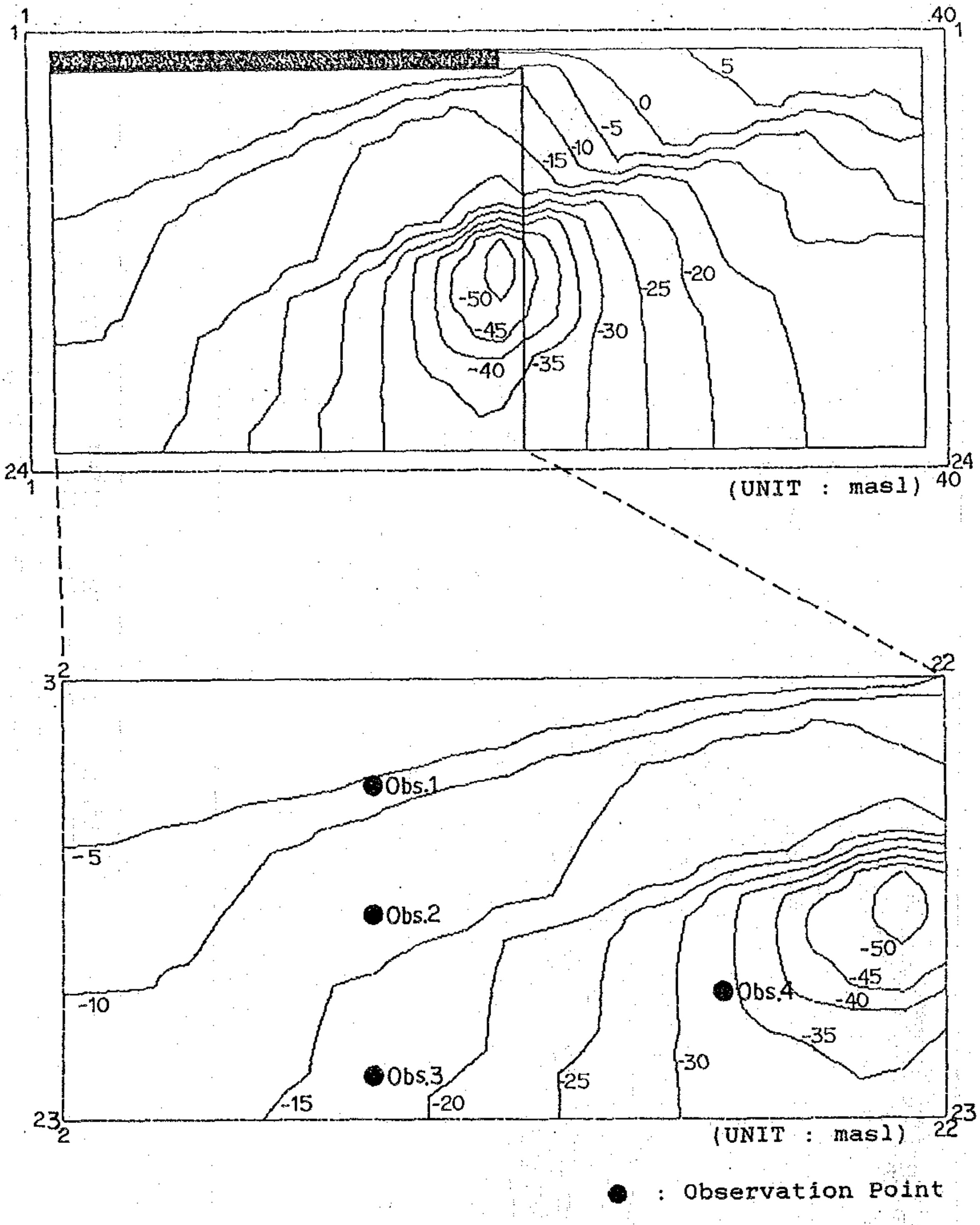

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FIGURE 8.6.8
SIMULATED PIEZOMETRIC HEADS IN TRANSPORT GRID

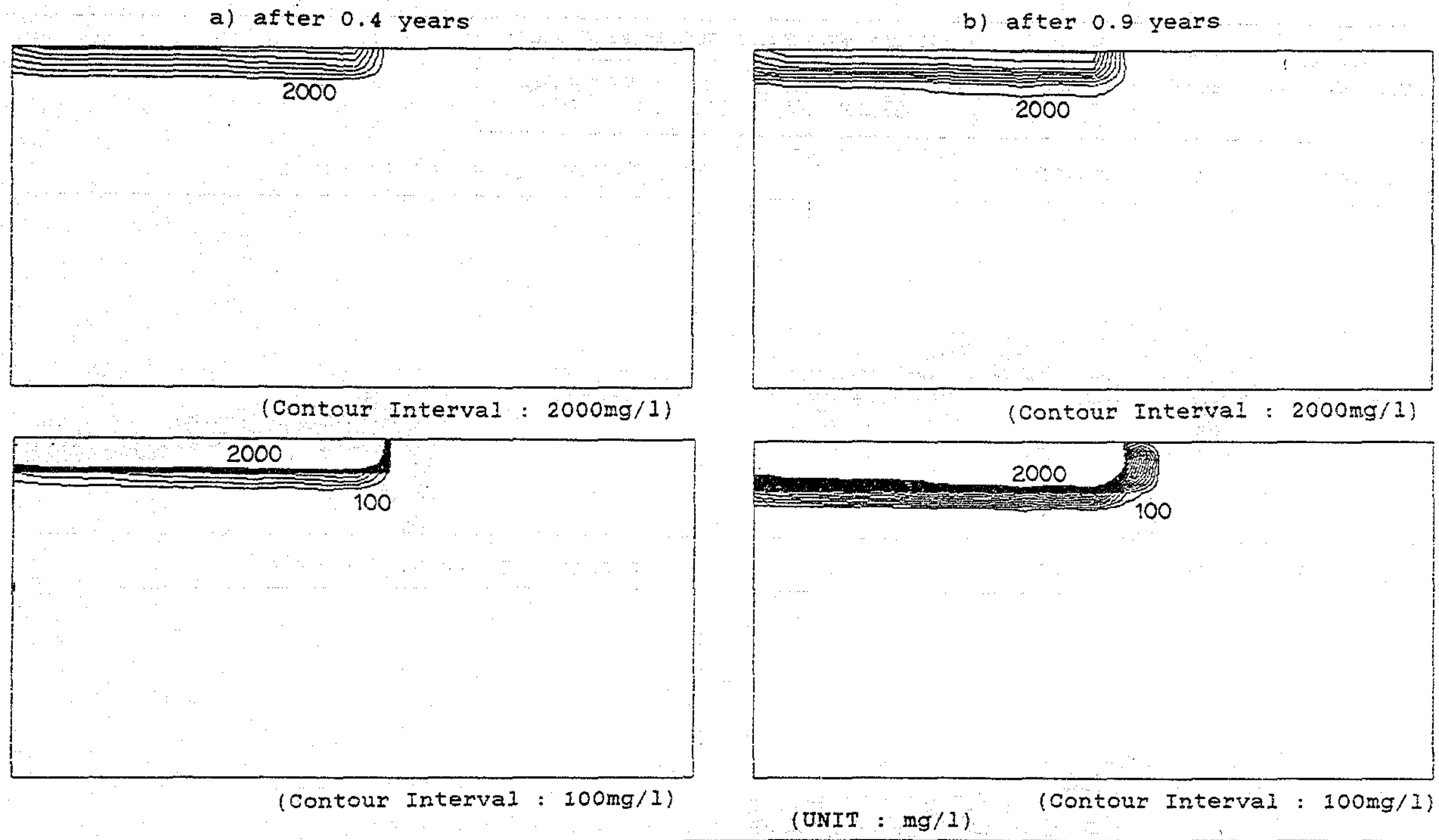

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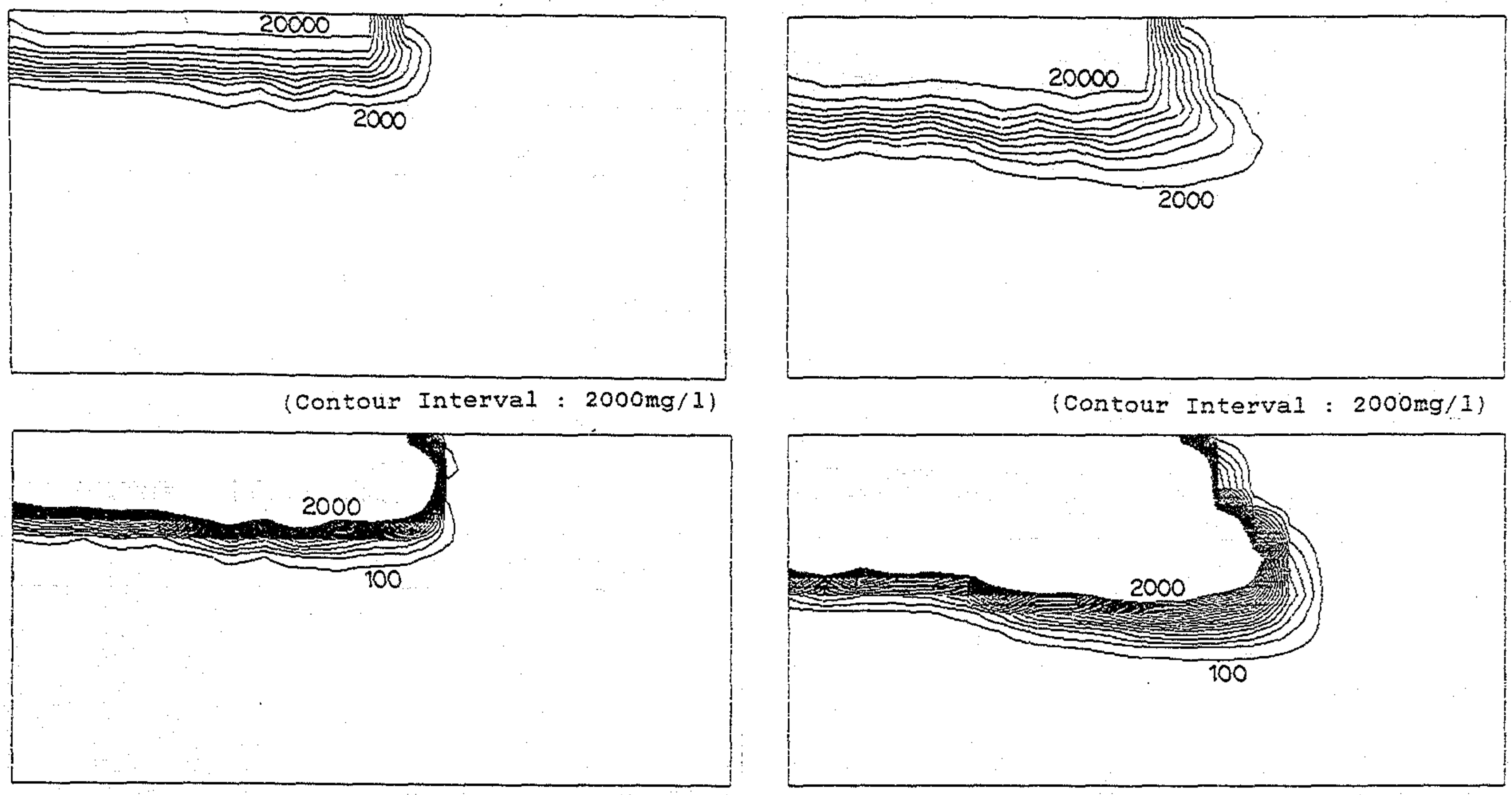
FIGURE 8.6.9
SIMULATED CHLORIDE CONCENTRATION
(AFTER 0.4 YEARS, 0.9 YEARS)

a) after 2.2 years

b) after 4.4 years



(Contour Interval : 2000mg/l) (Contour Interval : 2000mg/l)

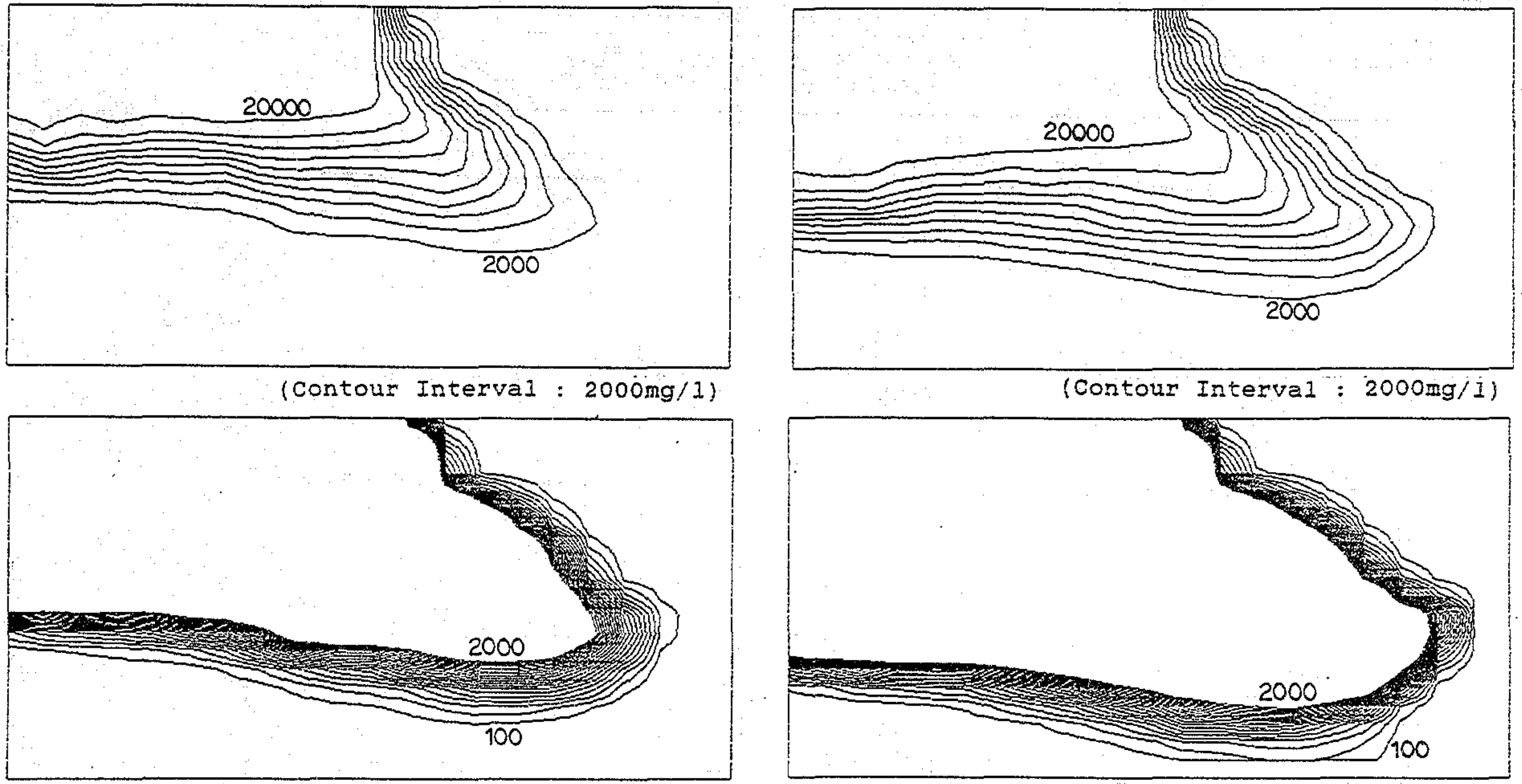
(Contour Interval : 100mg/l) (Contour Interval : 100mg/l)

(UNIT : mg/l)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.6.10 SIMULATED CHLORIDE CONCENTRATION (after 2.2 years, 4.4 years)
JAPAN INTERNATIONAL COOPERATION AGENCY	

a) after 7.1 years

b) after 10.0 years



(Contour Interval : 2000mg/l) (Contour Interval : 2000mg/l)

(Contour Interval : 100mg/l) (Contour Interval : 100mg/l)

(UNIT : mg/l)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 8.6.11 SIMULATED CHLORIDE CONCENTRATION (after 7.1 years, 10.0 years)
JAPAN INTERNATIONAL COOPERATION AGENCY	

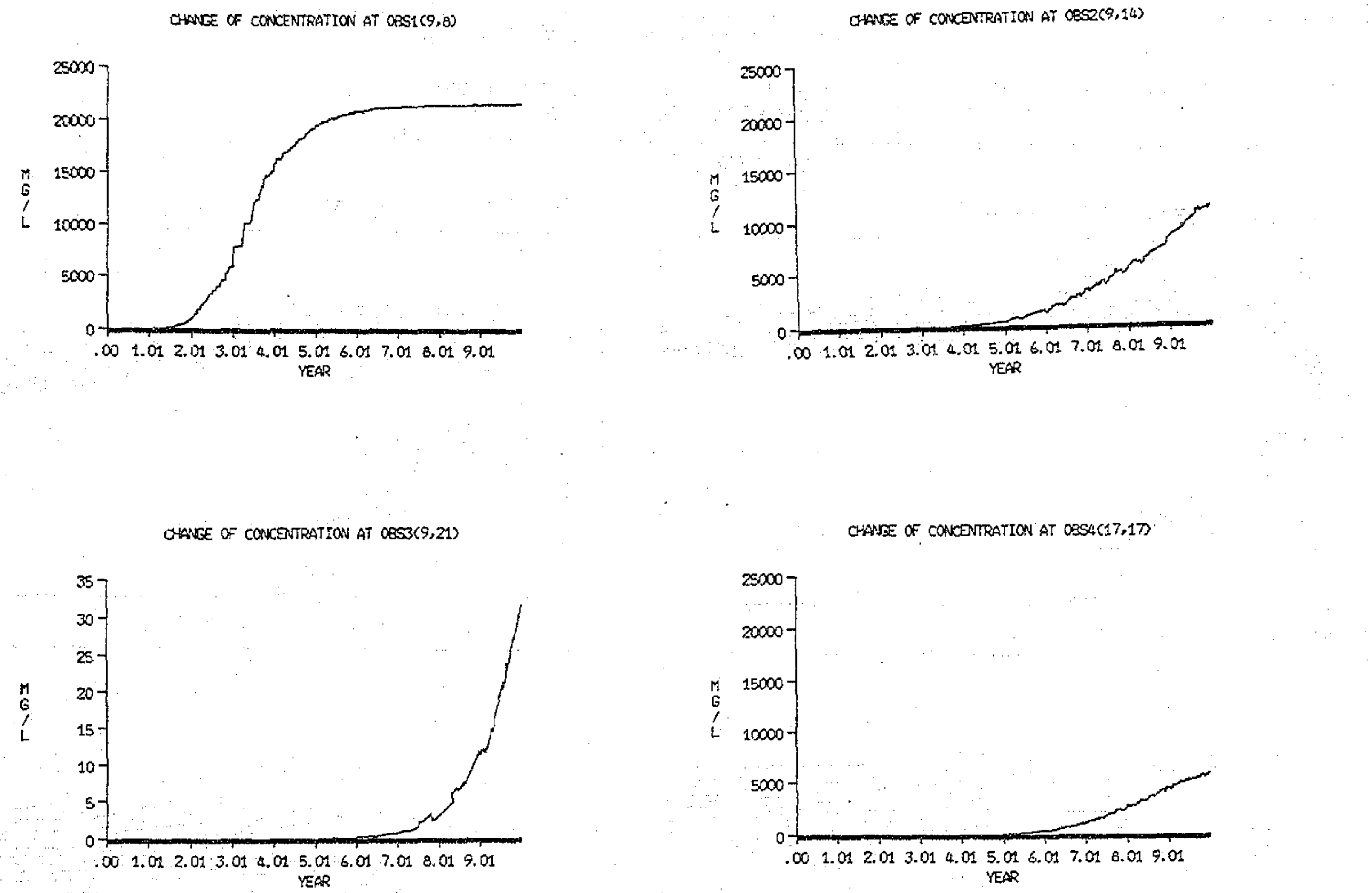


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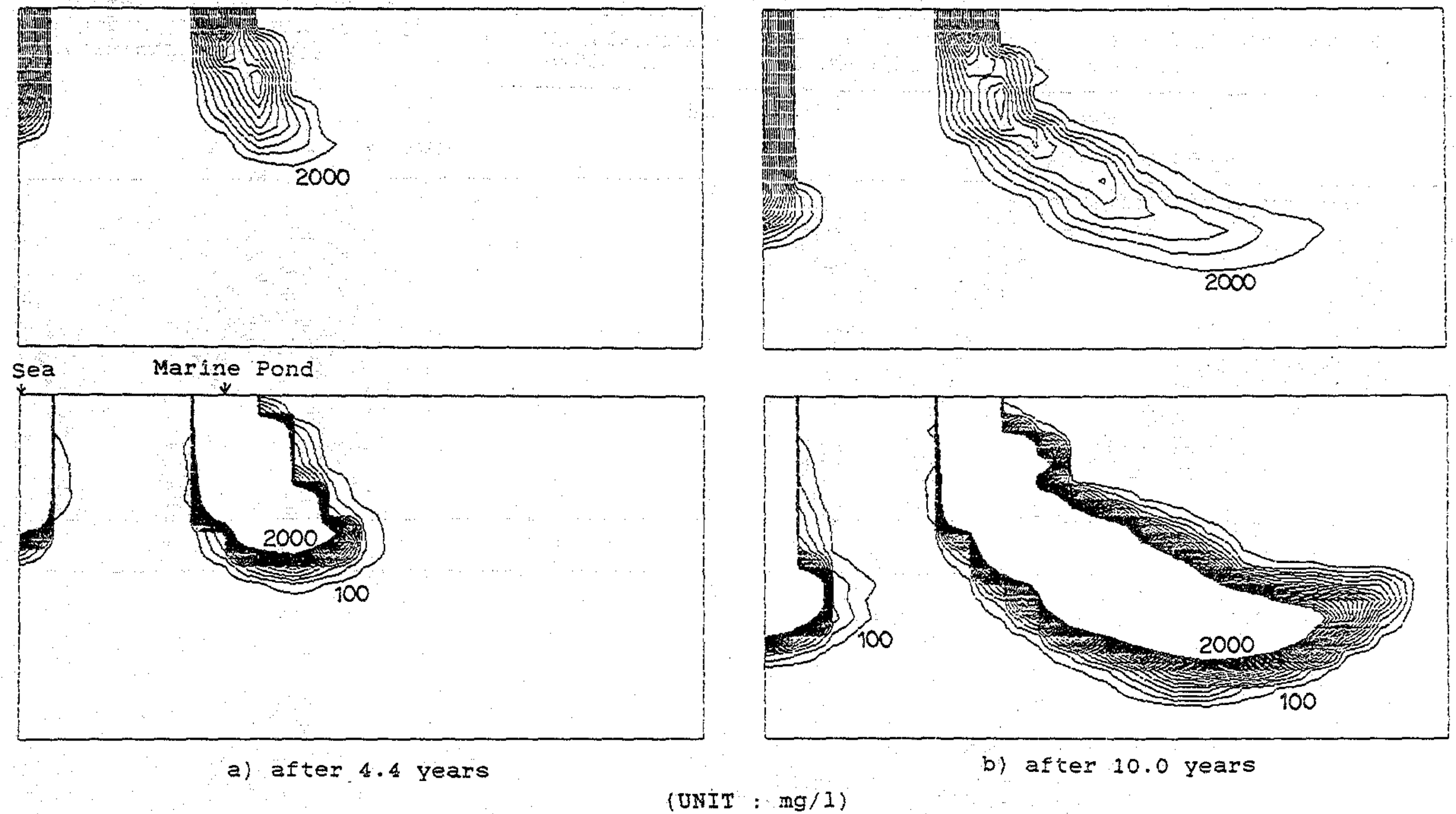
FIGURE 8.6.12
CHANGE OF CONCENTRATION AT OBSERVATION POINTS



[Contour Interval]
(Upper figure : 2000mg/l)
(Lower figure : 100mg/l)

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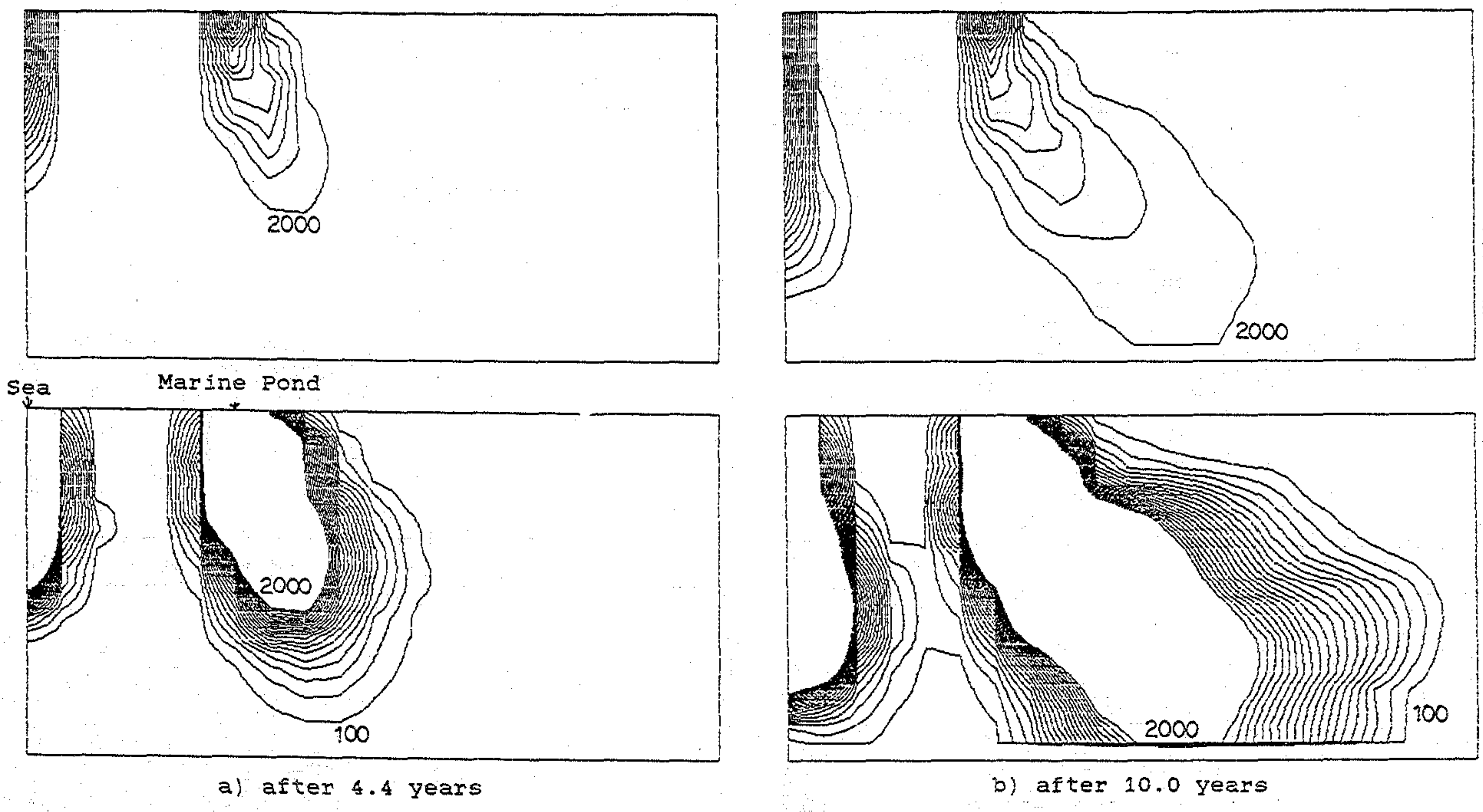
FIGURE 8.6.13
SIMULATED CONCENTRATION
(Dispersivity = 7.0 ft)



(UNIT : mg/l)

[Contour Interval]
(Upper figure : 2000mg/l)
(Lower figure : 100mg/l)

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FIGURE 8.6.14
SIMULATED CONCENTRATION
(Dispersivity = 33.0 ft)

CHAPTER 9

LAND SUBSIDENCE IN METRO MANILA

CHAPTER 9 LAND SUBSIDENCE IN METRO MANILA

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CHAPTER 9 LAND SUBSIDENCE IN METRO MANILA

9.1 INTRODUCTION

The rapid and heavy decline of groundwater levels in the coastal area throughout the 1960s and 1970s brought forth the belief that land subsidence may have occurred in some areas in Metro Manila.

Land subsidence in general is mainly caused by the withdrawal of groundwater, particularly in the alluvial plain. As the coastal areas of Manila Bay, Laguna de Bay and the area of Marikina River are covered by soft, clayey deposits of Alluvium age, the lowering of the groundwater head of underlying aquifers may cause the consolidation of these clayey deposits. Metro Manila in this sense has the requisite condition for land subsidence.

9.2 FIELD OBSERVATION

Indications of land subsidence are generally found at well sites, on roads, dikes, buildings, bridges, etc. They could also be observed on typical foundations such as piles of buildings and bridges. In the latter case, the displacement between ground surface and building can easily be identified. Inclination and cracks on walls of buildings due to unequal at-place subsidence rates may often be observed.

So that evidence regarding land subsidence in Metro Manila may be gathered, the Study Team conducted a field observation in the downstream area of the Pasig River and the coastal areas of Manila and Navotas. Several tall buildings and bridges located along the Pasig River -- from Nagtahan Bridge near Malacañang Palace to Jones Bridge--were investigated. No clear physical evidence of land subsidence was found by the Study Team. However, this does not mean that land subsidence is not happening in Metro Manila. What the outcome of the investigation provided was at least a negative evidence of land subsidence. The area's frequent flooding in the rainy season is due to its low elevation, not to land subsidence.

9.3 SOIL PROPERTIES OF ALLUVIAL CLAY

According to a previous soil and foundation study carried out by DPWH (1977), the ranges of consolidation characteristics of alluvial clay in the coastal areas of Pasay and Manila are those as shown in Figure 9.2.1 and Table 9.2.1. The data indicate that the alluvial clay is in normally consolidated condition. The range of consolidation parameters is basically the same as those of alluvial clays found in the world's coastal plains.

The clay layer can be consolidated easily by overburden or by the decline of pore water pressure. The final settlement is determined by the stress and thickness of the consolidated layer.

As mentioned earlier, the alluvial clay is generally thin with its distribution being limited to the coastal areas of Metro Manila. In addition, groundwater is mainly pumped from deep Guadalupe aquifers. For these reasons, the probability of land subsidence taking place is nil, even though the area has the soil properties required for land subsidence.

9.4 RISE OF MEAN SEA LEVEL

The Mean Sea Level (MSL) data at the Manila South Harbor tide station seem to provide evidence of land subsidence. Table 9.3.1 lists the data and variations. The data came from NAMRIA (National Mapping and Resource Information Authority), formerly Bureau of Coast and Geodetic Survey (BCGS)).

Tides at the Manila South Harbor are measured and logged automatically on a recorder with a corresponding tide staff. The recorder and tide staff installed at Pier 13 of the Manila South Harbor were used till 1969. They were moved to Pier 15 in 1970.

The MSL of Manila has marked by risen since the mid-Sixties (Figure 9.3.1). Though not as marked, the same rising tendency and fluctuation of the MSL can be observed at Legaspi, Cebu and Davao. Worth noting too, and if a tectonic movement of the islands is imagined, is the similarity between the steep rise of the MSL in Manila and those in Legaspi, Cebu and Davao for the period 1987-89.

From Table 9.3.1, it may be noted that from 1965 to 1989 the MSL at Manila appears to have risen by 0.478 m. Therefore, and assuming the MSL does not change, it may be inferred that land subsidence is occurring in the vicinity of the tide staff.

9.5 ELEVATION OF BENCHMARKS

NAMRIA established benchmarks of first, second and third order levelings in Metro Manila. The location map of benchmarks is given in Figure 9.4.1.

BM4 was used before as the reference benchmark until its loss in 1969. It was replaced by BM4a in 1970, which then became the reference benchmark throughout the 1970s up to the time of its loss in 1980.

BM4b is a benchmark located at Intramuros, Manila and is used as the reference benchmark for the elevation of all benchmarks established in Metro Manila and nearby provinces. The elevation of BM4b is reckoned from MLLW (Mean Lower Low Water). The height of MLLW is reckoned from OTS (Zero of Tide Staff). The height of BM4b reckoned from the OTS that was established in 1901 is maintained at 5.3065m.

Since the location and elevation of the reference benchmark changed thrice, a comparison between the old and new elevations is virtually impossible. Besides, and even if the elevation of BM4b can be adjusted, making such comparison is difficult because BM4b itself may be sinking, perhaps due to land subsidence in the vicinity.

Though elevation of the reference benchmark is different, several benchmarks were compared in order to know the vertical tendency of the displacements of land in Metro Manila.

Figure 9.4.2 shows the location of leveling routes for comparison. One route is located along the coast in the north-south direction. Another traverses Metro Manila in the east-west direction.

Presented in Table 9.4.1 are the elevations of the recovered benchmarks located along the year-1987 route. The table also presents the elevation of the same benchmarks surveyed before 1966. Differences in elevation of these benchmarks between years 1966 and 1987 appear to indicate land subsidence at almost all benchmarks.

Several benchmarks, for instance, OS-2, GM-R4 and GM-S9, are located on a hill composed of consolidated Guadalupe formation. From the viewpoint of the mechanical properties of the rock, this kind of location may not subside in response to the abstraction of groundwater. Therefore, if these benchmarks are immovable and the differences can be ignored, elevations in 1987 can be made the same as the elevations before 1966. Assuming that GM-S9 is the reference benchmark of the levelings in 1987 and those before 1966, the differences in elevation of other benchmarks become almost negligible errors. There is no definitive evidence therefore of land subsidence occurring.

Obtaining clear evidence of land subsidence thus requires the establishment of immovable points (control points) in the regional leveling in Metro Manila. The control points should be placed in a nearby mountainous area composed of hard rocks in order to properly evaluate the difference in elevation of two different levelings.

TABLE 9.2.1 RANGES OF CONSOLIDATION CHARACTERISTICS

Area	Py (kg/cm^2)	Cv (cm2/min) Primary consolidation	Cv (cm2/min) 24-hr consolidation	mv.P	Cc
BB-1	h-0.5	0.18 to 0.42	0.1 to 0.2	1.27×10^{-1}	0.58
BB-3	h+0.2	less than 0.43	0.1 to 0.45	8.15×10^{-2}	0.38
BRA-1	h+0.2				0.37
BRA-2	h+0.48				0.28 to 0.58
BRA-3	h+0.06 to 0.27				
BL-1	h-0.73 to -0.35	0.13 to 0.33	3.8×10^{-2} to 1.8×10^{-1}	9×10^{-2} to 2.3×10^{-1}	0.41 to 1.86
BL-2	h-0.07 to +0.25	1.3×10^{-2} to 4.4×10^{-2}	1.1 x 10 to 2.4×10^{-1}	1.4 x 10	1.21 to 1.71
BL-4	h-0.68 to +0.33	1.9×10^{-1} to 1.7	4.2×10^{-3} to 6.4×10^{-1}	8.5×10^{-2} to 2.2×10^{-1}	0.66 to 2.36

DATA SOURCE: DPWH, 1977

TABLE 9.3.1 ANNUAL MEAN SEA LEVELS AND VARIATIONS

DATA SOURCE: NAMRIA

Year	MANILA OTS (1901) Mean m.	Divergence m.	LEGASPI OTS (1947) Mean m.	Divergence m.	CEBU OTS (1935) Mean m.	Divergence m.	DAVAO OTS (1947) Mean m.	Divergence m.	JOLO OTS (1947) Mean m.	Divergence m.	SAN FERNANDO OTS (1947) Mean m.	Divergence m.
1947	2 [2.236]		4 [1.595]		5 [1.806]				10 [1.999]			
1948	2.188	2.188	[1.543]	-0.052	1.728	-0.078	2 [1.833]		1.968	-0.031	1.363	
1949	2.181	-0.007	1.542	-0.001	1.720	-0.008	1.832	-0.001	6 [1.948]	-0.020	1.352	0.031
1950	2.25	0.069	1.545	0.003	1.804	0.082	1.938	0.106	1 [2.079]	0.131		
1951	2.205	-0.045	1.558	0.013	1.733	-0.071	5 [1.820]	-0.118	2.022	-0.057		
1952	2.21	0.005	1 [1.607]	0.049	1.749	0.016	1 [1.912]	4 0.092	4 [2.034]	0.012		
1953	2.252	0.042	1 [1.630]	0.023	1.748	-0.001	1 [1.900]	-0.012	7 [1.994]	-0.040		
1954	2.238	-0.014	1 [1.626]	-0.004	1.773	0.025	1.894	-0.006	2.052	0.058		
1955	2.218	-0.02	1.633	0.007	1.781	0.008	1.928	0.034	2 [2.056]	0.004		
1956	2.234	0.016	1.620	-0.013	1.776	-0.005	2 [1.888]	-0.040	2.042	-0.014		
1957	2.173	-0.061	1.583	-0.037	5 [1.697]	-0.079	1 [1.842]	-0.046	1.988	-0.044		
1958	2.154	-0.019	1.592	0.009	10 [1.670]	-0.027	1.817	-0.025	2 [1.982]	-0.016		
1959	2.18	0.026	1.590	-0.002	1.714	0.044	1.838	0.021	-			
1960	2.245	0.065	1.605	0.015	1.742	0.028	1.912	0.074	2.016			
1961	2.215	-0.03	1.579	-0.026	1.711	-0.031	1.866	-0.046	1 [1.971]	-0.045		
1962	2.234	0.019	1.613	0.034	1.755	0.044	1.932	0.066	2.024	0.053		
1963	2.195	-0.039	1.571	-0.042	1.693	-0.062	1 [1.873]	-0.059	1.962	-0.062		
1964	2.219	0.024	1.594	0.023	1.718	0.025	1.903	0.030	1.975	0.013		
1965	2.238	0.019	1.612	0.018	1 [1.722]	0.004	2 [1.897]	-0.006	1.970	-0.005		
1966	2.262	0.024	1.618	0.006	1.725	0.003	1.912	0.015	1.972	0.002		
1967	2.288	0.026	1.572	-0.046	2 [1.724]	-0.001	1.904	-0.008	1.946	-0.026		
1968	2.283	-0.005	1.548	-0.024	1 [1.697]	-0.027	1.932	0.028	1.952	0.006		

[ ] Number of months due to instrument breakdown.

The integer above the bracket means the number of months.

TABLE 9.3.1 (CONTINUATION)

Page 2 DATA SOURCE: MAMRIA

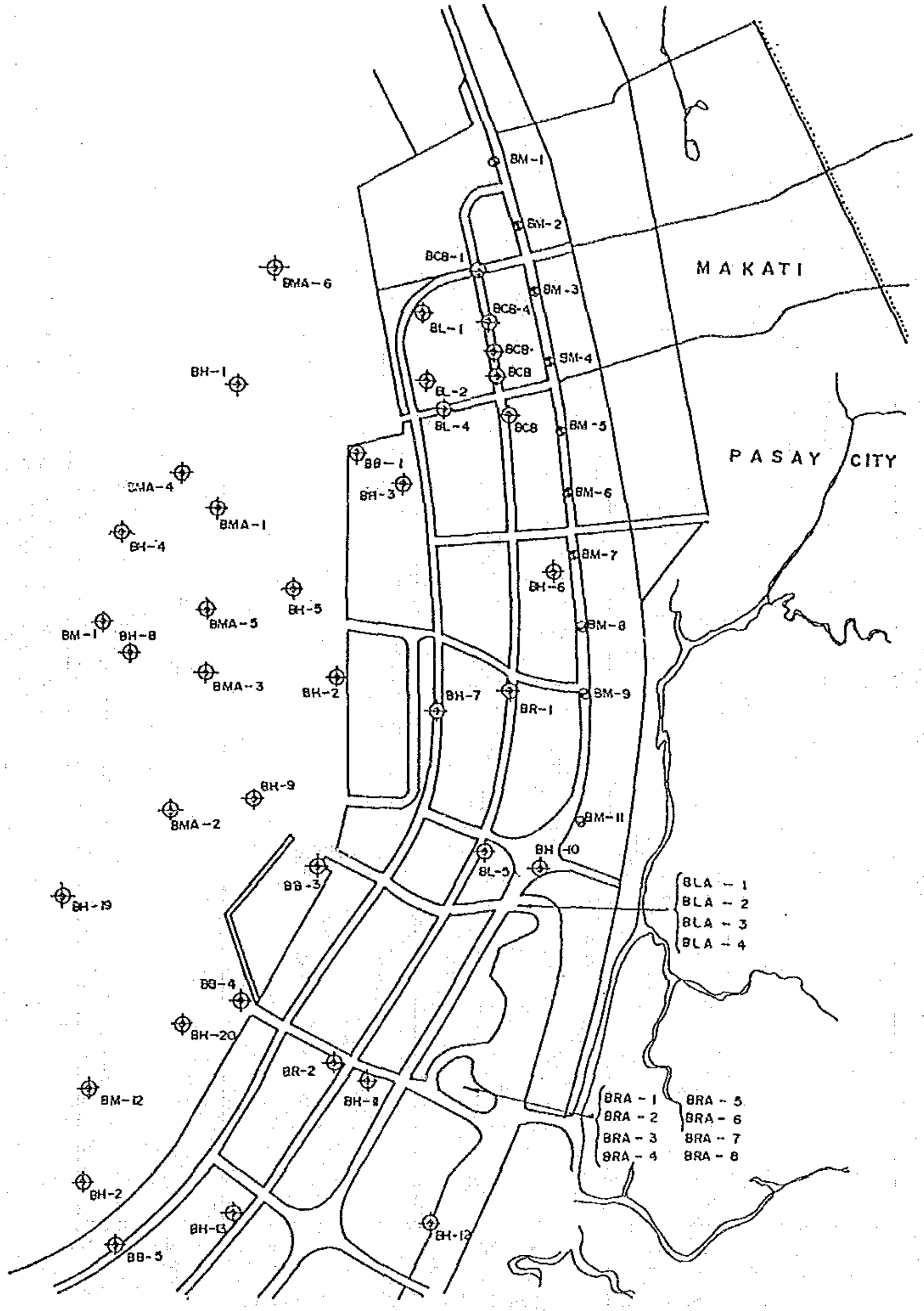
	MANILA OTS (1901)		LEGASPI OTS (1947)		CEBU OTS (1935)		DAVAO OTS (1947)		JOLO OTS (1947)		SAN FERNANDO OTS (1947)	
Year	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.
1969	2.328	0.045	1.533	-0.015	1.657	-0.040	1.888	-0.044	1.938	-0.014		
1970	2.400	0.072	1.593	0.060	4 (1.678)	0.021	1 (1.952)	0.064	2.008	0.070		
1971	2.431	0.031	1 (1.612)	0.019	3 (1.773)	0.095	2.022	0.070	2.019	0.011		
1972	2.441	0.010	1.588	-0.024	1.712	-0.061	6 (1.925)	-0.097	1.932	-0.087		
1973	2.423	-0.018	1.579	-0.009	1.781	0.069	1.998	0.073	1.991	0.059		
1974	2.488	0.065	1.652	0.073	1.871	0.090	1.994	-0.004	2 (2.031)	0.040		
1975	2.514	0.026	1.738	0.086	1 (1.788)	-0.083	2.056	0.062	1 (2.048)	0.017		
1976	1 (2.541)	0.027	1.698	-0.040	1.752	-0.036	1.979	-0.077	1.972	-0.076		
1977	1 (2.538)	-0.003	1.697	-0.001	1.745	-0.007	2.008	0.029	2.008	0.036		
1978	2.561	0.023	1.680	-0.017	7 (1.692)	-0.053	2.051	0.043	2 (2.004)	-0.004		
1979	2 (2.583)	0.022	1.668	-0.012	-		2.021	-0.030	-			
1980	2.536	-0.047	1.653	-0.015	6 (1.663)		1.956	-0.065	1.973			
1981	2.575	0.039	1.675	0.022	1.726	0.063	1.992	0.036	1 (1.991)	0.018		
1982	2.575	0.000	1.692	0.017	1.711	-0.015	1 (1.959)	-0.033	1.929	-0.062		
1983	1 (2.578)	0.003	1.745	0.053	1.668	-0.043	2.017	0.058	1.932	0.003		
1984	2.658	0.080	1.738	-0.008	1.769	0.101	2.130	0.113	1 (2.035)	0.103	1.484	
1985	2.632	-0.024	1.715	-0.022	6 (1.693)	-0.076	2.078	-0.052	4 (1.985)	-0.050	2 (1.461)	-0.023
1986	2.606	-0.026	1.682	-0.033	1 (1.726)	0.033	2.061	-0.017	1.980	-0.005	2 (1.397)	-0.064
1987	2.568	-0.038	1.657	-0.025	4 (1.745)	0.019	2.012	-0.049	3 (1.947)	-0.033	6 (1.433)	0.036
1988	2.647	0.079	1.762	0.105	1.787	0.042	2.113	0.101	2.022	0.075	1 (1.490)	0.057
1989	2.716	0.069	1.818	0.056			2.115	0.002			1.489	-0.001

( ) Number of months due to instrument breakdown.

The integer above the bracket means the number of months.

TABLE 9.4.1 ELEVATIONS OF SELECTED BENCHMARKS IN METRO MANILA

Bench Mark	Elevations (m) Above MSL 1987	Elevations (m) Above MSL before 1966	Difference (m)	Remarks
BM-25	3.220	3.254	-0.034	
GM-8A	2.812	2.834	-0.022	
GM-7A	3.371	3.348	0.023	
GM-6A	2.820	2.759	0.061	
GM-9M	3.235	3.317	-0.082	
GM-8Ma	3.014	---	---	
GM-7M	3.117	3.190	-0.073	
GM-6M	2.691	2.811	-0.120	
GM-5Ma	3.226	---	---	
GM-U2	2.645	---	---	
GM-U1A	3.098	---	---	
GM-V1A	2.817	---	---	
F-10	2.721	---	---	
BMX	2.813	---	---	
BM25	3.220	3.254	-0.034	
GM-3A	2.139	2.223	-0.084	
GM-9C	2.643	2.772	-0.129	
P2a	2.833	---	---	
CIMA18a	1.955	2.006	-0.051	
E-36a	2.089	---	---	
GM-4Ja	4.410	---	---	
GM-N3a	7.340	---	---	
GM-N4	9.140	9.347	-0.207	
OS-3	19.906	20.066	-0.160	
OS-2	25.159	25.310	-0.151	
OS-1a	36.162	---	---	
GM-R4	34.307	34.441	-0.134	
GM-S9	40.941	41.101	-0.160	
GM-S8	14.029	14.124	-0.095	
GM-S7a	8.135	---	---	
OC-1a	4.743	---	---	
OC-2	4.861	5.114	-0.253	
OC-3	5.421	5.547	-0.126	
OC-4a	6.697	---	---	
BMX	2.8132	---	---	
BM 81	1.831	---	---	
GM 9AB	3.446	---	---	
GM-1A	3.716	3.859	-0.143	
GM-1B	3.546	3.677	-0.131	
FA-1a	3.187	---	---	
GM-2B	2.738	2.866	-0.128	
GM-3Ba	3.429	3.567	-0.138	
GM-4Ba	2.919	---	---	
GM-1Eb	3.154	---	---	
GM-2Ea	2.325	---	---	
GM-1Fa	6.159	---	---	
GM-1Fb	6.133	---	---	
GM-2Fa	2.420	---	---	
GM-2Fb	1.732	---	---	
GM-3Fa	3.311	---	---	
GM-4F	2.100	2.660	-0.560	
D-1a	3.287	---	---	
GM-5Fa	1.994	---	---	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 9.2.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF FOUNDATION DRILLING (DPWH, 1977)

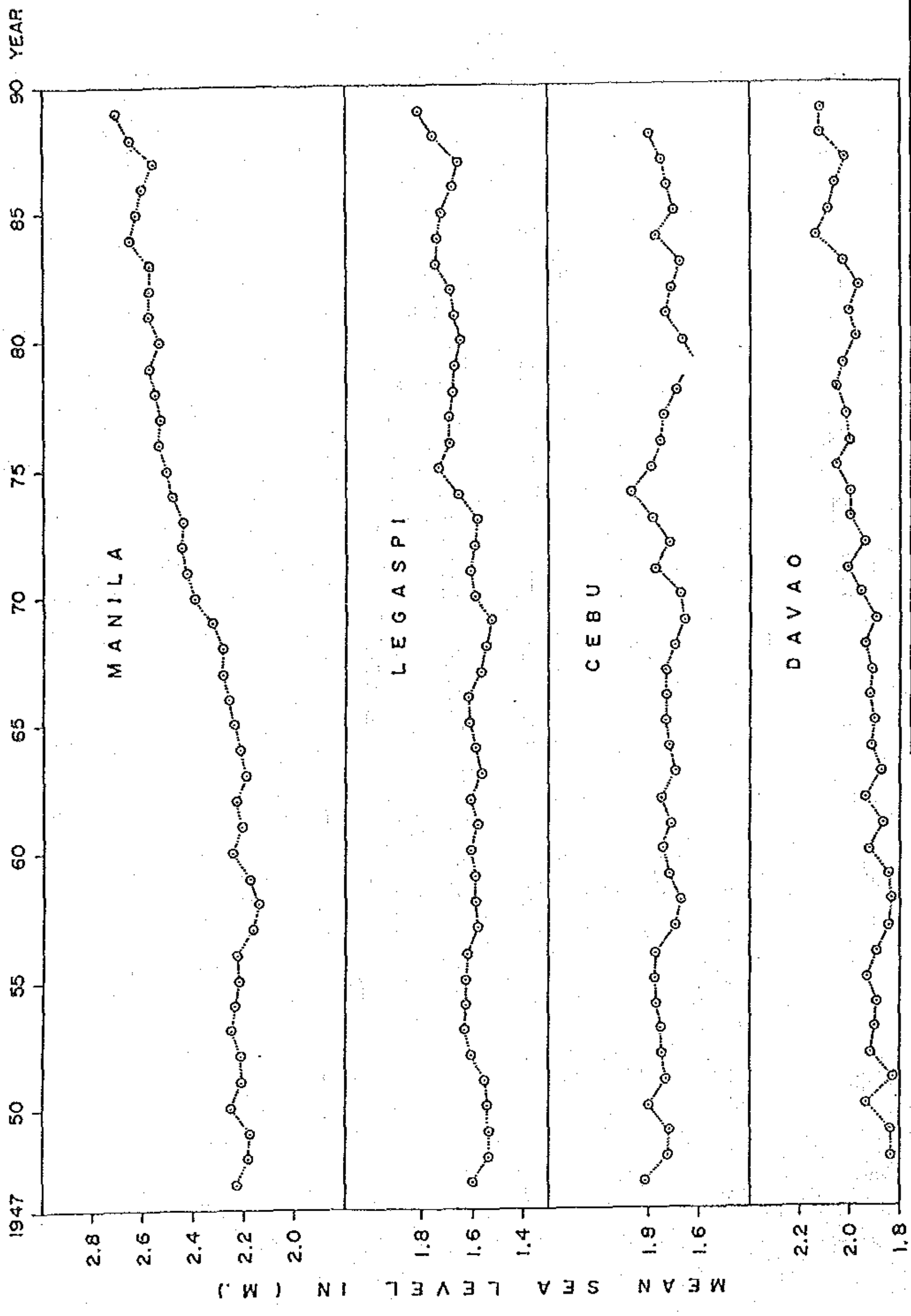
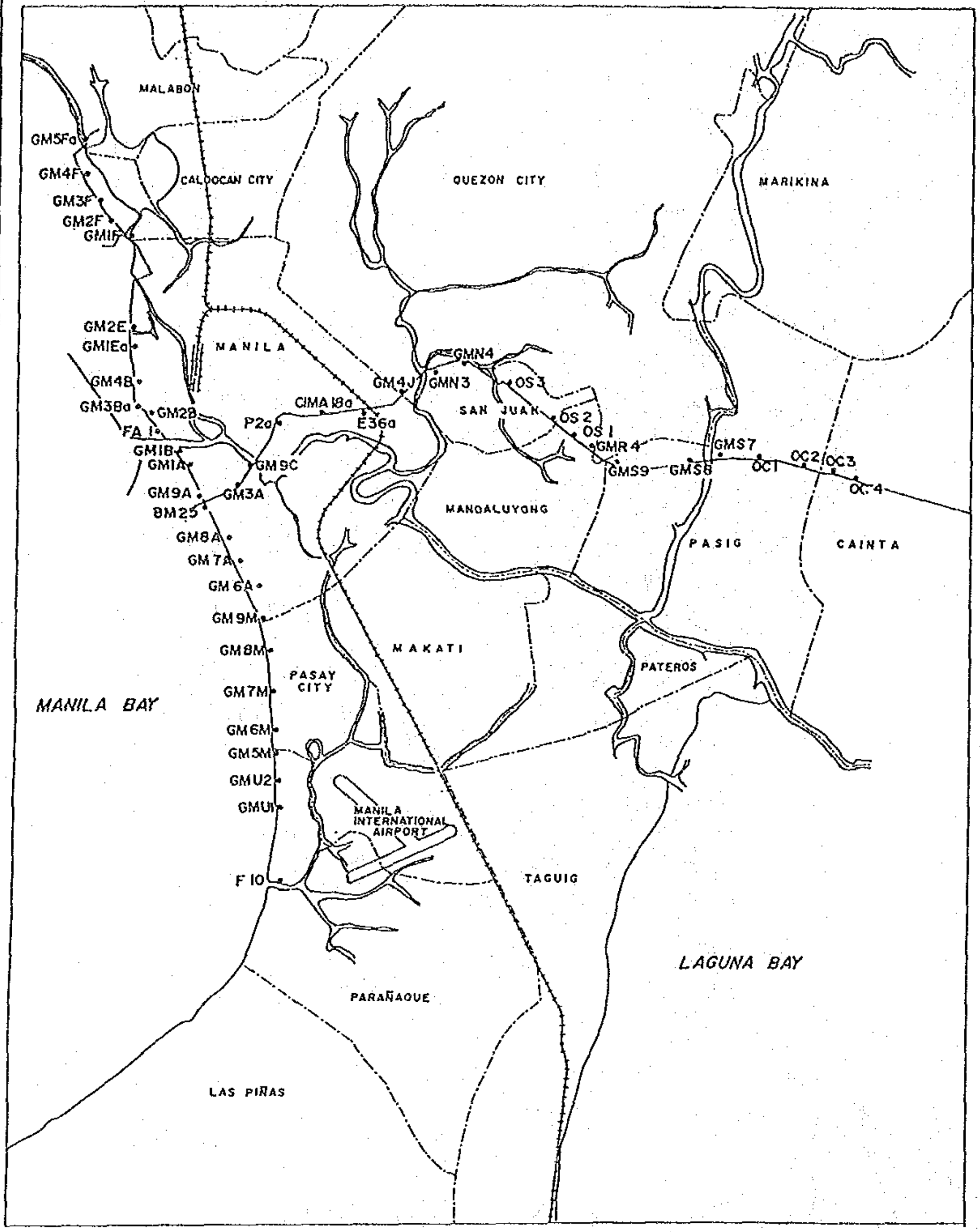


FIGURE 9.3.1 ANNUAL MEAN SEA LEVEL VARIATIONS

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 9.4.1
JAPAN INTERNATIONAL COOPERATION AGENCY	VERTICAL CONTROLS - METRO MANILA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 9.4.2
JAPAN INTERNATIONAL COOPERATION AGENCY	SURVEY ROUTE FOR COMPARISON

CHAPTER 10

ORGANIZATION AND MANAGEMENT

CHAPTER 10 ORGANIZATION AND MANAGEMENT

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CHAPTER 10 ORGANIZATION AND MANAGEMENT

10.1 MWSS ORGANIZATION

10.1.1 Introduction

The primary object of this chapter is to describe how the MWSS is organized, and then to examine, especially how the offices directly responsible for the operation, monitoring and maintenance of MWSS wells are managed.

The history of the modern water supply system in Metropolitan Manila has its roots in 1878 with the construction of the "Carriedo Waterworks", named after a retired Spanish Captain General, Don Francisco Carriedo y Pedro, who in 1743 bequeathed his entire fortune of ₱10,000 to Manila as the nucleus of a fund for the City's public water supply . This donation plus its accumulated interest was used in 1878 for the construction of said waterworks.

The "Carriedo Waterworks" which was completed in 1882 was the first properly-designed water supply system in the Far East. Its capacity of 15 Mlpd at the beginning was increased to 87 Mlpd in 1909, i.e., when its intake from the Marikina River in Santolan was transferred further upstream north to the town of Montalban.

In 1919, the Metropolitan Water District (MWD) was created by Republic Act No. 2832, to supply water for Manila and suburbs. Under its jurisdiction, the service area was expanded to include fourteen (14) adjoining cities and municipalities. With the Angat River as the new source of water supply, the construction of the Angat-Novaliches System was begun in 1925, with all the works completed in 1939. The first Balara treatment plant was constructed then, and this new system supplied 300 Mlpd.

After the World War II, on 18 June 1955, the National Waterworks and Sewerage Authority (NWSA) was created to take over the functions of the Metropolitan Water District, and at the same time, to centralize and consolidate under its administration all waterwoks and sewerage systems throughout the country, and so that the rehabilitation of water supply systems which were devastated during the war may be accelerated and the increasing demand met. During the NWSA period, the supply capacity of Metropolitan Manila Waterworks was increased to a total of 1,137 Ml/d.

On 19 June 1971, however, the Government of the Philippines set a policy goal to supply safe drinking water to every household throughout the country. NWSA was thus reorganized into two organizations, namely, MWSS and LWUA (Republic Act No. 6234, "An Act Creating the Metropolitan Waterworks and Sewerage System and Dissolving the National Waterworks and Sewerage Authority, and for Other Purposes").

Through its long history, MWSS has now become one of the largest water supply systems in the world. It supplies 2,500 Ml/d to 9.3 million inhabitants in Metropolitan Manila and its environs (served population is 5.3 million). At present, the MWSS Service Area (MSA) totals about 150,000 hectares and covers five (5) cities and thirty two (32) municipalities.

In addition to these five cities and thirty two municipalities, "Lungsod Silangan" was legally included as a proposed supply area, i.e., when the time for it becomes opportune. Also, MWSS can annex other areas which are deemed as appropriate expansion areas of MSA, by mutual agreement between the concerned national and local authorities, subject to the approval of the President of the Philippines.

10.1.2 Organization of MWSS

The organization of the MWSS is shown in Figure 10.1.1. The Board of Trustees formulates policy, determines staffing levels and remuneration, considers and approves budgets, approves large scale contracts, appoints MWSS's Deputy Administrators, and recommends tariff adjustment for the President's approval.

The Secretary of Public Works and Highways as a rule is the Chairman of MWSS Board of Trustees, unless the President of the Philippines designates another person. Also according to this rule, the Undersecretary (for Construction) of Public Works and Highways is the Administrator, unless another is designated by the President of the Philippines.

The Administrator is supported by a Senior Deputy Administrator and six Deputy Administrators whose respective areas are:
Engineering; Construction Management; Operation; Customers Services; Finance; Administration
The number of MWSS personnel is approximately nine (9) thousand, of which four thousand eight hundred is regular staff and the rest casual.

Table 10.1.1 and Table 10.1.2. show the number of MWSS personnel by area and by department, respectively.

10.1.3 Management of MWSS Deep Wells

(1) Responsibility on Operation

The actual operation of MWSS-owned/supervised wells are handled by the Water Distribution and Maintenance Department (WDMD) through its Pumping Plants Division down to the Deepwell Pumping Plants Section. This office is wholly responsible for the operation and monitoring of both existing and non-operational deepwells. The number of personnel assigned to every well station is scheduled by rotation. Data and information on the water production of each well are recorded daily.

(2) Responsibility on Maintenance

The maintenance of all MWSS-owned wells is the responsibility of the Central Maintenance Department (CMD) through its General Control and Repair Division and General Workshop Section. The cost of maintenance and repair of small damages and minor engine troubles are all handled by the CMD for this office has the budget for this purpose.

(3) Responsibility on Rehabilitation/Construction

Based on the recommendation of the Central Maintenance Department (CMD) and the Water Distribution and Maintenance Department (WDMD), the rehabilitation of existing MWSS wells are undertaken by the Groundwater Monitoring Unit of the Hydrology and Research Division (HARD) under the Planning and Programming Department (PPD).

For the drilling of new wells, it is the Groundwater Monitoring Unit, Hydrology and Research Division (HARD) under the Planning and Programming Department (PPD) which initiates the feasibility study for well specification and location.

10.2 ISSUES ON MANAGEMENT

10.2.1 Personnel and Training

MWSS staff are competent and hard working generally, and many of the technical staff, especially those in the senior-management and middle-management class, have served in their respective positions for several years, providing valuable continuity and making good use of their experience and in-depth knowledge of the system.

Also, MWSS's internal training system on human resource development is one of the most praiseworthy and successful training system in this field. MWSS's Human Resources Development Department (HRDD) is carrying out an extensive program, for all staff levels, from laborers to top management.

The program of training for 1990 as shown in Appendix C.3 includes 23 different courses for about 1,440 persons. In this program, training for the pump operators-WDMD is carried out in the course on "Plant Electrical Circuits and Motor Control." But this course focused mainly on the electrical aspect of pump operation, and not on the "well" itself. It may be recalled that as efforts in the past were largely focused on expansion projects, the maintenance of existing distribution facilities, especially of deep wells which supply water to outlying areas (those wells not connected to the CDS), received insufficient attention. Considering the serious state of MWSS deep wells, some program/seminar on basic strategies of deep well management in the MWSS should be planned.

10.2.2 Problem of Trimdown of Number of Personnel

Since the early 1980s, recommendations have been made in the MWSS regarding the relative highness of staff levels in relation to the number of connections and services provided. An appreciation of this problem may be gleaned from the increment in the ratio of number of staff per thousand water connections during 1986-1987 when the ratio rose from 10.1 to 12.7, presumably reflecting the social turmoil in those times.

A significant reduction of such ratio has been made since then, and as of end-April 1991 this ratio was already at 8.9. On the basis of world-wide statistics however, this figure is still higher than the ratio of 4 staff per thousand connections which were achieved in very efficient water utilities. In Japan, for instance, the contracting out of meter reading and bill collection to appropriate public entities had this ratio even reduced to about 2.5 in large water utilities.

The crux of the matter therefore appears to be the way the number of personnel can be reduced. There are existing administrative orders, executive orders, national budget circulars, and related economy measures that are supposed to address this problem. But such behests in the main are aimed at the cutting down of overhead expenses, and may, in their implementation, be counterproductive because necessary personnel could be sacrificed; and justifications for the exemption of such personnel would involve tedious processes and lost manhours. To obviate the loss of precious personnel, and to have an efficient organization in place, an organizational audit of the MWSS may be pursued.

It is necessary to ensure the required number of capable and competent personnel, particularly in the area of Engineering and Construction Management, to cope with the ever-continuing expansion of MWSS's area coverage. The salary schedule in the MWSS may also be worth reconsidering, especially when seen with the aim of bringing the MWSS the status of an attractive public body where the most capable characters are employed.

The experience in most of the large towns and cities may be worth looking into: For domestic customers, 80 to 90 % of bill collection is carried out by withdrawing the due amount from the customer's bank accounts in accordance with the agreement between the customers and the water supply authorities. This minimizes the number of personnel for bill collection.