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A GROUNDWATER DATABASE FOR METRO MANILA AND LAGUNA LAKE BASIN

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ABSTRACT

A groundwater database for Metro Manila and Laguna Lake Basin has been initiated in 1990 together with an on-going three-year research project on the conjunctive management and modeling of surface water and groundwater resources in the region. Through a formally organized multi-agency linkage and cooperation, a substantial collection of all agency-sourced secondary groundwater and other related data (circa: 1950-present) has been achieved after the first year. The regional database so far consists of 201 technical reports and publications, 234 maps of various types, lithology and other well data for 5911 wells, groundwater level data for 57 observation wells, water quality data for 35 sampling stations, streamflow and lake stage data for 29 surface water stations, climatic data for 17 climate stations, and seismic-reflection and georesistivity data for aquifer geometry. Aside from its immediate use in the on-going project, the database has other important long-term applications. The database collection and functions are being continually augmented and enhanced in order to realize their long-term utility and potential as a source of vital groundwater information for the general user, as management tool for water resources planners and technologists and as generator of research information and studies to be conducted by faculty, researchers, students, and practising engineers.

INTRODUCTION

The need to provide adequate water supply for the fast-growing population of Metro Manila (nine million in 1990) has always pushed the government to maximize the withdrawal of water mostly from existing surface water sources (Angat and La Mesa-Novaliches Reservoirs). On the other hand, the exploitation of the groundwater has been largely made by private well owners who are resident in the region. With the growing scarcity of water supply from surface sources which is being experienced not only due to occasional hydrologic drought but also due to existing source and distribution capacity constraints, the responsible agencies (MWSS and others) have started to take a serious look at the prospects of a systemwide exploitation of the groundwater resources in order to augment the surface water supply [2,3].

A rational approach to planning and development of groundwater resources should commence with the gathering of all available scientific, engineering, and natural resources data and information related to the regional groundwater situation. Without such an adequate database, aiming for a scientific understanding through modeling of the water cycle - the regional groundwater occurrence and movement - can hardly be initiated. Without a comprehensive scientific understanding, development programs and projects undertaken to widely exploit groundwater may suffer from poorly chosen well locations and design capacities and thus may fall short of supply targets in terms of low yield, short actual project life, fast decline of water tables and other indicators. In addition, lack of adequate knowledge about recharge patterns and amounts will introduce uncertainty in the long-term sustainability of the increased groundwater withdrawal rates.

The groundwater situation in Metro Manila cannot be completely dissociated from that of the Laguna Lake Basin (Figure 1), for the reason that their groundwater formations as well as river-lake systems are interconnected. Neither can it be dissociated from the overall hydrologic cycle because groundwater interacts with surface water (rainfall, streamflow, hydraulic control structures) through recharge or discharge, and also because conjunctive utilization of groundwater and surface water would require understanding of their interdependence.

MULTI-AGENCY COOPERATION

A three-year research project [1] whose main objective is to develop a Water Resources Management Model for Metro Manila was started in June 1990. It is sponsored by the International Development Research Center (IDRC) of Canada and jointly implemented by the U. P. Engineering Research and Development Foundation, Inc. (UPERDFI) through the U. P. National Hydraulic Research Center (NHRC) and the Geotechnical Research Center (GRC), McGill University. One achievement under the project was establishing linkage and cooperation with the following Philippine agencies, with advisory, technical, and data-source functions: NEDA, NWRB, MWSS, DENR-MGB, DENR-EMB, LLDA, UP (NIGS and University Library), LWUA, DENR-NAMRIA, PAGASA, DAF-BSWM, DPWH-BRS, DPWH-PMO-RWS, NIA, OEA-EDS, DOH-BRL, and WELDAPHIL.

The public water-resource agencies possess an underrated and sometimes unrecognized sectoral asset with a vast potential to evolve into a significant and integrated resource for national development - **water information**. The agencies have the specialized

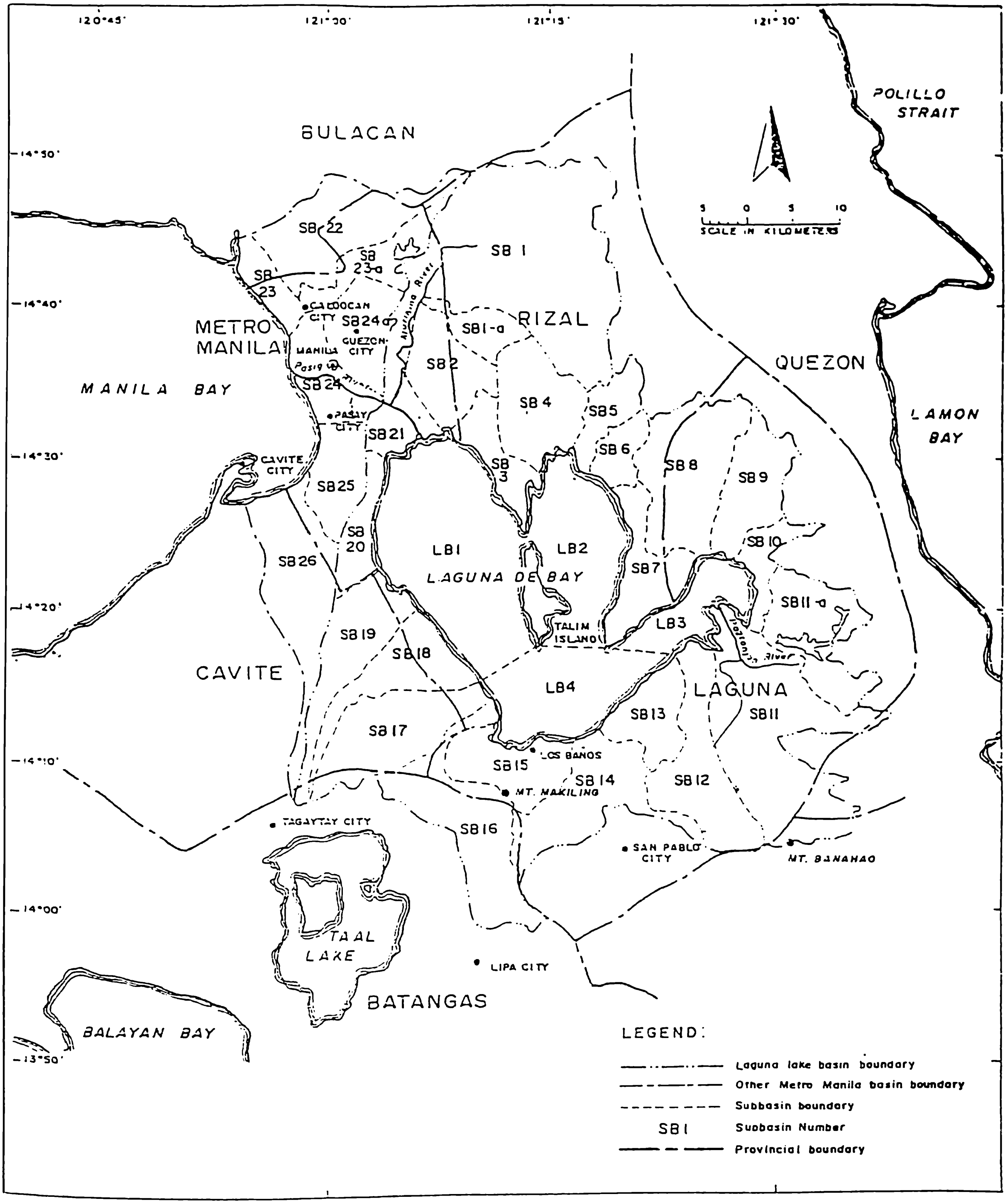

Fig. 1 Subbasins of study area

data and information, both published and unpublished, which are products of past and present water programs and projects (surveys, masterplans, reconnaissance and feasibility studies, design and construction plans, operational studies, rehabilitation plans, and others). In a few cases, some agencies also develop their own modest specialized databases. The sharing of these information, among themselves and with other sectors, is one activity that NHRC has opted to catalyze in a university-based research setting, in an atmosphere removed from the daily stress and pressure of agency concerns and duties, short deadlines, long budget cycles, and dearth of full-time agency research personnel. A university-based groundwater database, which is at the same time a database also of related surface water, geologic, soil, land-use, and other resource data and information, was initiated after formal linkage and cooperation with the agencies was established.

In line with the research objectives, the groundwater database, comprised of both documents and computerized materials, was initiated in 1990. The agencies contributed copies of technical reports, maps, office document and data files, and specialized database files in magnetic media and hardcopies. The agency representatives also attended quarterly consultation meetings in order to update each one with latest accomplishments, discuss and plan data collection activities, and open opportunities for more data and information.

COLLECTION OF DATA AND INFORMATION

Table 1 provides a summary table of source agency versus type of collected data and information. The table reflects the specialization of the different agencies in terms of what they can best provide to the collection. For example, majority of well data was derived from NWRB which initiated two years before the encoding of the well data submitted by other agencies, such as MWSS and LWUA. In addition, these agencies which implement well construction and development projects directly contributed latest available well data. On the other hand, water quality data were mostly received from EMB, LLDA, and DOH, since these are the agencies active in water quality sampling and analysis. PAGASA and DPWH supplied the climatic and streamflow data, respectively. UP NIGS provided vital hydrogeologic information while the University Library was generous in lending for reproduction Spanish-era maps of Metro Manila. The succeeding seven (7) sections discuss the different types of collected data and information.

TECHNICAL REPORTS

A collection of 201 published and unpublished technical reports was gathered from the various agencies. Table 2 presents a summary breakdown of the technical reports according to agency source and geographic coverage. Aside from Metro Manila, the Laguna Lake Basin subtends five (5) provinces - Bulacan, Batangas, Cavite, Laguna, and Rizal. The technical reports have varied contents - reconnaissance, surveys, feasibility, construction, modeling, special site studies, and data annexes. They were reviewed and annotated with particular emphasis on the type of maps, well data, water-quality, and general hydrologic data that they contain. Annotation forms were accomplished for internal recording purposes.

Table 1 Source agency versus type of collected data and information

AGENCY	TECHNICAL REPORTS	MAPS	WATER QUALITY DATA	WELL DATA	STREAMFLOW and LAKE STAGE DATA	CLIMATIC DATA	OTHER HYDROGEOLOGIC DATA
MWSS	•	•	•	•			•
MGB	•	•					
NWRB	•	•		•			•
EMB	•		•				
LLDA	•	•	•		•		
UR		•					
LWUA	•	•		•			
NAMRIA		•					
PAGASA	•					•	
BSWM	•	•					
DPWH				•	•		
DOH			•				
OEA							•
Others	•						

Table 2 **Summary breakdown of technical reports by agency source and geographic coverage**

AGENCY	METRO MANILA	BULACAN	BATANGAS	CAVITE	LAGUNA	RIZAL	REGIONAL	NATIONAL	GENERAL	TOTAL
MWSS	6					2				8
MGB	6	29	1	4	17	39	2			98
NWRB		1	1	1	1	1	1	1		7
EMB	5							13		18
LLDA							10			10
LWUA		1		2	9	1				13
PAGASA	3									3
BSWM		1	2	2	1					6
Others	1				1		3	2	31	38
TOTAL	21	32	4	9	29	43	16	16	31	201

CARTOGRAPHIC INFORMATION (MAPS)

The collection of all identified and available agency maps, 234 sheets in all, is complete for the moment and is kept in classified map filing cabinets. Several other maps, in smaller plate or figure formats, are bound with the technical reports. The map sheets, with their counts, are classified as follows:

1.	Surface Drainage Maps	(14)
2.	Well Location Maps	(11)
3.	Geologic Maps	(21)
4.	Groundwater-Level Maps	(9)
5.	Hydrogeologic Maps	(11)
6.	Iso-resistivity Maps	(11)
7.	Groundwater Quality Maps	(9)
8.	Water Permit Map	(1)
9.	Geologic Cross sections	(4)
10.	Groundwater Quality Stations Map	(1)
11.	Surface Water Quality Stations Map	(1)
12.	Soil Maps	(2)
13.	Topographic Contour Maps	(76)
14.	Slope Map	(1)
15.	Land Use/Condition/Management Maps	(57)
16.	Nautical Charts	(2)
17.	Historical Maps	(3)

SURFACE WATER AND GROUNDWATER QUALITY DATA

On hand are surface water quality data (period 1973-1987) from 35 sampling stations in Manila Bay, Laguna Lake and tributary rivers, and other Metro Manila Rivers. Also in possession are groundwater quality data (period 1981-1985) for Metro Manila sampling stations. On going is the encoding of the water-quality data.

GROUNDWATER WELL DATA

A complete set of available well data has been collected. The NWRB encoded the well data files for 5911 wells in Batangas, Bulacan, Cavite, Laguna, Rizal, and Metro Manila. Table 3 provides the statistics on the numbers and percentages of well records with coordinates and well logs, sorted according to province.

The well data obtained consist of well design, well log/lithology, pumping test data and analysis, resistivity, water permits and water level data. Figure 2 gives the coordinates and periods of records for 57 NWRB observation wells with groundwater-level data.

Table 3 Some statistics for NWRB well database

PROVINCE or REGION	TOTAL RECORDS	WITH COORDINATES		WITH WELL LOGS		WITH BOTH COORD. AND WELL LOGS	
		NUMBER	(%)	NUMBER	(%)	NUMBER	(%)
BATANGAS	1557	251	*16.12%*	894	*57.42%*	245	*15.74%*
BULACAN	433	43	*9.93%*	384	*88.68%*	13	*3.00%*
CAVITE	717	57	*7.95%*	227	*31.66%*	36	*5.02%*
LAGUNA	765	101	*13.20%*	386	*50.46%*	97	*12.68%*
RIZAL	450	74	*16.44%*	180	*40.00%*	47	*10.44%*
MANILA	1989	301	*15.13%*	599	*30.12%*	204	*10.26%*
TOTAL	5911	827	*13.99%*	2670	*45.17%*	642	*10.86%*

CODE	LOCATION	COORDINATES					
		LATITUDE			LONGITUDE		
		o	'	"	o	'	"
B3	Sta.Clara, Sta. Maria, Bulacan	14	49	25	120	56	55
B3A	Patag, Sta. Maria, Bulacan	14	49	45	120	58	25
B4	Poblacion, Norzagaray, Bulacan						
B9	Palasan, Valenzuela, Bulacan	14	41	55	120	56	40
BG8	Biga, Sto. Tomas, Batangas	14	6	35	121	8	25
BG12	Poblacion, Malvar, Batangas	14	2	50	121	9	30
CA7	Poblacion, Carmona, Cavite	14	19	30	121	3	25
CA8	Amolong, Silang, Cavite	14	13	50	120	58	25
LA1	San Antonio, Binan, Laguna	14	19	50	121	4	55
LA2	Sala, Cabuyao, Laguna	14	16	45	121	7	25
LA3	Poblacion, Magdalena, Laguna	14	12	40	121	25	20
LA4	Maahas, Los Banos, Laguna	14	10	45	121	15	0
LA5	Pila, Laguna	14	14	50	121	21	40
LA5A	San Antonio, Pila, Laguna	14	13	35	121	21	30
LA6	Poblacion, Sta. Cruz, Laguna	14	17	0	121	24	50
LA6A	Bubukal, Sta. Cruz, Laguna	14	15	50	121	23	45
LA7	Poblacion, Paete, Laguna	14	21	40	121	29	0
LA7A	Kinali, Paete, Laguna	14	21	5	121	28	55
LA8	Poblacion, Mabitac, Laguna	14	25	50	121	25	30
LA9	Poblacion, San Pablo City, Lag.	14	4	25	121	19	25
LA10	Dayap, Calauan, Laguna	14	8	55	121	19	10
LA11	Mabini, San Pedro, Laguna	14	21	35	121	3	10
LA12	Poblacion, Cavinti, Laguna	14	15	5	121	30	5
LA13	Maitim, Bay, Laguna	14	10	40	121	16	0
M3	Macabling, Sta. Rosa, Laguna						
P10	Sta. Cruz, Sta. Rosa, Laguna	14	16	42	121	4	57
P13	Manggara, Sta. Rosa, Laguna	14	15	21	121	4	48
P16	Pulong Sta. Cruz, Sta. Rosa,Lag.	14	16	18	121	4	59
P17	Dita, Sta. Rosa, Laguna	14	17	6	121	6	24
P19	Alas-asan, Sta. Rosa, Laguna	14	14	36	121	5	15
P20	Pulong Sta. Cruz, Sta. Rosa,Lag.						
P21	Alas-asan, Sta. Rosa, Laguna	14	14	37	121	4	57
P23	Sto.Domingo, Sta. Rosa, Laguna	14	14	4	121	3	1
P24	Alas-asan, Sta. Rosa, Laguna	14	14	41	121	5	12
P26	Macabling, Sta. Rosa, Laguna	14	18	39	121	6	6
P40	Langkiwa, Binan, Laguna	14	17	42	121	3	6
P43	Soro-soro, Binan, Laguna	14	19	42	121	3	33
P44	Palo Alto, Calamba, Laguna	14	11	27	121	6	48
P46	Pulong Sta. Cruz, Sta. Rosa,Lag.	14	16	50	121	5	3
P50	Mayapa, Calamba, Laguna	14	13	5	121	8	24
P52	Aplaya, Sta. Rosa, Laguna	14	19	18	121	7	5
RI1	Poblacion, Novaliches, MM	14	43	25	121	2	30
RI2	Poblacion, San Mateo, Rizal	14	41	40	121	6	25
RI3	Lopez Jaena St., Pasig	14	34	15	121	4	25
RI4	Pob., Kakarong St., Makati	14	33	45	121	1	40
RI5	Tambac, Taguig	14	31	20	121	4	35
RI6	Pamplona, Las Pinas	14	27	50	120	58	15
RI6A	Manuyo, Las Pinas	14	28	25	120	58	30
RI7	Poblacion, Binangonan, Rizal	14	28	25	121	11	50
RI7A	Darangan, Binangonan, Rizal	14	29	30	121	11	5
RI8	Poblacion, Morong, Rizal	14	30	10	121	14	25
RI9	Poblacion, Tanay, Rizal	14	30	24	121	17	5
RI10	Maybangkal, Teresa, Rizal	14	33	25	121	12	25
RI11	Poblacion, Jala-jala, Rizal	14	21	40	121	19	40
RI12	Halayhayin, Pililla, Rizal	14	28	35	121	19	5
RI13	Pob., Malinao St., Taguig, MM	14	33	45	121	4	25
RI14	Hagonoy, Taguig, MM	14	30	55	121	4	10

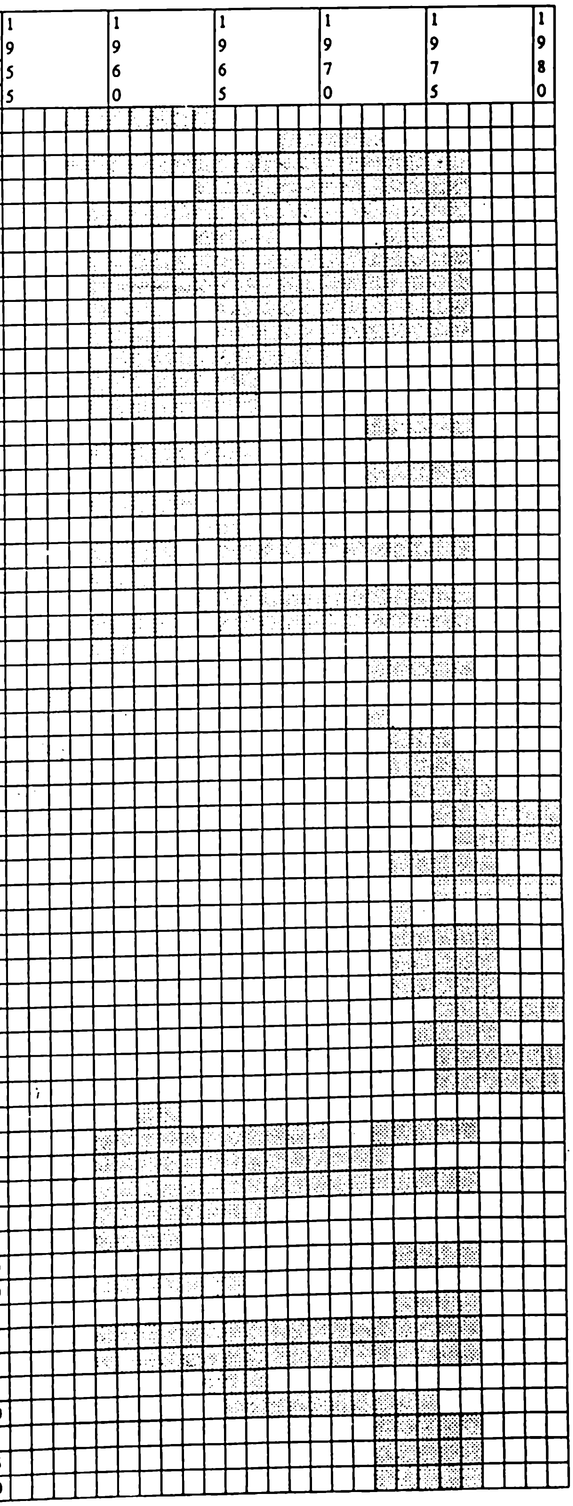

Fig. 2 Groundwater level data from NWRB

STREAMFLOW AND LAKE STAGE DATA

Also in the database is a complete collection of streamflow and lake stage (discharge measurements, rating curves and tables, daily gage heights or discharges, monthly and annual summaries) for 29 DPWH-BRD river or lake stations within the basin. Figure 3 presents the BRS streamflow and lake stage station coordinates and periods of records. On going is the encoding of the surface water data.

CLIMATIC DATA

Daily rainfall and other climatic data for 17 PAGASA stations within the basin were received in encoded forms (magnetic media and hardcopies) from PAGASA. Figure 4 gives the periods of records of the selected PAGASA stations.

SEISMIC-REFLECTION DATA

Seismic-reflection data were obtained from OEA-EDS for six (6) seismic lines (final stack/wave migration) located in eastern Cavite and western Laguna, and made in July-August 1981. UP NIGS interpreted the seismic data and developed for the project the hydrogeologic basement map for the eastern Cavite/western Laguna area.

SOFTWARE ACQUISITION

A certain philosophy was adopted at the start of the groundwater database activity in the issue of the type of software to be utilized for data encoding, storage, retrieval, and analysis. After a literature survey of the technical software market was made, the following criteria were finally chosen:

1. The principal software platform for the groundwater database must be sufficiently specialized for hydrogeological applications.

2. It must be commercially available at affordable cost, user-friendly, with proven track record in claimed application areas.

3. It must be under MSDOS and compatible with other general purpose software such as computer-aided design (Autocad), database (dBase), spreadsheet (Lotus 123), word-processing (Word), graphics (Grapher, Surfer, PaintBrush), and others - this is in terms of portability of text and graphics files in either direction.

4. It must admit map-based graphic input at least via digitizer and also be able to generate as output sophisticated 2-D and 3-D graphics displays of data and analysis results, in either screen display or hardcopy.

RIVER	LOCATION	COORDINATES						DRAINAGE AREA	1950	1955	1960	1965	1970	1975	1980	1985	1990
		LATITUDE			LONGITUDE												
		o	'	"	o	'	"	(SQ. KM.)									
Arangilan	Calamias, Cabuyao, Laguna	14	14	10	121	7	30	87.0		▨	▨	▨	▨	▨			
Balanac (Lower)	Bucal, Magdalena, Laguna	14	14	0	121	26	15				▨	▨	▨	▨	▨		
Balanac (Upper)	Bucal, Magdalena, Laguna	14	12	24	121	26	33	116.0			▨	▨	▨	▨			
Laguna Lake	Halang, Lumban, Laguna	14	18	58	121	27	50	3158.0			▨	▨					
Laguna Lake	Poblacion, Los Banos, Laguna	14	11	6	121	13	10	3158.0			▨	▨	▨		▨	▨	
Laguna Lake	Poblacion, Muntinlupa, MM	14	21	29	121	2	46	3158.0		▨	▨		▨				
Laguna Lake	Tayuman, Binangonan, Rizal	14	31	22	121	9	16	3158.0			▨		▨	▨			
Mabacan	Mabacan, Calauan, Laguna	14	9	52	121	17	29	46.0					▨	▨			
Marikina	Manggahan, Pasig	14	35	12	121	5	22	527.0			▨	▨	▨				
Marikina	Rosario, Pasig, MM	14	36	12	121	5	11	532.0			▨	▨	▨	▨			
Marikina	San Rafael, Montalban, Rizal	14	44	0	121	10	20	282.0		▨	▨	▨	▨	▨			
Marikina	Sto. Nino, Marikina	14	38	15	121	5	30	499.0			▨		▨				
Mata	Coralan, Sta. Maria, Laguna	14	29	13	121	25	0	35.0			▨	▨					
Mayor	Bagumbayan, Siniloan, Laguna	14	28	0	121	27	40	45.0			▨	▨	▨		▨		
Nangka	Nangka, Marikina, MM	14	41	53	121	6	30	542.0			▨		▨	▨			
Pagsanjan	San Isidro, Pagsanjan, Laguna	14	16	4	121	27	25	247.1							▨		
Paputok	Mabacan, Calauan, Laguna	14	8	12	121	21	3	8.5			▨	▨	▨	▨			
Pasig	Beata, Pandacan, MM	14	35	47	121	0	37	3923.0			▨	▨	▨	▨			
Pasig	Del Pan, Port Area, MM	14	35	48	121	58	2	3923.0			▨	▨					
Pasig	McKinley, Makati, MM	14	33	51	121	3	42	3807.0		▨	▨	▨	▨	▨			
Pasig	Napindan, Taguig, MM	14	32	28	121	5	44	3159.0	▨	▨	▨	▨	▨	▨			
Pasig	Pineda, Pasig, MM	14	33	50	121	3	39	3821.0	▨	▨	▨	▨	▨	▨			
Pasig	San Jose, Makati, MM	14	34	13	121	2	40	3824.0	▨	▨	▨	▨	▨				
Pililia'	San Lorenzo, Pililia, Rizal	14	18	53	121	18	26	37.0						▨	▨	▨	
San Cristobal	Calamba, Laguna	14	13	6	121	9	19	106.0							▨	▨	
San Juan	Parian, Calamba, Laguna														▨	▨	
Sta. Cruz	Calumpang, Liliw, Laguna	14	11	55	121	26	30	103.0			▨	▨	▨				
Sta. Cruz	Pagsawitan, Sta. Cruz, Laguna	14	15	46	121	25	20	124.0							▨	▨	▨
Sta. Maria	Makasipak, Sta. Maria, Laguna	14	29	0	121	25	0	25.0			▨	▨					

Fig. 3 Streamflow and lake stage data of the Laguna Lake Basin from BRS

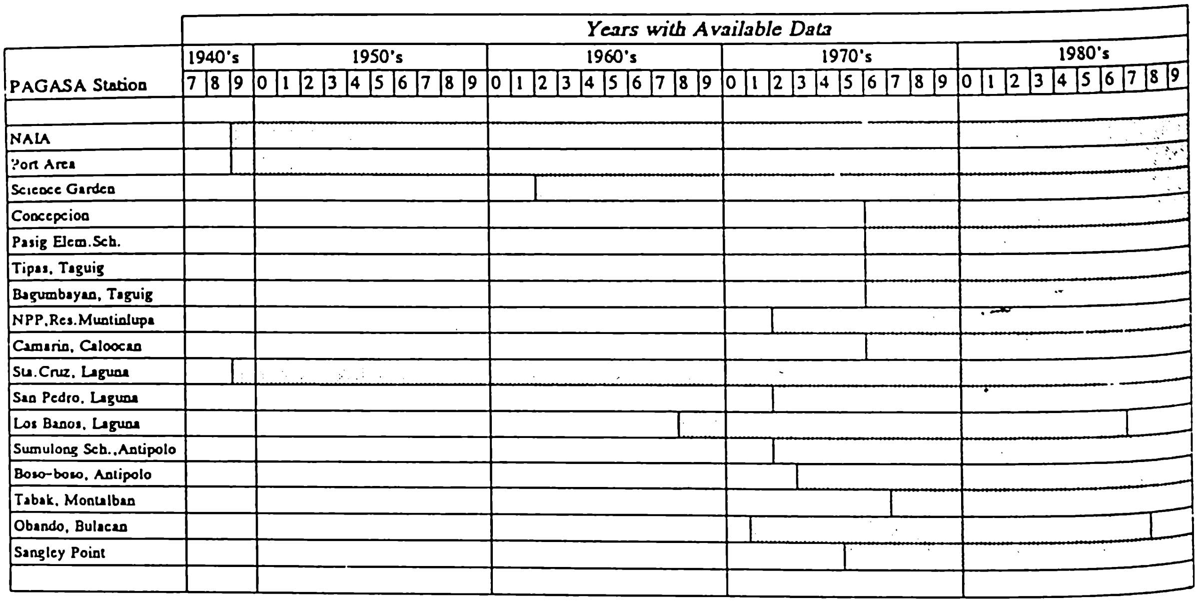

Fig. 4 Available climatic data from selected PAGASA stations

5. It must be available in the latest 80386 model versions so as to maximize the use of available hardware capabilities.

A narrow list of three (3) software packages was evaluated after receiving detailed brochures and quotations from suppliers. The final selection was made and the software acquired was ROCKWARE - a geological software made by Rockware, Inc., Colorado, U. S.

A. There are six (6) ROCKWARE module options acquired:

1. DIGITIZE - digitizing module
2. LOGGER - well lithology module
3. ROCKBASE - basemap preparation module
4. GRIDZO - contouring and 3-D graphic module
5. TOOLBOX - utilities module
6. ROCKPLOT - screen or hardcopy graphics module

The types of files accepted and internally generated are:

1. ASCII text files
2. ASCII data files (free or fixed format)
3. ROCKWARE Vector graphics files
4. BOCKWARE Raster graphics files
5. ROCKWARE Information Base files

The types of ROCKWARE-generated files exportable to other software packages are:

1. Word-compatible ASCII text files
2. dBase-, Lotus-, and Grapher-compatible ASCII data files
3. Surfer-compatible Vector Graphics files
4. Autocad-compatible Vector Graphics files.
5. PaintBrush-compatible Raster Graphics files

PROCESSING AND ANALYSIS OF GROUNDWATER DATA

The well data files were compiled and diagnosed using ROCKWARE. A systematic and simple well identification scheme, namely province/number, was adopted. The original NWRB-supplied dBase well data files were transcribed to ROCKWARE lithology format, containing records for well identification, sitio/municipality, well longitude and latitude coordinates, ground elevation, and layer-by-layer lithology (top depth, bottom depth, formation type). Well files without coordinates or well logs, or those with erroneous or inconsistent data or format (only in rare cases), were identified.

A computerized lithologic classification and graphical pattern system. was adopted. The following false-color lithologic visualization scheme was also adopted:

1. Yellow - good aquifers: sand, gravel
2. Green - fair aquifers: sandstone, limestone, tuff, ash, pumice
3. Red - poor aquifers: clay, shale, basalt

An example of a ROCKWARE well lithology file and the corresponding graphic well lithology plot are shown in Figure 5, for a well (coded LAG056) located in Cabuyao, Laguna. Other examples of well lithology plots are given in Figures 6, 7, and 8. Figure 6 is the plot for a Paco, Manila well (coded MAN177), tapping the Manila Bay/Pasig deltaic alluvium. Figure 7 is the plot for an Angono, Rizal well (coded RIZ006) which reaches down to the Antipolo-Angono basaltic basement. Figure 8 is for a Marikina, Metro Manila well (coded MAN200) located in the Marikina Valley alluvium.

Computerized well-to-well section diagrams for wells with coordinates and logs were also generated. An example is given in Figure 9 for the series of neighboring wells (coded LAG246, LAG257, LAG033, and LAG049) located in Biñan, Laguna, illustrating the interbedding of tuff, clay, sand, and gravel in Laguna aquifers.

Computerized well location basemaps for wells with coordinates and well logs were also prepared. Upon computerized overlay with basin basemaps, erroneous well locations (wrong coordinates, inconsistent with municipality or province) and duplicate well files (same coordinates) were identified. In general, these cases are very minimal and could be rectified using the sitio/municipality records.

Shown in Figures 10, 11, 12, 13, and 14 are the computerized well location basemaps for Manila, Rizal, Cavite, Laguna, and Batangas wells, respectively. Not shown are Bulacan wells of which only 13 have coordinates.

Noticeable in Figure 10 for Manila wells is the greater concentration of privately owned wells in the more-recently (post-war) developed Metro Manila suburbs of Quezon City, Novaliches, Marikina, Pasig, Paranaque, and Las Pinas. This is in contrast to the lower well density in Manila proper, which is the oldest area served by MWSS with water supply coming from surface sources.

Figure 11 for Rizal wells displays the greater concentration of wells in the populated towns of Cainta, Taytay, Antipolo, and Angono, with very few in the rural parts. Figure 12 for Cavite wells shows the majority of the wells to be lying outside the basin, with only a handful found inside, near the Cavite towns of Imus and Bacoor. Fig. 13 for Laguna wells depicts the large extent of groundwater exploitation along the southern banks of Laguna Lake, notably in the Laguna towns of Biñan, Sta. Rosa, Cabuyao, Calamba, and Los Banos. Figure 14 for Batangas wells gives another case where the majority of the wells lie outside the basin and few are located inside, just southwest of Mt. Makiling.

On-going still are the editing of well log files in order to achieve the selection of wells with at least 100-meter depths, the assignment of estimated coordinates to wells without coordinates, and the correction of other inconsistencies. Afterwards, a master file of data-reliable wells will be created to be used as input in the computerized preparation of representative lithologic sections and profiles, and piezometric and water table maps.

```
SETUP: lag056.plt lag056.inf 2 -592.00  0.00 121.1244 14.2617 0.00  LAG056 (, CABUYAO)
OPERATOR: NHRC GROUNDWATER MODELING & MANAGEMENT TEAM
LITHOLOGY:  -0.00  -10.00   -0.00
GRAY ADOBE:  -
LITHOLOGY:  -10.00  -50.00    -45.54
SANDY CLAY AND SHALE:  -
LITHOLOGY:  -50.00  -95.00    -91.08
BROWN SHALE:  -
LITHOLOGY:  -95.00  -120.00    -136.62
GRAY SANDY SHALE:  -
LITHOLOGY:  -120.00  -190.00    -182.15
BROWN SHALE WITH GRAVEL:  -
LITHOLOGY:  -190.00  -254.00    -227.69
GRAY SHALE SANDY:  -
LITHOLOGY:  -254.00  -302.00    -273.23
SANDY CLAY:  -
LITHOLOGY:  -302.00  -438.00    -318.77
FINE SANDY CLAY:  -
LITHOLOGY:  -438.00  -460.00    -364.31
COARSE SAND:  -
LITHOLOGY:  -460.00  -500.00    -409.85
SANDY CLAY:  -
LITHOLOGY:  -500.00  -548.00    -455.38
BROWN SANDY CLAY:  -
LITHOLOGY:  -548.00  -555.00    -500.92
SANDY CLAY:  -
LITHOLOGY:  -555.00  -592.00    -546.46
BROWN STICKY CLAY:  -
END-LOG
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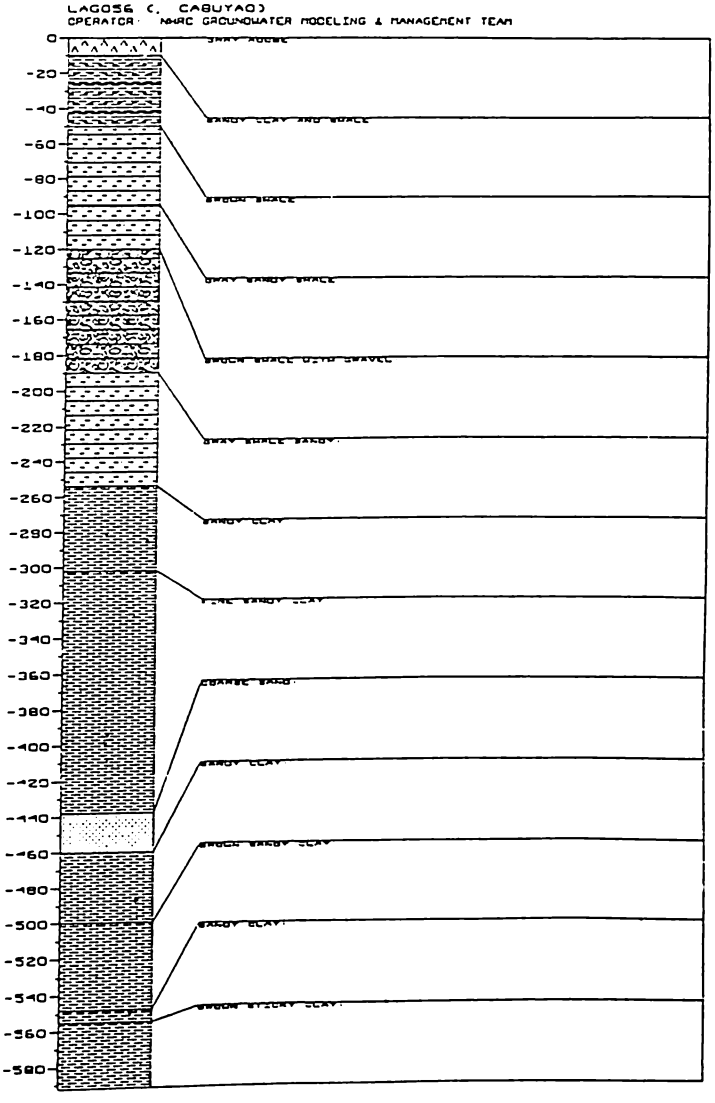

Fig. 5 A well lithology file and corresponding well lithology plot (Example 1)

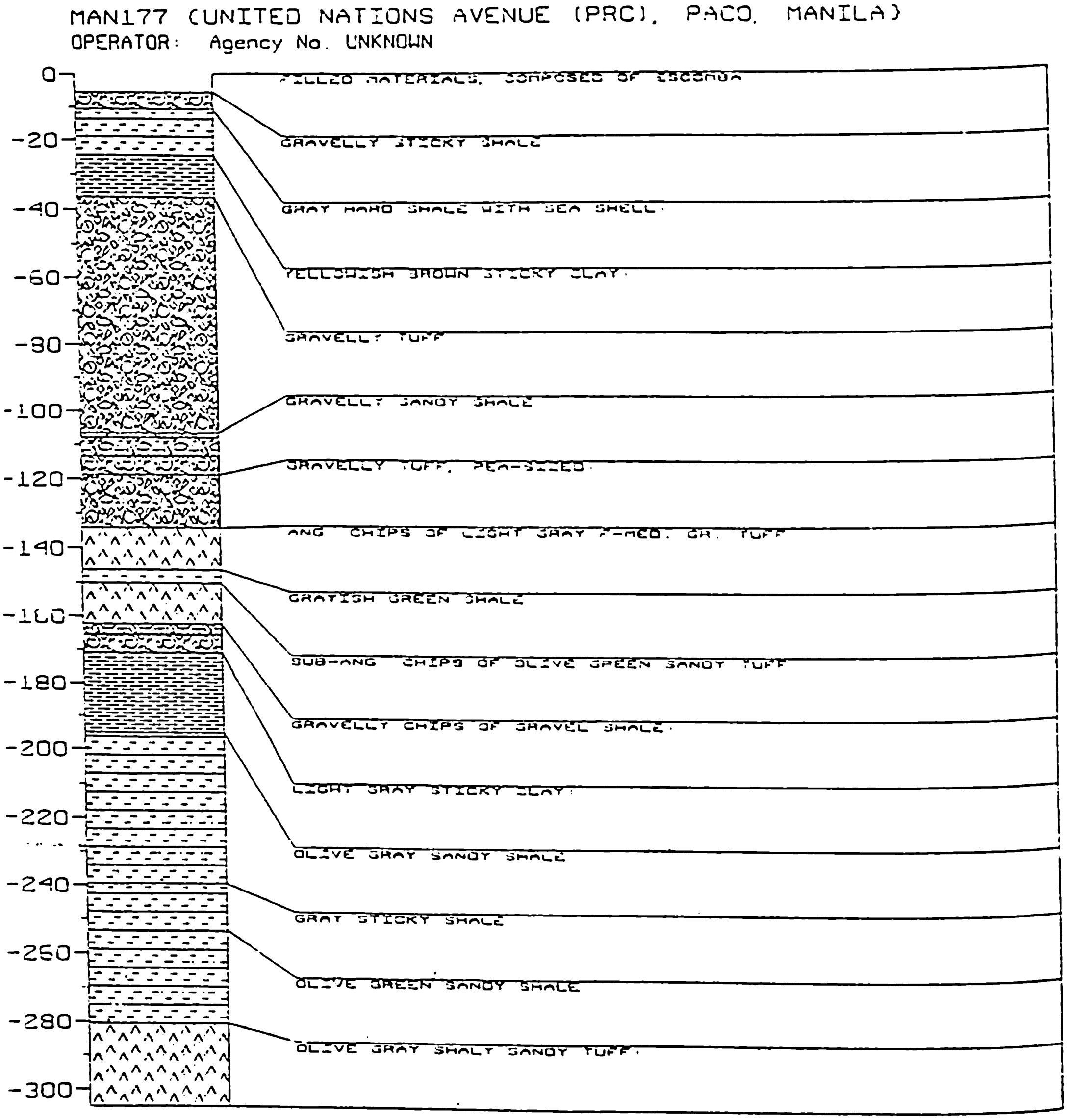

Fig. 6 Well lithology plot (Example 2)

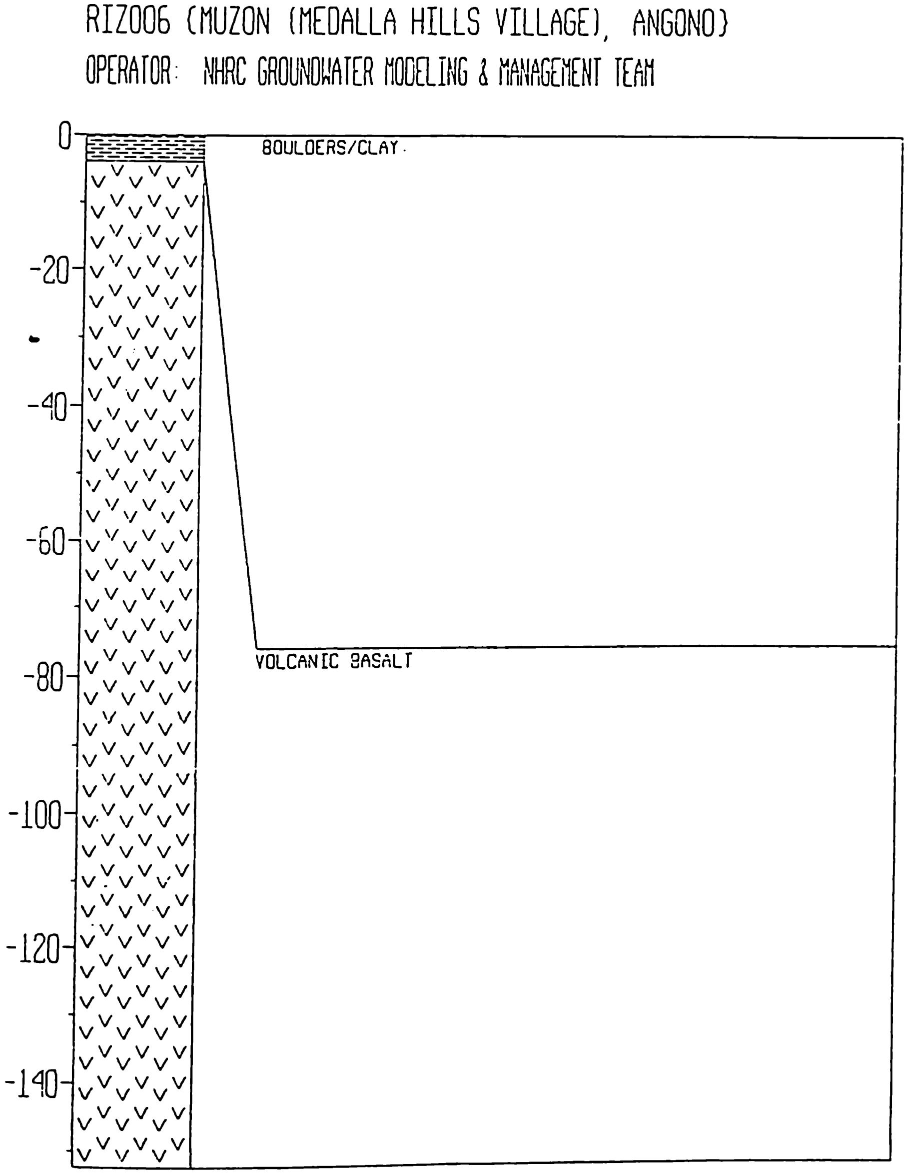

Fig. 7 Well lithology plot (Example 3)

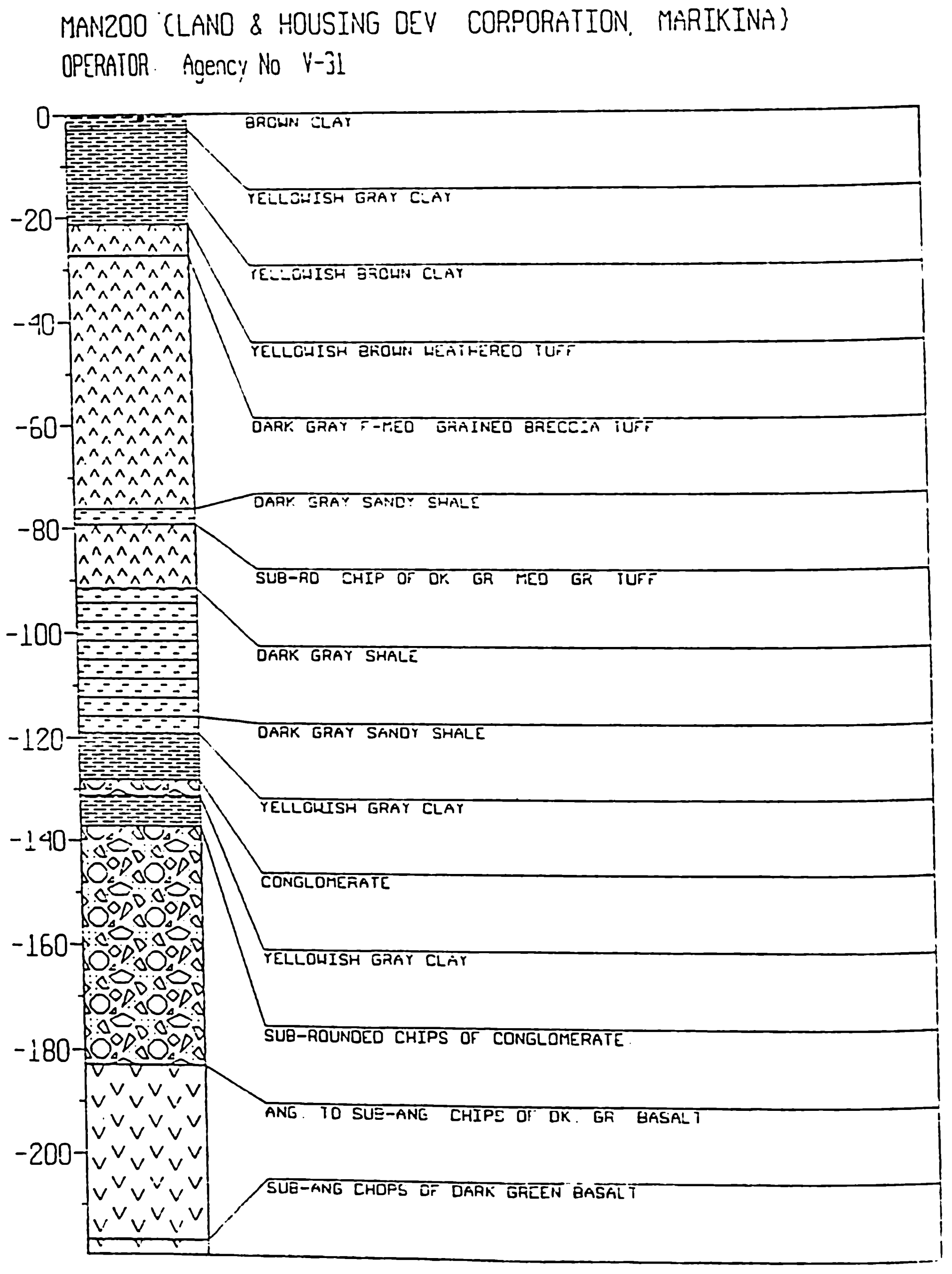

Fig. 8 Well lithology plot (Example 4)

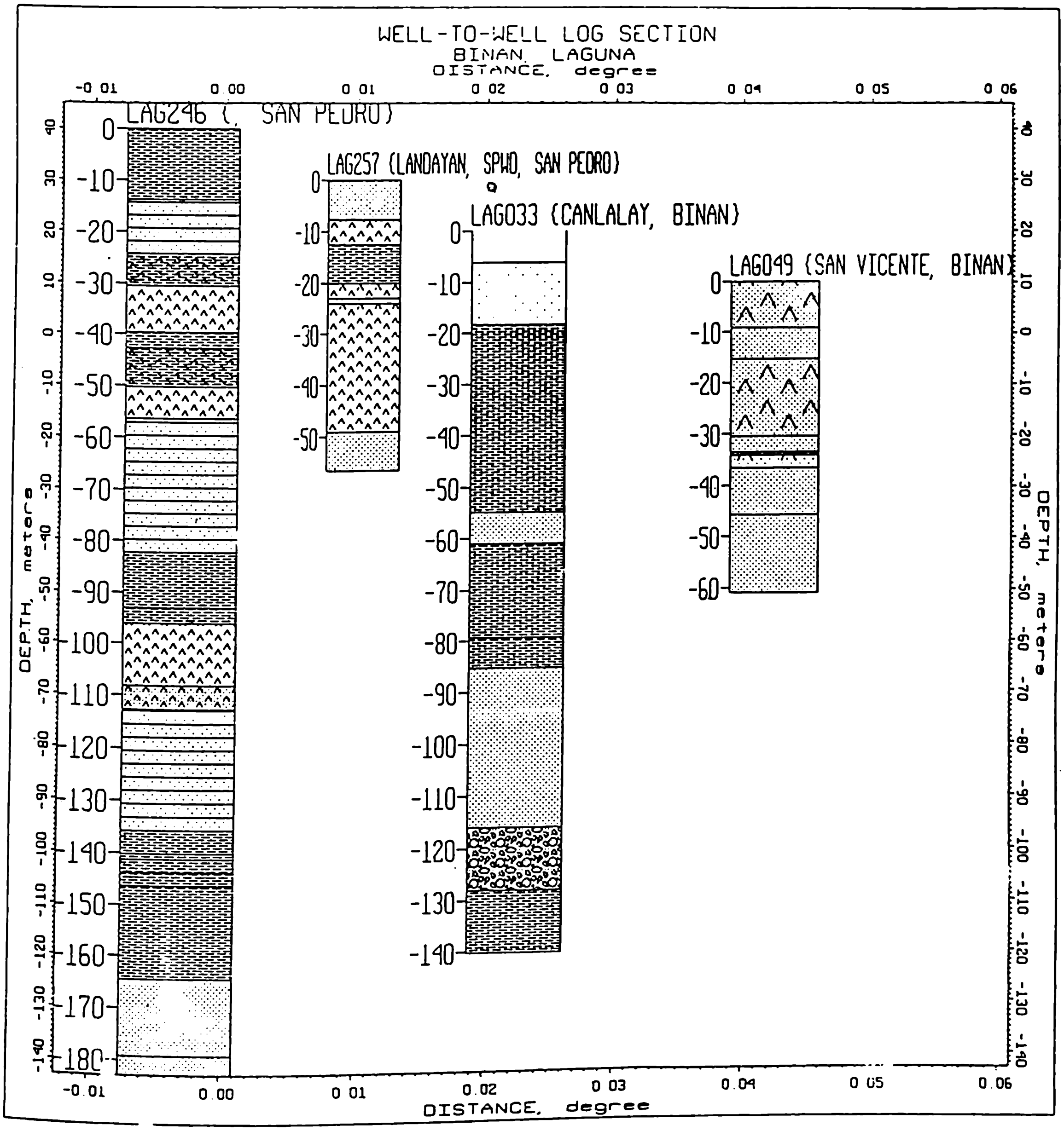

Fig. 9 Well-to-well section plot

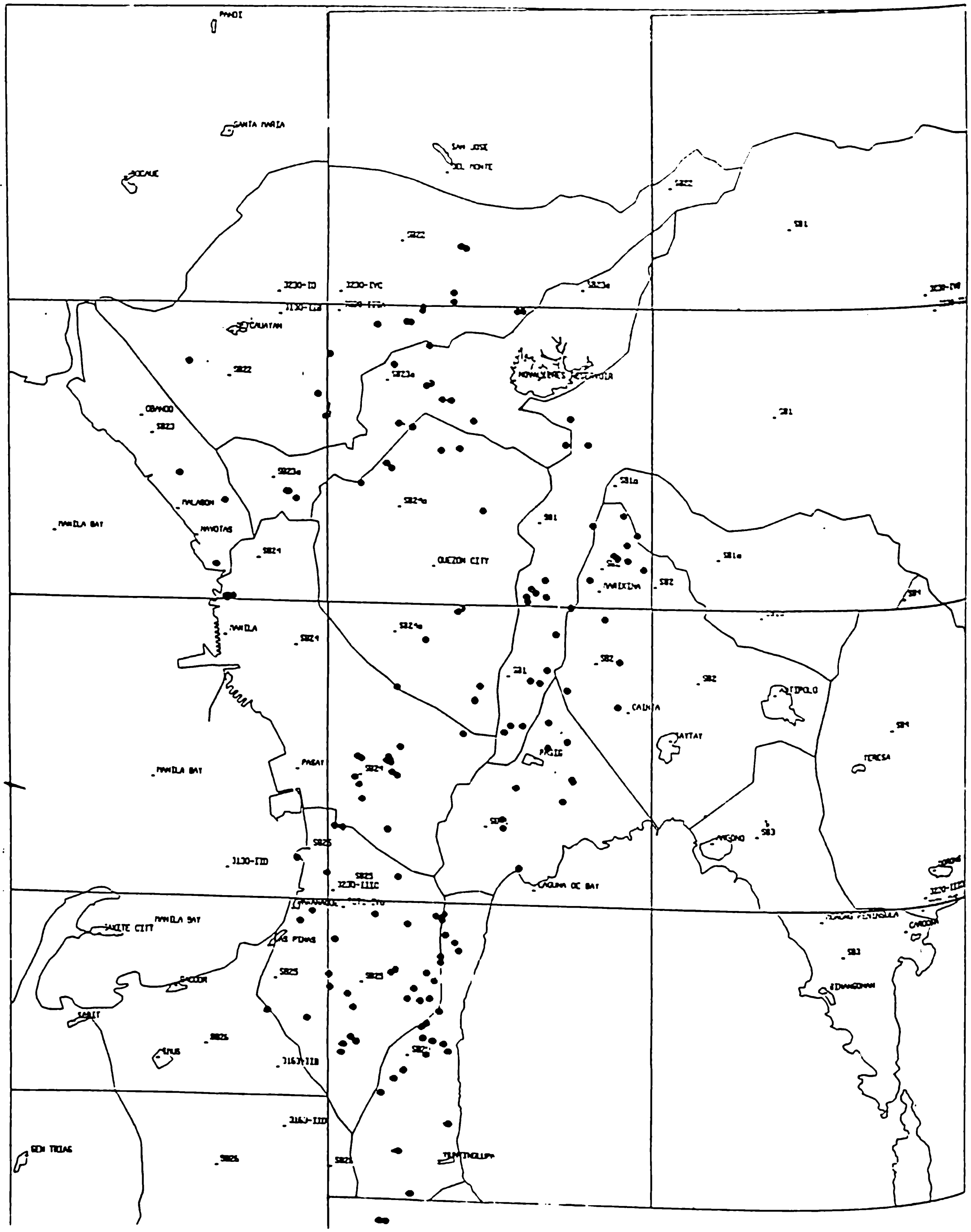

Fig. 10 Well location basemap (Manila)

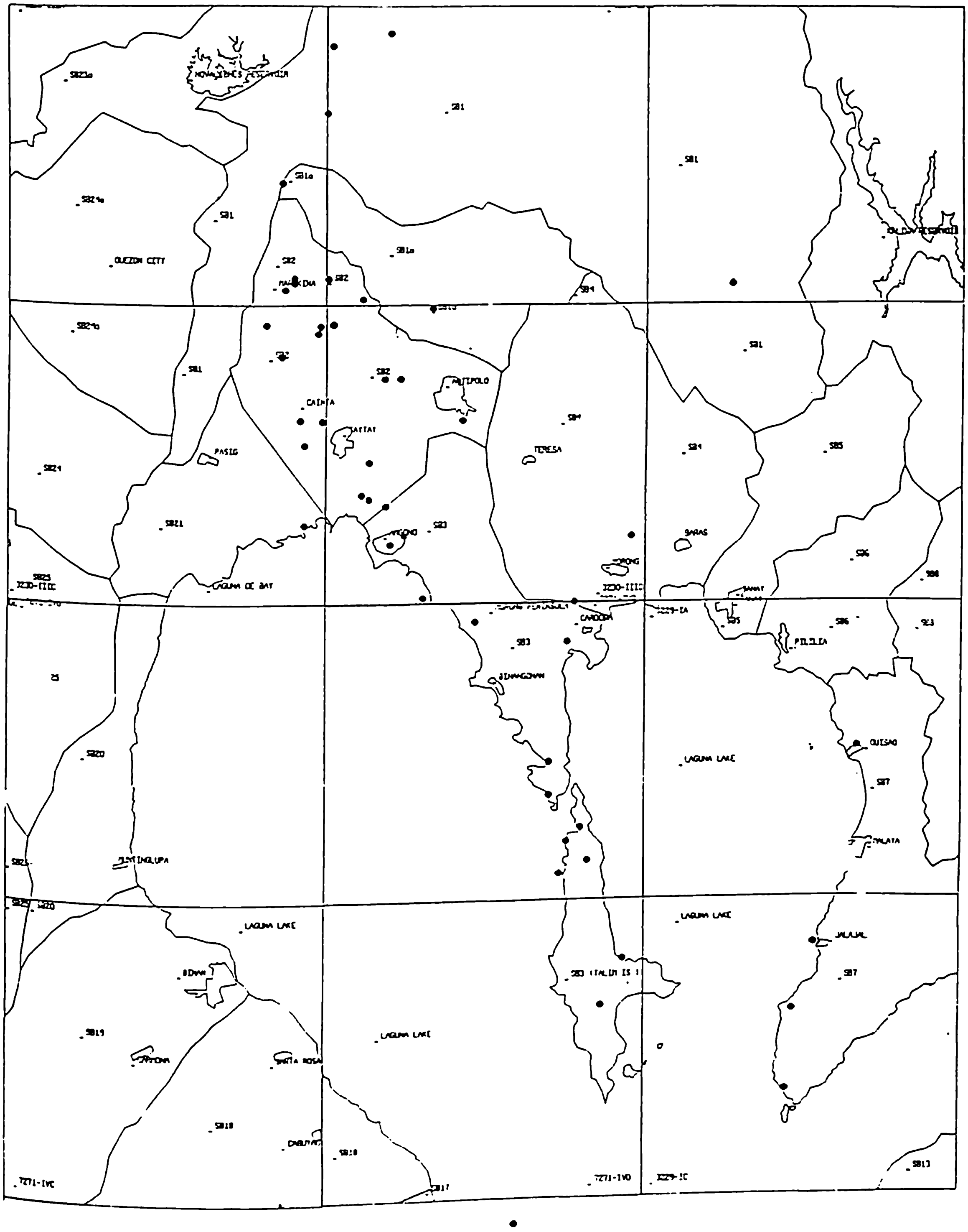

Fig. 11 Well location basemap (Rizal)

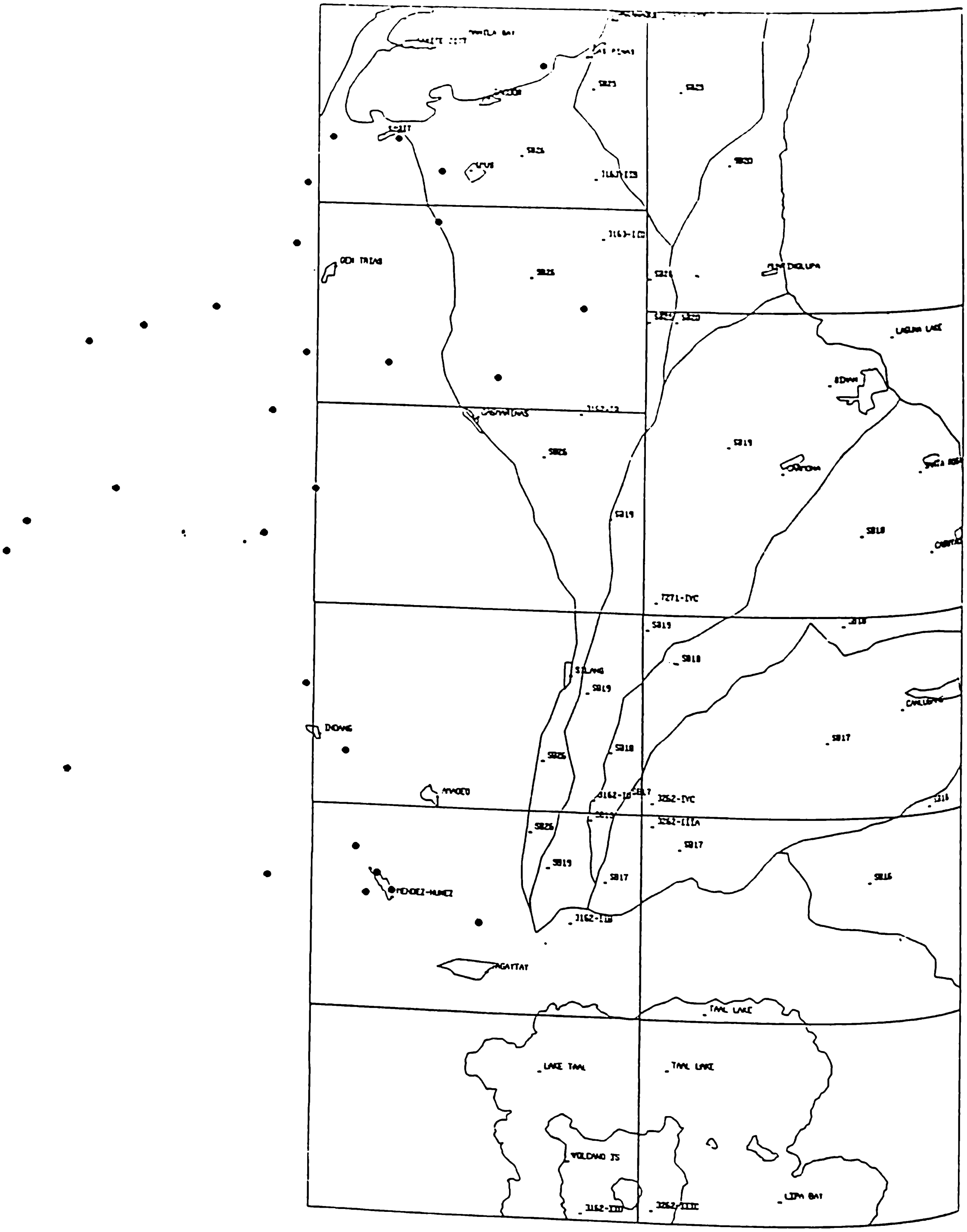

Fig. 1·2 Well location basemap (Cavite)

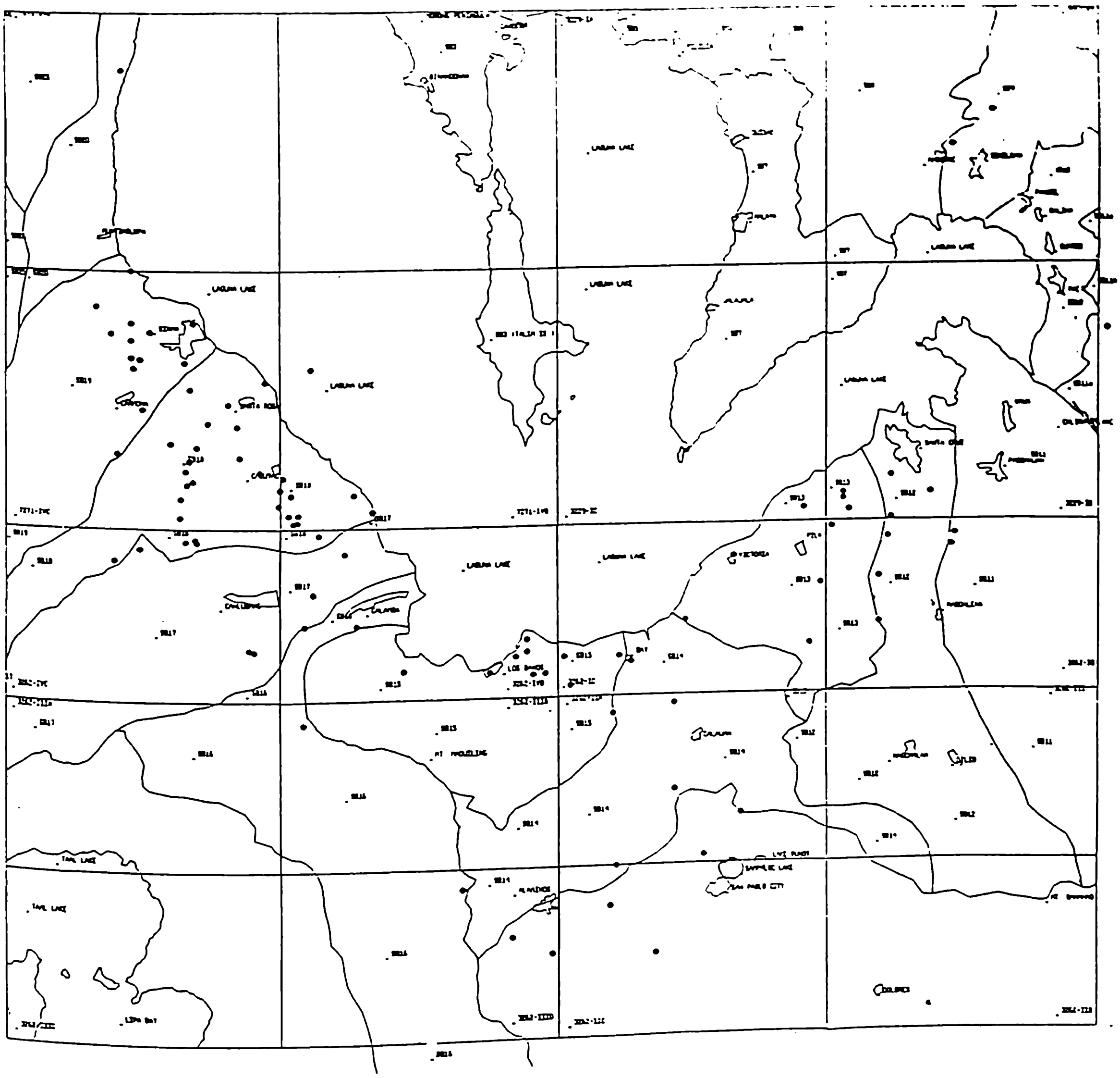

Fig. 13 Well location basemap (Laguna)

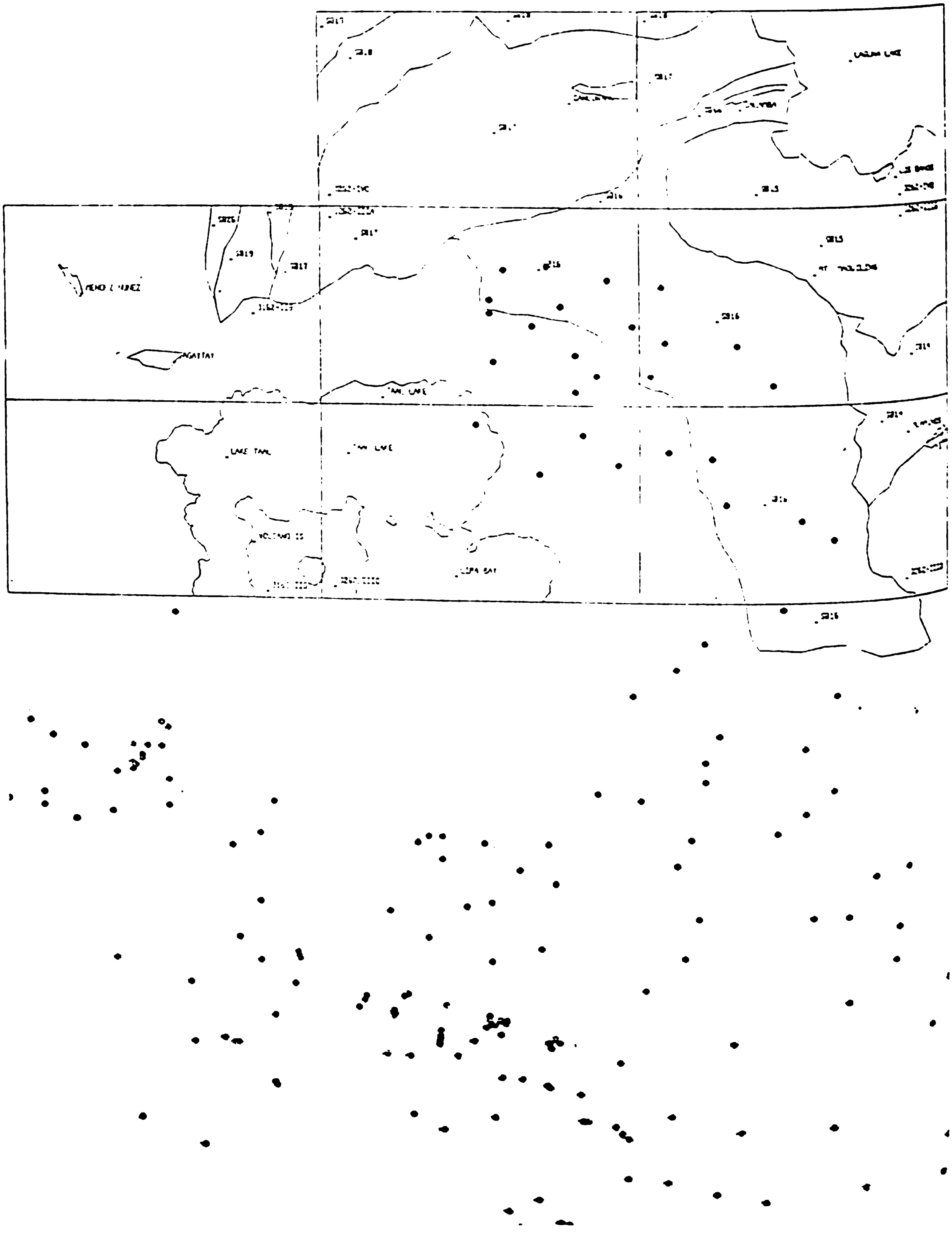

Fig. 14 Well location basemap (Batangas)

Monthly water level data or well hydrographs from 57 NWRB observation wells were compiled. An example is given in Figure 15 of a well hydrograph with monthly data points, located at Poblacion, Tanay, Rizal. Evident in the well hydrograph is the seasonality of the groundwater levels - falling during the dry season and rising during the wet season.

An activity in the task of definition of basin properties was the selection and delineation of thirty (30) subbasins and four (4) lake subareas in the Metro Manila and Laguna Lake basins. This was made by digitizing 20 quadrangles of 1:50,000 NAMRIA topographic maps. Automatic computations of subbasin drainage areas yield the entries in Table 4. Basin and subbasin basemap, textual and vector/raster graphic files were created for purposes of computer display and map overlay with other information, such as well location or depth contours. Figure 16 gives the digitized basemap of the study area.

The initial project effort in defining aquifer geometry is the determination of hydrogeologic basement. There are two localized studies which developed basement information:

a. OEA provided seismic-reflection survey data which were interpreted by NIGS to yield depths below ground surface (BGS) of the hydrogeologic basement in the eastern Cavite and western Laguna area. Figure 17 gives the survey location while Figures 18 and 19 provide the depth contours and 3-D surface of the hydrogeologic basement, respectively.

b. MWSS/JICA reported electro-resistivity survey data and interpretation of the depths of the hydrogeologic basement in the Antipolo, Rizal area. Figure 17 also gives the survey location while Figures 20 and 21 provide the depth contours and 3-D surface of the hydrogeologic basement, respectively.

LONG-TERM APPLICATIONS

The database collection and functions are being continually augmented and enhanced in order to realize their long-term utility and potential as a source of vital groundwater information for the general user, as management tool for water resources planners and technologists and as generator of research information and studies to be conducted by faculty, researchers, students, and practising engineers.

Information of significance to conjunctive surface water hydrology and modeling shall be overlayed with each subbasin. These include climatic data (rainfall and evaporation), topography (elevation), soil type, land use and cover, surface geology, and river-lake network. These data are available in the forms of maps and documents, and will require digitization or transcription to computerized data files prior to overlay.

Another important overlay to be made is that between the surface and subsurface hydrology at subbasin scale. The topography of the surface subbasins will provide the essential surface boundary conditions for the subsurface flows in particular aquifers, in conjunction with the other natural boundaries posed by the major rivers, lakes, faults, rock

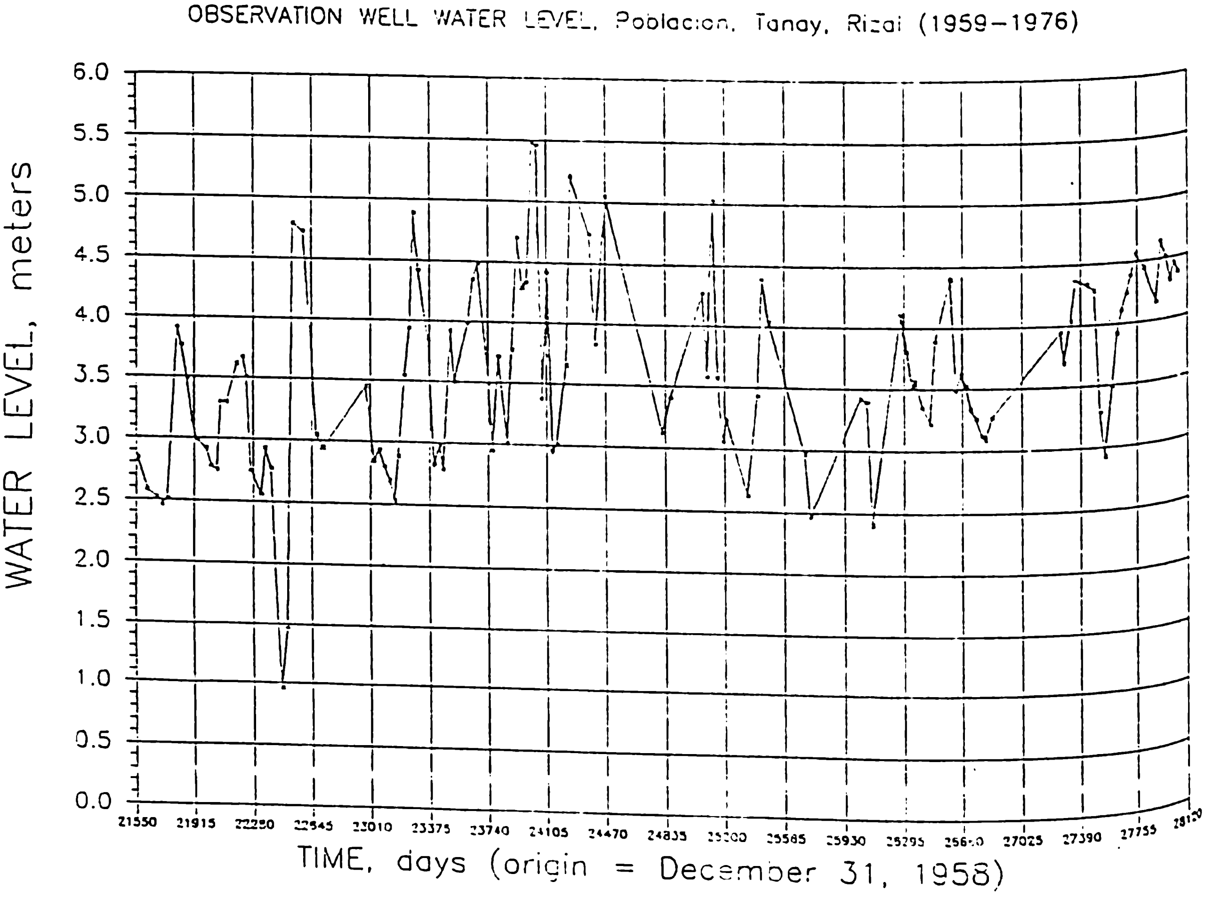

Fig. 15 Observation well water level (Poblacion, Tanay, Rizal, 1959-1976)

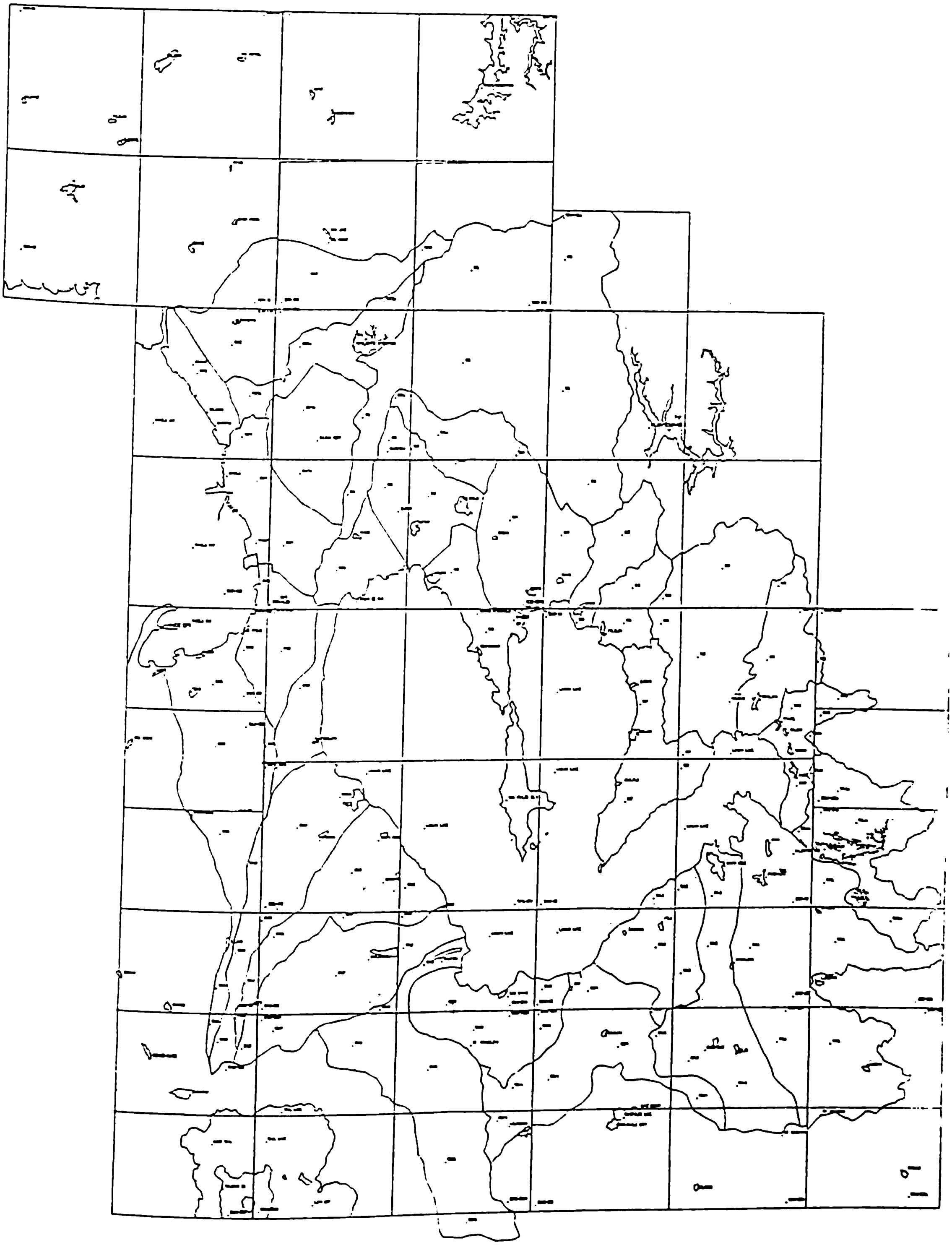

Fig. 16 Digitized basin and subbasin basemaps

Table 4 Subbasin codes, names and drainage areas

Code	Subbasin Name	Drainage Area (sq.km.)	
SB1	*Marikina River Basin*	472	
SB1-a	*Nangka River Basin*	57	
SB2	*Mangahan Floodway-Taytay Basin*	63	
SB3	*Angono-Morong Peninsula-Talim Island*	61	
SB4	*Morong-Baras River Basin Group*	123	
SB5	*Tanay River Basin*	53	
SB6	*Pililia River Basin*	42	
SB7	*Jala-jala Peninsula*	96	
SB8	*Sta.Maria River Basin*	180	
SB9	*Siniloan/Romero River Basin*	75	
SB10	*Paete Basin*	54	
SB11	*Pagsanjan River Basin*	315	
SB11-a	*Caliraya Reservoir Basin*	129	
SB12	*Sta. Cruz River Basin*	124	
SB13	*Pila Basin*	87	
SB14	*Calauan Basin*	155	
SB15	*Los Banos-Mt.Makiling Basin*	102	
SB16	*Calamba/San Juan River Basin*	156	
SB17	*Canlubang/San Cristobal River Basin*	139	
SB18	*Sta Rosa-Cabuyao River Basin Group*	120	
SB19	*San Pedro-Binan River Basin Group*	132	
SB20	*Sucat-Alabang-Muntinlupa Basin*	43	
SB21	*Taguig-Napindan Basin*	45	
	subtotal		2823
SB22	*Meycauayan River Basin*	169	
SB23	*Obando-Malabon-Navotas Estuary*	35	
SB23-a	*Novaliches Reservoir/Tullajan River Basin*	72	
SB24	*Pasig River Basin*	91	
SB24-a	*San Juan River Basin*	94	
SB25	*Paranaque-Las Pinas River Basin Group*	73	
SB26	*Zapote-Bacoor-Imus River Basin Group*	168	
	subtotal		702
LB1	*West Bay of Laguna Lake*	398	
LB2	*Central Bay of Laguna Lake*	214	
LB3	*East Bay of Laguna Lake*	134	
LB4	*South Bay of Laguna Lake*	183	
	subtotal		929
	Laguna Lake Basin		3752
	Other Metro Manila Basins		702
	Study Area		4454

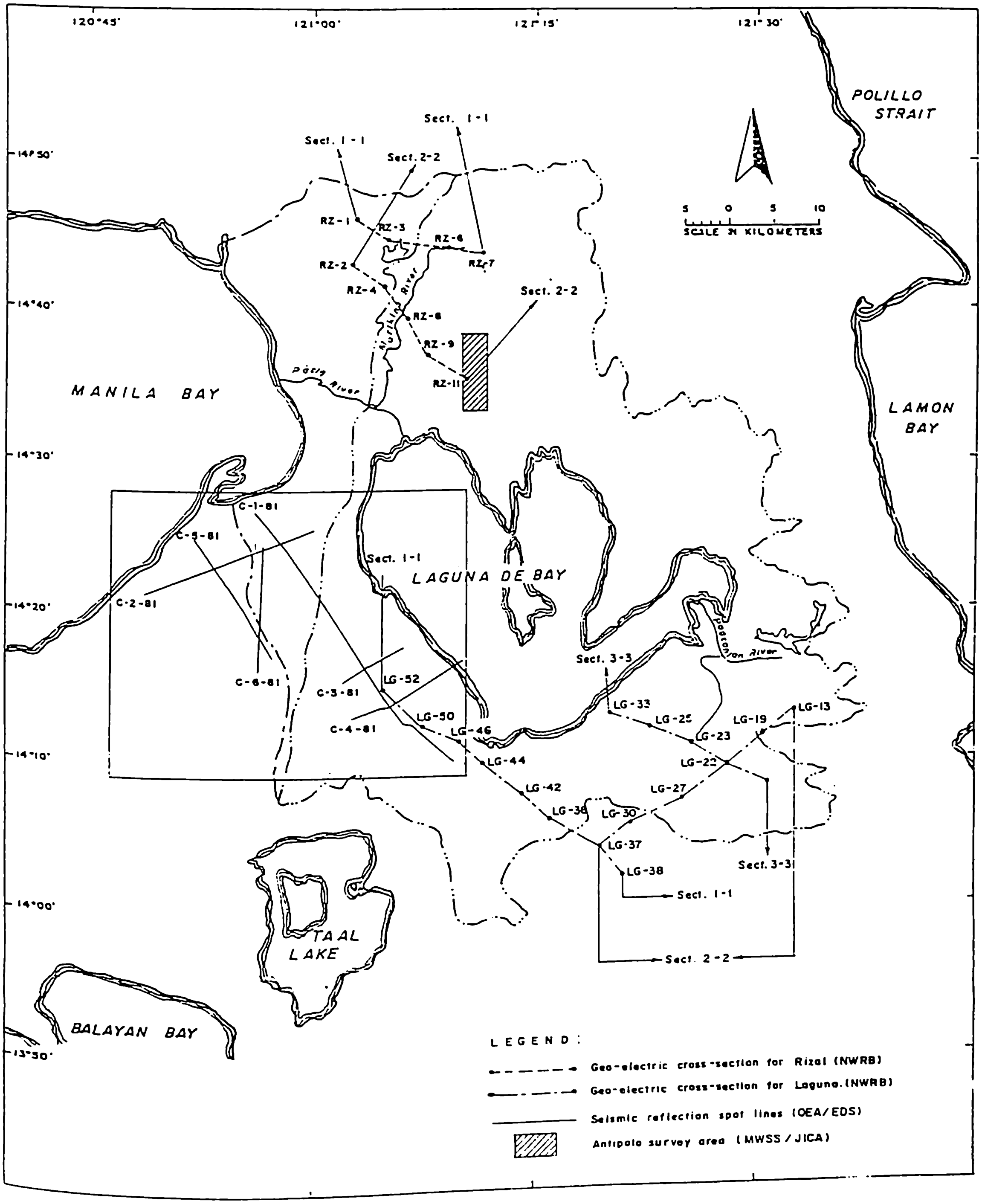

Fig. 17 Location map for geophysical surveys of OEA, MWSS/JICA and NWRB

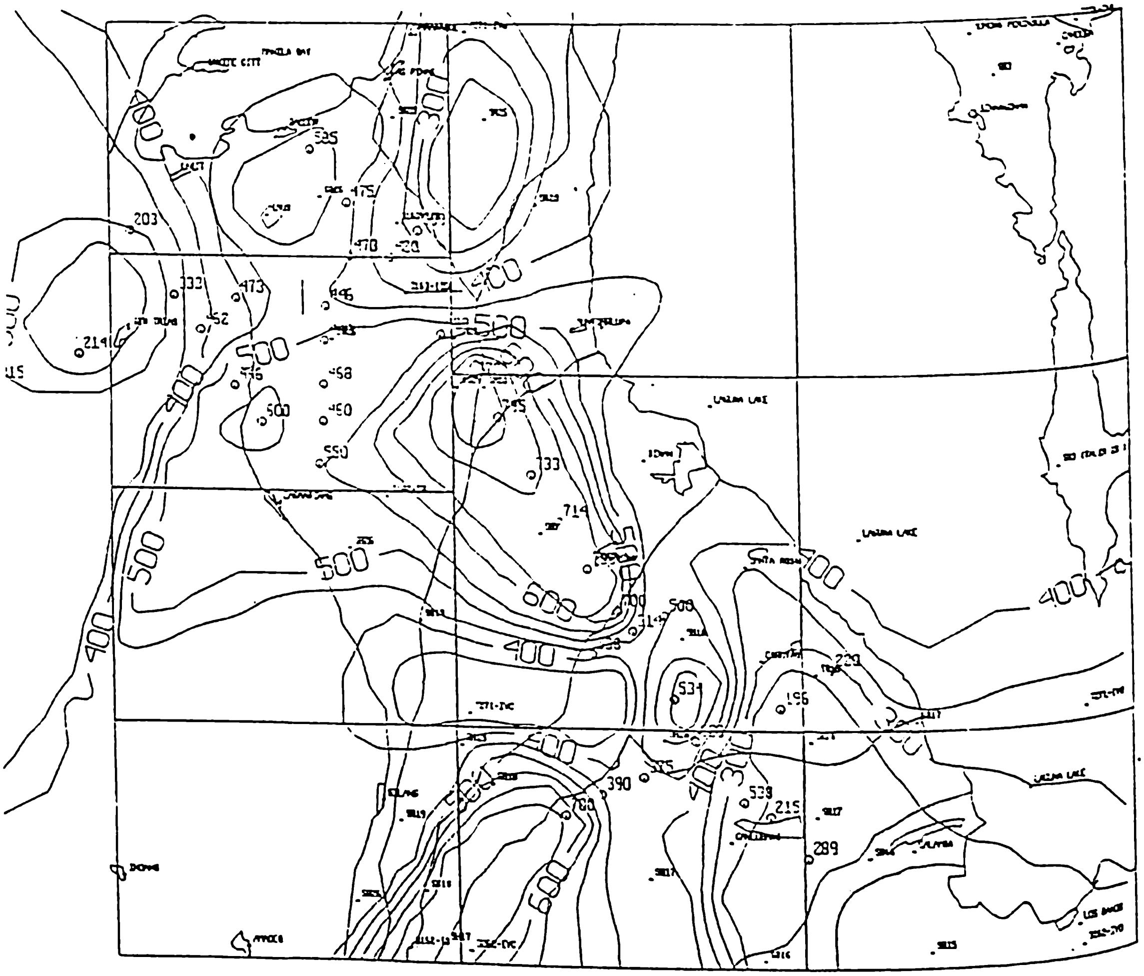

Fig. 18 Hydrogeological basement (depth contours in meters BGS)
Cavite-Laguna area

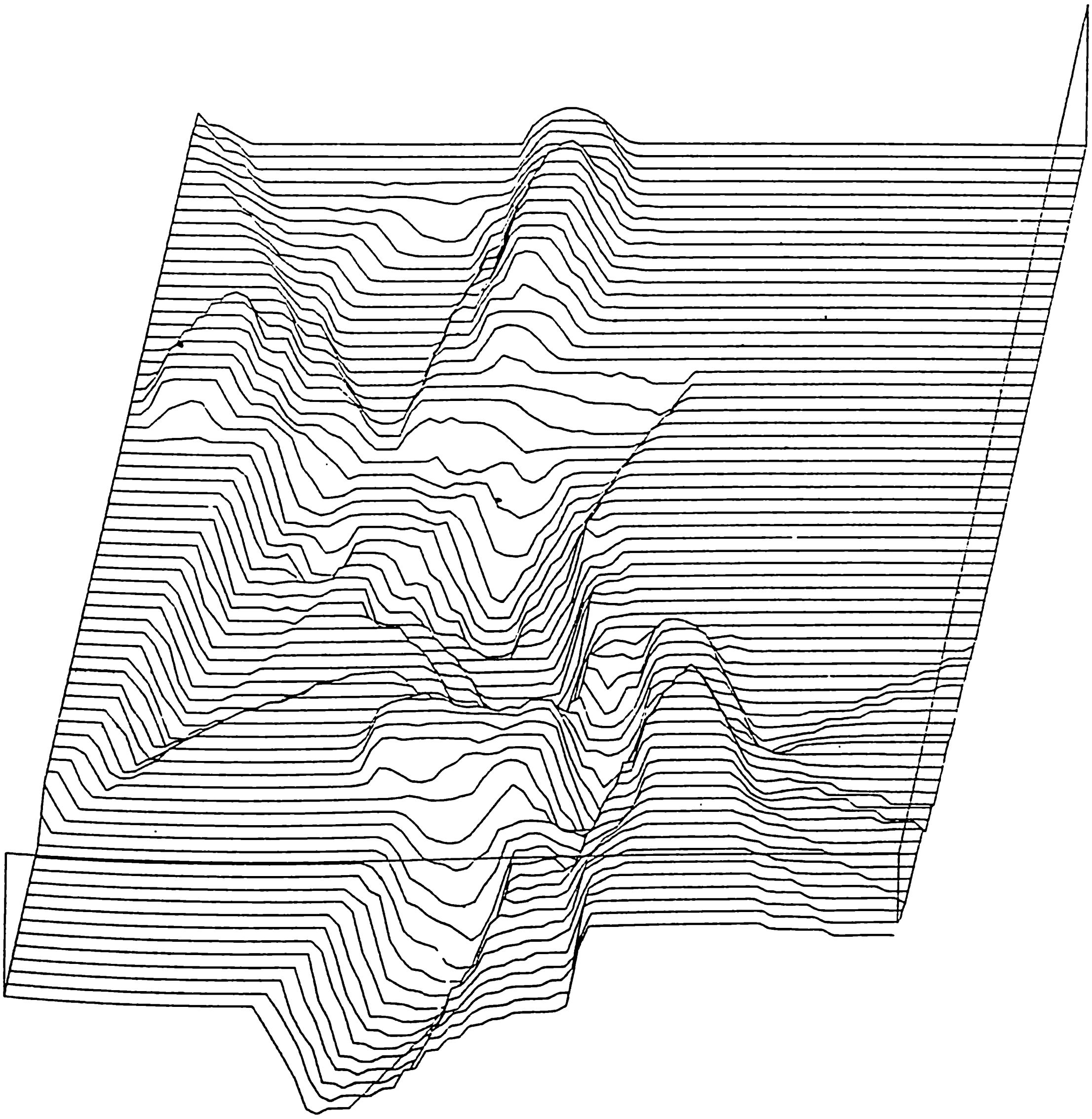

Fig. 19 3-D surface of hydrogeologic basement, Cavite-Laguna area

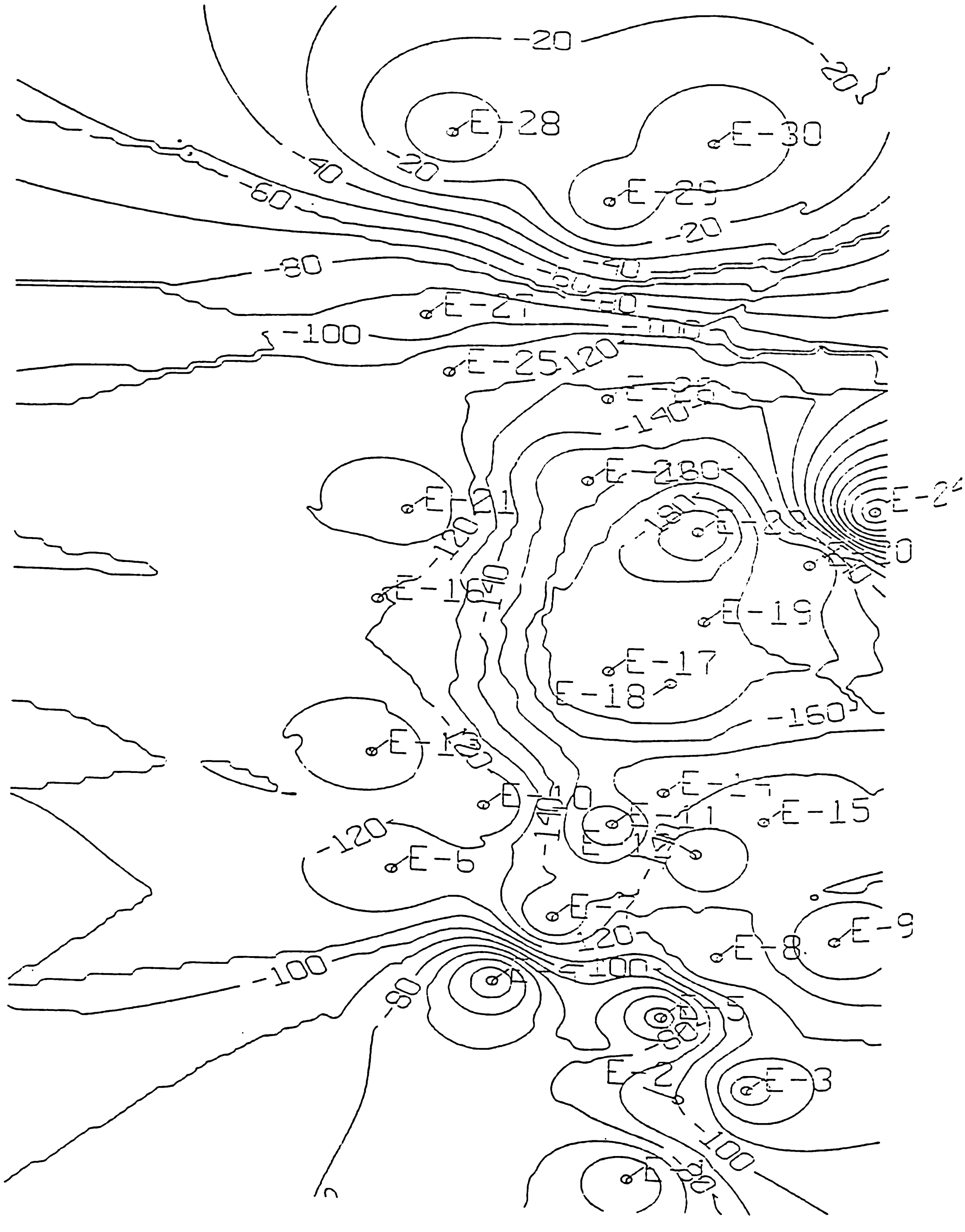

Fig. 20 Hydrogeological basement (depth contours in meters BGS) Antipolo,Rizal area

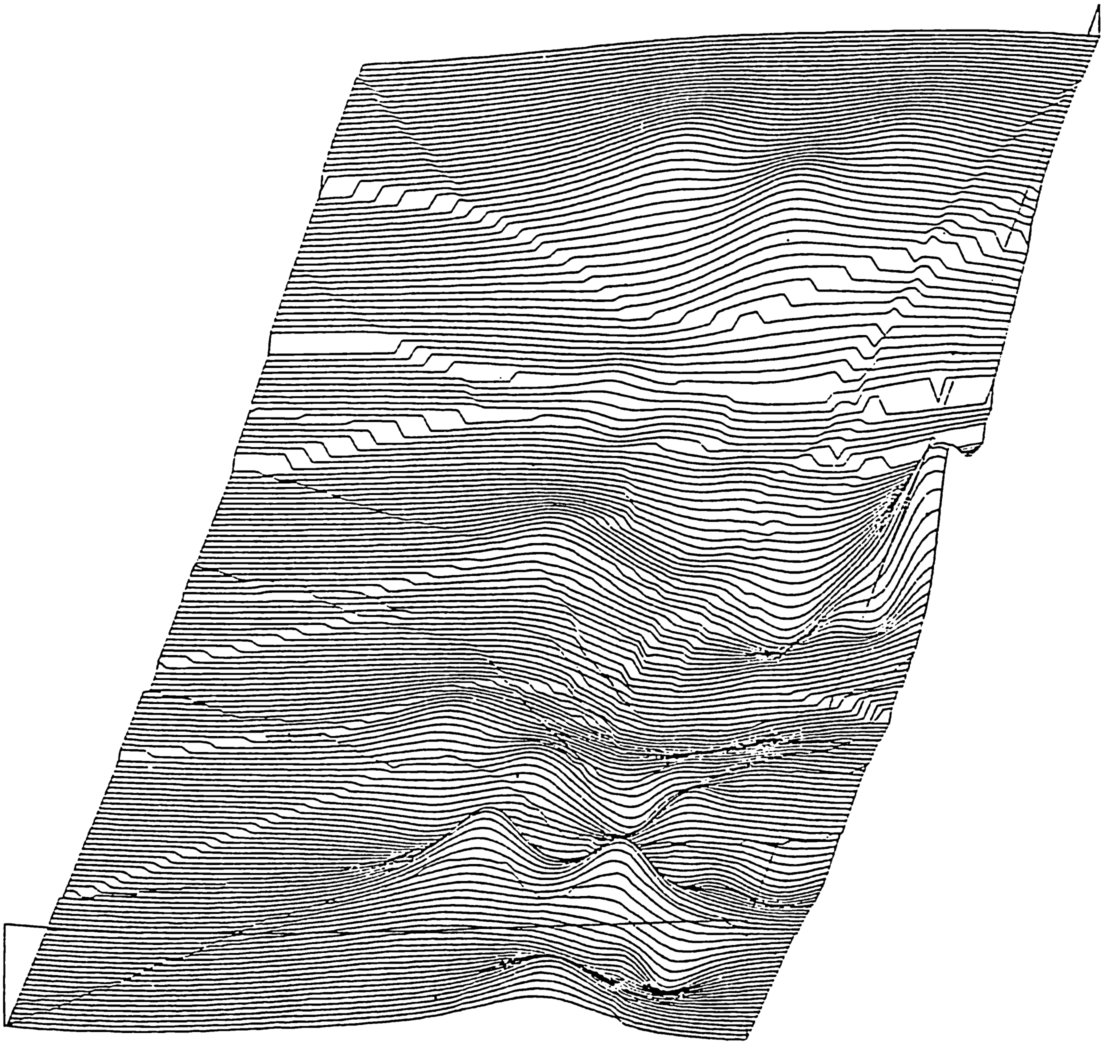

Fig. 21 3-D surface of hydrogeologic basement, Antipolo, Rizal area outcrops, and hydrogeologic basement. Lumping together of adjacent rural subbasins for modeling purposes may be expected where low data resolution warrants the scheme. On the other hand, highly-exploited urbanized subbasins with high data resolution shall be modeled in more detail at that scale.

A possible fertile area of endeavor is the utilization of the database to identify critical water data gaps and the recommendation for focused and remedial data collection programs by specialized agency. This is a self-fulfilling function since more collected data will then be available for the database.

CONCLUSION

The groundwater database developed at NHRC for the immediate modeling task as well as for long-term applications has been described. The importance and effectiveness of multi-agency linkage and cooperation have been demonstrated in the success of the data collection effort. The choice and utilization of proven software platform with the required specialized functions provided a cutting edge in the rapid production of meaningful and useful output. Enhancement of the input phase of the water management modeling effort has been achieved.

The first-year experience with the database activity has confirmed the pre-project thinking that the scattered data and information, once integrated in a single repository of knowledge, can rapidly start to evolve into a useful resource for water resources planning and development. The combination of multi-agency cooperation, a university-based research setting, and affordable computer technology appears to be deciding factors which can be replicated for databases in other similar branches of engineering.

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2. MWSS (1990). Study for the Groundwater Development in Metro Manila: Inception Report.

3. MWSS (1990). Study for the Groundwater Development in Metro Manila: Progress Report I.