REPUBLIC OF THE PHILIPPINES
METROPOLITAN WATERWORKS AND SEWERAGE SYSTEM

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

MANUAL REPORT

JUNE 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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GROUNDWATER EXPLORATION
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GROUNDWATER EXPLORATION MANUAL

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1. ELECTRIC RESISTIVITY SURVEY

1.1 GENERAL

The electric resistivity method is a major geophysical tool used in groundwater exploration efforts. Electric resistivity is undertaken to determine geology and geological structure based on resistivity, σ, the electrical property of geological formations. Each type of formation has an inherent resistivity value in unit cubic volume, and particular values in accordance with geological conditions. Unit of resistivity is Ω - m. Electric resistivity may be measured by vertical electric sounding for the distribution of resistivity toward vertical direction, or by horizontal electric sounding for the distribution of resistivity toward horizontal direction. Both methods however, do not have substantial differences.

In measuring electric resistivity, four electrodes are used. These electrodes are arranged along a straight line as shown in Figure 1.1. The outer two electrodes (C_1, C_2) are current electrodes and the inner two (P_1, P_2) are potential electrodes to measure potential difference. If potential difference between P_1 and P_2 at the time of flow of electricity (I) should be V, resistivity is calculated by the following equation:

$$\sigma_a = 2\pi \times 1/C \times V/I \text{ ---------- } (1)$$

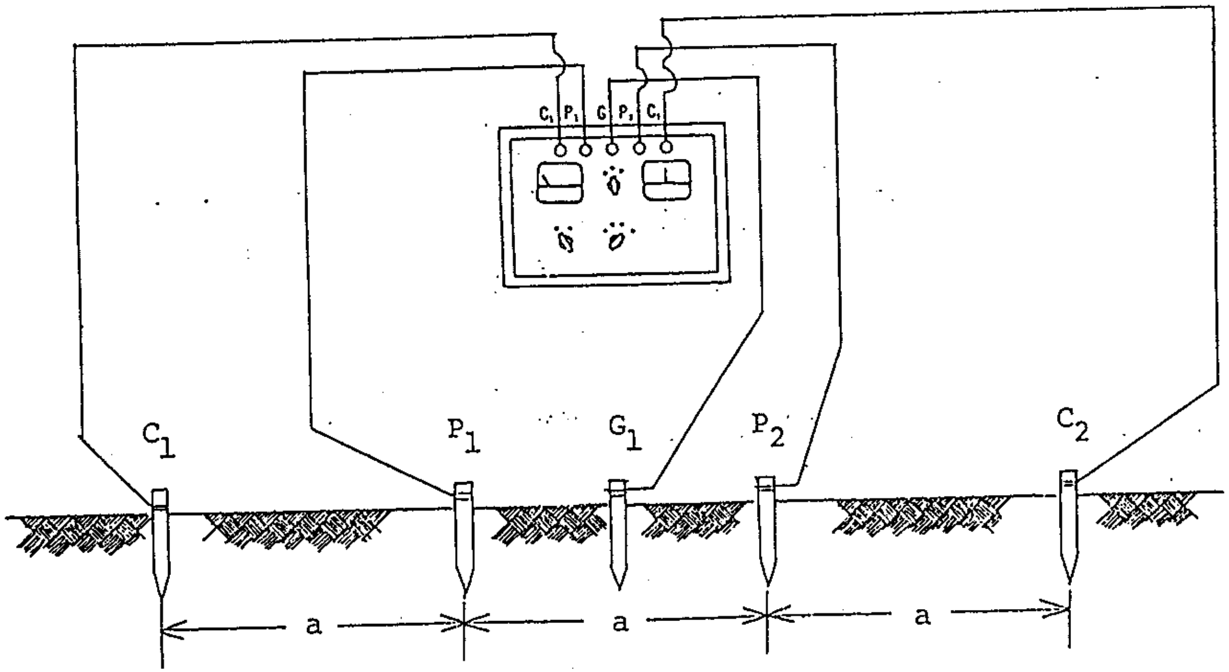
$$C = 1/C_1P_1 - 1/C_2P_1 - 1/C_1P_2 + 1/C_2P_2$$

Electrodes may be set in several ways based on electrode interval. The most common electrode setting is the Wenner's method, putting equal interval between each electrode.

In this condition, $C_1P_1 = P_1P_2 = C_2P_2 = a$
thus, equation (1) is converted as follows:

$$\sigma_a = 2\pi a \times V/I \text{ ---------- } (2)$$

If geological formations are semi infinite and isotropic, σ_a would indicate the resistivity of the formation, and would become constant



P_1, P_2 : Potential Electrodes

C_1, C_2 : Current Electrodes

Figure 1.1. MEASURING METHOD OF ELECTRIC RESISTIVITY SURVEY (WENNER METHOD)

notwithstanding electrode interval and electrode setting.

Actual formations have variable characteristics in vertical and horizontal directions, and are quite different from isotropic condition of geologic formation. As such, measured value σa is referred to as apparent resistivity, indicating resistivity in some range in accordance with electrode interval and geological structure.

If electrode interval is large, much electric current flows in deeper portions. As a result, apparent resistivity includes the influence of geological formations. Vertical electric sounding makes use of this phenomenon. In other words, the distribution of resistivity in the vertical direction is measured and estimated by the relation between a series of electrode intervals and apparent resistivity values. On the other hand, horizontal electric sounding estimates the variation of geological formation in horizontal direction based on horizontal distribution of apparent resistivity in a specified electrode interval.

1.2 MEASUREMENT

Resistivity is conducted by using the following materials and equipment:

Electric Resistivity Meter : 1 set

Electric Wire : 4 sets
(Length of the wire depends on maximum measuring depth)
(Color of the wire should be different from each other)

Electrode : 5 pieces
(Stainless, Large diameter)

Battery : 1 unit
(Type depends on electric resistivity meter type)

Tester : 1 unit

Measuring Tape : 1 lot
(Length of the tape depends on maximum measuring depth)

Hammer (1.0 - 1.5 kg) : 6 pieces

Electrical Vinyl Tape (different colors) : 1 lot

Hostel : 1 piece

Transceiver : 4 sets

Before the start of the survey, measuring tape shall be marked by electrical vinyl tape at every measuring point.

Measurement is generally conducted by flowing alternating current ranging from 5 to 40 Hz through the electric wire connecting the measuring equipment and electrodes as shown in Figure 1.1. The setting interval of electrodes in vertical sounding should be symmetrical on both sides, in the right and left sides of center point in horizontal direction. Thus, the direction of measurement is expected to extend along contour lines and in the direction of flow on river terraces or river beds.

After determining the area to be surveyed, lines connecting measuring points shall be checked. This distribution shall be determined considering surveying objective, topography, and geology. The interval of measuring points shall depend on the type of geological formations i.e., it will be longer if geological formations are simple and shorter if formations are complicated.

In vertical sounding, measurement is carried out step by step at a constant electrode interval. Data shall be recorded in a data sheet as shown in Table 1.1.

In order to detect the boundary between some formations and an underlayer, electrode interval(a) shall be expanded up to two or three times as long as the estimated depth of the boundary. On the other hand, horizontal sounding is carried out at constant electrode interval by using jointly two or three kinds of electrode intervals.

Measuring equipment indicates voltage and electric current in each measured point. Apparent resistivity σ_a is calculated by multiplying

TABLE 1.1 Data Sheet Sample for Electric Resistivity Survey (Measuring Depth: 300 m)

Area: Date:

No:

a	$2\pi a$	R	ρ	a	$2\pi a$	R	ρ
1	6.28			32	201.0		
2	12.56			34	213.5		
3	18.84			36	226.0		
4	25.1			38	238.5		
5	31.4			40	251.0		
6	37.7			42	263.8		
7	44.0			44	276.0		
8	50.25			46	288.6		
9	56.5			48	301.5		
10	62.8			50	314.0		
11	69.1			52	326.3		
12	75.4			54	339.0		
13	81.6			56	351.5		
14	88.0			58	364.0		
15	94.2			60	376.5		
16	100.5			64	402.0		
17	106.9			68	427.0		
18	113.0			72	452.0		
19	119.2			76	477.0		
20	125.6			80	502.5		
22	138.1			84	527.5		
24	150.9			88	553.0		
26	163.2			92	578.0		
28	175.9			96	602.5		
30	188.4			100	628.0		

Area: Date:

No:

a	$2\pi a$	R	ρ	a	$2\pi a$	R	ρ
1	6.28			32	201.0		
2	12.56			34	213.5		
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30	188.4			100	628.0		

$2\pi a$ by ($R = V/I$) in Table 1.1. In vertical sounding, σ - a curve is made by plotting σ_a and electrode interval a on log-log papers (Refer to Figure 1.3). In horizontal sounding, the relation between σ_a and horizontal distance of measuring points on semi-log and section papers shall be plotted.

1.3 ANALYSIS

The analysis of data is conducted by assuming that geology below ground surface would be stratified horizontal formations at any measuring point. In Wenner's electrode intervals, the standard curve of Sundberg (refer to Figure 1.2), the theoretical method is generally used. In case measured geological structures will be of two layers, the following analyzing procedures are used as shown in Figure 1.3.

a. Determination of resistivity value and thickness in first layer: laying σ_a - a curve on top of standard curve, selecting standard curve matched and plotting a standard point (0) (in the condition of $\sigma_a/\sigma_1 = 1$, $a/d = 1$). In this case, 0 point in vertical coordinate on the log-log papers becomes the resistivity of first layer (σ_1) and the horizontal coordinate indicates layer thickness (d).

b. Determination of resistivity in second layer:

If parameter of a standard curve matched with σ-a, curve shall be $\sigma_2/\sigma_1 = \infty$, the resistivity of second layer is calculated by the equation of $\sigma_2 = \infty \times \sigma_1$.

In case the geological structures are more than three layers, an auxiliary curve is necessary to replace the case of two layers. Therefore, the above treatment and procedures become complicated.

Draw the matching auxiliary curve starting from standard point (0) on the log-log paper (auxiliary curve I in Figure 1.3).

FIGURE 1.2-A Sundberg's Standard Curve

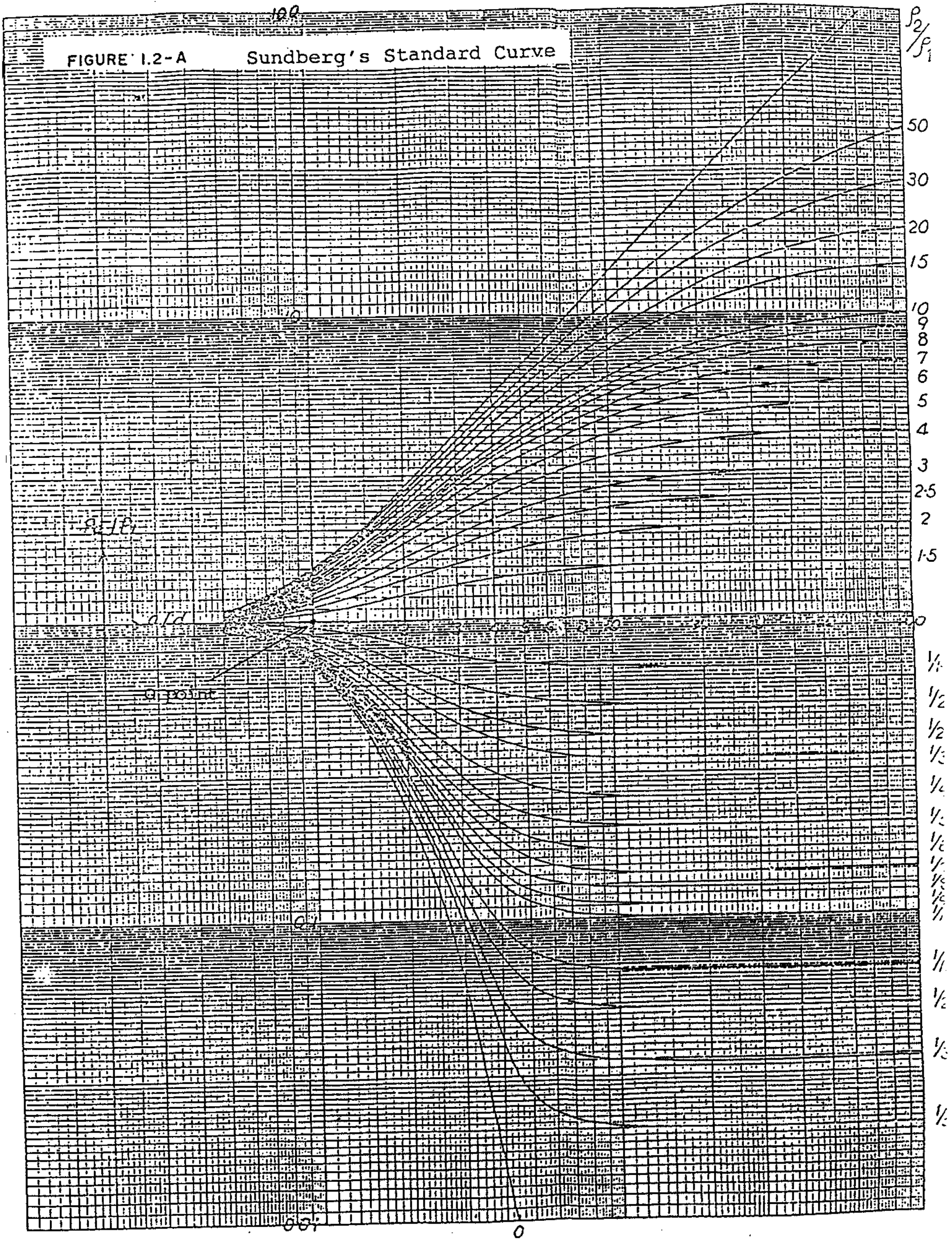
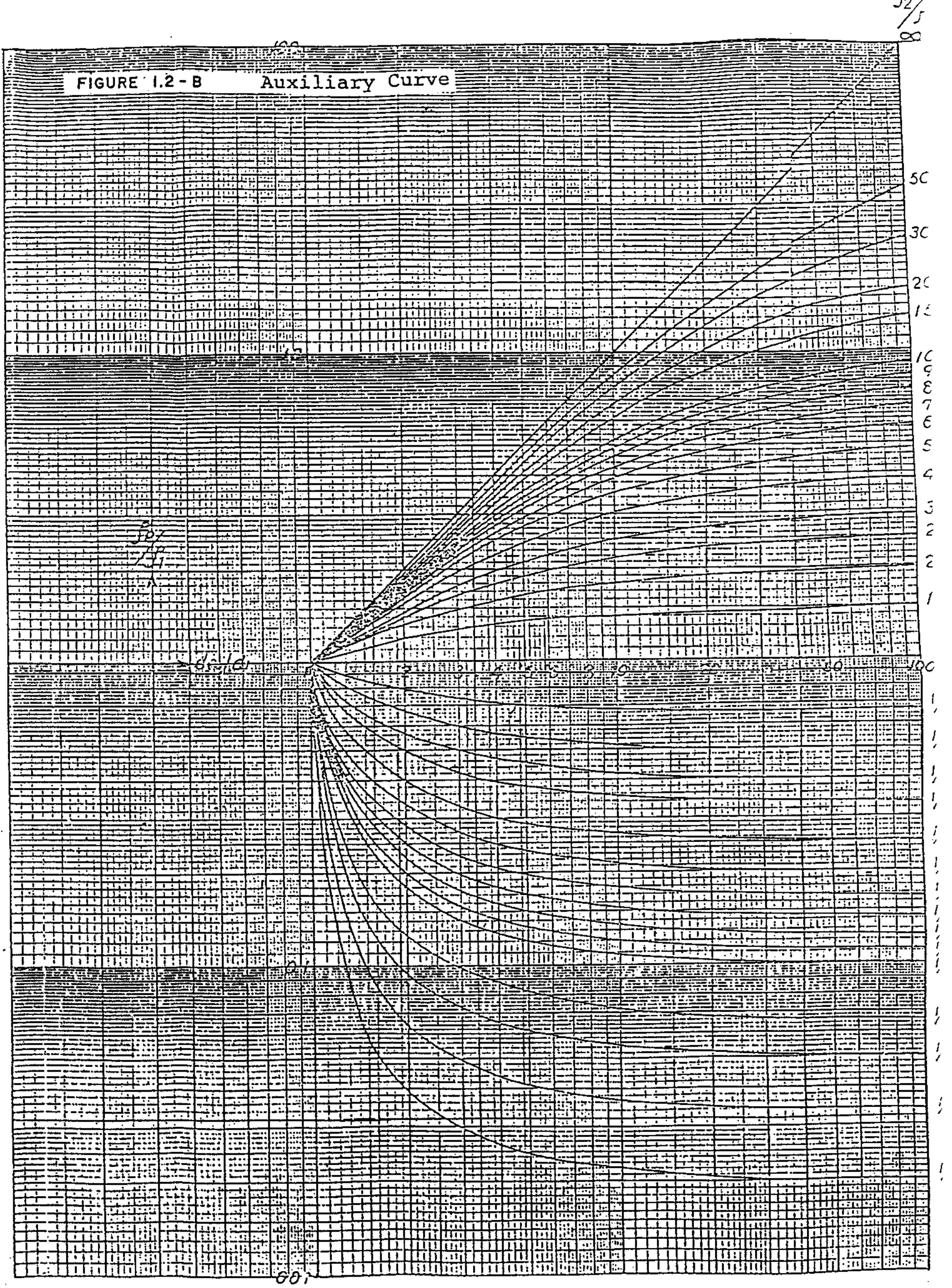


FIGURE 1.2 - B Auxiliary Curve



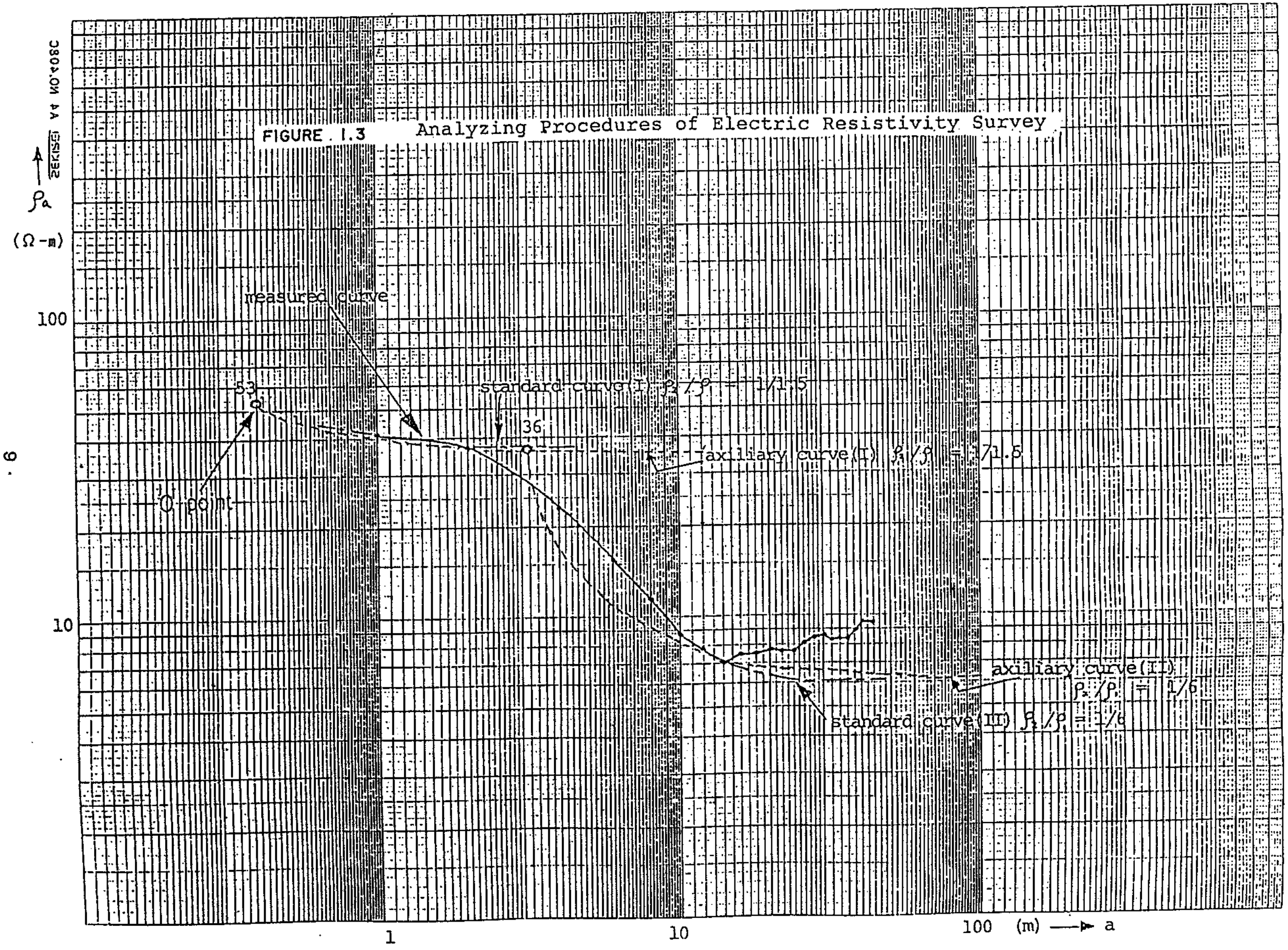


FIGURE 1.3 Analyzing Procedures of Electric Resistivity Survey

1.4 INTERPRETATION

As the resistivity reflects formations, structures, porosity, percentage of clay, groundwater quality and moisture content, specific geological conditions cannot be easily and simply determined based on analyzed results, and the most probable geological condition is selected after considering several possibilities.

Resistivity values in geological formations are shown in Table 1.2 for reference in interpretation. In sand and gravel layer, resistivity is fairly high because groundwater has tendency to flow easily with few dissolved matter. The resistivity of igneous rock is generally high because of the influence of minute structure. Therefore, the identification of igneous rocks as a basement rock is comparatively easy, but for Tertiary formations is difficult.

In the interpretation of measured values, resistivity values are firstly classified into some blocks in each measuring point, and geological condition will be roughly estimated from every resistivity value. In addition, the results need to be examined and interpreted based on the detailed observation of survey area on geology and topography.

Table 1.2 Apparent Resistivity in Geological Structures of Two Layers (after Dobrin)

Geology		Apparent Resistivity (Ω-m)
Alluvium	Clay	10 - 100
	Sand	100 - 600
	Sand/Gravel	100 - 1,000
Diluvium	Loam	100 - 250
	Sand/Gravel	300 - 1,000
Neogene	Sandstone	50 - 500
	Shale	20 - 200
	Conglomerate	100 - 500
Volcanics	Tuff	20 - 200
	Lava	500 - 10,000
	Andesite	100 - 2,000
	Granite	1,000 - 10,000

2. PHYSICAL LOGGING

2.1 ELECTRIC LOGGING

2.1.1 General

Electric logging is undertaken to determine the character and thickness of the various strata at the well site. Electric logging in drilled holes measures the resistivity of the earth materials by recording the potential difference when current flows through the earth from one electrode to another.

The log can only be run in uncased holes filled with water or mud water to provide electrical connection between the logging tool and the formations. Current flow is generated between an electrode down the hole and one at the surface. Electrical potential is measured between these, or another pair of electrodes. Resistivity is measured in ohmmeters, a unit which allows for variations in the size of the flow path. The logging probe which will have one or more exposed electrodes is usually used. The sheave to support the logging cable will have to be rigged in the tripod and held so as to keep the cable in the center of the hole. The surface electrode is connected to any point of good ground contract preferably, the mud pit. The logging system is shown in Figure 2.1.

Electric logging measures resistivity around the drilled hole in a similar manner to electric resistivity survey. Two, three or four electrodes methods based on setting manners of electric current electrodes (A, B) and potential electrodes (M, N) may be used. Electrodes set in a drilled hole are dropped and lifted and are assembled in one probe with other electrodes set on ground surface fixed.

The two-electrodes method is generally used because identification with geological formation is comparatively easy. In the two electrode method, resistivity is calculated from the following equation:

$$\sigma = 4\pi a \times V/I$$

In the equation, a is equal to electrode interval, σ indicates not true resistivity of geological formation but its apparent resistivity for

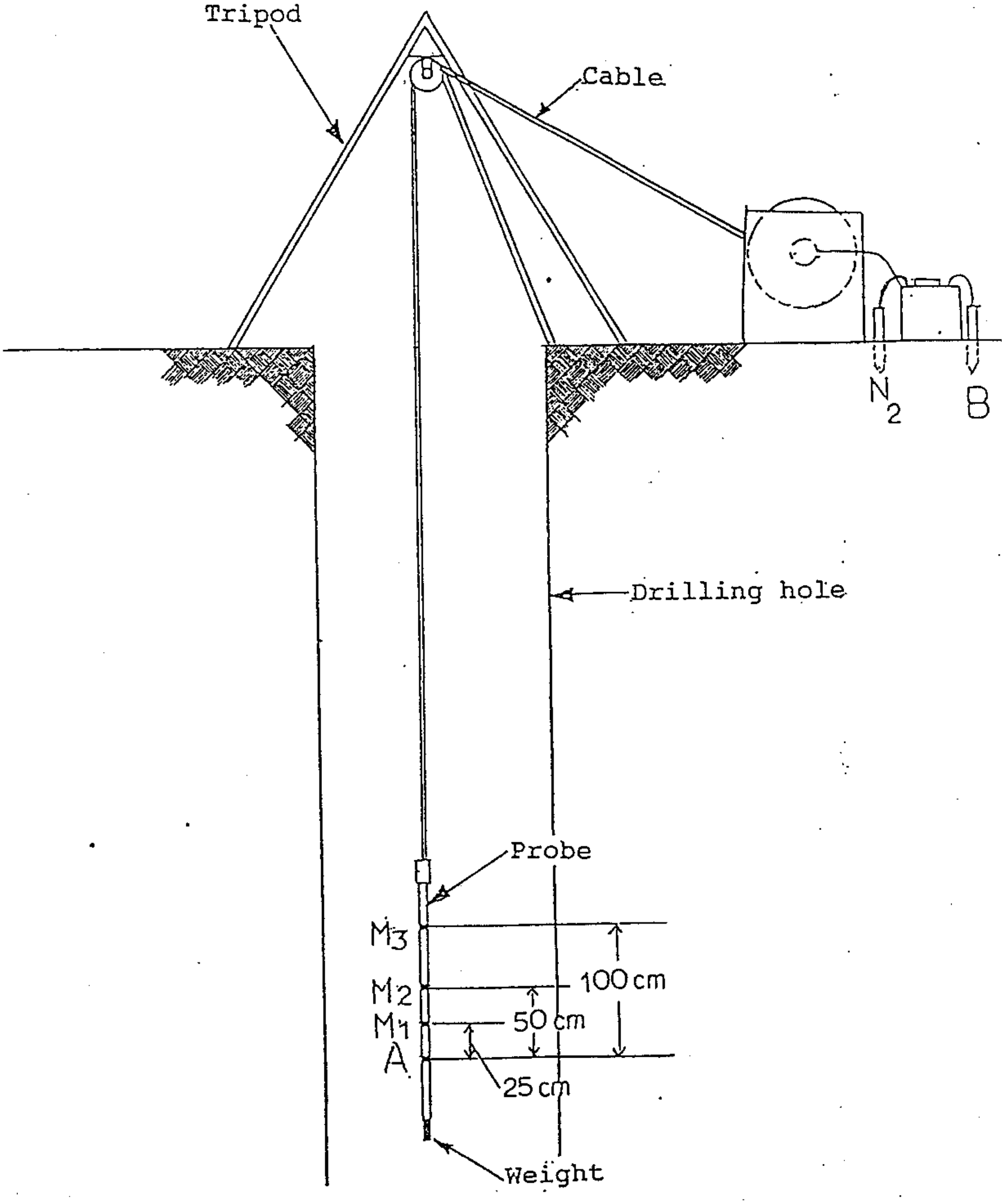


Figure 2.1 ELECTRIC LOGGING (Normal)

including the influence of thickness of geological formation, the diameter of drilled hole and mud water.

2.1.2 Measurement

In electric logging, the following electric logging equipment or electric resistivity survey equipment are used:

Measuring equipment with recorder : 1 unit
Normal resistivity-SP probe : 1 unit
(and other probes based on measuring items)
Weight for probe : 1 unit
Tripod stand with pulley : 1 unit
Cable with connector : 1 set
(Length depends on measuring depth)
Wrench : 1 unit

Electrode interval is based on the thickness of geological formation or drilled hole diameter. In case electrode interval is small, detection capability of thinner layers shall increase influenced by mud water inside hole. If the interval is large, the equipment can measure resistivity in deeper portions in horizontal direction in drilled hole wall. Reversely, the thinner layers shall be difficult to detect. Therefore, in many cases, several electrode intervals shall be actually combined.

In combining electrode intervals in two electrodes method, the intervals of AM = 0.25, 0.5, 1.0 m or 0.5, 1.0, 1.5 m are generally used. The setting of electrodes is indicated in Figure 2.1. At measuring time, electrode interval is changed by a switch and is measured in different intervals. Fixed electrodes set on ground surface shall be at a distance from drilled hole. Potential electrode should be up to ten meters from each other and far more than 30 meters from a drilled hole for current electrodes.

After washing the inner side of drilled hole, probe is dropped to the well bottom and measurement is successively carried out with lifting of the equipment. Electric logging data are usually measured at intervals of one or two meters depth. The results of resistivity in a drilled hole with water shall be effective and useful in analysis and interpretation.

2.1.3 Interpretation

The result of measurement will be influenced by drilled hole diameter and mud water. Apparent resistivity properly reflects the variation of geological formation, thus, the result of measurement has to be properly analyzed.

General interpretations shall be based on the following:

a. Low resistivity is usually associated with saturated formations and saline water e.g. shales, clays.

b. Medium resistivity indicates fresh water sand or porous rocks.

c. High resistivity is exhibited by dense and impermeable rocks.

2.2 SPONTANEOUS POTENTIAL LOG

2.2.1 General

Spontaneous potential logs (S.P.) are records of the naturally occurring electrical potential at different depths along the bore hole. In the drilling hole, electrochemical potential is caused by the occurrence of the difference of chloride concentration between water inside drilled hole and groundwater, together with clay layer. In addition, electric flow occurs in case water inside the drilled hole intrudes in its peripheral formations.

Spontaneous potential comprise of electrochemical potential and potential of electric flow, and is affected by geological formation and chloride concentration in drilled hole.

Spontaneous potential is caused by a complex mixture of the different formations and the bore hole fluid. Mud water intrusion in the formation or an increase in bore hole diameter affects the measured values.

2.2.2 Measurement

To obtain the data required, it is only necessary to run a single electrode probe made of lead.

In general, spontaneous potential is measured with a pair of electrodes connected to a sensitive voltmeter used also for resistivity logging. An S.P. log is often and simultaneously run with the resistivity logs.

2.2.3 Interpretation

Spontaneous potential affects not only absolute values but also relative values. Standard value for the difference of relative values is generally electric potential. Spontaneous potential shall be interpreted with the result of resistivity logging, with both of them complementing the other. A sample of spontaneous potential log data is shown in Figure 2.2.

General conditions in the aquifer are as follows: Good aquifer including fresh water indicates high resistivity values and spontaneous potential moves to positive side. The resistivity values of aquifer with brackish or saline water is lower in comparison to that with fresh water, but is higher than resistivity values of adjacent clay layer and the values shift to negative side.

Considering the above, the evaluation of the occurrence of aquifers, the identification and comparison between the same formations, and alterations of groundwater quality are possible.

2.3 Gamma and Other Geophysical Log

A gamma ray log records the natural radiation of the formations. A gamma ray log can record in a dry hole and a cased hole; it will provide a log of an old hole when no other information about the hole is available. The gamma log usually distinguishes between aquifers (sand) and non water producing beds (clay and clayey sand) in unconsolidated formations. Difficulties in getting clear results from a gamma log arise from excessive clays in the mud layers in large diameter holes and high

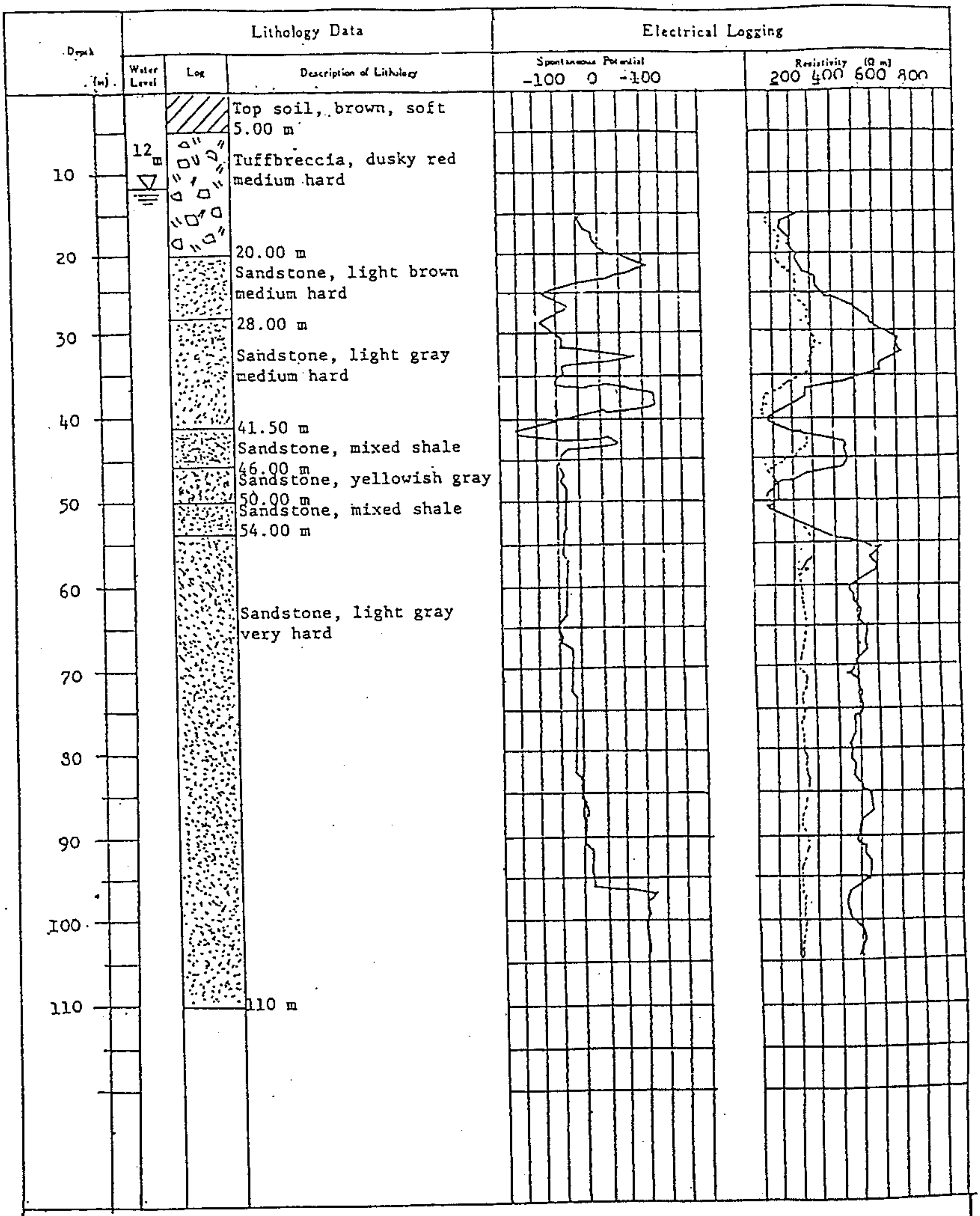


Figure 2.2 SAMPLE OF SPONTANEOUS POTENTIAL LOG DATA

radioactivity in some sand beds due to heavy minerals in the sand.

The gamma radiation from clays is usually much higher than that from sand. When the sand contains radio-active minerals, the relationship is reversed.

2.4 Neutron Log

Neutron logs are used primarily as an indicator of total porosity under saturated conditions.

2.5 Caliper Log

The caliper log measures the diameter of the bore hole. In some cases, it can detect casing couplings and reveal the position of screens in a cased hole. Most caliper tools contact the walls of the hole with three or more curved springs. Flexing of the springs to follow hole size is translated into diameter measurement and recorded as a graph of diameter against depth. Caliper measurement is recorded with the tool moving up the hole.

2.6 Temperature Log

The temperature gradient and irregularities in the gradient measured in the borehole are an important factor in hydrogeological survey. A temperature log will indicate the location f water inflow zones.

3. PUMPING TEST

3.1 GENERAL

Pumping test comprise of the step drawdown test, continuous drawdown test and recovery test. In general, pumping test is carried out to determine the safe yield of new wells, hydrogeological aquifer constant of transmissivity, storage coefficient and specific yield.

Step drawdown test involves five to seven steps with two pumping hours duration each step. Drawdown of dynamic water level in each step is continuously measured at specific time intervals. Results of step drawdown test reveal the safe yield, the constant aquifer loss and well loss. Safe yield of the well is necessary in the determination of pump capacity.

Continuous drawdown test, after completion of step drawdown, is carried out to obtain the transmissivity and storage coefficient. The test is generally undertaken by measuring drawdown under conditions of constant discharge for 24 hours pumping duration.

The aquifer constant, transmissivity and permeability and storage coefficient are used to determine the characteristics of the aquifer and to calculate radius of influence of cone of depression and other factors during pumping.

Transmissivity (T) is the multiplier coefficient of thickness of aquifer and permeability and is the product of thickness of saturated portion of aquifer. Storage coefficient (S) is defined as the volume of water released when the piezometric surface is lowered by one unit of its depth.

Recovery test is immediately executed after the continuous drawdown test. The recovery of lowered water level at specified time interval is determined by this test. The test also defines the constant of transmissivity.

3.2 Measurement

Pumping test involves preparation work, observation work and data analysis. The procedures and equipment required to carry out the pumping test are as follows:

a. Measurement of pumping rate

In the pumping test, the discharge must be measured continuously with the weir and orifice devices. Weirs are triangular or rectangular in shape. Considering discharge measurement, the triangular weir is more useful than the rectangular one. The completed or prefabricated weir is made of iron plates.

i) Triangular Weir

The cutting degrees of weir can be divided into two types, 60^{o} and 90^{o} according to the range of the measuring discharge. The weir plate section must be right angled between its inside and upper portions and the edge must be cut sharply. The width of upper portion of weir plate is about 2 mm. The cutting angle of weir plate shall be 60 or 90 degrees of which the bisection line must be located perpendicular to the center of the width of weir water channel as shown in Figure 3.1. Range of measuring discharge is 0.018 to 0.26 m^{3} in 60^{o} triangular weir and 0.110 to 1.5 m^{3} in 90^{o} triangular weir. Calculating equation for discharge is as follows:

60^{o} triangular weir

$$Q = 0.577\ k \ x \ h^{5/2} \quad \text{---------} \quad (3)$$

$$K = 83 + 0.00624/B \ x \ R^{3/4}$$

$$R = B \ x \ 0.1 \ x \ h \ \grave{o}h/{}_{\Pi}\$$$

${}_{\Pi}\$$ = kinematic viscosity of pumping solution = 10^{-6} (m^{3}/s)

90^o triangular weir

$$Q = K \times h^{5/2} \text{ -------------- } (4)$$

$$K = 81.2 + 0.24/h + (8.4 + 12/\text{ò}D) \times$$
$$(h/B - 0.09)_2$$

Q : discharge, h : water head in weir (m)
D : height of weir spill way (m)

The discharge is determined only by the width of weir and water head. Thus, the length of side direction (refer to Y sign in Figure 3.1) of weir box is not related to estimating factor of the discharge. However, the ample length shall be planned to make not a turbulent flow but laminate one in the box. Design plan of typical orifice and weir is also shown in Table 3.1 and Figure 3.1 and Figure 3.2. Discharge is pre-calculated as shown in Table 3.2 Relationship Between Height and Discharge in 90 Degree Triangular Weir.

Table 3.1 Design of Typical Weir

Type of Weir	X	Y	B	D
60^o triangular	0.24	1.5	0.8	0.12
90^o triangular	0.32	2.2	1.0	0.12

(Note) X, Y, B and D unit : m

ii) Orifice Weir

The orifice is a round hole with clean and square edges in the center of a circular steel plate and is set in the outlet of discharge pipe. A device called a piezometer (manometer) is installed in the discharge pipe. The piezometer consists of a clear plastic tube with 4 or 5 ft (1.2 or 1.5 m) length. The set-up of orifice weir is shown in Figure 3.2. Discharge is calculated as follows:

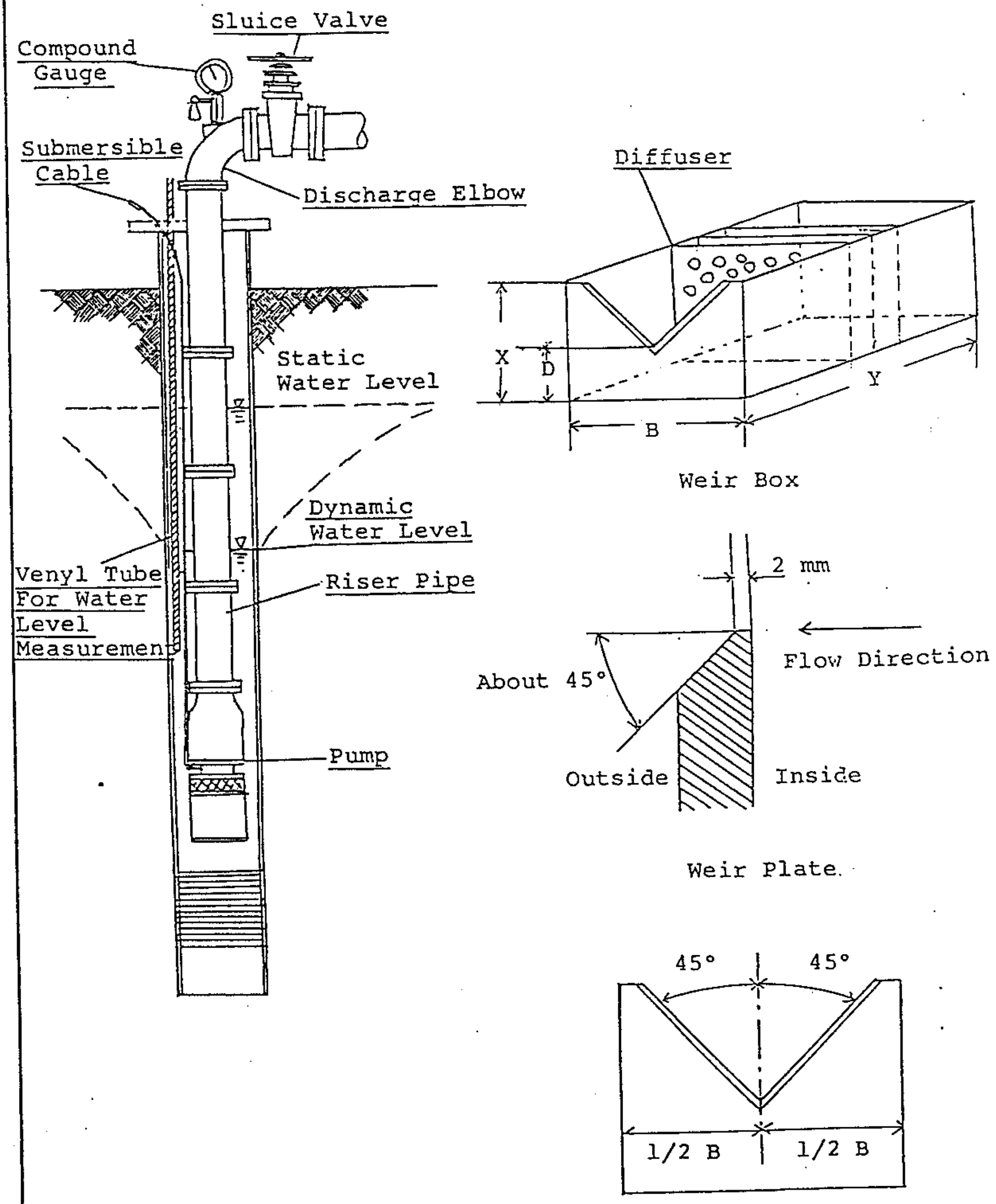


Figure 3.1 OUTLINE OF PUMP SETTING AND STRUCTURE OF TRIANGULAR WEIR

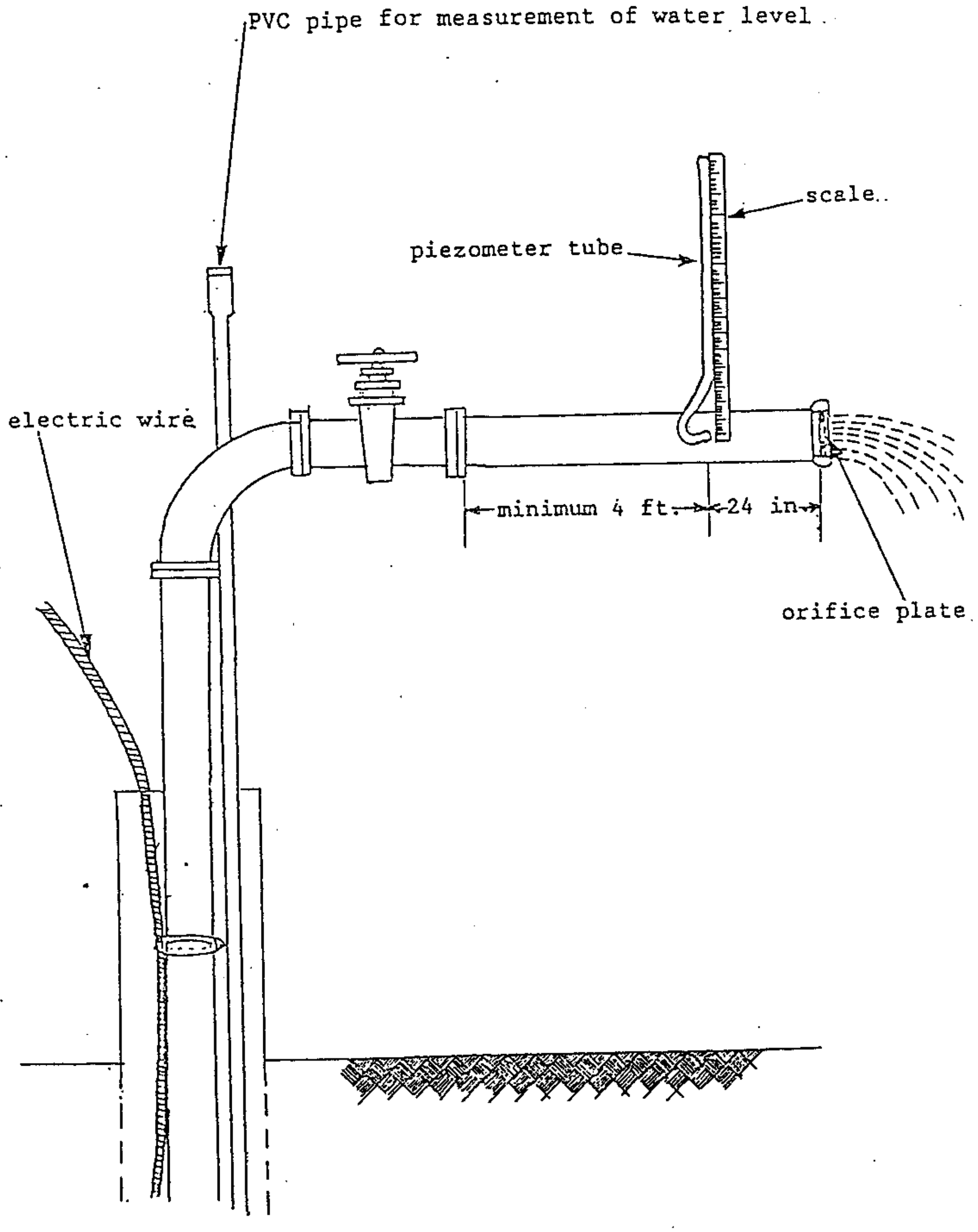


Figure 3.2 SET-UP OF ORIFICE WEIR

Table 3.2 Relationship Between Height and Discharge in 90 Degree Triangular Weir

(After S. YAMAMOTO)

Q = Discharge (l/sec), H = Height of Weir (cm)

H	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	0.000045	0.00025	0.00069	0.0014	0.0025	0.0039	0.0057	0.0080	0.0114
1	0.014	0.018	0.022	0.027	0.032	0.039	0.015	0.053	0.061	0.070
2	0.079	0.089	0.1	0.112	0.125	0.138	0.153	0.166	0.184	0.200
3	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.37	0.39	0.42
4	0.45	0.48	0.51	0.54	0.57	0.60	0.64	0.67	0.71	0.74
5	0.78	0.82	0.86	0.91	0.95	0.99	1.04	1.09	1.13	1.18
6	1.23	1.29	1.34	1.39	1.45	1.51	1.57	1.63	1.69	1.75
7	1.8	1.9	2.9	2.0	2.2	2.2	2.2	2.3	2.4	2.5
8	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3
9	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3
10	4.4	4.5	4.7	4.8	4.9	5.0	5.1	5.2	5.4	5.5
11	5.6	5.7	5.9	6.0	6.1	6.3	6.4	6.6	6.7	6.8
12	7.0	7.1	7.3	7.4	7.6	7.7	7.9	8.0	8.2	8.4
13	8.5	8.9	8.9	9.0	9.2	9.4	9.5	9.7	9.9	10.1
14	10.3	10.5	10.6	10.8	11.0	11.2	11.4	11.6	11.8	12.0
15	12.2	12.4	12.6	12.8	13.0	13.2	13.5	13.7	13.9	14.1
16	14.3	14.6	14.8	15.0	15.2	15.5	15.7	16.0	16.2	16.4
17	16.7	16.9	17.2	17.4	17.7	17.9	18.2	18.5	18.7	19.0
18	19.2	19.5	19.8	20.1	20.3	20.6	20.9	21.2	21.5	21.7
19	22.0	22.3	22.6	22.9	23.2	23.5	23.8	24.1	24.4	24.7
20	25.0	25.4	25.7	26.0	26.3	26.6	27.0	27.3	27.6	28.0
21	28.3	28.6	29.0	29.3	29.7	30.0	30.4	30.7	31.6	31.4
22	31.8	32.1	32.5	32.9	33.2	33.6	34.0	34.4	34.8	35.1
23	35.5	35.9	36.3	36.7	37.1	37.5	37.9	38.8	38.7	39.1
24	39.5	39.9	40.3	40.8	41.2	41.6	42.0	42.4	42.9	43.3
25	43.8	44.2	44.9	45.1	45.5	46.0	46.4	46.9	47.3	47.8
26	18.3	48.7	49.2	49.7	50.1	50.6	51.1	51.6	52.1	52.5
27	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.6
28	58.1	58.6	59.1	59.6	60.2	60.7	61.3	61.8	62.3	62.9
29	63.4	64.0	64.5	64.1	65.6	66.2	66.7	67.3	67.9	68.4
30	69.0	69.6	70.2	70.6	71.3	71.9	72.5	73.1	73.7	74.3

$$Q = CAV \text{ -------------- } (4)$$
$$= CA\sqrt{2gh}$$
$$= 8.025CA\sqrt{h}$$

Q : pumping rate (gpm)
A : orifice area (square inch)
V : velocity of flow through the orifice
h : water level in the piezometer tube (inches)
C : coefficient of discharge for the orifice as shown in Figure 3.3
Coefficient of Discharge, C. (after Fletcher G. Driscoll, 1987, Groundwater and Wells)

iii) Other Equipment

submersible pump	1 unit
generator	1 unit
drain hose	4 m
water level indicator	more than 2 sets
dia. 1" PVC pipe	less than 150 m
measuring tape	2 sets
transceiver	2 sets
cutting pliers	1 set
whistle	1 set
electric torch	2 sets
vinyl tape	4 pieces
transit	1 set
stopwatch	1 unit

3.2.1 Preparation Work

The preparation work begins with the selection of source well. Generally, the construction of a new well is carried out as it is difficult to find appropriate observation wells and existing pumping wells which can be utilized and are of no use to the owner. The location of the wells must be selected considering the following:

o There should be easy access to the site and large working area for well construction

- The well should not be near canals, rivers, lakes, roads and embankments.

- There are no existing wells close to the proposed well.

- Preferably, the boundary of geological formation should be avoided.

- There is access to electricity.

Observation wells shall be constructed based on the sectional groundwater contour map. The observation wells shall be set in the same aquifer as the existing pumping wells. In addition, screens of observation wells must be located in the aquifer portion corresponding to the center of pumping wells.

Discharge capacity could not be determined beforehand, but it can be estimated based on the pumping rate of existing wells. Drawdown is estimated to be 1 to 4 m in unconfined groundwater and 10 to 30 m in confined groundwater.

Furthermore, data required such as distance from pumping well to observation well, ground level of observation wells and pumping wells and other information shall be derived.

In newly constructed wells, submersible pumps shall be set at an interval of over several meters below the dynamic water level in maximum pumping rate and above the screen. If dynamic water level is below the pump setting near the screen, the pump impeller will be damaged by sand flowing through the screen slots at high velocity inflow of groundwater.

a. Measurement of static water level

Before the start of pumping tests particularly for new wells, static water level shall be measured at specific times.

b. Preliminary pumping test

Prior to the actual pumping test, a preliminary test shall be carried out. The relation between drawdown and pumping rate shall be checked to determine pumping rate and the approximate length of water level sounding tube. In addition, the appropriate size of notch box is determined. The measuring depth of dynamic water level will be within 150 meters because of possible problems in the wire of water level measurement instrument. Pumping duration in preliminary test shall be approximately 30 minutes. Water level will be measured every ten minutes.

3.2.2 Pumping Test and Analysis

Pumping test data shall be taken at intervals as shown in sample pumping test records shown in Table 3.2. Measurement interval of water level during pumping tests shall be fairly short, i.e., every minute within the first 10 minutes from starting time. The interval shall be longer after 10 minutes as shown in the following:

	starting time	interval
o	from after 10 minutes to after 20 minutes	every 2 minutes
o	from after 20 minutes to after 60 minutes	every 5 minutes
o	from after 1 hour to after 2 hours	every 10 minutes
o	from after 2 hours to after 3 hours	every 15 minutes
o	from after 3 hours to after 6 hours	every 30 minutes
o	from after 6 hours to after more than 10 hours	1 hour

This time interval shall be used for the step drawdown test, aquifer test and recovery test.

TABLE 3.3 (A) PUMPING TEST RECORD

PUMPING TEST
(Step Drawdown Test)

WELL LOCATION : ____________________

SITE ELEVATION : ____________________ PUMPING EQUIPMENT : ____________________

WELL DEPTH : ____________________ EQUIPMENT CAPACITY : ____________________

CASING DIAMETER: ____________________ RISER PIPE: DIA. __________ L : __________

SWL : __________ PWL : __________

DATE CONDUCTED : ____________________ DATE COMPLETED : ____________________

TIME		INTERVAL		WATER LEVEL	DRAWDOWN	V-NOTCH	DISCHARGE	REMARKS
HOUR	M.	HOUR	M.	m (mbgl)	(m)	90 deg.	(l/sec)	
	0		0					
	1		1					
	2		1					
	3		1					
	4		1					
	5		1					
	6		1					
	7		1					
	8		1					
	9		1					
	10		1					
	12		2					
	14		2					
	16		2					
	18		2					
	20		2					
	25		5					
	30		5					
	35		5					
	40		5					
	45		5					
	50		5					
	55		5					
1	00		5					
1	10		10					
1	20		10					
1	30		10					
1	40		10					
1	50		10					
2	00		10					

TABLE 3.3 (B) PUMPING TEST RECORD

PUMPING TEST
(Continuous Drawdown Test)

WELL LOCATION :

SITE ELEVATION :

PUMPING EQUIPMENT :

WELL DEPTH :

EQUIPMENT CAPACITY :

CASING DIAMETER:

RISER PIPE: DIA. L :

SWL : PWL :

DATE CONDUCTED :

DATE COMPLETED :

TIME		INTERVAL		WATER LEVEL	DRAWDOWN	V-NOTCH	DISCHARGE	REMARKS
HOUR	M.	HOUR	M.	m (mbgl)	(m)	90 deg.	(l/sec)	
	0		0					
	1		1					
	2		1					
	3		1					
	4		1					
	5		1					
	6		1					
	7		1					
	8		1					
	9		1					
	10		1					
	12		2					
	14		2					
	16		2					
	18		2					
	20		2					
	25		5					
	30		5					
	35		5					
	40		5					
	45		5					
	50		5					
	55		5					
1	00		5					
1	10		10					
1	20		10					
1	30		10					
1	40		10					
1	50		10					
2	00		10					
2	15		15					
2	30		15					
2	45		15					
3	00		15					
3	30		30					
4	00		30					
4	30		30					
5	00		30					

TABLE 3.3 (B) PUMPING TEST RECORD

TIME		INTERVAL		WATER LEVEL m (mbgl)	DRAWDOWN (m)	V-NOTCH 90 deg.	DISCHARGE (l/sec)	REMARKS
HOUR	M.	HOUR	M.					
6	00	1	00					
7	00	1	00					
8	00	1	00					
9	00	1	00					
10	00	1	00					
11	00	1	00					
12	00	1	00					
13	00	1	00					
14	00	1	00					
15	00	1	00					
16	00	1	00					
17	00	1	00					
18	00	1	00					
19	00	1	00					
20	00	1	00					
21	00	1	00					
22	00	1	00					
23	00	1	00					
24	00	1	00					
25	00	1	00					
26	00	1	00					
27	00	1	00					
28	00	1	00					
29	00	1	00					
30	00	1	00					
31	00	1	00					
32	00	1	00					
33	00	1	00					
34	00	1	00					
35	00	1	00					
36	00	1	00					
37	00	1	00					
38	00	1	00					
39	00	1	00					
40	00	1	00					
41	00	1	00					
42	00	1	00					
43	00	1	00					
44	00	1	00					
45	00	1	00					
46	00	1	00					
47	00	1	00					
48	00	1	00					

TABLE3.3(C) PUMPING TEST RECORD

RECOVERY TEST DATA

DATE: ____________________

TIME		INTERVAL		WATER LEVEL (m)	RESIDUAL DRAWDOWN (m)
HR.	M	HR.	M		
	0		0		
	1		1		
	2		1		
	3		1		
	4		1		
	5		1		
	6		1		
	7		1		
	8		1		
	9		1		
	10		1		
	12		2		
	14		2		
	16		2		
	18		2		
	20		2		
	25		5		
	30		5		
	35		5		
	40		5		
	45		5		
	50		5		
	55		5		
1	00		5		
1	10		10		
1	20		10		
1	30		10		
1	40		10		
1	50		10		
2	00		10		
2	15		15		
2	30		15		
2	45		15		
3	00		15		
3	30		30		
4	00		30		
4	30		30		
5	00		30		
6	00	1	00		
7	00	1	00		
8	00	1	00		
9	00	1	00		
10	00	1	00		
11	00	1	00		
12	00	1	00		
13	00	1	00		
14	00	1	00		
15	00	1	00		
16	00	1	00		
17	00	1	00		
18	00	1	00		
19	00	1	00		
20	00	1	00		
21	00	1	00		
22	00	1	00		
23	00	1	00		
24	00	1	00		
25	00	1	00		
26	00	1	00		
27	00	1	00		
28	00	1	00		
29	00	1	00		
30	00	1	00		
31	00	1	00		
32	00	1	00		
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34	00	1	00		
35	00	1	00		
36	00	1	00		
37	00	1	00		
38	00	1	00		
39	00	1	00		
40	00	1	00		
41	00	1	00		
42	00	1	00		
43	00	1	00		
44	00	1	00		
45	00	1	00		
46	00	1	00		
47	00	1	00		
48	00				

1) Step Drawdown Test

The step drawdown test involves several steps. When dynamic water level becomes stable in the first step of the pumping test, the next step would be at a larger discharge rate. This generally consists of five or six steps with a duration of 1 to 2 hours each stage.

Analysis

In the results measured by step drawdown test, if drawdown will be plotted in vertical axis and pumping rate will be plotted in horizontal axis, then both would be indicated in relation to a straight line. In case groundwater flow will be a laminate flow during pumping test, the inflow should be matched with Darcy equation and the slope in the straight line would be 45° in laminate flow and more than 45° in turbulent flow. In this case, variation of several degrees from the straight line in the results of step drawdown test indicates critical pumping rate. An actual analyzed sample is shown in Figure 3.3.

2) Continuous Drawdown Test

The continuous drawdown test is carried out by checking drawdown under constant pumping rate condition. Duration of pumping test is more than 24 hours. Pumping rate adopted shall be the rate before the last stage of step drawdown test. This is done to ensure that the pumping rate to be used is within the range capable of water level measurement while the pumping test was carried out at the pumping rate in the last stage of step drawdown test.

Analysis

To calculate aquifer constant from observation data, the equations of equilibrium and nonequilibrium may be used. Of the two equations, the nonequilibrium equation is generally used.

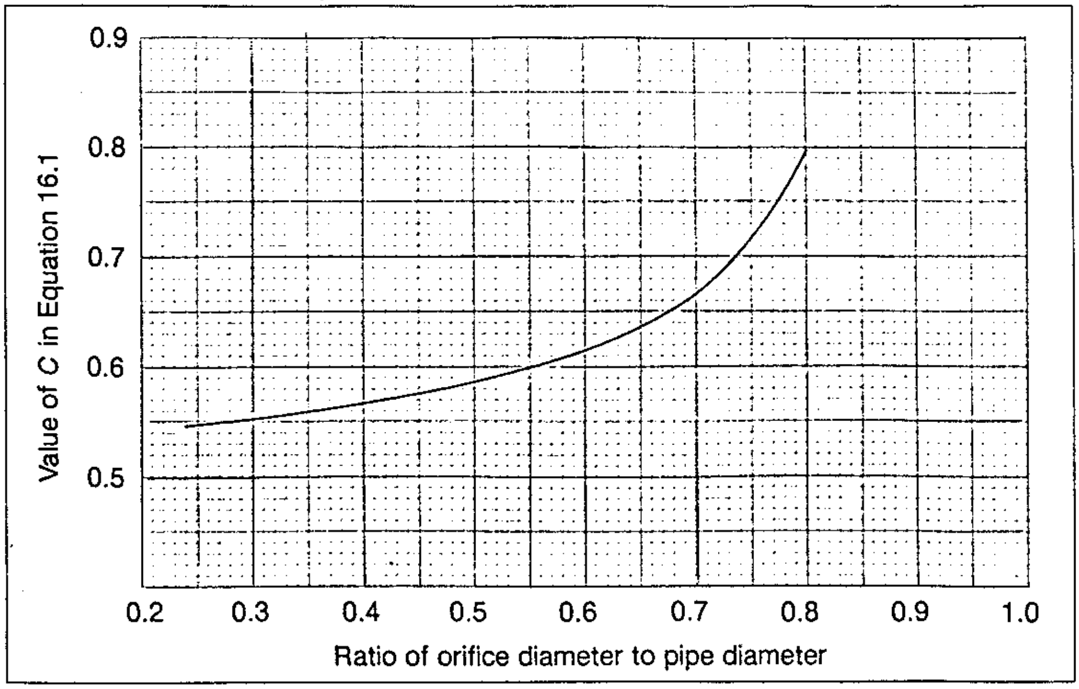


Figure 3.3 COEFFICIENT OF DISCHARGE, C, IN THE ORIFICE-WEIR VARYING WITH THE RATIO OF ORIFICE DIAMETER TO PIPE DIAMETER (AFTER FLETCHER G. DRISCOLL, 1987, GROUNDWATER AND WELLS)

a) Theis' Nonequilibrium Equation

When constant rate is continuously pumped up through limitless aquifer from well, the influence of pumping, the cone of depression continuously and radially spreads around the well. The cone of depression spreads so as to equal multiplying drawdown speed and the coefficient of storage together, and is compensated with decrease of storage in aquifer. Nothing is at a steady state in this aquifer. Drawdown of water head will continue because of limitless sequence of aquifer. But the rate of drawdown continuously decreases while influence of depression of water level enlarges. In this standpoint, Theis' nonequilibrium equation was induced. When pumping rate in well and drawdown in observation wells (or recovery of drawdown) is known, transmissibility and coefficient of storage is calculated by this equation.

Theis' basic equation is as follows:

s = Q/4πTûe /u du --------------- (6)

$u = r^2S/4Tt^{-n}$ ---------------------- (7)

s : drawdown, m
Q : pumping rate, M^3/sec
T : transmissivity, m^2/sec
(k = T/m, m : aquifer thickness, m)
r : distance from center of pumping well to measuring point
S : coefficient of storage
t : duration time for pumping, sec.

b) Theis' Standard Curve Analyzing Method

Replacing integral of exponent to well function W(u),

s = Q/4πT*W(u) -------------------------- (8)

W(u) = -0.5772 -In u +u - u^2/2.2ù + u^3/3.3ù - u^4/4.4ù

The Wenzel (1942) analyzing method uses standard curve plotted 1/u in X axis W(u) in Y axis in log-log paper as shown in Figure 3.4 Theis standard curve. The t-s curve is made by plotting duration time for pumping in X axis and drawdown s in Y axis from observation data in log-log paper with the same size. The t-s curve is reflected on standard curve, and read t, s, 1/u, W(u) at a point and then transmissibility (T) and coefficient of storage (S) can be calculated:

$T = Q/4\pi T*W(u) = 0.0796Q/s * W(u)$ ------- (9)
$S = 4Tt/r^2(1/u) = 4uTt/r^2$ --------------- (10)

One analyzed sample is indicated by the pumping test data superimposed on the type curve as shown in Figure 3.5.

In the illustrated pumping test, discharge and radius are as follows:

$Q = 4{,}500$ cu.m/day, $r = 15$ m.

On the diagraph, match point is $1/u = 10$, $W(u) = 1.9$, $s = 1.1$ m and $t = 8$ min (0.0056 day).

Therefore

$T = 0.0796\ Q/s * x\ W(u)$
$= 0.0796 \times 4500 / 1.1 \times 1.9$
$= 618$ sq.m/day

$S = 4uTt/r^2$
$= 4 \times 1 \times 618 \times 0.0056 / (10 \times 15^2)$
$= 6.15 \times 10^{-3}$

This method requires much experience and individual difference is fairly large in choice of match point. As T-S curve can also and often be gotten, the following Stallman's manner may also be used.

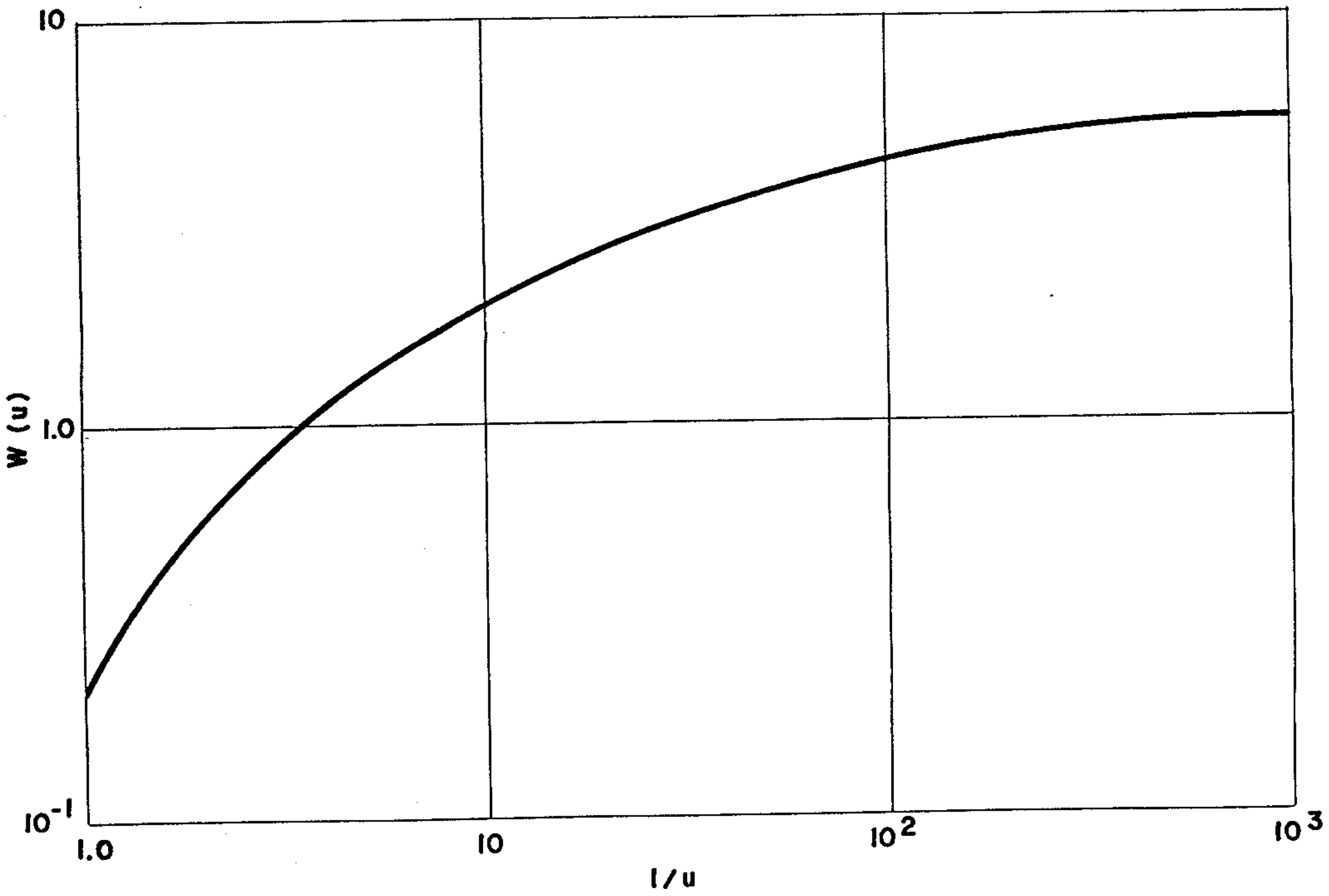
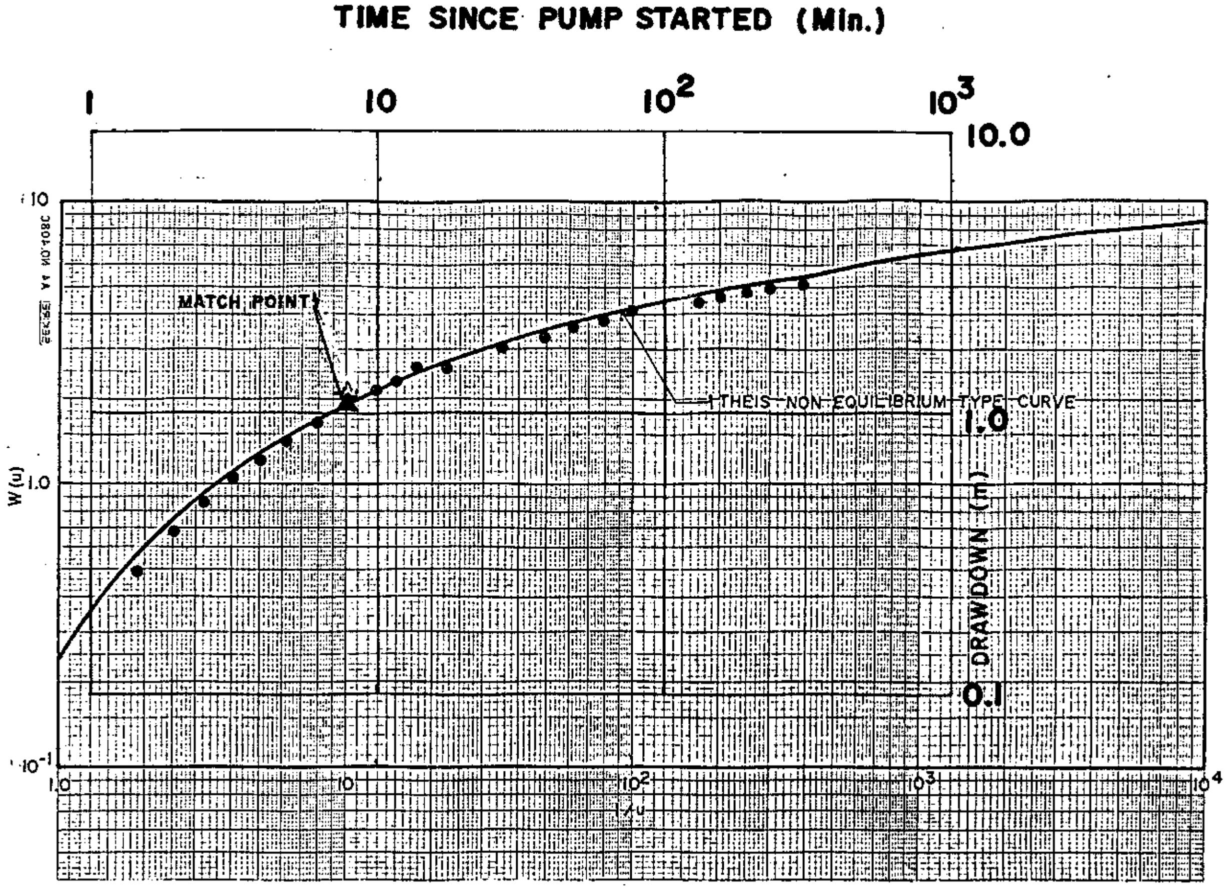


Figure 3.4 THEIS STANDARD CURVE (NON EQUILIBRIUM TYPE CURVE)



MATCH POINT, $1/u = 10$, $W(u) = 1.9$

$S = 1.1 m.$, $t = 8 min.$

$T = 0.0796\ Q/s * W(u)$

$= \dfrac{0.0796 \times 4500}{1.1} \times 1.9$

$= 618$ Sq.m. / DAY

$S = 4uTt/r^2$

$= 6.15 \times 10^{-3}$

Figure 3.5 DIAGRAM OF PLOTTED POINTS REPRESENTING PUMPING TEST DATA SUPERIMPOSED ON THE TYPE CURVE

c) Stallman's Analyzing Method

Stallman's analyzing method is as follows:

When one duplicates two curves and reads t_1 and s_1 in the point of W(u) = 1 and 1/u = 1 in standard curve, T and S are simply calculated.

$$T = 0.0796Q/s_1 \text{ ----------------- } (11)$$
$$S = rTt_1/r^2 \text{ -------------------- } (12)$$

3) Recovery Test

The recovery test immediately measures the recovery from lowered dynamic water level after pumping stops at the instant that continuous drawdown test was performed. Measuring time interval is the same as that of step drawdown and constant discharge tests. Drawdown will be rapidly recovered in first several minutes, thus, measurement should be carried out immediately.

Analysis

The nonequilibrium equation may be used in the recovery of lowered groundwater level. Lowered groundwater level goes up when pumping stops after a certain duration. In this method, recovery discharge is assumed to be equal to the pumping rate.

Based on the nonequilibrium equation the following was derived:

$$T = 2.30Q/4_{\pi}s_r * \log (t/t') \text{ --------- } (13)$$

where:

s_r : residual recovery drawdown

t' : duration time after pumping stops

In this diagram analyzing method, t/t'-s_r curve on a semi log paper is done by plotting t/t' in log scale of X axis and s_r in regular scale of Y axis.

Supposing that residual recovery drawdown in one cycle of log (t/t') is Σs, the equation of log (t/t') = 1 is formed. Thus, equation (12) is converted as follows:

$$T = 0.183Q/\Sigma s_r \text{ --------------------------(14)}$$

With the relation between Q and s_r, T is calculated. Figure 3.5 shows an analyzed example based on the pumping test data. In this pumping test, discharge (Q) was 691.2 cu.m/day. In the diagram, $S_r = 0.27$

Therefore,

$$T = 0.183 \text{ Q} / \ S_r$$
$$= 468.5 \text{ sq.m/day}$$

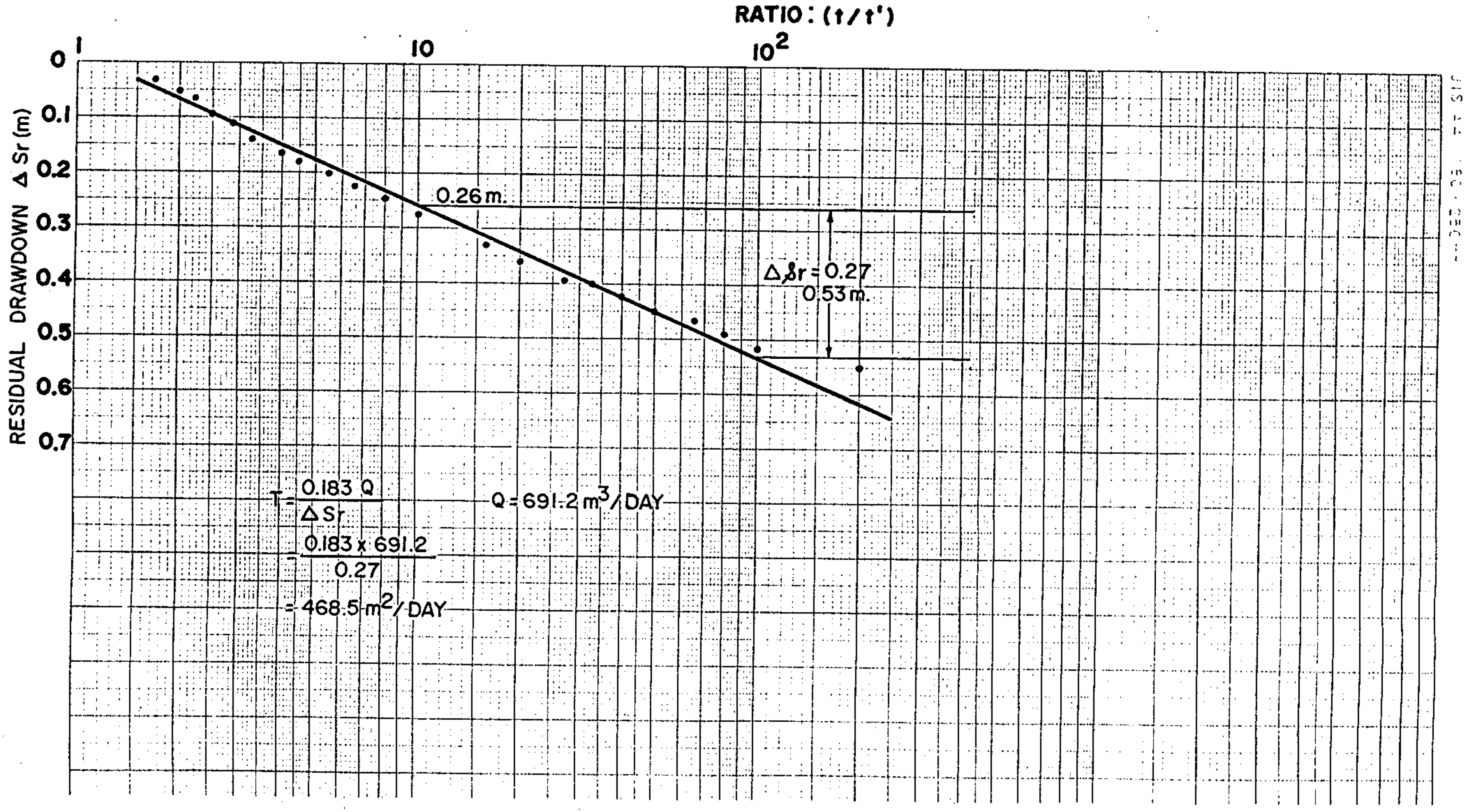


Figure 3.6 RESIDUAL DRAWDOWN PLOTTED AGAINST THE RATIO t/t' IN RECOVERY TEST

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WELL CONSTRUCTION MANUAL

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1. WELL CONSTRUCTION

1.1 WELL DRILLING METHODS

Well drilling methods are classified into: (1) percussion, (2) rotary and (3) air drilling.

1.1.1 Percussion Drilling Method

The percussion drilling method involves the repeated lifting and dropping of a heavy string of drilling tools into the borehole. The drill bit breaks or crushes consolidated rock into small fragments, whereas the bit primarily loosens the material when drilling in unconsolidated formations. The reciprocating action of the tools mixes the crushed or loosened particles with water to form a slurry or sludge at the bottom of the borehole. If little or no water is present in the penetrated formation, water is added to form a slurry. Slurry is removed at intervals from the borehole by a sand pump or bailer.

This method is appropriate for drilling unconsolidated formations such as alluvium and diluvium including gravel, cobble and boulders. It is not suitable for drilling granite, andesite and arkose sand since it will take a long time to drill and would be very costly. Figure 1.1 presents the percussion type drilling machine and Figure 1.2 the drilling bits, bailer pump and sand pump for percussion drilling.

1.1.2 Rotary Drilling Method

The rotary drilling method was developed to increase drilling speeds and to reach greater depths in most formations. The borehole is drilled by rotating a bit and cuttings are removed by continuous circulation of a drilling fluid as the bit penetrates the formation. The bit is attached to the lower end of a string of drill pipe which transmits the rotation action from the rig to the bit. In the rotary drilling system, drilling fluid is pumped down through the ports or jets in the bit; the fluid then flows upward in the annular space between the hole and the drill pipe carrying the cuttings in suspension to the surface.

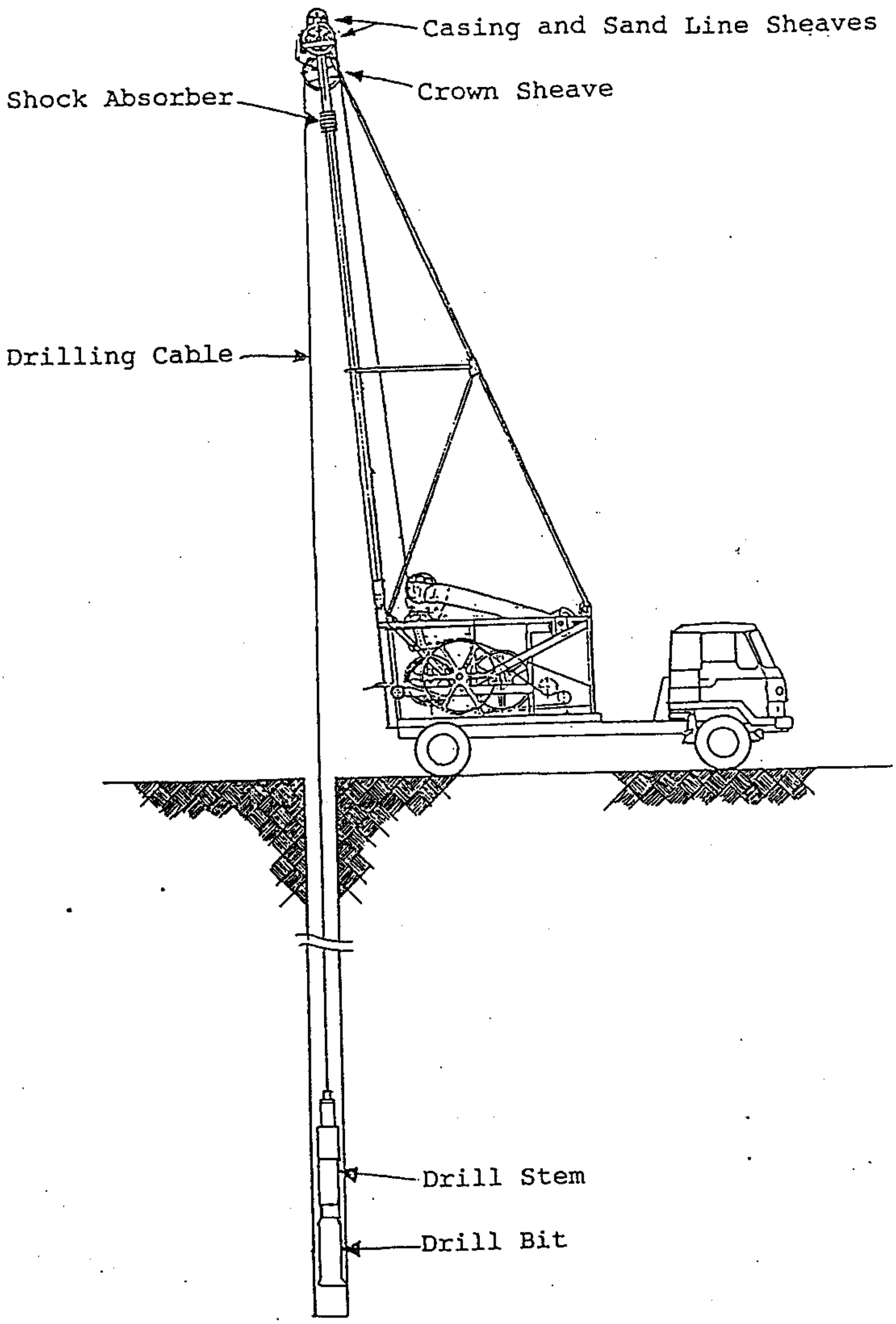
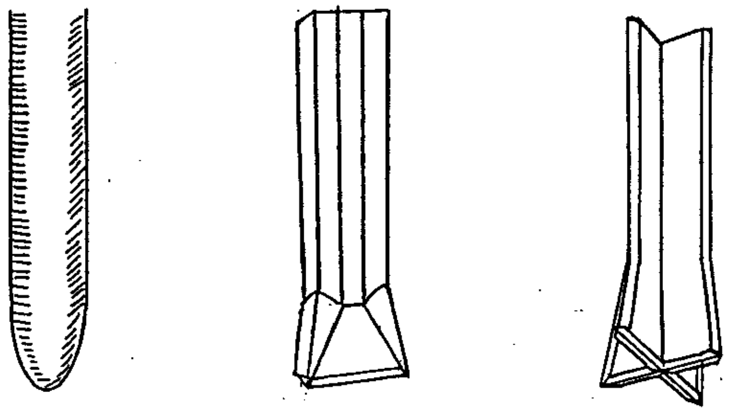


Figure I.I PERCUSSION TYPE DRILLING MACHINE

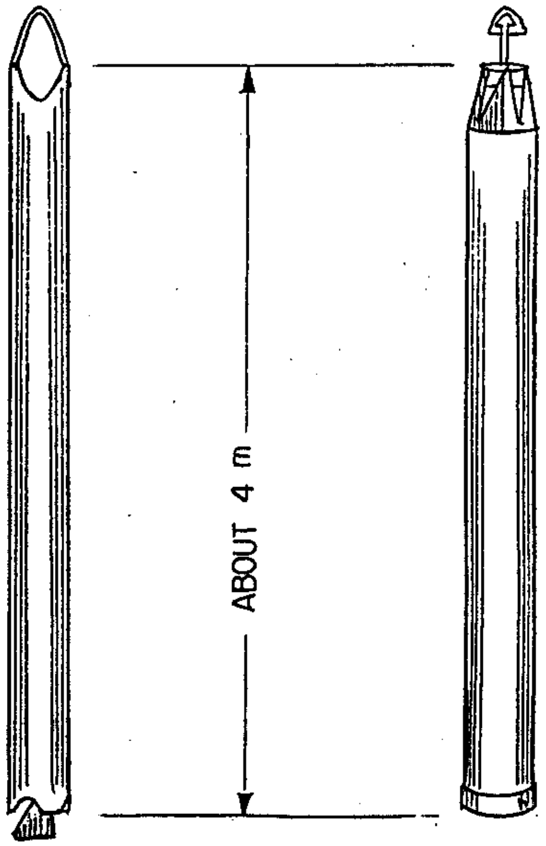
Percussion Drilling Bit



Sharp-pointed Bit

Straight Line Bit

Star Bit



Bailer

Sand Pump

Fig. 1.2 Drilling Bits And Bailer And Sand Pump For Percussion Drilling

(1) Spindle Type

The spindle type drilling machine is a small sized machine with a drilling capacity of less than 1,200 m.

With the spindle type, drilling work is carried out by rotation of the spindle with a pressure weight that is lifted and dropped through the rotation pipe fixed by the chuck of spindle. The typical spindle type drilling machine is shown in Figure 1.3.

(2) Rotary Table Type

The rotary table type is larger in size than the spindle type and can drill up to more than 2,000 m. It is usually of the truck-mounted type, therefore, drilling can be smoothly and quickly executed in a short time.

With the rotary table type, the drill stems connected to drill pipes are rotated by connecting with a square hole located in the center of rotating table. The pressure weight for the bit should be appropriately adjusted by the weight of drill stems, drill pipes, drill collars and bits.

Drilling machines of the rotary table type are fairly easier to maintain since these are mechanically operated. The typical rotary table type drilling machine is shown in Figure 1.4.

(3) Top-head Drive Type

The top-head drive type drilling machine is similar in size to the rotary table type, capable of drilling very deep below the ground and is of the truck-mounted type. Rotation of bit is by hydraulic mechanism with the water swivel with chuck hung in the upper portion of mast. This type is different from the rotary table type in that the full system is operated by hydraulic power while the rotary table type is operated mechanically.

Drilling machine of top-head drive type is easy to operate even with the connection of additional drill pipe during drilling time.

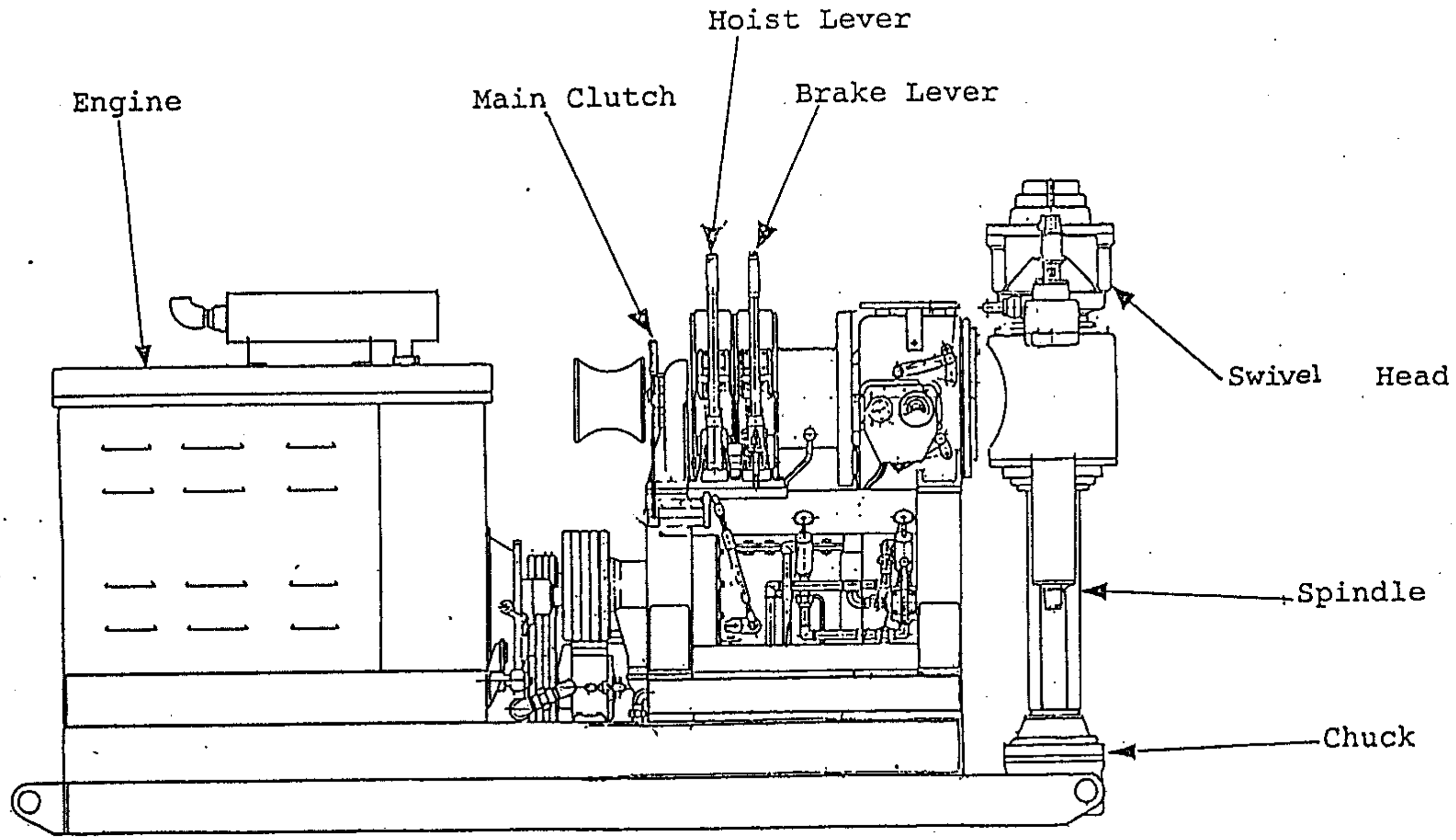


Figure 1.3 SPINDLE TYPE DRILLING MACHINE

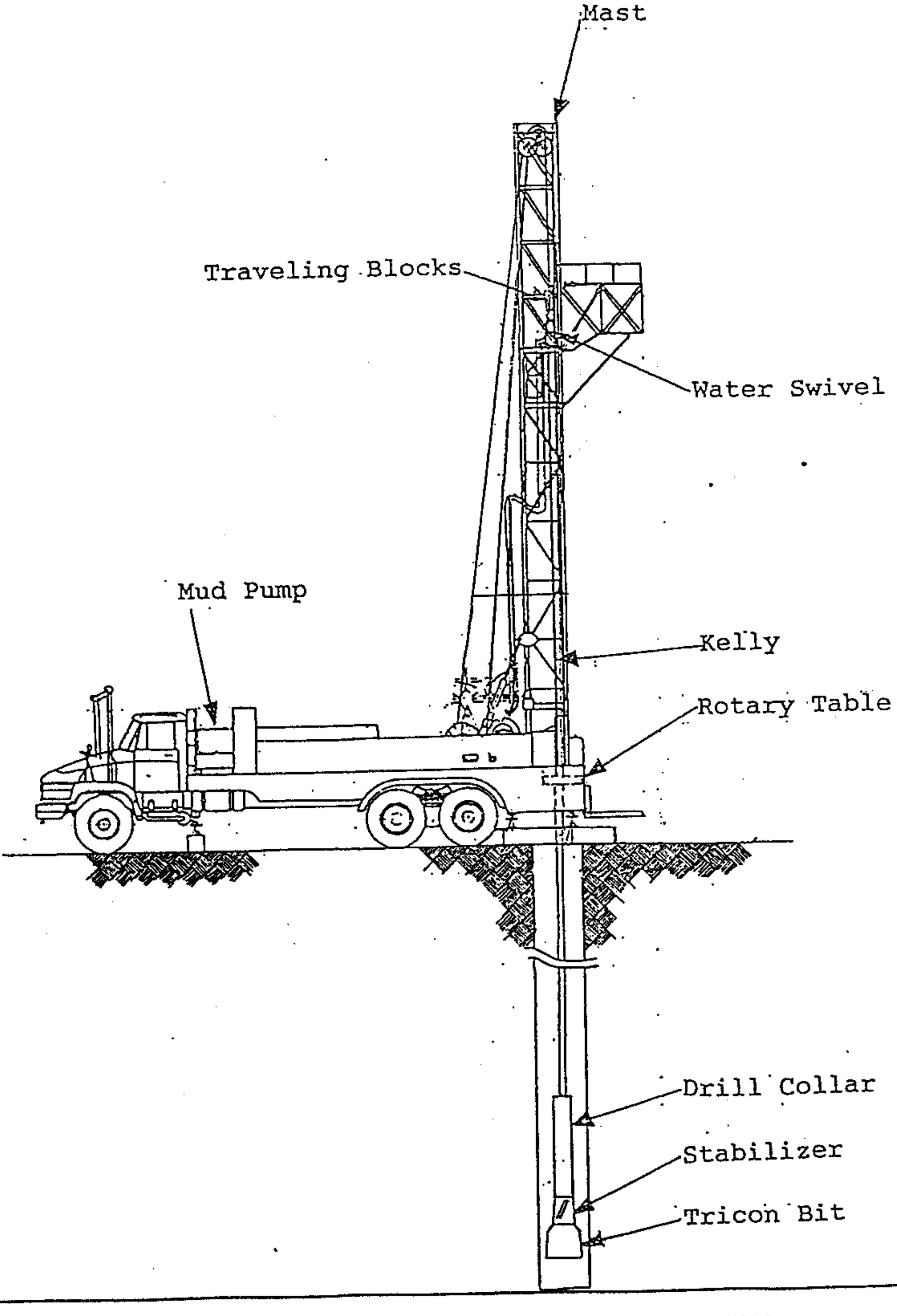


Figure I.4 ROTARY TABLE TYPE DRILLING MACHINE

Maintenance, however, is very difficult because the whole system is hydraulically operated. The top head drive type of drilling machine is shown in Figure 1.5

1.1.3 Air Drilling (Down the Hole Drill)

Down the hole drilling is a method wherein the drilling bit hammer is moved by air pressure and crushes hard rock. Air necessary for air drilling is supplied through the boring rods by an air compressor, with rotation and driving done through boring rods connected between drilling bit hammer and rotary drilling machine. In down the hole drilling, air is used as percussion action of bit and as medium to convey drilling debris moving up between the drilled hole and boring rod up to outer hole.

Down the hole drilling is the most suitable drilling method for hard rock formation and drilling can be undertaken with the highest speed compared with other drilling methods. Hard rocks are crushed with the vibration of down the hole hammer operated by compressed air and pressure against the rotation of the hammer transmitted by rotary drilling machine of truck-mounted type, table rotary type or top-head drive type.

The down the hole drilling method has the following advantages:

- A good natural drilling hole is maintained.
- Drilling in fissured rocks may be done efficiently.
- A straight hole can be attained with high speed drilling.
- A longer life span of the rod is assured.

However, this method has the following disadvantages:

- The equipment has to be regularly inspected, cleaned, lubricated and maintained to function effectively.
- Circulating air speed has to be more than 20 m/second to convey drilling debris out of the drilling hole.

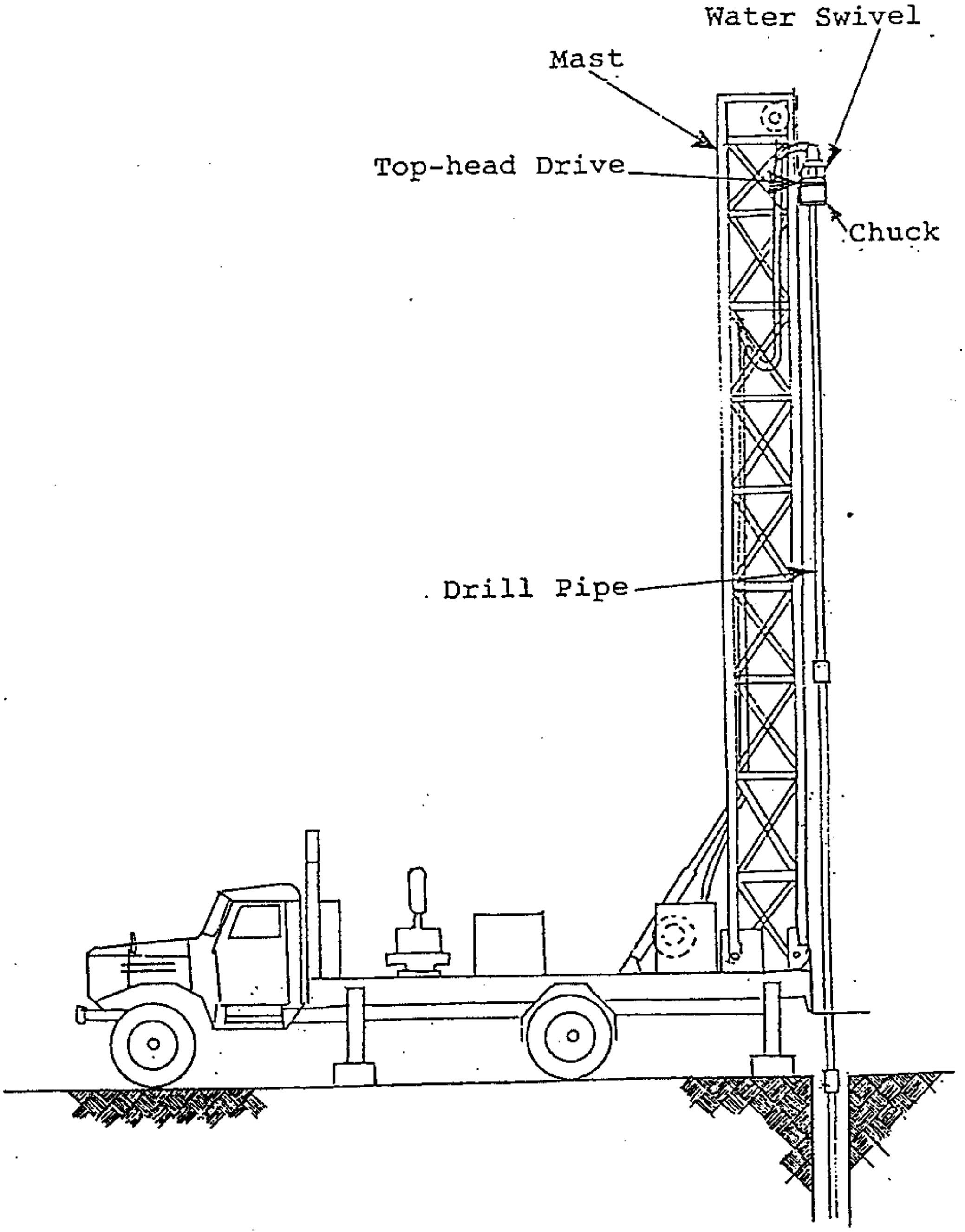


Figure I.5 TOP-HEAD DRIVE TYPE DRILLING MACHINE

- To compensate the loss caused by back pressure due to water level in drilling hole, an air compressor with large capacity of air flow and pressure has to be used.

In the down the hole drilling, the following equipment and materials are required:

- Drilling hammer (consisting of hammer, cylinder, chuck cylinder, bit and check valve and others),
- Boring rods (normal rods more than 50 mm in diameter),
- Base machine of rotary table type or top-drive type (normal type boring machine which supplies rotation and pressure to bit),
- Air compressor (air pressure: 7-18 kg/cm2, air amount: 10-20 m3/min),
- Generator to operate air compressor,
- Foaming agent.

The air drilling method is shown in Figure 1.6.

1.2 HOLE CLEANING METHODS

With the rotary drilling method, boreholes may be cleaned either by normal circulation or by reverse circulation. Drilled cuttings must be completely removed from the hole and the wall of the hole be stabilized. Unless the hole is clean and open, drilling cannot be continued. The hole cleaning methods discussed below are illustrated in Figure 1.7.

(1) Normal Circulation Method

Normal circulation is generally used when the circulation medium of either air, water or drilling mud is pumped under pressure down the drill rods through the bit and carries drill cuttings to the ground surface between the wall of the hole and the drill rods.

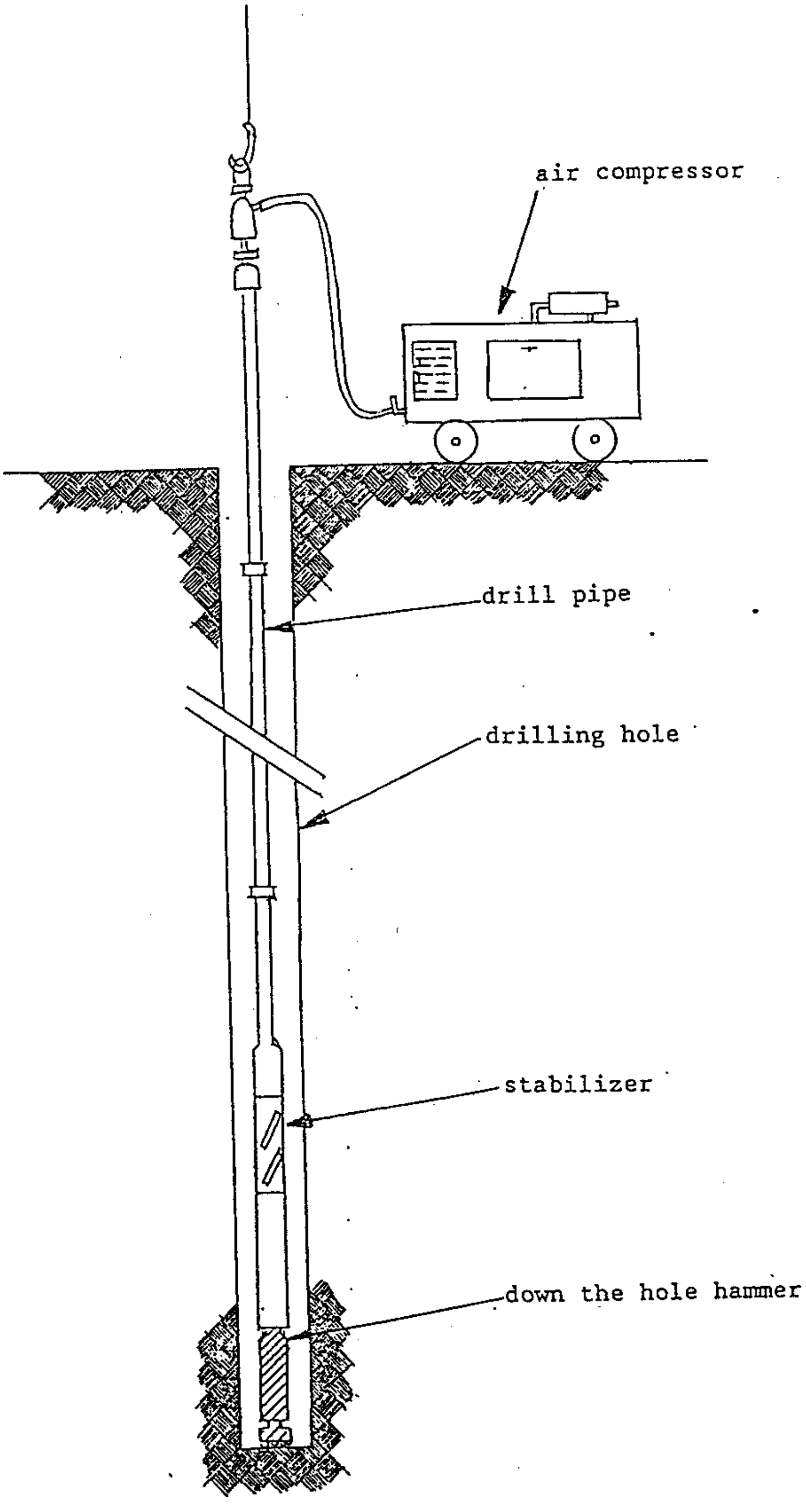
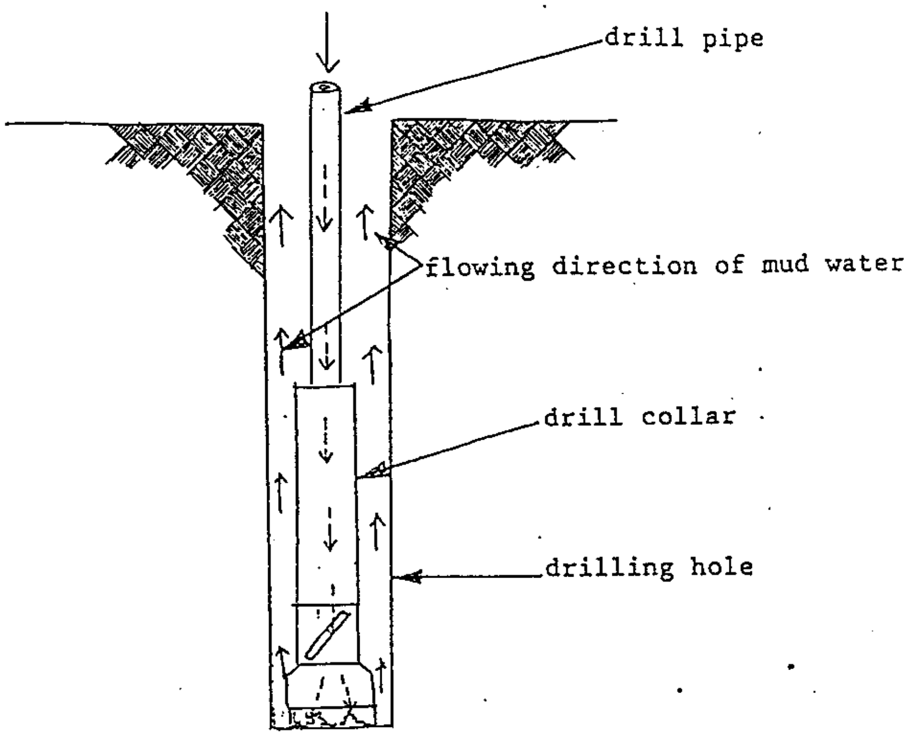


Figure I.6 AIR DRILLING METHOD

Normal Circulation Drilling



Reverse Circulation Drilling

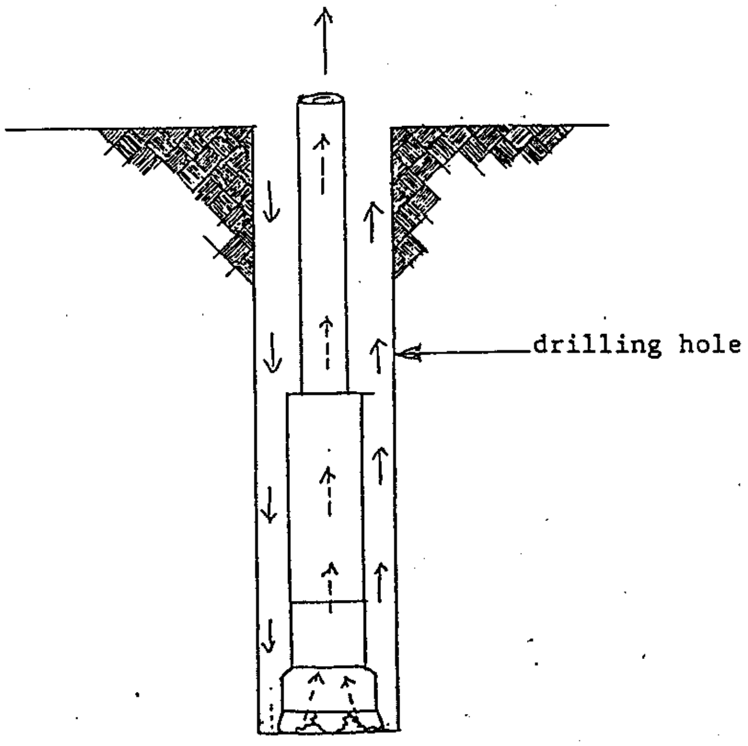


Figure I.7 HOLE CLEANING METHOD

Normal circulation method is most commonly used in the construction of deep water wells with casing diameters ranging from 4" to 16".

(2) **Reverse Circulation Drilling Method**

Reverse circulation drilling is the least expensive method for the drilling of large diameter holes in unconsolidated formations. When geologic conditions are favorable, the increasing diameter of the borehole does not necessarily increase the cost of the well. Therefore, most water wells 24 inches in diameter or larger (up to 60 in) are drilled using the reverse circulation method.

Reverse circulation drilling is most suitable to soft sedimentary rocks and unconsolidated sand and gravel where the static water level is 3 m or more below ground level. In case of high static water level, ramps are built above grade to support the drilling rig, or the specific gravity of the drilling fluid is increased to obtain the necessary hydrostatic pressure. The reverse circulation drilling method may not be satisfactory when the static water level is too high and adequate water supplies are not available. Reverse circulation has the flow circulating down the hole between the bit and up to the inside of the drill rods. Circulation is obtained by the following methods:

(a) A suction lift pump is introduced between the drilling rig swivels and mud pit providing typically a 10 m suction lift to the fluid contained in the drill pipe. Circulation is then achieved by displacement.

(b) Two air pipes are installed on the side of the drill pipes and are capable of being alternated to allow air to be introduced to the drilling fluid inside the drill pipe at typically 10-20 meters submergence.

The introduction of air makes the drilling fluid in the drill rods less dense than the fluid between the hole wall and rods. Circulation is achieved by displacement.

(c) A stuffing box is installed on surface casing and the fluid is pumped under pressure down between the hole wall and drill rods, through the bit and up inside the drill rods.

In this system, the drill rods are attached with an inner and outer tube. Air passes between the inner and outer tube through the bit and returns with cutting debris up in the inner tube.

1.3 WELL DESIGN AND CONSTRUCTION

Generally, well construction is carried out in the following manner:

(1) Determination of Well Design

Prior to well drilling, well design shall be roughly determined based on geological and hydrogeological conditions and designed pumping rate. Well design comprise of well depth, well structure, length, size and material of screen and casing. After the survey and gathering of data on existing wells particularly static water level, dynamic water level, well depths, screen portion, columnar sections, geological formation and electric resistivity, groundwater development potential of the groundwater basin of the project area is analyzed and the final well design is determined.

(2) Selection of Drilling Method and Equipment

Based on the results of geological and hydrogeological studies, drilling methods and equipment suitable to geological condition, drilling depth and hole diameter will be determined.

(3) Determination of Drilling Point

Determination of drilling point is most important in drilling work. In low potential areas for groundwater development such as rocky and mountainous areas covered by hard rock on ground surface, selection of drilling point is very difficult and to get groundwater and to encounter fault lines and fissure zone unlike alluvium and diluvium is fairy difficult in the area. Metro Manila area is underlain by fairly thick alluvium and diluvium formation in which high groundwater potential occurs except for the plateau like Antipolo. The determination of drilling points, it is considered, are not so difficult. In addition, drilling point shall be also determined under the consideration of groundwater quality.

Drilling points should be also selected in the point of view from the drilling work. The drilling sites must have good accessibility for drilling machine and vehicles to approach easily and afford an enough working space for drilling work.

(4) Mobilization of Drilling Equipment and Materials

Drilling equipment and materials will be mobilized, assembled and set up at the site. Work shall be done by skillful drillers and engineers and arrangements made to place each equipment and material in the drilling sites as required.

(a) Setting of drilling machine

Drilling machine shall be set up with care in the site. Unlike the assembly type of mast in the site, the drilling machine is generally very heavy weighing over several ten tons. The drilling machine shall be tightly set up using strong and solid timber and iron bars and the mast shall be held stable by tying between the four corners of the mast and fixed natural materials.

(5) Drilling

Drilling work is generally carried out by a team of one skilled driller and some laborers. The driller shall always check drilling condition by observing cutting debris and specific gravity of mud water and groundwater level in drilled hole and operating condition of equipment. Free flowing of mud water from drilled hole and/or the lowering of static groundwater level will imply the encounter with aquifer on the way to well drilling.

(6) Electric Logging

After designed drilling depth is attained, electric logging tests shall be carried out in the drilled hole. The methodology is described in another manual on prospecting method for groundwater survey. In general, the electric logging tests shall be carried out by short normal and long normal methods at different intervals of each electrode. Based on the results of the electric logging test, the most suitable casing program particularly the screened portion in the well depth shall be established. The screen is generally located in the portion of fairly large difference between results of short normal and long normal because this area is identified as sand and gravel formations of good aquifers. On the contrary, low and similar values can be assumed to coincide with clay formation or aquiclude. An example of a casing program is shown in Figure 1.8.

(7) Installation of Casing

Casings and screens are to be installed in the drilled hole in accordance with the results of casing program. Casings and screens welded together are slowly lowered into the hole.

(8) Gravel Packing

Immediately after the installation of the casings and screens, gravel is packed in to ensure its stability. Since the final performance of the well is highly dependent on the correct construction of the intake, the installation of the gravel pack has to be carried out with all possible care. This takes the place of the graded zone of the permeable material that is produced by the natural development process. When properly constructed, the wells are efficient and stable. Size of gravel pack materials or particles is determined by the geological condition and type of screen. The thickness of gravel packing is a primary factor in the effectiveness of the development procedures taking place at the interface of the pack and formation. The minimum practical thickness

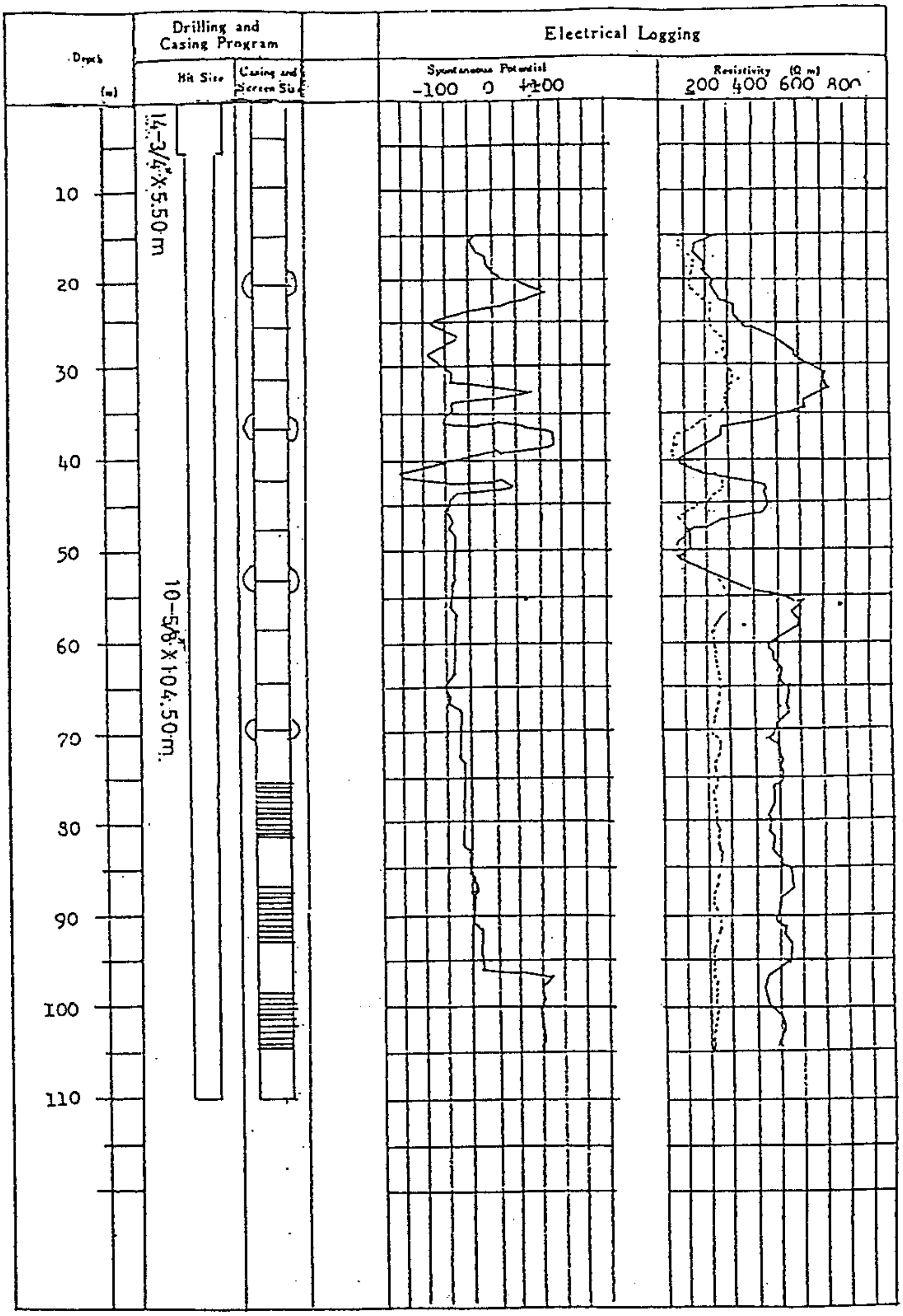


Figure I.8 CASING PROGRAM AND RESULTS OF ELECTRIC LOGGING for the pack is 76 mm. Gravel packs thicker than 203 mm are not recommended because the effectiveness of the development procedures may be impaired.

(9) Well Development

The basic principle of well development involves the dislodgement and removal of any material hindering the free flow of water to or from the well. When deciding on the type of development which best suits the well and the situation existing in the zone to be developed, a driller must be sure that the undesirable material is dislodged or removed. Any method which dislodges the undesirable material but fails to remove it from the aquifer is not a suitable one. The method is particularly unsuitable if it tends to push clogging material further into the aquifer. This means that the most effective methods are those that continually draw water from the aquifer while intermittent surges or short reversals in the flow, serve to dislodge stubborn particles.

Where mud fluids or mud cake are in the aquifer, the mud is cleared from inside the screen and casing and the appropriate break or dispersing chemicals are introduced. Where a gap exists between the screen and the walls of a hole in an unconsolidated aquifer, the aquifers collapse against the screen. A gentle washing action is used, commencing at the lower end. The full screened interval is developed using a washing technique while the yield of the well and the movement of sand into the well is checked. Sluicing techniques may be required to complete development. These techniques are best applied to the screen, a short length at a time, commencing at the bottom. Open hole completions may be developed using shock methods. Sometimes shock development in the open hole is followed by casing and screening.

As development proceeds, the following shall be checked:

1) the net flow from the well,
2) the drawdown (below S.W.L.),
3) the quantity and size of the sand drawn into the well.

(a) Air lift development

Air lifting, when used for development has the following advantages:

1) the pump is not damaged by sand
2) the air lift column can be used to clean the bottom of the hole by suction
3) the intermittent nature of air lift pumping provides a gentle surging action
4) stronger agitation or surging can be achieved easily by lowering the air tube below the column, and closing the top of the casing with a tight head.

(b) Mechanical surging and high velocity jetting

Vigorous sluicing methods should not be used where the high energy action is likely to disperse thin clay or silt horizons through the more permeable parts of the aquifer. Aquifers of this type must be developed using washing techniques which draw water through the sand and gravel beds only.

The risk of damage to the aquifer during plunger surging or jetting operations, is reduced considerably if the material dislodged by the sluicing action is drawn into the well immediately. A continual flow of water from the aquifer into the well, will prevent the dislodged material moving back into the aquifer. The surge plunger equipment used for mechanical surging is shown in Figure 1.9.

1) Mechanical surging

For surging to be successful, the energy of the high velocity water must be directed to the material to be broken or dislodged. The effectiveness of the method is greatly reduced if there are insufficient openings in the screen or if a thick layer of pack material dissipates the energy of the water.

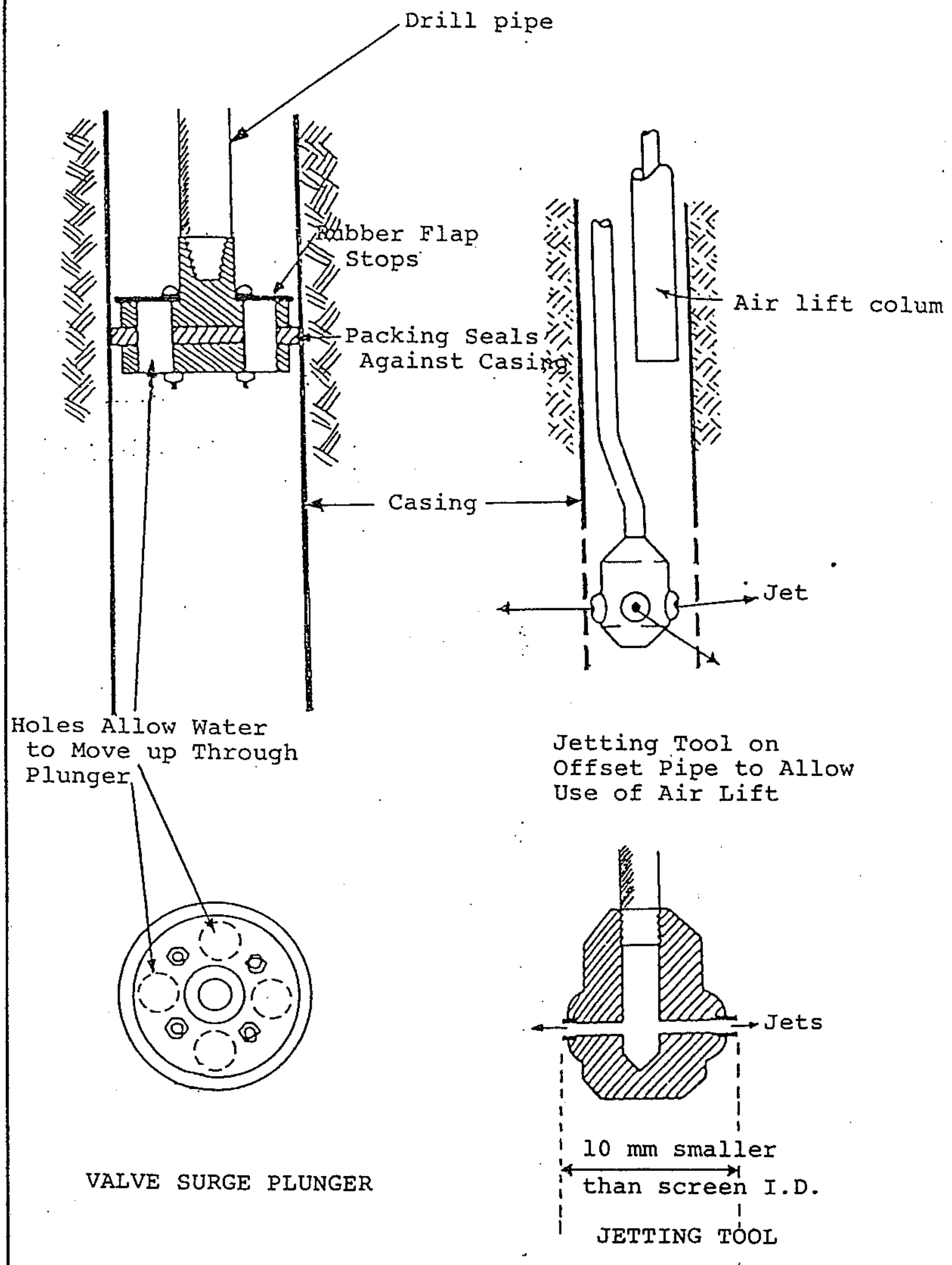


Figure 1.9 SURGE PLUNGER EQUIPMENT (for Mechanical Surging)

A surge plunger should be used only when the aquifer is free of clay or after initial bailing has produced a free flow of water into the well. The surge plunger packing must fit well in the casing. The plunger is made up on a drill stem (sinker bar) and run into the hole to a position about 5 m below the water level (but above the screen). With the rig on its longest stroke, the plunger spuds very slowly up and down for 10 minutes. The operation of the valve will cause the plunger to work as a pump and lift water and fine sand out of the hole. After ten (10) minutes, the plunger is withdrawn from the casing and a small bailer is used to clear sand from the screen. The plunger is then run again and the cycle repeated until no more sand is brought out. This process may be repeated with the spudded operating at a higher speed. It should be ensured that the rig action and the motion of the plunger remain smooth. Solid surge plungers (without the valve holes) are sometimes used to obtain a strong backwash flush but as the solid plunger does not move water out of the hole, it is more likely to damage the aquifer. Similarly, the operation of surge plunger inside the screen is not advisable. Surging with a plunger should not continue for more than an hour before conducting a short bailer test to check the specific capacity of the well.

2) Jetting method

Jetting is the ideal way of developing flowing wells. The jet is operated while the well is flowing. Before jetting commences, the hole should be cleared of mud by air lifting with the air lift operating at the bottom of the screen. Jetting must commence at the bottom of the screen. With the jets and the air lift (or well pump) operating, the tool is rotated slowly by hand and very slowly lifted (lifted at about 10 minutes per meter). When the jets have covered the full length of the screen, development by pumping shall continue only until the well is clean.

For the products of development to be drawn out of the aquifer, jetting should be done simultaneous with pumping. Pumping must be at a rate above the rate of injection through the jets. In a large diameter hole, this is not a problem as the pump can be run alongside the jetting pipe. The jetting pipe may be offset for operation in smaller wells. The offset type tool can not be rotated but must be oscillated by hand, during jetting. Rig equipped with a dual pipe string may be developed by jetting while air lifting pumping operates between the string and the casing.

Jetting tools are easily fabricated. Special jetting nozzles are preferable and should be replaceable so that the jet size can be adjusted to suit the pump capacity. Nozzle diameters may vary from 4 mm to 10 mm. The pump capacity must be sufficient to provide a nozzle flow velocity of 50-70 meters per second. The jets should operate with the end of the nozzle about 5 mm clear of the inside of the screen.

3) Chemical method

Chemical methods are often used in conjunction with other techniques for development particularly where remedial development is required to break up mud cakes or flush out gelled mud.

Chemical methods, other than acidifying find their main application in unconsolidated sands and gravels. The following chemicals may be used:

a) breakdown chemicals for polymer muds

b) dispersant to break down clay smears, wall cakes, bentonite filter cakes or to assist in the removal of gelled bentonite

c) chlorine or chlorine producing chemicals to assist in breaking colloids and to act on bacteria.

(10) Pumping test

Pumping test consist of step drawdown test, continuous drawdown test and recovery test.

prior to pumping test, trial test shall be conducted in order to check and determine the relation between pumping rate and drawdown. Trial test, often a short 15 minute test is run to confirm the specific capacity of the well and thus allow selection of the most suitable pumping rate for longer tests or to check that the pumping equipment and measuring equipment are operating satisfactorily.

(a) Step drawdown test

The step drawdown test is carried out to reveal the safety yield and the constant of aquifer loss and well loss. To check the safety yield is necessary for the decision of pump capacity, in a word, a pumping rate in newly drilled wells. The constant of aquifer loss and well loss is often used to calculate actual drawdown in wells. The test is executed by from five to seventh steps with two pumping duration hours in each step. The well loss is caused by a turbulent flow in the well which become a major factor in causing drawdown at high pumping rates. At lower rates, the aquifer losses in the formation are more significant. Pumping at a range of different rates allows these factors to be separated.

(b) Continuous drawdown test

Continuous drawdown test usually at the desired yield rate or at a rate within 20% of the capacity of the bore, are conducted with the pumping rate held constant (within 10%). This constant rate must be maintained for the full period of the test. Wells for domestic or communal use may be tested for short periods (2 to 8 hours). Wells for high demand uses, such as irrigation or town supplies, are tested under the condition of constant discharge for periods of 24 to 48 hours.

The test is carried out to obtain the transmissibility and storage coefficient. The aquifer constant, transmissibility and permeability and storage coefficient are used to reveal the characteristics of aquifer and to calculate the radius of influence of cone of depression and others during pumping test. These data are effective to estimate the development potential of groundwater, especially.

(c) Recovery test

Recovery test is a measurement of residual drawdown during the recovery period. As pumping continues, groundwater gradient develops carrying water in to support the flow of the well. When the pump is turned off, the flow through the aquifer continues until the gradient is no longer present. The drawdown readings thus decrease in the same way they were established.

At the beginning of the pumping test, there is a need for accurate timing. Records of exactly when pumping starts and when the measurements are taken during the first 10 minutes, must be accurate to within a half minute. During the first minutes, the pump operator, who is a member of the drilling crew, must get the test pump engine to the correct speed and stabilize the pumping rate at the desired level. Flow measurements must be made every minute or so to check that the flow rate does not vary as the drawdown increases.

Accuracy of flow measurements must guarantee a reading within 10% of the true figure. This means that while orifice plates or weir boards are adequate for large flows, small flows are better measured by timing the filling of containers. The drawdown is best measured by reading the distance of the pumping level below the static water level. The measurements must be accurate to within 5 mm of drawdown. Some tests may require even higher accuracy.

(11) Demobilization

Demobilization shall be started after completion of the drilling work. The site should be cleaned and restored to the original condition.

(12) Submission of drilling report

Drillers shall accomplish the daily progress report and submit it to the engineers. The drilling report shall include columnar section, the result of electric logging test, drilling speed and depth, water level in drilling hole, drilling work and performance. Sample format of daily progress report is shown in Figure 1.10.

Project Name:

Site No.: Date:
Site Name: Location:

Drilling performance:

Date/time	Drilling depth (m)	Items
		S.W.L(starting time, final time), Lithology Bit size and type and other performance

Remarks:

Figure 1.10 SAMPLE FORMAT OF DAILY DRILLING REPORT

2. CORE BORING

2.1 CORE BORING METHODS

Core boring methods were developed to directly investigate and check geological conditions below ground surface and to determine geological structure and the possibility of mining and ore development. The object of core boring is to take core samples which shall be subject to geological, lithologic and civil engineering inspections.

The most commonly used core boring methods are:

1) Single Core Tube method

2) Double core Tube method

3) Wire Line Core Barrel method

These methods have different characteristics mentioned below.

2.1.1 Single Core Tube Method

The single core tube is a simple tool that is easy to operate and maintain at a fairly low cost. With this method, a larger core can be obtained and it has a larger drilling ratio compared to the large size double core boring bit tool. However, this method is only applicable to uniform hard formations and not on fault and fissure zones and nonuniform formations.

2.1.2 Double Core Tube Method

The double core tube tool is of two types, namely the rigid and the swivel type.

The rigid type is a fairly simple tool. The inner and outer tube rotate simultaneously resulting in crushing of core samples. Operation cost is high due to the required wide cutting plane and large bit.

The swivel type is a more effective sampling tool and does not crush core samples against every formation because the inner tube rotates independently from the outer tube.

2.1.3 Wire Line Core Barrel Method

The wire line core barrel is a swivel type - double core tube. This equipment was used in the core boring survey of the Metro Manila Groundwater Development Project. This effective method is carried out at high drilling and core sampling speed in formations of every geological age. The wire line core barrel system is illustrated in Figure 2.1. In case the underground formation includes water, the inner tube goes down with the core tube. Otherwise, it overshoots the drilling bottom in the dried formation. If the inner tube is filled with the drilled formation during drilling, the inner tube is immediately lifted by wire rope. With this method, there is no need to bring up the entire system except for changing the bit, therefore, the working period is shortened. Wire line core barrel method comprise the following equipment:

a) Outer tube assembly - reaming shell and diamond core bit are attached at the bottom of this tube and drill rod is connected to the upper rim of the tube.

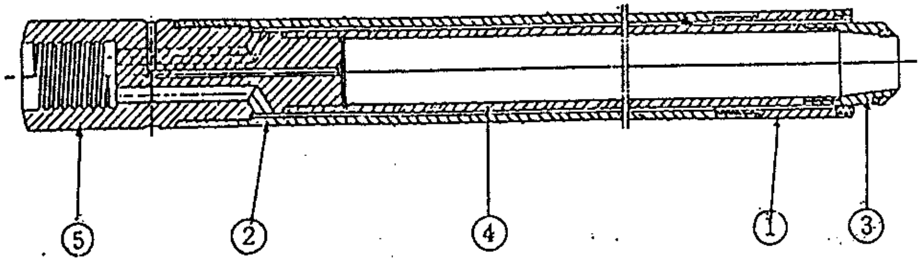
b) Inner tube assembly - after core samples have been taken, the tube is lifted to ground surface. The end of the tube is equipped with a core lifter to protect the dropping of core samples.

c) Swivel assembly - outer tube and inner tube are connected by this swivel assembly to allow the outer tube to rotate without moving the inner tube.

d) Overshot assembly - the tip is equipped with a lifting dog to grasp the inner tube and lift and drop it down the inner tube assembly.

e) Wire line bit - the outer tube and inner tube diameters of the wire line bit differ largely due to the size of the connecting tube mechanism.

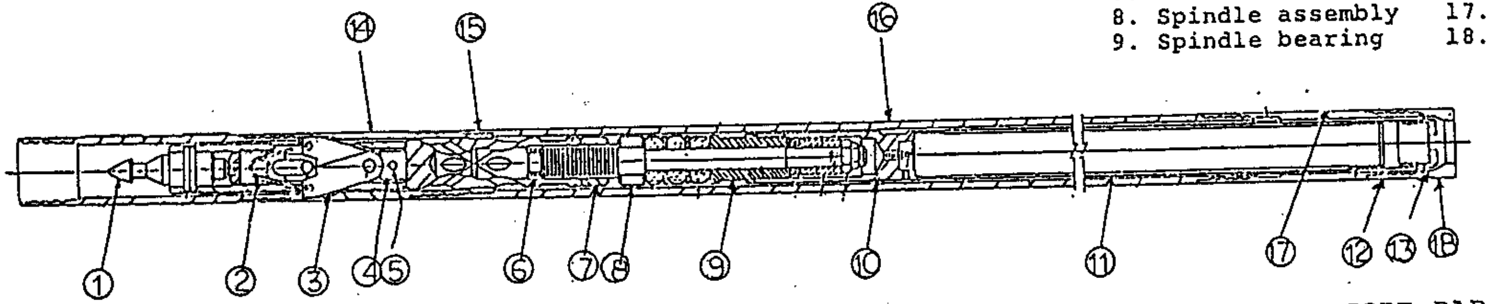
Wire line core boring has recently been applied in hard rock formations



DOUBLE CORE TUBE

DOUBLE CORE TUBE

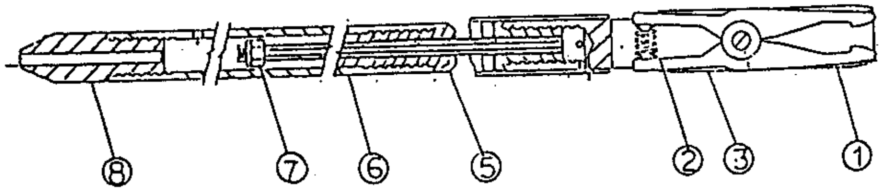
1. Outer metal crown
2. Outer tube
3. Inner metal crown
4. Inner tube
5. Core barrel head



WIRE LINE CORE BARREL COMPLETE

WIRE LINE CORE BARREL COMPLETE

1. Spear head
2. Latch spring
3. Latch
4. Latch support
5. Spring pin
6. Latch body
7. Lock nuts
8. Spindle assembly
9. Spindle bearing
10. Inner tube cap
11. Inner tube
12. Core lifter case
13. Core lifter
14. Adapter capling
15. Landing ring
16. Outer tube
17. Reaming shell
18. Core bit



OVERSHOT FOR WIRE LINE CORE BARREL

OVERSHOT FOR WIRE LINE CORE BARREL

1. Lifting dog
2. Lifting dog spring
3. Overshot head
4. Jar head
5. Jar tube
6. Nut
7. Wire line socket

Figure 2.1 WIRE LINE CORE BARREL SYSTEM

and fissure zones after different types of bits were developed, the shapes and types of which are shown in Table 2.1. For high efficiency,types and sorts of bits are selected based on drilling formation as follows:

Formation	Type of Bit
soft to hard rocks	taper bit
hard rocks	step type multi stage bit
fissure zone	combination reverse taper bit

2.2 EFFECTIVE CORE BORING

In case the inner tube of wire line core bore is clogged with the core samples, the core barrel shall be lifted up to ground surface. Core sampling work executed to check the groundwater and geological conditions often clogs inner tube because geological formation sometimes includes the clay. To avoid the clogging of barrel by the core samples, the special type bit (S crown type) and double core tube with mud water shall be used and care shall be taken to control mud water.

For effective drilling and smooth core boring, proper pressing weight should be applied to drilling bit, rotation of drilling bit is maintained and supply of water for bit is ensured. However, to ensure the above, ample experience is necessary.

(1) Bit pressure and weight

Effective bit pressure and weight to crash and drill the rocks are different for every type of drilling formation, the number of bolts of bit and the rotation speed of bit.

(2) Rotation speed of bit

Rotation speed of the bit depends on the cutting action of bit and on abrasion loss. Small bolts bit is ideally used with light weight and pressure which slightly exceed crushing drilling pres-

Table 2.1 Specifications of Wire Line Core Barrel

Type of Core	Q Series				TV Series			
	AD	BE	NO	HA	EX	AX	BX	NX
Dia. of Drilling Hole (mm)	48.0	60.0	75.8	96.0	37.7	48.0	60.0	75.7
Dia. of Core (mm)	27.0	36.5	47.6	63.5	20.0	27.0	36.4	47.6
Outer Dia. of reaming shell (mm)	48.0	60.0	75.8	96.0	37.72	48.01	59.94	75.69
Outer Dia. of outer tube (mm)	46.0	57.2	73.0	92.1	36.0	46.0	57.2	73.0
Outer dia of inner tube (mm)	32.5	42.9	55.6	73.0	24.5	32.5	42.9	55.6
Length of core barrel (ft)	5 10 ----	5 10 15	5 10 15	5 10 ----				
Weight of one set of core barrel (kg)	16.0 26.3	24.2 38.2 52.2	43.0 62.9 82.9	70.2 104.3				
Outer dia. of drilling rod	44.5	55.6	69.9	88.9	35	44.5	55.6	70
Inner dia. of drilling rod	34.9	46.0	60.3	77.8	26.5	35	46	60
Outer dia. of diamond core bit	47.6	59.5	74.6	95.6	37.34	47.64	59.56	75.31
Inner dia. of diamond core bit	27.0	36.5	47.6	63.5	20	26.97	36.40	47.63

sure and high rotation speed. Large bolts bit is used with heavy weight and slow rotation speed. In general, bolts abrasion becomes larger if rotation speed and bit weight operate effectively.

(3) Selection of diamond bit

Type of diamond bit shall correspond to the size of diamond and matrix of the drilling formation.

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REHABILITATION MANUAL

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1. THE CAUSES OF DAMAGES IN MWSS WELLS

The main causes of wells' low or no output of water are discussed as follows.

1.1 REGIONAL DECLINE OF GROUNDWATER LEVEL

Regional decline of water level occurs in the whole Metro Manila Area. The rate of decline is estimated at four (4) meters per year, as shown in Figure 1.1. Figure 1.1(A) shows the well condition immediately after its completion. Figure 1.1(B) shows the well condition 5 or 10 years later. Both the static and pumping water levels declined yearly, because of the overpumping of the well itself and/or its nearby wells. The declining water level has made the capacity of the submersible pump not fitted to the well condition: higher-head submersible pump is needed.

1.2 DEFECTIVE PUMPING UNIT

Pumping unit must be checked periodically, because it deteriorates and superannuates.

Defects in pumping unit are caused by: superannuation of pumping unit, regional decline of groundwater level, well cave-in, dirty water intrusion, drying up of well, etc.

1.2.1 Superannuation of Pumping Unit

Pumping unit deteriorates and superannuates, because of bad quality of water, sand pumping, etc. Pumping unit must be checked and overhauled periodically.

1.2.2 Regional Decline of Groundwater Level

Once the static water level declines, the discharge rate begins to drop, because the capacity of the pumping unit is not fitted anymore to the condition of the well. The pumping unit is now overloaded and required to have a higher head.

If the pumping water level almost reaches the pump setting position, tripping of pumping unit occurs frequently. The on and off operations will happen frequently, causing the pumping unit to deteriorate easily.

1.2.3 Well Cave-in

Once well cave-in occurs, when the formation surrounding the well collapses, sand, gravel or clay enters the well. If the submersible pump is operated under this condition, sand, gravel or clay comes into the pump impeller, causing its vanes to wear and the well yield to decrease.

1.2.4 Dirty Water Yields

Once surface water with iron bacteria enters the well, the iron bacteria produce accumulations of slimy gel-like material which causes plugging of openings in well screens, riser pipes and impeller of submersible pump. This material is soft at first and hardens gradually, because it dries especially when inside the riser pipes and submersible pump.

In this case, the submersible pump is operated under overload condition. When it is operated for a long time under this condition, the pump will deteriorate easily.

1.2.5 Drying Up of Wells

Once well dries up, pumping water level will subsequently reach the pump setting position and make the pumping unit to trip frequently. The submersible pump will deteriorate easily because of the on and off operations of the pump when tripping happens, and also because of the intrusion of sand, gravel, clay or rust that have accumulated at the bottom of the well into the pump.

1.3 SALT WATER INTRUSION

Salty water were observed in wells along the coastal areas of Manila Bay and Laguna de Bay. Figure 1.2(A) shows the condition of the well immediately after its completion; this well yielded fresh water. Salt and fresh water zones were balanced at that time, because the fresh water piezometric head was so high that salt water could not intrude into its zone.

Figure 1.2(B) shows the well condition 5 or 10 years later. Well has yielded salt water. The fresh water level has lowered because of overpumping of the surrounding wells and also due to regional decline of groundwater level. The fresh water level has declined so much that salt water from marine ponds, Manila Bay or Laguna de Bay easily intruded the fresh water zone.

1.4 WELL CAVE-IN

Well cave-in was observed in eight (8) municipalities: Caloocan City, San Mateo, Manila, Pasig, Cavite, Imus and Kawit. Figure 1.3(A) shows the condition of the well immediately after the completion of drilling. This well operated very well. Figure 1.3(B) shows its condition after well cave-in occurred. "Well cave-in" means that some formation surrounding the well collapsed, and the material consisting the formation, such as gravel, sand or clay, enters the well. The Study Team observed some fragile formations consisting of tuff when it carried out core borings at Las Piñas in 1990. The tuff formations could easily collapsed by overpumping, because the mass were not that firm or strong. Once well cave-in occurred, the submersible pump could easily become defective due to sand-pumping or low well yields: gravel, sand or clay that accumulated at the bottom of the well could block openings and prevent groundwater from passing through.

1.5 DIRTY WATER INTRUSION

Dirty well yields were observed in five (5) municipalities along Marikina Fault: San Mateo, Quezon City, Cainta, Makati and Muntinglupa. Figure 1.4(A) shows the wells' conditions immediately after the completion of drilling. Fresh water was pumped up from these wells. Figure 1.4(B) shows the wells' conditions after dirt water has intruded. Dirty surface water which is sometimes contaminated with iron bacteria has intruded the wells because the well design was not proper that surface water could easily enter the well.

1.6 DRYING UP OF WELLS

Drying up of wells was observed in Cavite: Cavite City, Imus and Bacoor. Figure 1.5(a) shows the well condition immediately after its completion. These wells operated very well. Figure 1.5(b) shows the wells' operating conditions after well cave-in has occurred.

Drying up of a well seems to occur when the well depth is shallow, when the well did not penetrated a confined aquifer, or when well cave-in occurs. In the first case, the water level has reached the bottom of the well due to its continuous decline. In the case of well cave-in, the groundwater could hardly enter the well due to the accumulation of gravel, sand or clay at the well bottom.

2. THE PROCEDURE AND METHOD FOR REHABILITATION

2.1 THE STANDARD PROCEDURE AND METHOD FOR REHABILITATION

2.1.1 Scope

The experimental work for rehabilitation was drawn up for five (5) MWSS deepwells in Metro Manila. In accordance with the results of the work, the following standard procedure and method for rehabilitation are recommended.

The standard work for rehabilitation involves the following activities:

1) Preparation and mobilization
2) Pulling out of existing pumping unit
3) Measuring of well depth and water level
4) Inspection of existing pumping unit
5) Installation of test pumping unit
6) First pumping test
7) Surging, bailing and airlifting
8) Second pumping test
9) Installation of new pumping unit
10) Demobilization

2.1.2 Preparation and Mobilization

(1) Preparation of Equipment and Materials

The Contractor should prepare and provide equipment and materials necessary to complete the work within the contract period.

(2) Mobilization

The contractor should mobilize equipment and materials and conduct preparatory work under the direction of the Consultant.

(3) Pulling out of existing pumping unit

The Contractor should pull out the existing pumping unit (riser pipes, submersible cables and submersible pump) carefully.

(4) Measuring of well depth and water level

Measurement

The Contractor should measure the well depth and static water level after pulling out the existing pumping unit. The accumulation of sand, mud, rust and other materials at the bottom of the well shall be investigated throughout the measurement.

(5) Inspection of existing pumping unit

The Contractor should check the existing pumping unit that includes submersible pump and motor, submersible cable, riserpipes and control panel. Slight damage should be repaired. The scales adhering to the units should be removed and the units should be cleaned up.

(6) Installation of test pumping unit

The Contractor should provide, install and operate a test pumping unit to carry out the following pumping test.

- Step drawdown test

- Constant discharge test
- Recovery test

The Contractor should provide the test pumping unit that will be able to deliver a discharge rate which will be the expected yield of the well where gate valve will be suitably throttled.

The Contractor should set the test pumping unit with accessories into the well under the direction of the Consultant.

The Contractor should install a temporary sounding tube of 3/4 inch diameter from top of the well to pump bowl assembly to sound water level easily.

(7) First pumping test

One of the following types of pumping test should be carried out at each well under the direction of the Consultant. Pumping water level should be observed and measured continuously by the use of notched weir and electrical sounding wire.

Step drawdown test

The step drawdown test should be conducted at five (5) steps with duration of two (2) hours for each step. The pumping rate should be decided at the site by the Consultant.

(8) Surging and bailing

After the first pumping test, the wells should be surged throughout the screen section. The wells should be bailed when any accumulation are observed. Surging and bailing should be performed more than two (2) days, at eight (8) hours per day.

(9) Airlifting

Upon completion of surging and bailing, the wells should be discharged by airlifting for more than two (2) days, also at eight (8) hours per day. The compressor used for pumping by airlifting should have a developing pressure of 8 kilograms per square centimeter (114 psi), and the delivery rate should be 17 cubic meter of air per minute. From time to time, the air blow should be stopped to facilitate the loosening of trapped materials.

Airlifting should be completed with the eductor pipes almost at the bottom of the well to ensure that all materials are cleaned out of the pipe.

(10) Second pumping test

After airlifting, three (3) types of second pumping test should be conducted as follows.

Step drawdown test
Step drawdown test should be conducted in the same manner as already described.
Continuous Pumping Test
This test should be conducted for 24 hours continuously.
The pumping rates should be directed by the Consultant.

Recovery test
After constant discharge test, the recovery of water level should be measured for eight (8) hours.

(11) Installation of new pumping unit

The Contractor should install a new pumping unit into the well after completion of the second pumping test under the direction of the Consultant. Sounding tubes of 3/4 inch diameter should be installed with the new pumping unit to facilitate measurement of water level.

(12) Demobilization

Upon completion of the rehabilitation work, the Contractor should provide and operate all equipment and materials necessary to restore the well site as neat as possible to its condition before the commencement of the rehabilitation work. This work includes, but not limited to, restoration of structures, removal of sand, mud and other materials. After restoration work, all the equipment and materials used for the rehabilitation work should be demobilized by the Contractor.

2.2 COUNTERMEASURES FOR REHABILITATION OF MWSS DEEPWELLS

Of the 258 MWSS deep wells, 70 were identified as damaged wells with defective pumping unit, salty well yields, well cave-in, dirty well yields and drying up.

2.2.1 Regional Decline of Groundwater Level

Pull out of the submersible pump is recommended. The new pump which replaces the pulled-out one must be checked periodically.

Rehabilitation work shall be carried out at the same time, and after that, a more suitable pump should be selected and installed at a suitable setting position determined according to the result of pumping test. It is better to re-install and use the existing submersible pump with some additional pump bowls attached to increase the head.

Wells having water level reaching almost the bottom of the well and yielding little amount of water should be abandoned after plugging with cement.

If a well is intended for rehabilitation, then in case of regional decline of groundwater level, the existing pumping unit shall be pulled out at first, and then the well shall be drilled deeper to penetrate a confined aquifer. Some wells have iron plate attached to the bottom of casing pipes or have reduced casing pipe diameter at the bottom. In these cases, the well cannot be drilled any more.

If wells can still be drilled deeper, casing pipes with screens shall be installed at the deeper drilled position, gravel shall be placed surrounding the well screens, and cement grouting shall be carried out at the upper formation to protect the well from sand, gravel or clay intrusion. But this work is very difficult, and it is costly to drill deeper and to shut off completely the upper formation by cement grouting, so that the wells, where the water level has reached almost the bottom of the well, shall be recommended for abandonment. Drilling of a new well with a proper design is recommended instead.

2.2.2 Defective Pumping Unit

If a pumping unit is defective, it shall be pulled out from the well as soon as possible. The well shall be rehabilitated in the same manner as described in Section 2.1 and then a suitable submersible pump shall be installed at a suitable setting position in accordance to the pumping test result.

2.2.3 Salty Water Yields

If a well yields salty water, it shall be abandoned after plugging with cement.

If wells yielding salty water is intended for rehabilitation, at first, the existing pump shall be pulled out, and then electric conductivity logging shall be carried out in order to detect the formation with salt water intrusion. Fine sand shall be charged into the well beneath the formation with salt water intrusion by using triplex mud pump and drilling pipes. After that, cement milk shall be charged from top of the sand to ground level with the use of drilling equipment, such as triplex pump and drilling pipes, in order to shut off or plug the salt water intrusion zone. One day later, the cement milk hardens, and the cementation remaining inside the well shall be cut by using tricone bit. The sand shall also be removed by the tricone bit and drilling mud. But this work is very difficult, and it is costly to shut off the salt water intrusion zone completely, so that wells yielding salt water shall be recommended for abandonment. Drilling a new well with a proper design is recommended instead.

2.2.4 Well Cave-In

If well cave-in occurs, the well shall be abandoned after plugging with cement.

If the well is intended for rehabilitation, at first, the existing pump shall be pulled out, and then the well depth shall be measured in order to detect the position of the collapsed formation. Gravel, sand or clay from the collapsed formation shall be removed out of the well by using triplex mud pump, tricone bit and drilling pipes. The removal shall be up to the original bottom of the well and done in the same manner as in drilling a new well. After that, new casing pipes which have smaller diameters than the existing ones shall be installed inside the well from ground level to the bottom of the collapsed formation. Then, overhauled and repaired submersible pump shall be installed into the well. If the existing submersible pump cannot be installed because of the new smaller casing pipes, it shall be replaced by a smaller one. This smaller pump shall reduce the discharge rate after rehabilitation. This work is very difficult, and it is costly to remove the collapsed materials inside the well and to install new casing pipes, so that in the case of well cave-in, the well shall be recommended for abandonment. Drilling a new well with a proper design is recommended instead.

2.2.5 Dirty Water Yields

If well yield is dirty, the well shall be abandoned after plugging with cement.

If the well is intended for rehabilitation, at first, the existing pumping unit shall be pulled out, and then TV camera shall be lowered into the well in order to detect the formation with dirty water intrusion. Fine sand shall be charged into the well beneath the formation by using triplex mud pump and drilling pipes. After that, cement milk shall be charged from top of the sand to ground level with the use of drilling equipment, such as triplex pump and drilling pipes, in order to shut off or plug the dirty water intrusion zone. One day later, the cement milk shall harden, and the cementation remaining inside the well shall be cut by using tricone bit. The sand shall also be removed by the tricone bit and drilling mud. But this work is very difficult, and it is costly to shut off the dirty water intrusion zone completely, so that wells yielding dirty water shall be recommended for abandonment. Drilling a new well with a proper design is recommended instead.

2.2.6 Drying Up of Wells

If a well dries up and yields little amount of water, the well shall be abandoned after plugging with cement.

If the well is intended for rehabilitation, at first, the existing pumping unit shall be pulled out, and the well shall be drilled deeper in order to penetrate a confined aquifer. Some wells have iron plate attached to the bottom of casing pipes or have reduced casing pipe diameter at the bottom. In these cases, the well shall not be drilled any more.

If wells can still be drilled deeper, casing pipes with screens shall be installed at the deeper drilled position, gravel shall be placed surrounding the well screens, and cement grouting shall be carried out at the upper formation to protect the well from sand, gravel or clay intrusion or dirty water intrusion. But this work is very difficult, and it is costly to drill deeper and to shut off completely the upper formation by cement grouting, so that the wells, where the water level has reached almost the bottom of the well, shall be recommended for abandonment. Drilling of a new well with a proper design is recommended instead.

3. MAINTENANCE OF WATER WELLS AND SUBMERSIBLE PUMPS

3.1 WATER WELLS

3.1.1 Scope

A number of factors, including hydrogeologic conditions, well design and construction, and operational procedures, combine to determine the necessity, frequency and success of well maintenance. Any viable program of well maintenance must be founded on an understanding of these factors.

Aquifer characteristics and water quality parameters play a major role in determining maintenance requirements. If these basic hydrogeologic considerations are not considered during well design, or if actual well construction is faulty or inadequate, well failure is likely to result, giving rise to the need for frequent, costly and often extreme well maintenance measures.

Effective well maintenance programs rely on accurate, detailed record keeping. Records should contain up-to-date information on well conditions such as yields, drawdown and specific capacity. These data are derived through various well testing procedures.

The results of well testing provide essential information that can be used to determine if and when maintenance is needed. Test results additionally suggest the nature and extent of maintenance required.

3.1.2 Manual of Well Maintenance

(1) Keeping of Construction Records

Like water well drilling, well maintenance procedures have, until now, been considered a well driller's "art". Very little has been published about the nature of maintenance problems encountered by drillers, and even less about the techniques they use to solve these problems.

More has been published about the operation, inspection and maintenance of pumps because pump failure is much more common and is more likely to occur. Well failure, on the other hand, occurs much less frequently, and when it does, the decline is gradual-usually over a period of years. Sometimes well failure suddenly and unpredictably occur. An understanding of well maintenance problems and treatment techniques make this subject less of an art and more of a science.

It is important that only necessary work be performed on a well. Proper preventive maintenance of well will prevent expensive, unneeded work.

A comprehensive well maintenance program begins with proper record keeping at the time of well construction. The water well driller should provide the well owner with a copy of the well design, a geologic log, and information regarding water quality, static water level, yield of the well,and pumping level. In addition, the contractor should keep a copy of this information for his own records. Too often such records are not kept by the contractor or by the well owner. Without such information, it is often difficult to recognize problems that can cause a reduction in well yield.

Well logging techniques are also useful in evaluating well maintenance needs. The information gathered from a geophysical survey or other logging technique can be compared to subsequent surveys to evaluate changes in formation porosity and permeability or damage to the well casing. Without preliminary well records and logging of a well that is performing poorly may require more time and more elaborate tests.

Well testing is also important to a timely and accurate evaluation of well maintenance needs. Measurements of well yield and specific capacity, in conjunction with logging techniques and accurate record keeping, will help ensure proper interpretation of a well's maintenance and rehabilitation requirements.

Many variables can cause a reduction in well performance. These include: pump damage or wear,well screen and casing corrosion or incrustation, incrustation of the producing formation, and structural failure of the well itself. These problems can often be traced to factors such as poor well design or construction or improper selection of pump materials.

There are, however, times when reduced well yield is not related to the well or the pump, but is instead the result of hydrogeologic conditions. These conditions may include reduced aquifer recharge, local overpumping of the aquifer, or interference from nearby wells. In addition, ambient groundwater quality is often a significant factor in well performance decline.

(2) Record evaluation

No set of rules exist for determining when a well or pump will require major rehabilitation work. Such rehabilitation may be required every six months or every 10 years. But, rehabilitation work should be carried out when the submersible pump will be pulled out of the well at the time of checking periodically or troubleshooting.

Many variables affect well performance, including well design and construction, pumping demand, and local hydrogeologic conditions.

As a result of these variables, operational records must be maintained in order to determine whether changes in well performance are due to problems in the power supply or pumping equipment, troubles within or adjacent to the well bore, or conditions within the aquifer surrounding the well. The frequency with which observations should be recorded varies according to the history of operation for a given well or areas. For high capacity units, the recording of different types of information is usually required on a daily, monthly or annual basis.

(3) Daily records

Daily observations should be made of the quantity of water discharged and/or the discharge pressure.

Documentation of daily observations can often identify problems at an early stage, thus leading to relatively inexpensive solutions.

Variations in the turbidity, color and sand content of the water should be recorded daily. Turbidity and color indicate the presence of foreign substances, generally organic compounds and certain metallic ions. Sand should not be present in a properly constructed and developed well, but small amounts are often found in wells completed in sand and gravel aquifers. Large amounts of sand can fill the well screen, reduce well yield and cause excessive pump wear. Actual physical tests for these traits are preferred, but simple visual observations can be very helpful. By recording these observations, variations once thought to arise from normal operation can be linked to external sources such as rainfall, streamflow, or nearby pollutant discharge, and future problems can often be rapidly identified.

(4) Monthly records

Pumping water level, discharge rate at the time of measurement and static water level should be recorded monthly. It is preferable to measure the pumping water level in the production well with steel tape, electric sounder, or device of similar sensitivity. MWSS deepwells have no sounding tubes attached with riser pipes, water level can be measured hardly, because sounding wire sometimes trapped with the submersible cables. Sounding tube of 3/4 inch diameter should be installed inside the well when the submersible pump will be pulled out of the well at the time of checking the pump periodically or trouble shooting.

Discharge, or pumping rate, should be determined by metering equipment if possible. The importance of accurate metering cannot be over emphasized; without it, there are no reliable ways to make value judgments concerning production costs and operating efficiency.

Static water levels should be measured monthly. Changes in static water level may be the result of water storage depletion, seasonal fluctuations in water level, or changes in recharge conditions. These changes may be temporary or permanent, of regional or local extent. In many instances, problems thought to emanate from a production well have actually resulted from regional changes in static level; hence, maintenance would be completely ineffective. In this case, the setting of the existing submersible pump changed to a more deeper position.

If local water levels are controlled by a nearby surface recharge source such as river, the elevation of the source's surface should be measured and recorded with the discharge and drawdown measurements.

Measurements of drawdown should be taken monthly. As a rule, drawdown increases in all wells with continued production and advancing age. If the well is properly designed and pumped in proper relationship to its design, the drawdown should increase very slowly.

Aside from continued use and age, an increase in drawdown may result from well inefficiency or aquifer depletion. Well inefficiency may arise within the borehole, screen, or well due to particulate plugging, chemical corrosion, chemical incrustation, biological fouling or a combination of these conditions.

Aquifer depletion may caused by seasonal variations in water level or when water withdrawals exceed recharge to the aquifer.

Determining whether increase drawdown is a function of well inefficiency or aquifer depletion is very important-well maintenance is only successful in the former case. Such a determination can be made by installing one or more observation wells in the aquifer outside the influence of the pumping well or wells. The comparison of changes in water levels of the pumping and nonpumping wells over a period of time will usually differentiate between lost well efficiency and aquifer depletion. Complete shutdown of production to allow the water level to return to its nonpumping or static state can provide comparable information.

(5) Yearly records

Water quality variations in alkalinity and hardness should be monitored on a yearly basis. Water can be aggressive, incrusting or both within a very small area. Hence, proper maintenance requires the identification of all water quality variations and the manner in which they may affect the well. The behavior of the well: static water level, pumping water level, discharge rate and etc. should be recorded monthly and analyzed on a yearly basis.

3.1.3 Establishment of Proper Well Design

Proper well design should be established to avoid well failure such as salty water intrusion, dirty water intrusion, well caved-in and drying up of well. Fig 4.1 and 4.2 shows samples of proper well design.

(1) Proper Well Design Along Coastal Area

Fig. 3.1 shows a sample of proper well design at coastal area to prevent salty water intrusion or "Well caved-in". A 22" diameter surface casing should be installed from 0.5-1 meter above ground level to 5-10 meters below ground level in order to protect from destroyed surface formation. Cement grout should be carried out in the clearance between 25" borehole and 22" surface casing pipe. 16" conductor pipe should be installed from 0.5-1 meter above ground level to 100-200 meters below ground level in order to prevent salty water intrusion or "well caved-in". The actual length of 16" casing pipes should determine the surrounding conditions: lithology log, electric log and conductivity log.

Cement grout should be carried out in the clearance between 20" borehole and 16 "casing pipe.

8"casing pipe should be installed from 0.5-1 meter above ground level to 300 meters below ground level with wire wounded screen. Emplacement of gravel in the annular space between the 14" 1/4 diameter borehole and 8" diameter casing pipe from 10 meters above the top of the screen to the bottom of the well. Emplacement of sealing clay follows for about 20 meters from the top of the gravel packing followed by sand packing or cement grout from 5 to 10 meters below the ground level to the top of the clay seal. Cement should be poured from 0.5-1 meter above the ground level to the top of the sand packing or cement grout.

(2) Proper Well Design for Another Area

Figure 4.2 shows a sample of proper well design for another area to prevent dirty water intrusion or "Dry up of well". A 22" diameter casing should be installed from 0.5-1 meter above ground level to 5-10 meters below ground level in order to protect from destroyed surface formation. Cement grout should be carried out in the clearance between 25" borehole and 22" surface casing pipe. A 16" diameter conductor pipe should be installed from 0.5-1 meter above ground level to 30-70 meters below ground level in order to prevent dirty water intrusion. The actual length of 16" casing pipes should determine the surrounding conditions.

Cement grout should be carried out in the clearance between 20" borehole and 16 " casing pipe.

8" casing pipe should be installed from 0.5-1 meter above ground level to 300 meters below ground level with wire wounded screen. Emplacement of gravel in the annular space between the 14" 1/4 diameter borehole and 8" diameter casing pipe from 10 meters above the top of the screen to the bottom of the well. Emplacement of sealing clay follows for about 20 meters from the top of the gravel packing followed by sand packing or cement grout from 5 to 10 meters below the ground level to the top of the clay seal. Cement should be poured from 0.5-1 meter above the ground level to the top of the sand packing or cement grout.

3.2 SUBMERSIBLE PUMPS

3.2.1 Product Specifications

See the name plate for the performance of the pump such as head (HEAD), discharge capacity (CAP), rotational speed (SPEED), voltage of the motor, current and the like.

Refer to the specifications. Do not use the pump beyond the limits of the specifications.

3.2.2 Installation

(1) Items To Be Checked Before Installation

- Sealing liquid inside the motor: it is filled up when delivered from the factory. Check for any leak removing the pouring plug. If the solution should be short, replenish with clean water (equivalent to drinking water). Even when the solution was fully filled, shake a few times to assure there remains no air inside. Replace the plug securely after checking.

- Measurement of insulation resistance: measure the insulation resistance between the ground and the motor cable (except power supply connected part) with the motor and the cable immersed in water. If the respective insulation resistance are 20 Mohm or more, there is no problem. When measuring, the core wire of the cable should be off the ground.

(2) Installation

Install the pump after completing the pumping test and the cleaning of the well.

1) Position of the well strainer and the pump

Install the pump at the upper part of the well strainer without fail. If the well strainer is plural and the pump is to be installed between them, set the pump slightly lower from the middle position. If the pump should be installed at the same position as the well strainer, it will suck a larger amount of sand leading to wear of the pump. On the contrary, if the pump is installed at the lower part than the lowest-positioned strainer, the area of dead water is generated around the outer periphery of the motor, and the motor might be damaged due to overheating, which should be noted. Sand and mud will be deposited gradually at the bottom of the well. Install the pump 20m or more from the bottom of the well so that the pump may not be buried.

2) Depth of submergence for the pump

The pump may be subject to failure when the external water pressure is 100m or more. Therefore set the position for installation so that the pump may not be submerged exceeding the specified value from the natural water level. The pump may be also damaged due to generated cavitation if the depth for submergence is not enough. Determine the fitting position of the electrode for low water level to provide the value more than the specified one in the outline drawing for pump in the gap between the lowest water level for operation and the upper end of the pump.

3) Caution during installation work

- Handle the pump not to apply the bending moment to it when it transported and installed.
- When the pump is lowered into the well, take care not to damage the cable by pinching it between the inner face of the casing for well and the flange for the drawing-out pipe.
- The cable should be retained with the cable band and the like on the drawing-out pipe to avoid sliding down.
- When the well is not straight and the pump may not be placed at the specified position, take an appropriate step such as changing the model of the pump not forcing to install.

4) Piping on ground

- The foundation area should not be thoroughly sealed but provided with smaller holes or gaps to remove the air.
- The well cover must be mounted correctly and horizontally and secured with the anchor bolts.
- Mount the check valve and the gate valve to the end of the discharge bend in this sequence.
- Fit the automatic air vent valve and the coupling gauge to the discharge bend. The hose for the automatic air vent valve should be fixed by putting it into the hole of the well cover to avoid moving.
- Tilt the coupling gauge to assure easy reading.

5) Treatment of cable

Install the cable not to be exposed to sunshine in a windy state in order to avoid overheating of the cable taken out of the hole provided in the well cover. Take care that any longer cable kept bundled will cause overheating. In case two or more cables for electrode for low water level are mounted, wrapping color tapes for identification to the ends will be helpful.

(3) Electrical Wiring

Concerning the power source unit for the motor and wiring work, they should be conducted correctly in accordance with the technical standard for electrical facilities and provisions for internal wiring. Any incomplete wiring, grounding (earth) and the like by unqualified person are not only very dangerous but constituting a breach of law, which should not be done absolutely.

If the submersible cable is connected, do contact the service men of the pump maker, for it is required to carry out the predetermined work with specified connecting kit.

For a single-phase model refer to the wiring diagram on the reverse side of the door for the control panel.

(4) Grounding

The grounding shall be arranged in accordance with such regulations as "Grounding work of the 3rd class" or "Special grounding work of 3rd class" for safety using tightening bolts for piping on ground or anchor bolts.

(5) Circuit Breaker

The user is required to mount the circuit breaker by law to prevent the worst case of electrification accident.

(6) Motor Protective Device

For the use of the control panel of the pump maker, the motor protective device (detection and protection of overcurrent, open-phase, and chattering) is adjusted beforehand.

When any control panel is provided by user, adjust the sensitivity of overcurrent and open-phase etc. conforming to the pump.

3.2.3 Operation

(1) Before starting the pump

(a) Measure the insulation resistance again after the installation work as been completed. If the reading is 20 Mohm or more immediately after the installation, there is no problem.

(b) Check whether the water level in the well is sufficient. Never operate the pump dry, for it may cause the pump to burn out.

(c) Check the state of the primary power source, the electrical wiring, capacity of the breaker and the present value for the overcurrent protective relay.

(2) Test Operation

(a) Open the gate valve fully before turning on the switch.

(b) Turn the switch on and off one or two times to check its normal start (provided however once the switch has been turned off, interval of three minutes or more should be kept before the next start).

(c) Check the rotational direction of the pump when no abnormal start has been found. Higher shutoff pressure and lower current represent the correct direction when the pump is operated.

The reverse rotation will show not only lower shutoff pressure but also generate sudden rise in current as the gate valve is gradually opened. Change the wiring to provide the correct rotation when it is reverse. (in this case the shutoff operation time shall be ten minutes as maximum).

(d) Open the gate valve one-half to one full turn under the correct rotation and operate for a while. Open the gate valve gradually when the water discharged becomes clear. If it is opened too quickly, the pump may clog with sand.

(e) When the discharge amount reaches the specified valve, check the pump whether the total head (water level in the well + pressure on ground + piping loss) and current value are closely near those in test results. If any imbalance of current is found in each phase, there is no problem when the maximum value is within + 5% of the current value stated on the nameplate. Also check any abnormal vibration and/or noise.

(f) The test operation will be completed when no abnormality is found But check no severe water hammer is generated in this case.

(3) Regular Operation

Regular operation can be started as soon as the test operation has been completed.

(a) Be sure to operate the pump (discharge volume) within the "suitable operation range". In case it is operated beyond the range, adjust the gate valve.

(b) Do not open and close valves once they have been adjusted. Establishment of the pumped water volume will prolong the well life.

(c) Keep the cock of the coupling gauge closed other than the measuring time. If this is kept open, it may cause frequent failure.

(d) Suitable operation range of pump

Set the discharge volume so that it may be between the first main point and the second main point in the right figure. Too smaller discharge volume will cause overheating of motor and may lead to burning out, while too larger discharge volume may be cause for vibration and troubles such as failure of bearings.

(e) Number of starting of pump operation per hour were shown below.

Output of motor (kW)	Number of start per hour
7.5 or less	Within 12 times
11 - 22	Within 6 times
26 - 45	Within 4 times
Starting time	3 minutes or more after stop

3.2.4 Maintenance

Check pressure, discharge volume, voltage, current, insulation resistance and others. If these are found to be different from normal ones, it will represent the sign of troubles. Take earlier action referring to the cause and remedy for troubles in the troubleshooting section 3.2.5. Preparation for a spare pump is recommendable for the worst case.

(1) Daily Inspections

Daily inspection shall be made as follows. Recording the data measured at inspection in "Records for Operation Management" will serve as the reference data in prediction of life of the pump and catching the state of the well.

If the facilities are critical ones, inspect more often than this.

(a) Check of current value: once a day

Measure the current value and check whether it is closely near the valve shown during the test operation. Also check fluctuation of current, imbalance of three-phase and voltage simultaneously.

(b) Check of discharge volume: once a week

Where any flow meter is mounted, check if the discharge volume is very near the value shown during the test operation for total head.

In case of flow meter is provided, measure the total head during the shutoff operation as necessary (once a month approximately) and check whether the valve is closely similar to that seen during the test operation.

(c) Check of vibration resistance: once a month

Check whether any abnormal vibration and/or noise are produced in pump.

(d) Check of insulation resistance: once a month

Pump can be operated when the insulation resistance shows 1 Mohm or more. If the value shows sudden decrease, take every care such as by shortening interval of measurement and taking other steps.

(e) Check of water level in well:

Measurement and recording of the water level in the well will form the data for state of well and serve as reference data to predict the well life.

(2) Records for Operation Management

Recording the data measured at daily inspection in the records for operation management as the table shown below will serve as a reference data to predict the life of the pump and catch the state of the well.

Pump for deep wells Records for operation management	Mfg. No. of pump: Model of pump:

Well dia: mm	Water level for operation m	Main spec. of pump:
Well depth: m	Installed position of pump m	Rated current:

Date/ Time	Pumping water level (m)	Discharge pressure (kg/cm)	Discharge volume (m/min)	Voltage (V)	Current (A)	Insulation resistance (Mohm)	Note

(3) Overhaul

(a) The first overhaul is recommended to be done one to two years later after starting the operation. The time of the second overhaul should be determined upon the inspection results of the first overhaul. The same procedure shall be applied to the third overhaul and hereafter. The time of the first overhaul shall be judged depending on importance of the facilities, hardness of the operation, the water quality and other factors.

Installation and start of operation

The first overhaul	one to two years later
The second overhaul	To decide on results of the first overhaul (five years as max.)
The third overhaul	To decide on results of the second overhaul (five years as max.)

(b) Another opportunity to overhaul is provided by finding out any sign of troubles through assuming the deterioration progress of the pump from the water level of pump, discharge pressure, discharge volume, current value, insulation resistance and others measured at daily inspections. In this case, the data shall be provided from the continuous measurement as possible to catch the deterioration progress easily.

(c) When the damaged pump is taken out to repair without overhauling in management, it is advisable to prepare a spare pump, by which the spare pump can be installed without any delay after the pump was damaged to minimize the influence over the pumped water plan. The damaged pump can be stored as a spare pump after repair and inspection.

(4) When Operation is suspended

When the operation is suspended for a long time or the pump is installed as a spare pump, operate it for about ten minutes once a month. The operation should be started in accordance with the section 3.2.3.

(5) Storage of Pump

The following point should be taken care when the pump is stored for a long time without installation. If the use is required after storage. Follow the section 3.2.2 for installation and then the section 3.2.3 to start the operation.

(a) Store the pump where there is no direct sunshine and no higher temperature and humidity.

(b) Remove any water inside the pump and dry it thoroughly,but,do not remove the water inside the motor.

(c) Apply taping to the ends of cable to avoid water.

(d) Put a cover on the pump not to cause any failure to the motor and the cable.

3.2.5 Trouble Shooting

Trouble	Cause	Remedy
Does not start.	Wiring disconnected or cut.	Repair or replace.
Start, but immediately stops.	No power.	Contact power company.
	Dry operation prevention electrode or pressure switch etc. damaged.	Replace.
	Not connected well.	Connect correctly.
	Voltage drops (10% or more).	Contact power company.
	Circuit breaker functioning.	Repair or replace point of short circuit.
	Pump or motor locked.	Remove pump and repair.
	Magnet switch flutters.	Replace.
	Motor burned out.	Remove pump and repair or replace
Overcurrent during operation.	No connected well.	Connect correctly.
	Voltage drops (10% or more).	Contact power company.
	Pump clogged with sand.	Clean the well.
	Pump or motor shaft worn.	Remove and repair.
No water.	Pump exposed.	Lower pump position.

	Faulty connection.	Connect correctly.
Rated flow not provided. Not enough discharge.	Inside of pump worn.	Replace worn parts.
	Hole in piping.	Repair.
	Hole in piping.	Replace.
	Scales inside piping.	Remove scales and clean.
	Foreign matter clogged in impeller or casing.	Remove, disassemble and clean.
	Foreign matter clogged in pump strainer.	Remove, disassemble and clean.
	Gate valve damaged.	Repair or replace.
	Water level extremely low.	Replace with a pump having higher total head
	Not connected well.	Connect correctly.
Low Insulation resistance	Motor deteriorated.	Replace motor.
	Motor burned out.	Replace motor.
	Submersible cable damaged.	Remove and repair.
	Water leaking into connection of cable under water.	Remove and repair.
Vibration & Noise	Water hammer in piping above ground.	Take countermeasure to prevent water hammer.
	Gate valve closed too far.	Increase opening of gate valve.
	Built-in check valve damaged.	Remove and repair.
	Pump worn.	Remove and repair.

Figure 1.1 REGIONAL DECLINING OF WATER LEVEL

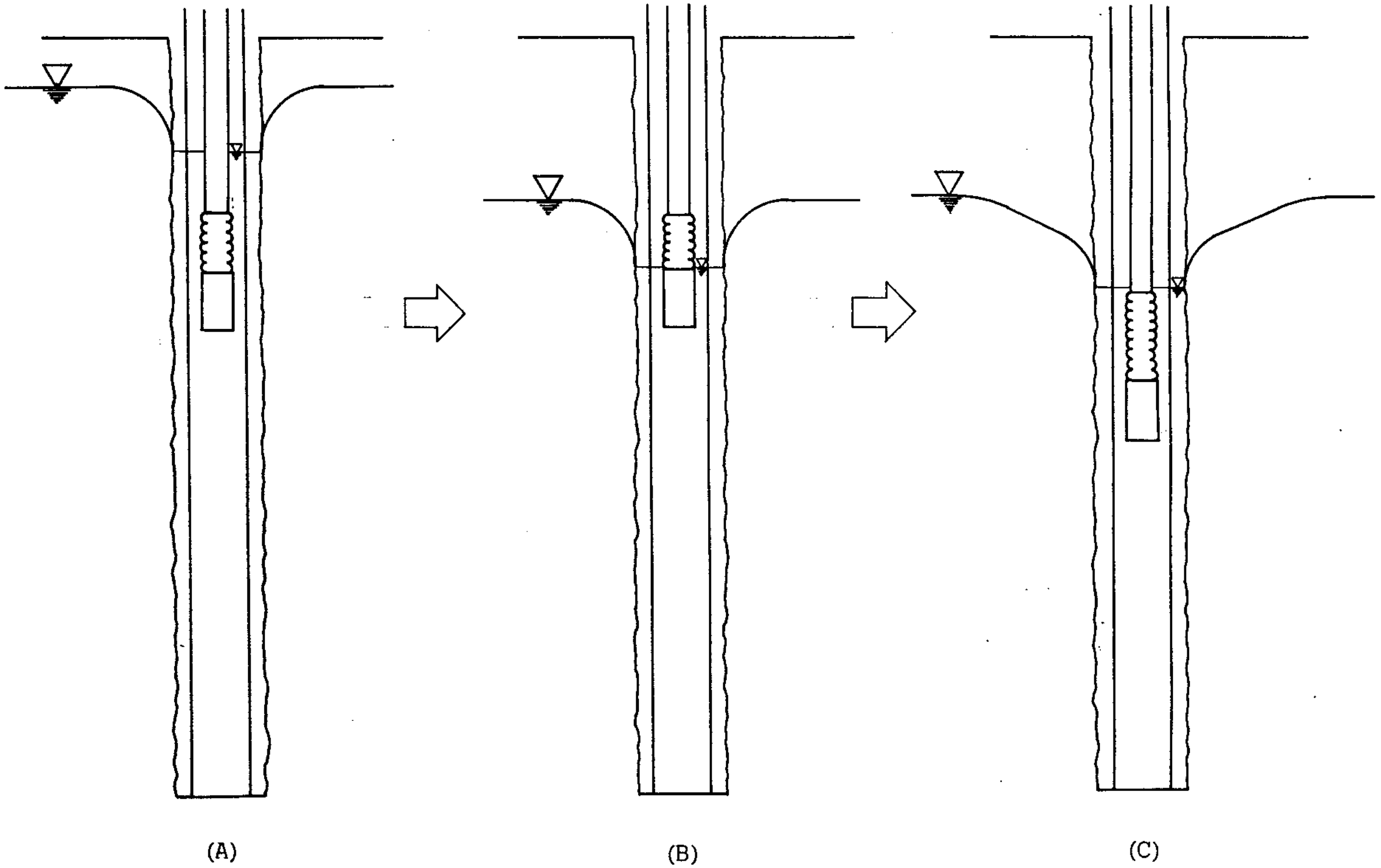


Figure 1.2 SALTY WATER INTRUSION

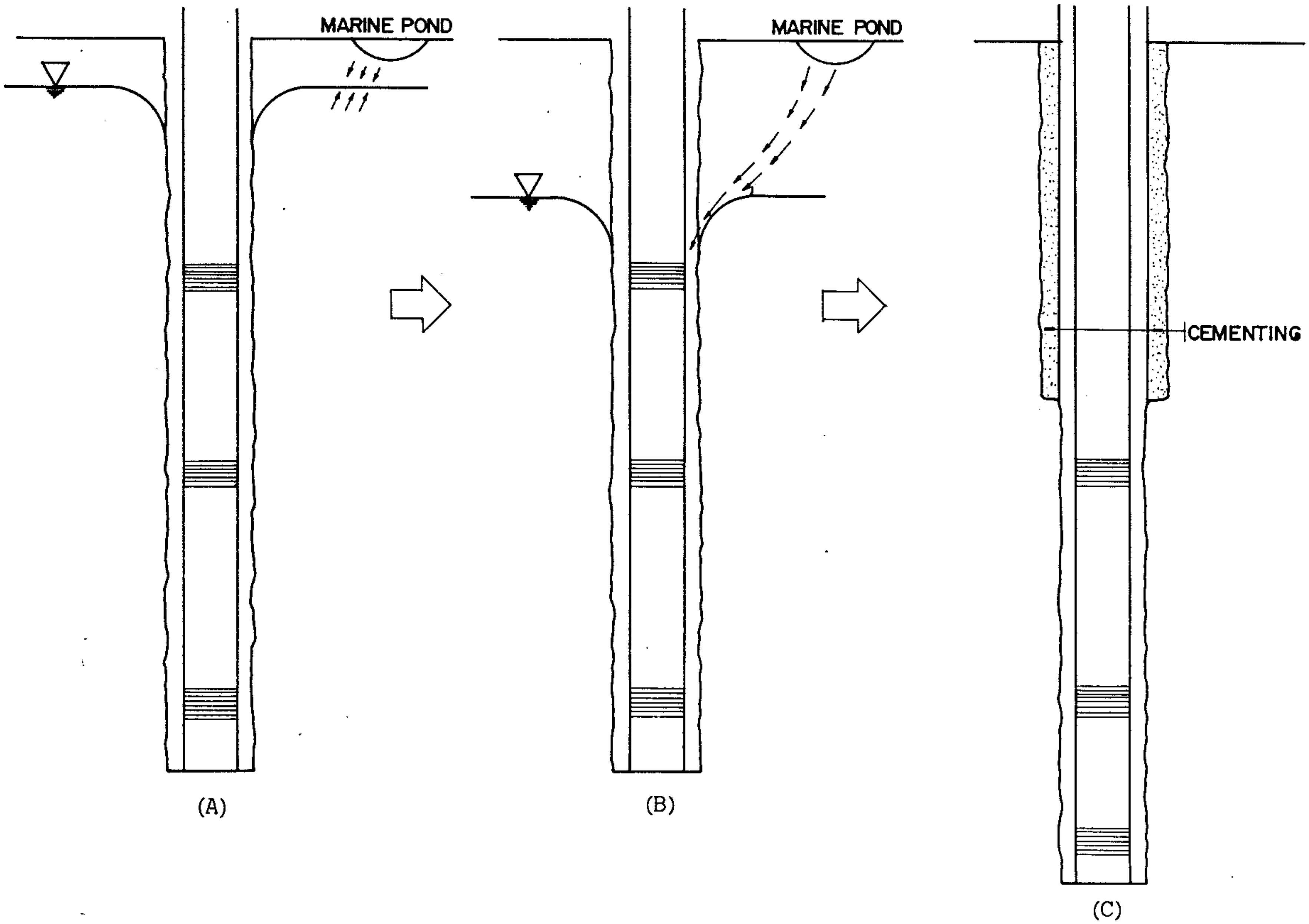


Figure 1.3 WELL CAVED-IN

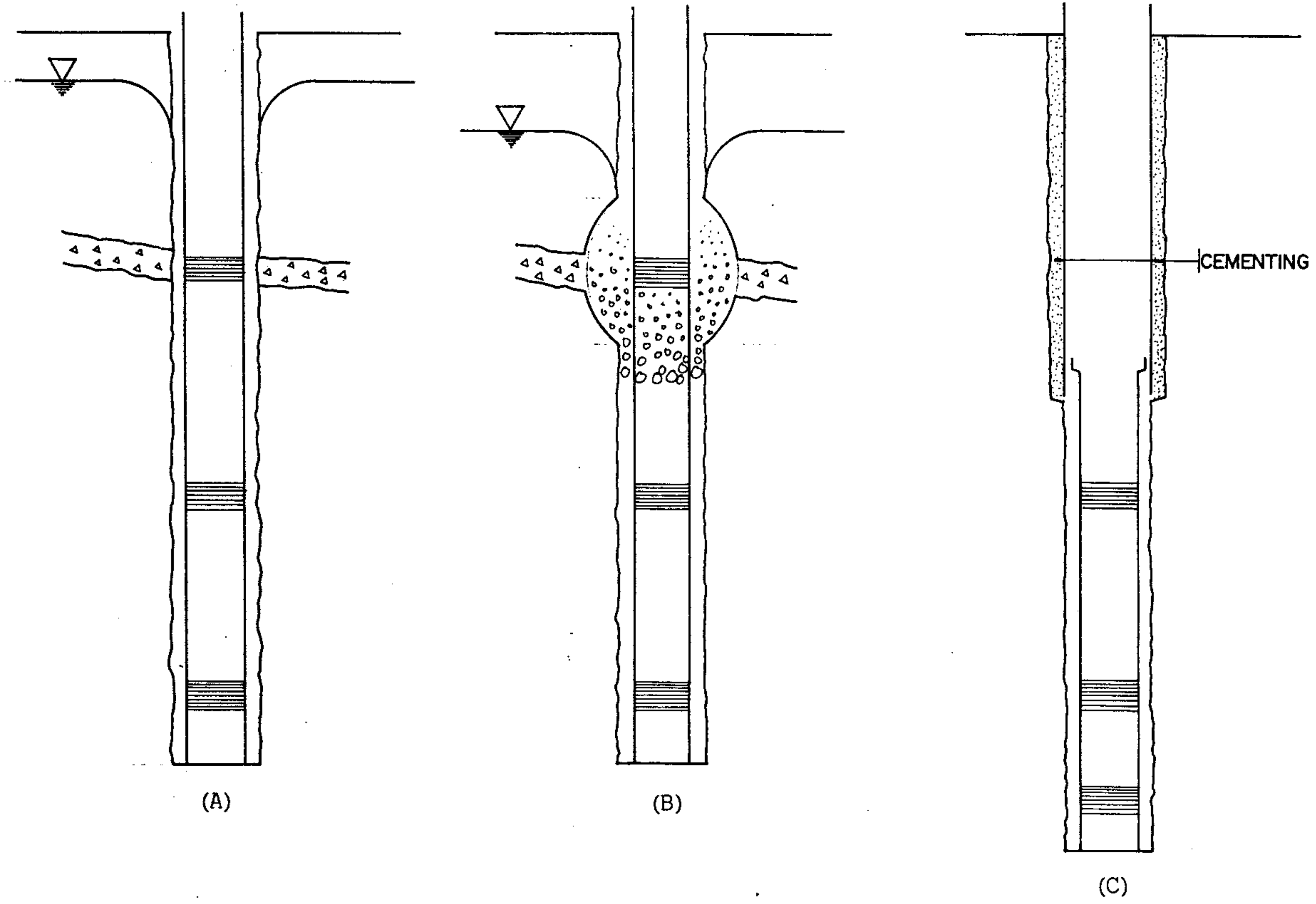


Figure 1.4 DIRTY WATER INTRUSION

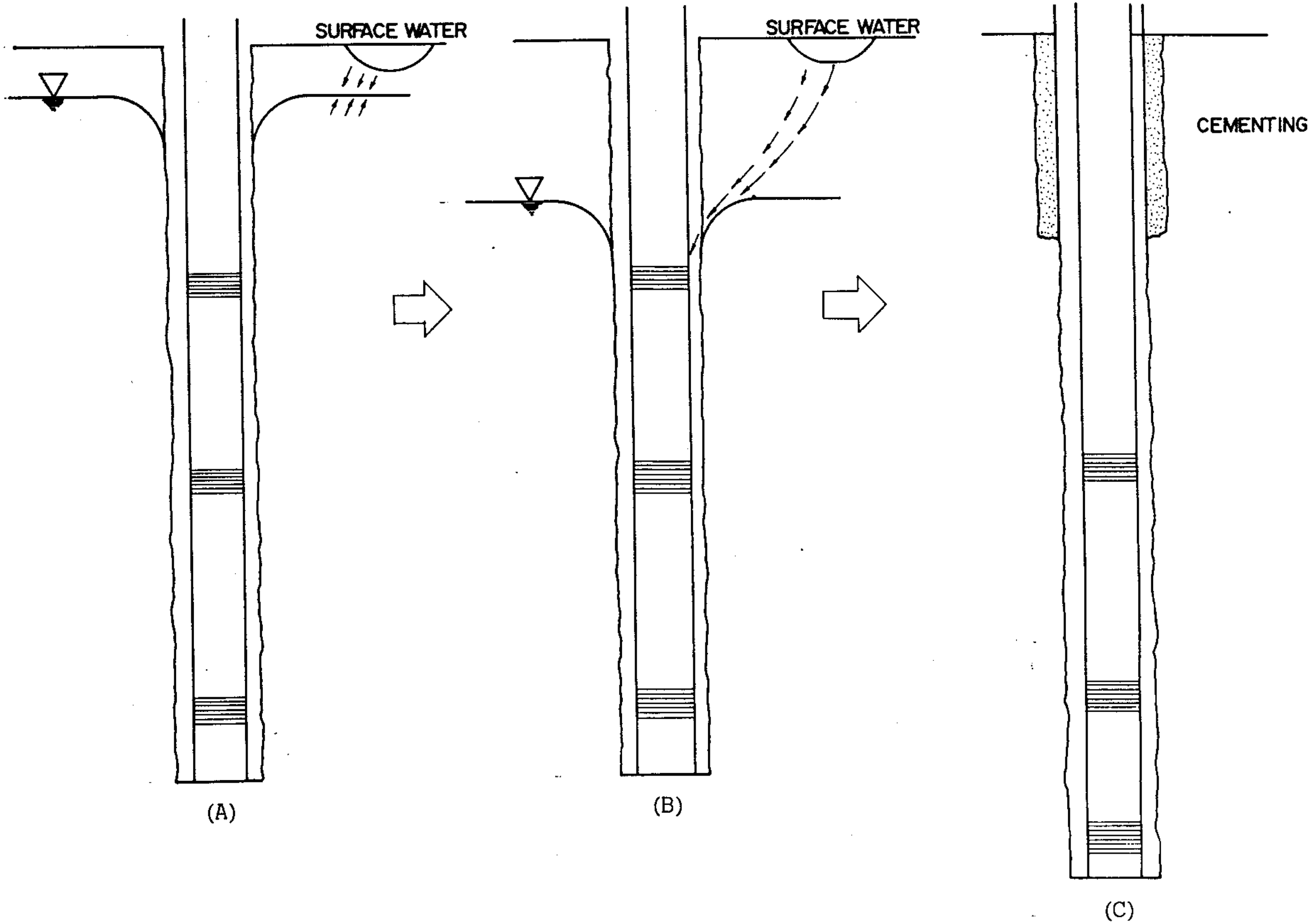
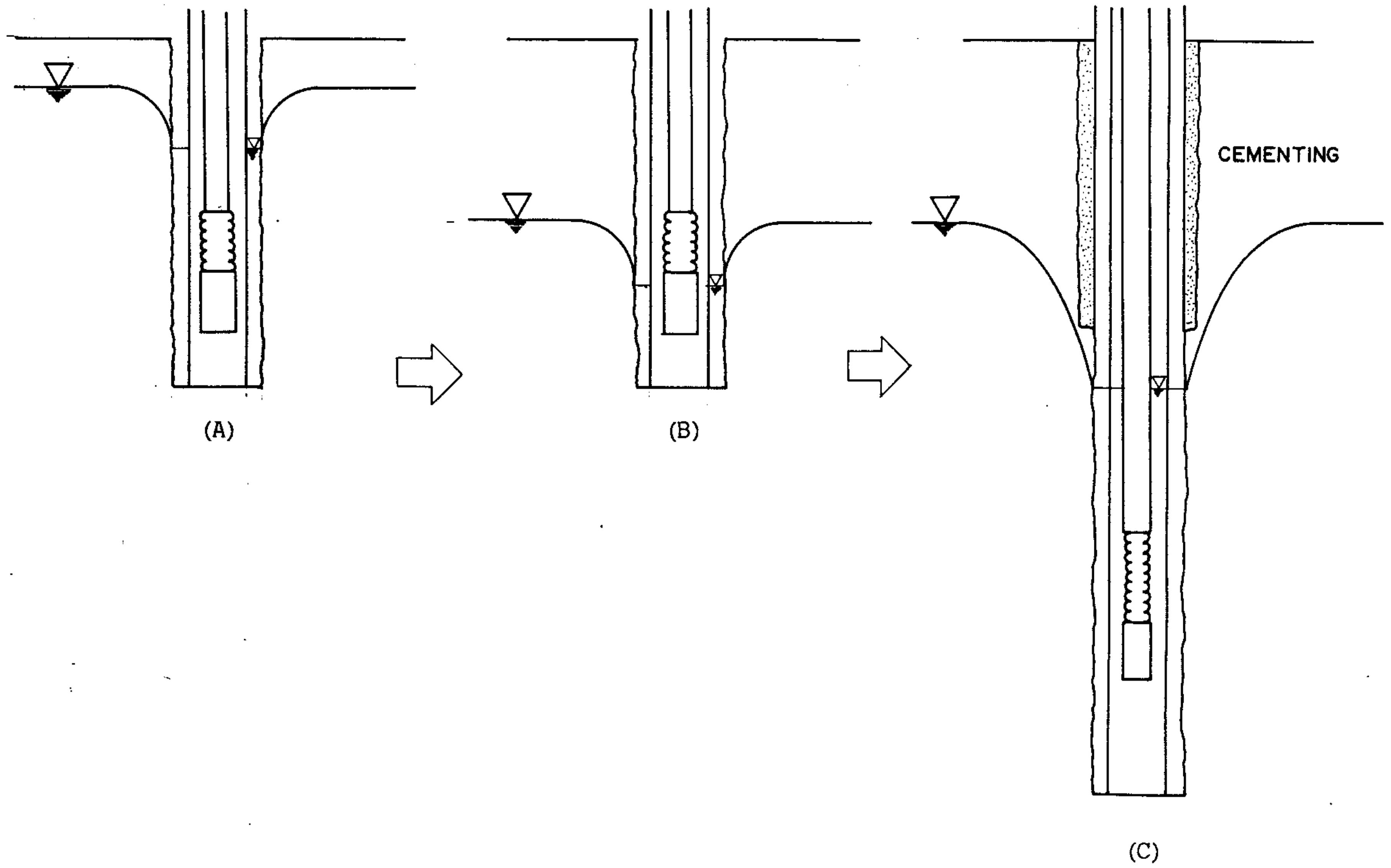


Figure 1.5 WELL IS ALMOST DRY



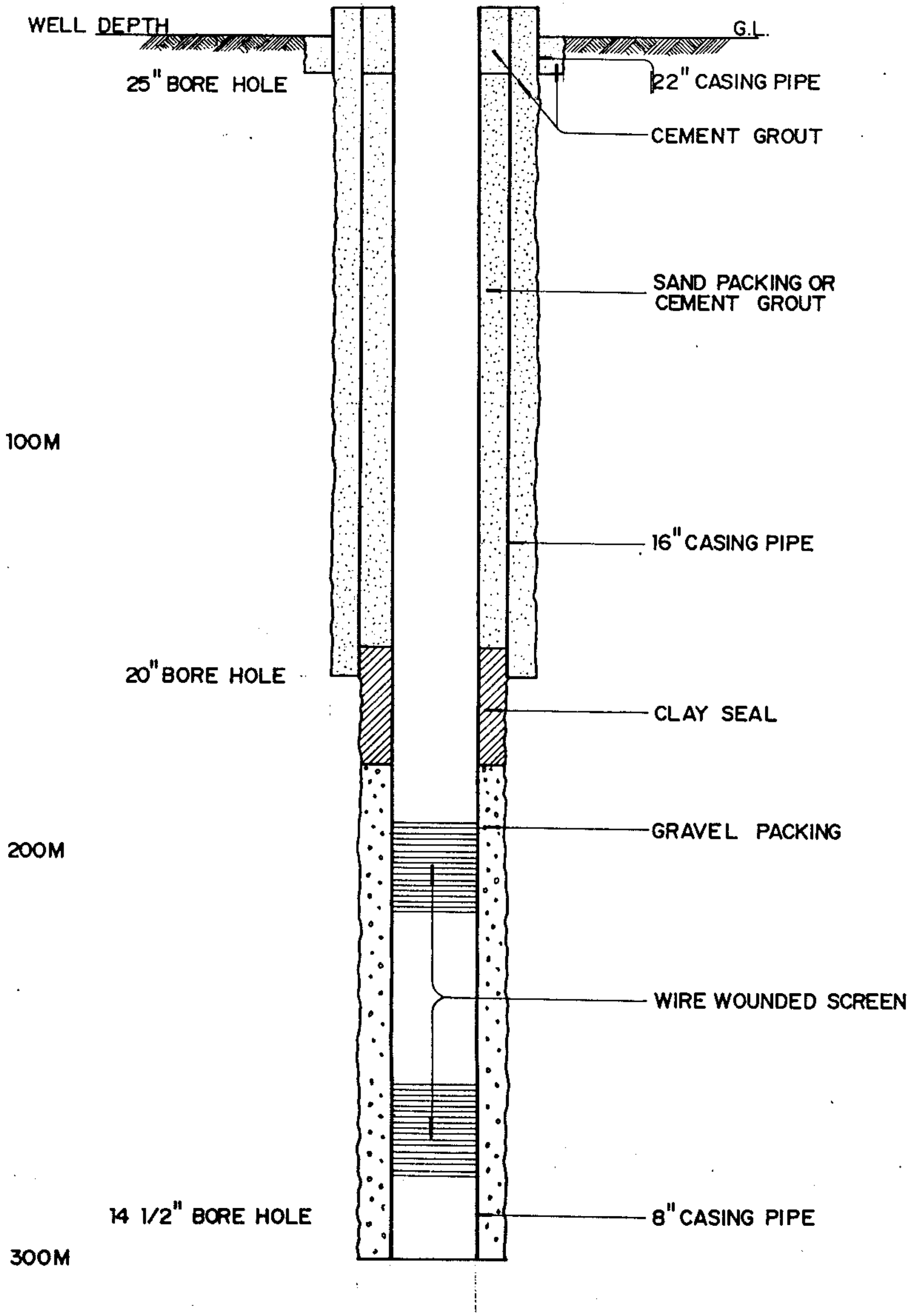


Figure 3.1 PROPER WELL DESIGN I

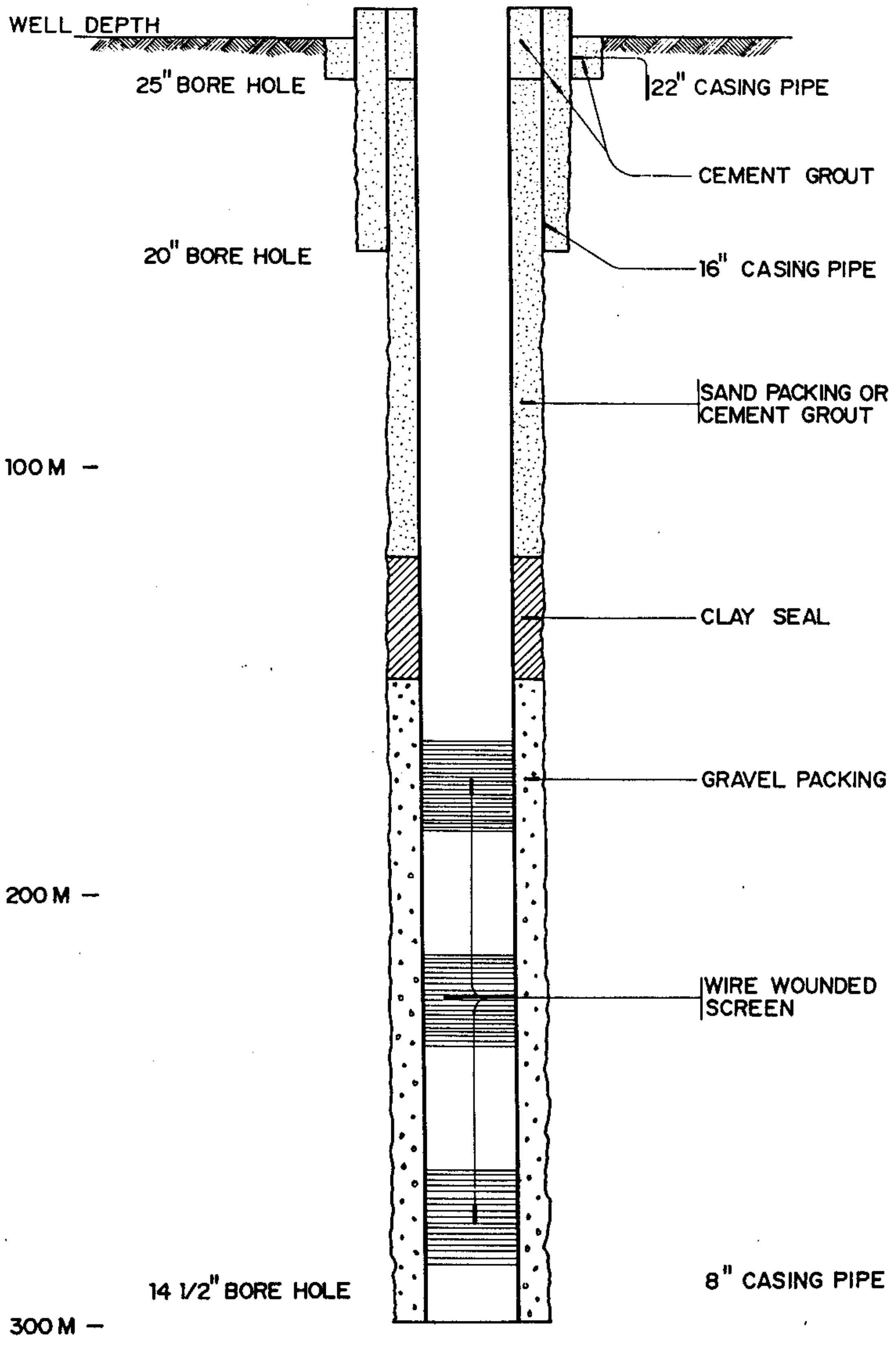


Figure 3.2 PROPER WELL DESIGN II

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REPUBLIC OF THE PHILIPPINES
METROPOLITAN WATERWORKS AND SEWERAGE SYSTEM

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

GROUNDWATER DATABASE SYSTEM USER'S MANUAL

JUNE 1992

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GROUNDWATER DATABASE SYSTEM

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GROUNDWATER DATABASE SYSTEM

The Groundwater Database System aims to support the groundwater development and conservation program of the Metropolitan Waterworks and Sewerage System (MWSS). The system was designed to facilitate the retrieval of necessary information from the database as well as the inputting of data directly (from the source document) into the computer.

The system is composed of five databases containing the following information:

- well inventory data
- meteorological data
- hydrological data
- hydrogeological data
- related literature records.

HARDWARE REQUIREMENT

The system runs on IBM PC/AT or any similar compatible micro-computer system whose configuration is characterized by the following:

1. A memory size of at least two megabyte (MB) -- without the graph, the system needs only at least one megabyte
2. With at least one 3.5" (and 5.25") floppy disk drive
3. With hard disk of at least 40 megabytes storage capacity
4. With DOS 3.3 or higher
5. A printer similar to Epson FX-1000.

SOFTWARE REQUIREMENT

The system was designed to be user-friendly and has a program named WELL. It was developed specifically for the system to hide the complexity of the database internal structures and procedures.

The system utilizes Lotus-123 (Release 2) software for the graphs.

```
+-----------------------------------------------+
| IMPORTANT:                                    |
|                                               |
|  CONFIG.SYS installed in the computer must    |
|  contain FILES=100 (or more); otherwise the   |
|  Groundwater Database System will not run.    |
+-----------------------------------------------+
```

LOADING THE SYSTEM

1. From the roott directory, create sub-directory MWSS

   ```
   C:\>MD MWSS                and press the <Enter> key
   ```

2. Enter sub-directory MWSS

   ```
   C:\>CD MWSS                and press the <Enter> key
   ```

3. Copy the programs, data file structures and other support files stored in three 3.5" diskettes. Diskettes #1, #2, #3 are program diskettes. DIskette #4 contains the data file structures (Appendices A.1 to A.5).

   - Insert Diskette #1 in Drive B and copy all the contents.

     ```
     C:\MWSS>[path]XCOPY B:/s        and press the <Enter> key
     ```

     XCOPY is a DOS 3.3 command. [path] indicates the drive and/or ub-directory where the DOS commands are stored or where the command XCOPY is to be called.

   - After copying Diskette # 1, insert Diskette # 2, copy the contents, and so on until all diskettes have been copied.

STARTING THE SYSTEM

After the successful loading of the program WELL and the data file structures, the user can gain access to WELL by following the instructions below:

1. Activate the WELL program from sub-directory MWSS.

   `C:\MWSS>WELL` and press the <Enter> key

   - Screen 1 is displayed.

2. Press any key to continue.

   - The Main Menu appears on the screen. The user can choose from any of the five modules comprising the system (Screen 2).

3. Type the letter corresponding to the module to be chosen and press the <Enter> key to activate the selected module.

   - W for well inventory data, M for meteorological data, H for hydrological data, G for hydrogeological data, and L for literature records.

   - A message "Please wait... setting up the files" is displayed onscreen.

ENDING THE SYSTEM

Pressing the Esc key allows the user to go back to the previous screen. When Screen 2 appears, no module is active.

WELL INVENTORY DATABASE

Well inventory includes MWSS-supervised wells and turned-over deep wells, private wells applying for water rights from NWRB, wells inventoried during the Electrowatt project, wells from MGB (NWRB's countrywide inventory of existing wells), wells visited during the groundwater use survey and groundwater levelling, test wells drilled during the JICA study, wells inventoried in NWRB's Philippine Groundwater Summary, and wells from drilling companies.

The data file structures and coding instructions for well inventory are described in Appendix A.1.

When this module is activated, Screen W1 is displayed onscreen and the list of wells is shown. The user can browse through the list and select the desired well for more detailed information. In the Edit mode, the user can make changes on the data shown in Screen W1.

A. To browse data in Screen W1.

The user can browse through the list of wells by using the command keys described in Appendix B. In this "display" mode, the user can also print the data by location.

To print, press F4.

The system will prompt:

SET THE PRINTER ON (in condensed mode)... Press any key when ready

Pressing any key except Esc key (cancels the print option), readies the user for printing. The system prompts for the location code.

LOCATION CODE: __

The user responds by typing the location code (See Appendix A.1). If valid, the location name appears beside the code. If not, a message appears onscreen:

"INVALID CODE... Please try again"

Pressing the Esc key aborts this option.

B. To edit data in Screen W1.

- Press F5.

The screen changes to the Edit mode and some of the data previously displayed are changed to codes. In this mode, the user can select the data item to be edited, add new record(s), delete record(s), print information displayed on the screen and/or extract data from the database for further processing (see Appendix B).

C. To obtain more detailed information about the selected well:

1. Be sure Screen W1 is in the "display" or "browse" mode.

2. Select the desired well.

   There are two ways of selecting the desired well:

   a. By positioning the highlighted bar to the desired well.
   b. Pressing Shift-F2 (Shift key + F2 key simultaneously).

      When Shift-F2 is pressed, the system prompts:

      WELL CODE ==> ________

      The user responds by typing the code of the desired well. (Pressing the Esc key aborts this option.) If the code is mistyped or not available, the message below appears onscreen:

      " << WELL CODE not found... Please try again >> "

      After the code has been accepted, the highlighted bar immediately goes to the record of the selected well.

3. Press F3.

Screen W2 appears and displays the basic information about the well. At the bottom, there are command options to choose from.

- Press the left or right arrow key to move from one option to another. The active option is the one with the highlighted bar.

- Press the <Enter> key to activate the command.

Command options:

Edit -	allows the user to modify the data items displayed on the screen. Data items that are selected for editing are highlighted. The user can traverse through these fields and make some modifications. The <Esc> key returns the cursor to the command mode.
Print -	allows the user to get a hardcopy of the displayed information.
Quit -	exits the user to the previous screen.

The box at the right-hand bottom corner of Screen W2 contains more information about the well -- Well Design, Log Record, Pumping Test and Well Production (for MWSS wells only). To enter this section,

- Press the right arrow key until the highlighted bar reaches the desired information inside the box.

Design - allows the user to enter Screen W3
Log Record - allows the user to enter Screen W4
Pumping Test - allows the user to enter Screen W5
Production - allows the user to enter Screen W6.

- Press the <Enter> key to select.

Well Design

Screen W3 displays the Well Design. There are command options (Edit, Print, Quit) at the bottom of the screen whose functions are similar to Screen W2.

Information on the casing schedule or well screen section can be displayed by choosing any of the two options located at the bottom right-hand corner of the screen.

1. Press the right arrow key until it reaches the box at the bottom right-hand corner of the screen.

   Screen Section - allows the user to enter Screen W3.1. This contains information about the well screen section.

   Casing Schedule - allows the user to enter Screen W3.2. This contains information about the well casing.

2. Press the <Enter> key to select.

When in Screen W3.1 or Screen W3.2, the user can either browse through the list, add new record(s), delete record(s), edit, print information displayed or extract data using the command keys described in Appendix B.

Well Log Record

The Well Log Record describes the well strata (Screen W4). The user can either browse through the records, add new record(s), delete record(s), edit, print information displayed or extract data using the command keys described in Appendix B.

Pumping Test

Screen W5 gives the result of the pumping test. There are command options at the bottom of the screen whose functions are similar to that of Screen W2.

Production

Well production data are available only for MWSS wells. Monthly pumpage is measured in cubic meters and yearly data are automatically generated by the system.

To choose from monthly and yearly data, press the right or left arrow key to move the highlighted bar to the desired data and then press <Enter> key to select.

Screen W6.1 displays the monthly data while Screen W6.2, that of the yearly data.

Editing and Extracting Data

Editing is accepted only when monthly data is requested. User can add, modify or delete records. Command and function keys available for editing as well as extracting data are described in Appendix B.

Updating

To update yearly data:

- Press F8.

  A message appears onscreen: *** UPDATING ***

  The system (re)computes the annual data.

Mean and Standard Deviation

To request for the mean and standard deviation:

1. Be sure the screen is in Screen W6.1 or W6.2.

2. Press F9.

   The system prompts for the years (e.g. 1980) covered (Screen W6.1.1).

3. After supplying the years, press the <Enter> key.

   A message "*** COMPUTING ***" appears at the bottom left corner of the screen.

   After a while, the mean and standard deviation, will be displayed.

4. To print the mean and standard deviation, press F4.

Graph

Graph can be requested while in Screen W6.1 or Screen W6.2. This option makes use of Lotus' graphing capability.

1. To activate the graph, press F10.

2. Type-in the years (e.g. 1980) to be graphed and press the <Enter> key.

   The system activates Lotus 123.

   Within Lotus 123:

   - Select the type of graph -- Linear or Bar graph.

   - Select End to quit.

The system returns to Screen W2.

METEOROLOGICAL DATABASE

The meteorological database contains the daily, monthly, and annual records of rainfall, temperature (mean, minimum and maximum), evaporation, humidity, wind velocity and sunshine duration measured from meteorological stations. The codes and the data file structures used in this database are described in Appendix A.2.

When this module is activated, Screen M1 is displayed onscreen and the list of meteorological stations is shown. As in Screen W1, the user can browse through the list, print, and select the desired station for more detailed information. In the Edit mode, the user can make changes on the data. The user can also extract data from the database.

Command options and function keys necessary for selecting, editing, adding, deleting, printing and extracting of data are similar to those in well inventory database.

Screen M2 displays the basic information about the selected station. Data being observed -- rainfall, temperature, evaporation, humidity, sunshine duration and wind velocity -- are listed at the bottom right-hand corner of the screen. Choosing any of these data items, brings the user to Screen M2.1 for daily data, Screen M2.2 for monthy data, or Screen M2.3 for yearly data.

The user can input and/or modify existing data for daily observations only. To display the data , the user has to move the highlighted bar from any of the desired frequency of measurement -- Daily, Monthly, and Annual -- and press the <Enter> key to select.

If Daily data is requested, the system prompts for the desired YEAR (e.g. 1989). If the desired YEAR is not available, the system displays message onscreen:

YEAR is not available... Want to input data (Y/N)?

If Y(es), the system automatically generates blank fields for the YEAR and DAY. Command and function keys for editing, adding, deleting, printing and extracting data are described in Appendix B. YEAR and DAY cannot be altered.

Monthly and yearly data are automatically computed by the system. No editing can be done when these data are requested.

Function keys for updating data, requesting for mean, standard deviation and graph are similar to those described in well inventory database (well production section).

HYDROLOGICAL DATABASE

The hydrological database provides information about the hydrological gaging stations as well as the daily, monthly, and annual continuous observations on the river discharge and gage height measured from the said station. It also contains the simultaneous observations on spring discharge and streamflow in the Antipolo area. The data file structures and codes used in this database are described in Appendix A.3.

The first screen (Screen H1) of the database provides the user with two options for hydrological observations -- Simultaneous and Continuous.

To select the desired observation:

- Move the highlighted bar to the desired observation -- Simultaneous or Continuous.

- Press the <Enter> key.

  Either Screen H2 (simultaneous observation) or Screen H3 (continuous observation) appears on the screen with the list of hydrological stations. The user can either browse through the list, print or extract data.

To obtain detailed information:

- Press F3.

  Screen H2.1 or H3.1 is displayed showing the basic information about the hydrological station and the data being observed for each station.

- Move the highlighted bar to the desired data -- spring and streamflow discharge or river discharge and gage height -- located at the bottom right-hand corner of the screen and press the <Enter> key.

  Either screen for simultaneous observation -- Spring Discharge (Screen H2.1.1) and Streamflow Discharge (Screen H2.1.2) -- or, for continuous observation -- River Discharge (Screens H3.1.1 to Screens H3.1.3) and Gage Height (Screens H3.1.4 to H3.1.6) -- is displayed.

Command keys and function keys for selecting, modifying, printing and extracting of data are similar to those in well inventory database.

Graph as well as mean and standard deviation are provided for data on hydrological continous observation. Function keys are similar to those in Meteorological Database.

HYDROGEOLOGICAL DATABASE

The hydrogeological database contains data only of those wells tested and measured during the actual test drillings, rehabilitation studies, pumping test and groundwater quality investigations of wells. The data file structures and codes used for the database are described in Appendix A.4.

When activated, the list of wells is displayed (Screen G1). Like Screen W1 and Screen M1, the user can browse through the list and select the desired well for more detailed information.

After the desired well is selected, Screen G2 appears with five options for the user to choose from -- pumping test data, groundwater level (continuous and simultaneous observation), chemical and physical quality of water. The option Pumping Test brings the user to Screen G3, Groundwater Level (continuous) to Screen G4.1 to G4.3, Groundwater Level (simultaneous) to Screen G5, Chemical Quality of Water, to Screen G6 and Physical Quality of Water to Screen G7.

Command options and function keys for selecting, modifying, printing and extracting of data are similar to those in the well inventory database.

Graph as well as mean and standard deviation are provided for the Groundwater Level Continuous observation data. The function keys are similar to Meteorological database.

LITERATURE DATABASE

The literature database provides literature records relevant to the groundwater development study. The data file structures and codes used are described in Appendix A.5.

When this module is activated, Screen L1 is displayed. There are command options at the bottom of this screen whose functions are the following:

Edit - allows the user to modify the data items displayed on the screen. Data items that are selected for editing are highlighted. The user can traverse through these fields and make some modifications. The <Esc> key returns the cursor to the command mode.

Previous - displays the record preceding the record currently displayed.

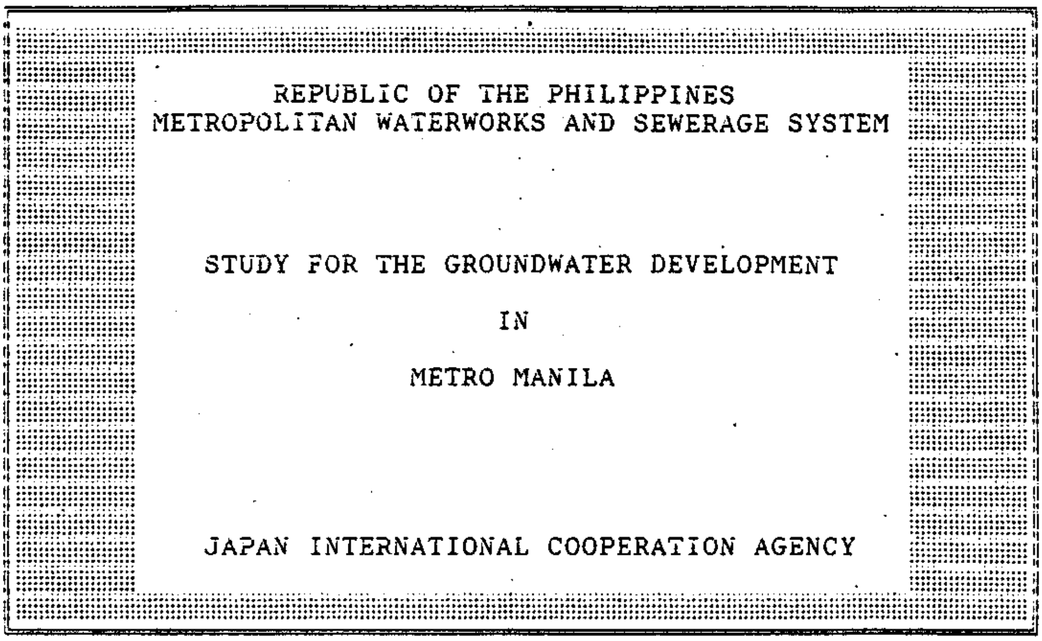
Next - displays the next record.

Print - allows the user to get a hardcopy of the displayed information.

Quit - exits from the database.

SYSTEM SCREEN DESIGNS

Screen 1



```
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                     IN

                METRO MANILA



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```
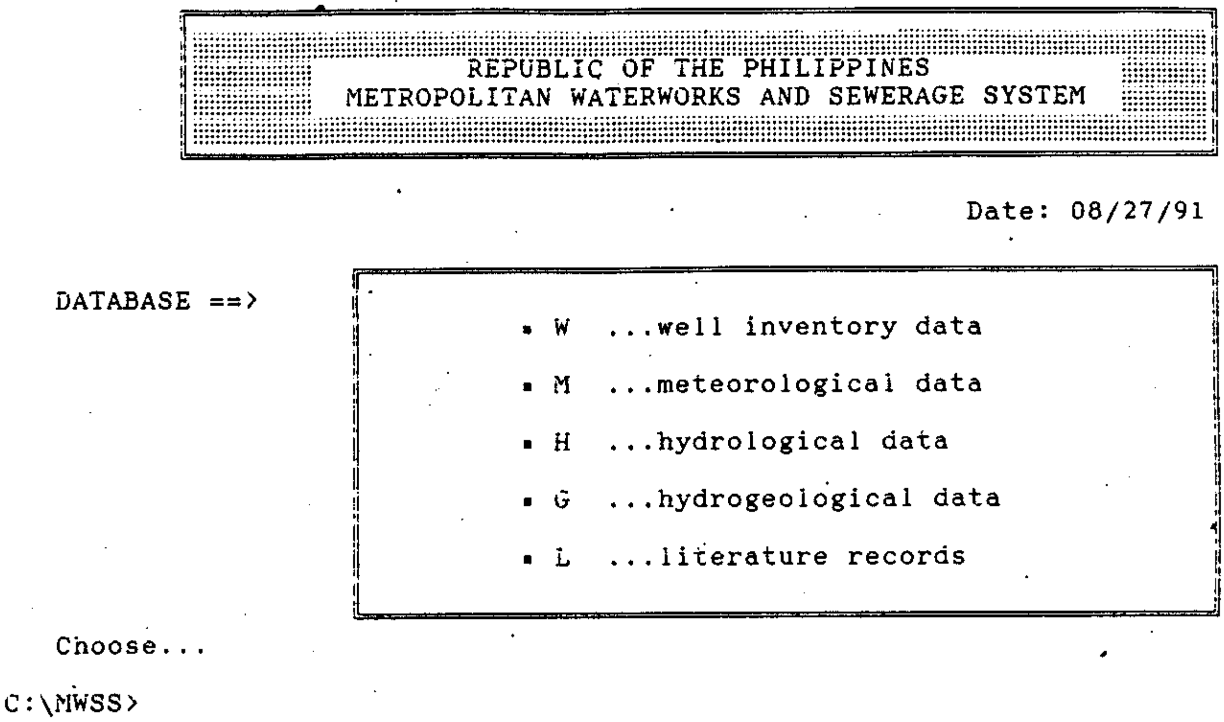

```
Press any key to continue...
```

Screen 2



```
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                                          Date: 08/27/91

DATABASE ==>

               ▪ W  ...well inventory data

               ▪ M  ...meteorological data

               ▪ H  ...hydrological data

               ▪ G  ...hydrogeological data

               ▪ L  ...literature records

Choose...
C:\MWSS>
```
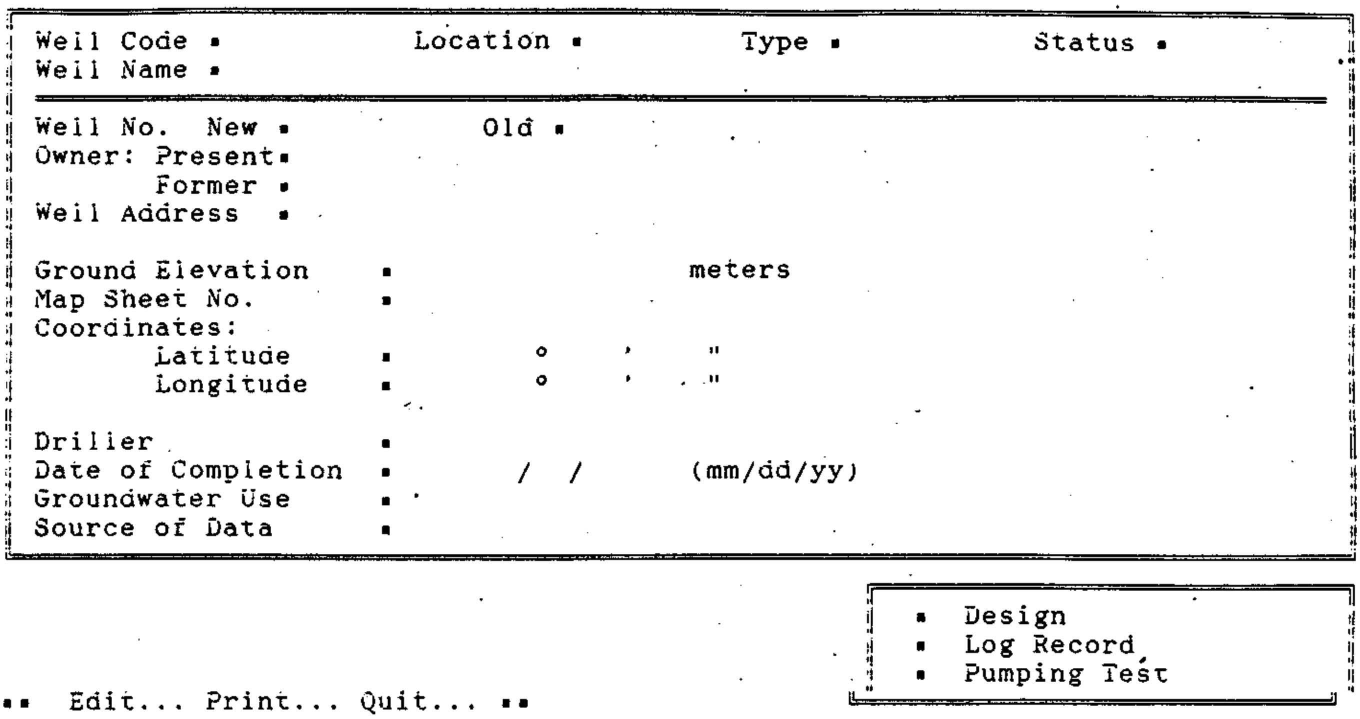

Screen W1

*** WELL INVENTORY DATA ***

Wcode	Location	Type	Well Name	Status

Screen W2



```
Well Code ▪              Location ▪          Type ▪            Status ▪
Well Name ▪
──────────────────────────────────────────────────────────────────────────
Well No.  New ▪              Old ▪
Owner: Present▪
       Former ▪
Well Address  ▪

Ground Elevation     ▪                 meters
Map Sheet No.        ▪
Coordinates:
       Latitude      ▪       °    '    "
       Longitude     ▪       °    '    "

Driller              ▪
Date of Completion   ▪      /  /       (mm/dd/yy)
Groundwater Use      ▪
Source of Data       ▪

                                                     ▪  Design
                                                     ▪  Log Record
                                                     ▪  Pumping Test

▪▪  Edit... Print... Quit... ▪▪
```

Screen W3

```
Well Code ▪          Location ▪          Type ▪          Status ▪
Well Name ▪

                        *** WELL DESIGN ***

  Well Depth                  ▪                  meters
  Diameter of Riser Pipe      ▪                  centimeters
  Rated Pump Capacity: Old    ▪                  LPS
                       New    ▪                  LPS
  Total Dynamic Head:  Old    ▪                  meters
                       New    ▪                  meters
  Pump Setting:        Old    ▪                  meters
                       New    ▪                  meters
  Motor HP Rating:     Old    ▪
                       New    ▪

  Aquifer Type                ▪

                                                   ▪ Casing Schedule
                                                   ▪ Screen Section
▪▪  Edit... Print... Quit... ▪▪
```

Screen W3.1

Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

*** WELL SCREEN SECTION ***

Screen	Type	Diameter, in centimeters	Depth, in meters	
			From	To

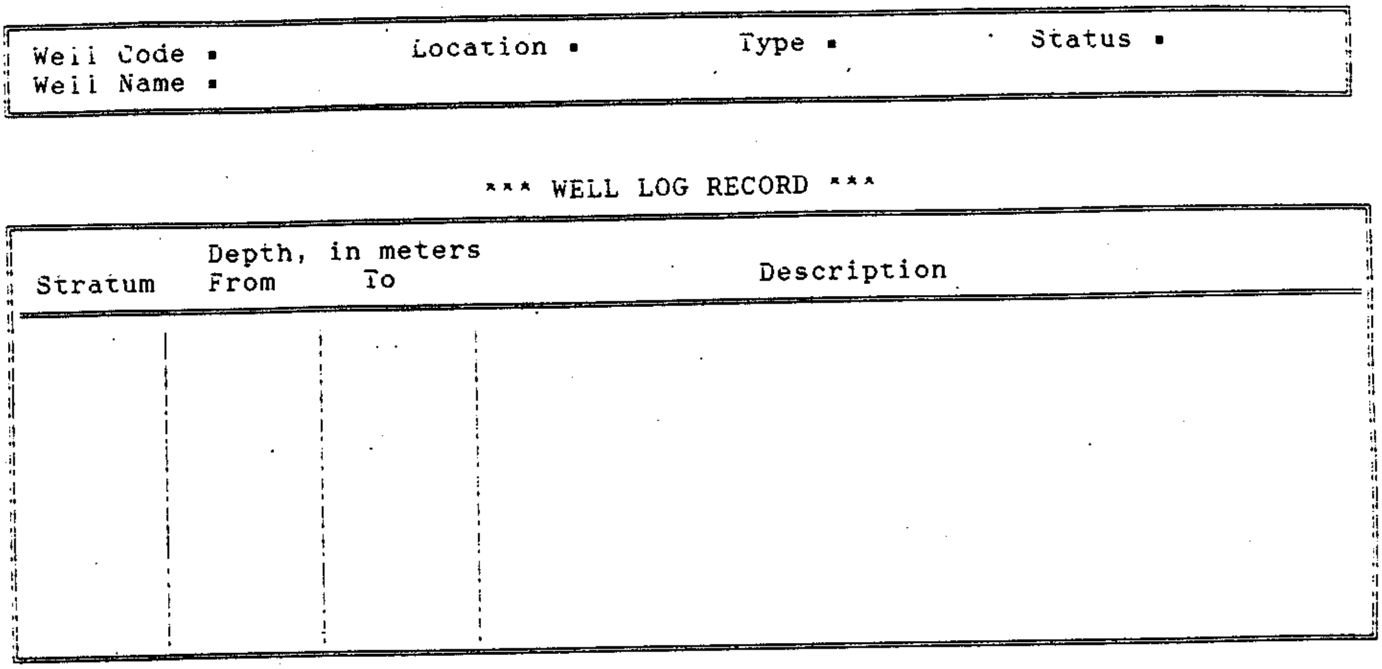
Screen W3.2

Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

*** WELL CASING SCHEDULE ***

	Diameter, in	Depth, in meters	
Casing No.	centimeters	From	To

Screen W4



Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

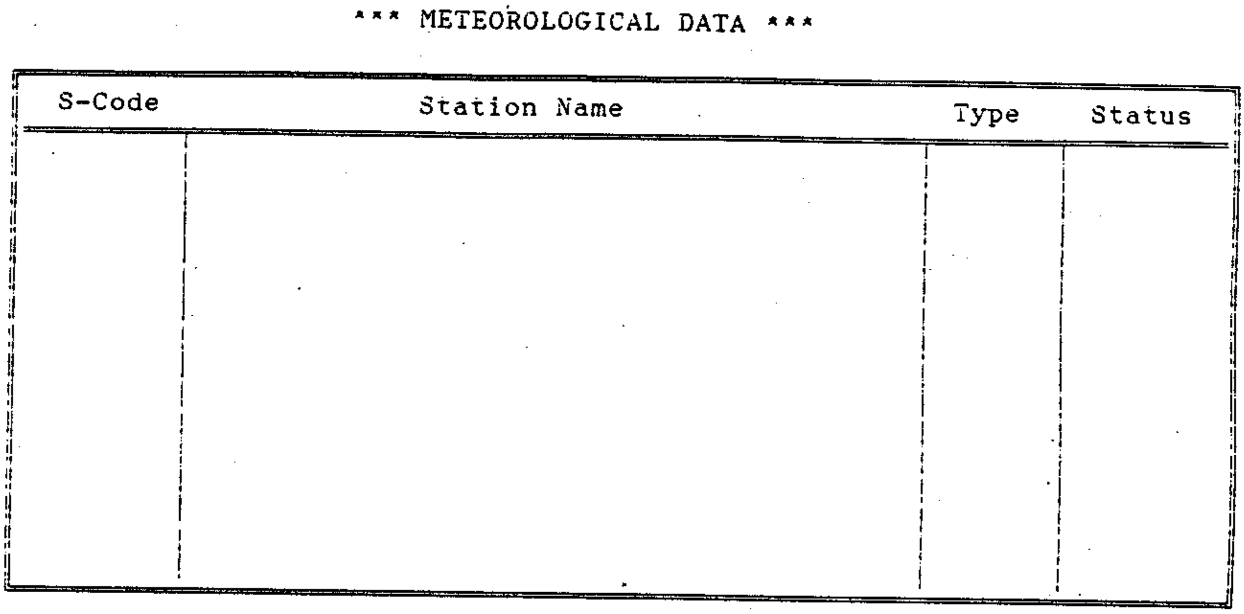
*** WELL LOG RECORD ***

Stratum	Depth, in meters From	To	Description

Screen W5

```
Well Code ▪               Location ▪          Type ▪               Status ▪
Well Name ▪

                         *** PUMPING TEST DATA ***

  Static Water Level...........................Date ▪ (mm/dd/yy)
     After Construction ▪              meters            /  /
     Recent Measurement ▪              meters            /  /
  Pumping Water Level..........................Date ▪
     After Construction ▪              meters            /  /
     Recent Measurement ▪              meters            /  /
  Actual Discharge.............................Date ▪
     After Construction ▪              LPS               /  /
     Recent Measurement ▪              LPS               /  /

  Specific Capacity     ▪              LPS/M
  Transmissibility      ▪              M^2/day
  Storage Coefficient   ▪
  Pumping Duration      ▪              hours
  Type of Pumping Test  ▪

▪▪  Edit... Print... Quit... ▪▪
```

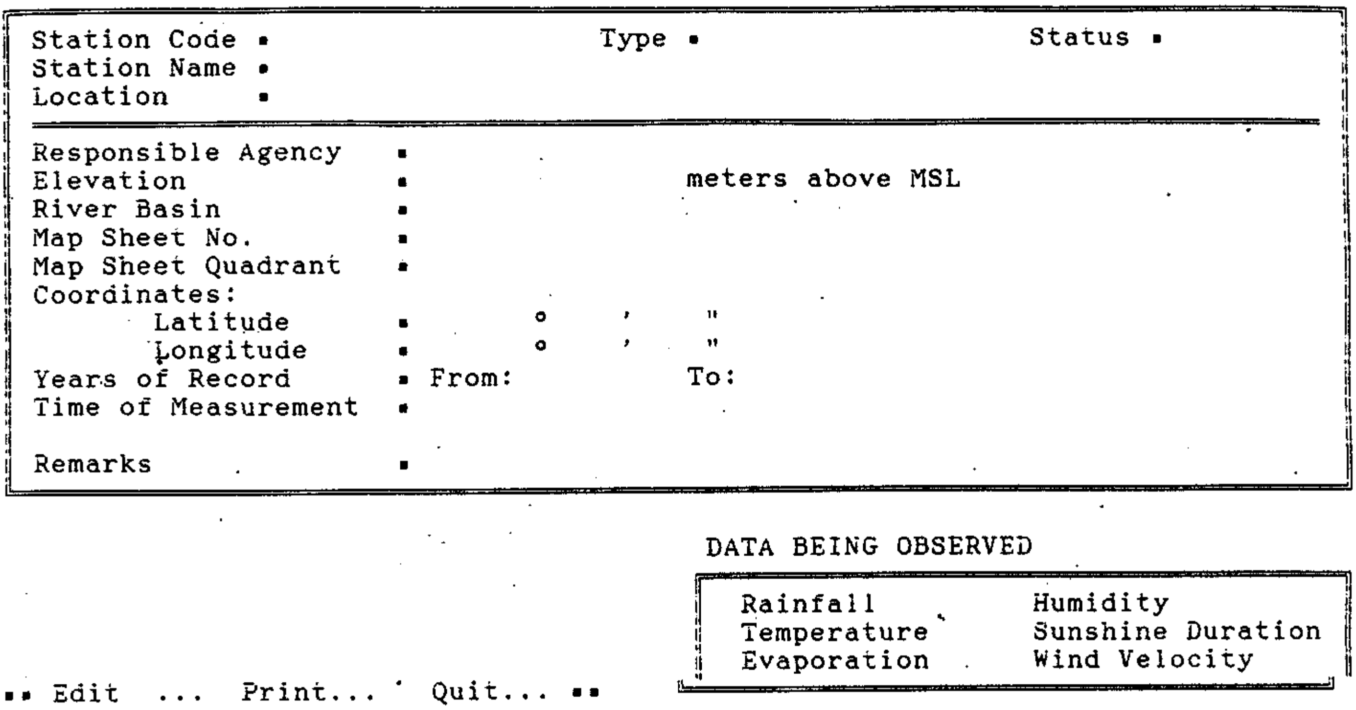
Screen M1



*** METEOROLOGICAL DATA ***

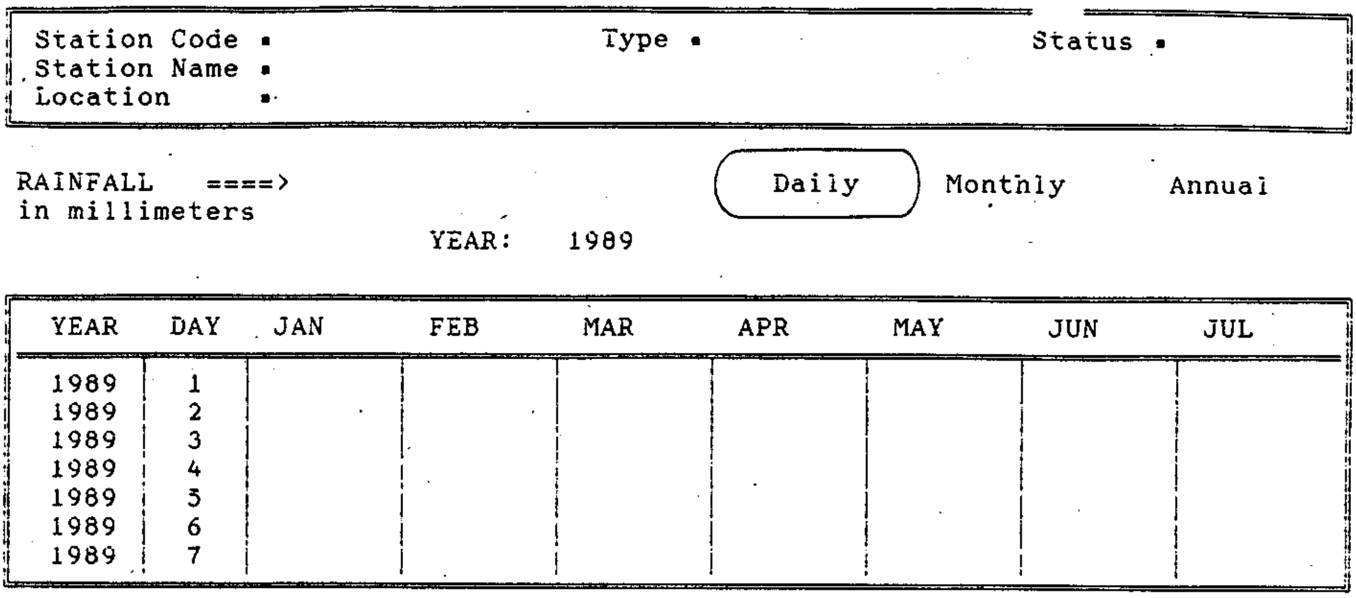
S-Code	Station Name	Type	Status

Screen M2



```
Station Code ▪                     Type ▪                     Status ▪
Station Name ▪
Location     ▪

Responsible Agency   ▪
Elevation            ▪                  meters above MSL
River Basin          ▪
Map Sheet No.        ▪
Map Sheet Quadrant   ▪
Coordinates:
       Latitude      ▪       °    '    "
       Longitude     ▪       °    '    "
Years of Record      ▪ From:            To:
Time of Measurement  ▪

Remarks              ▪

                                         DATA BEING OBSERVED

                                           Rainfall        Humidity
                                           Temperature     Sunshine Duration
                                           Evaporation     Wind Velocity
▪▪ Edit  ...  Print...  Quit... ▪▪
```

Screen M2.1



Station Code ■ Type ■ Status ■
Station Name ■
Location ■

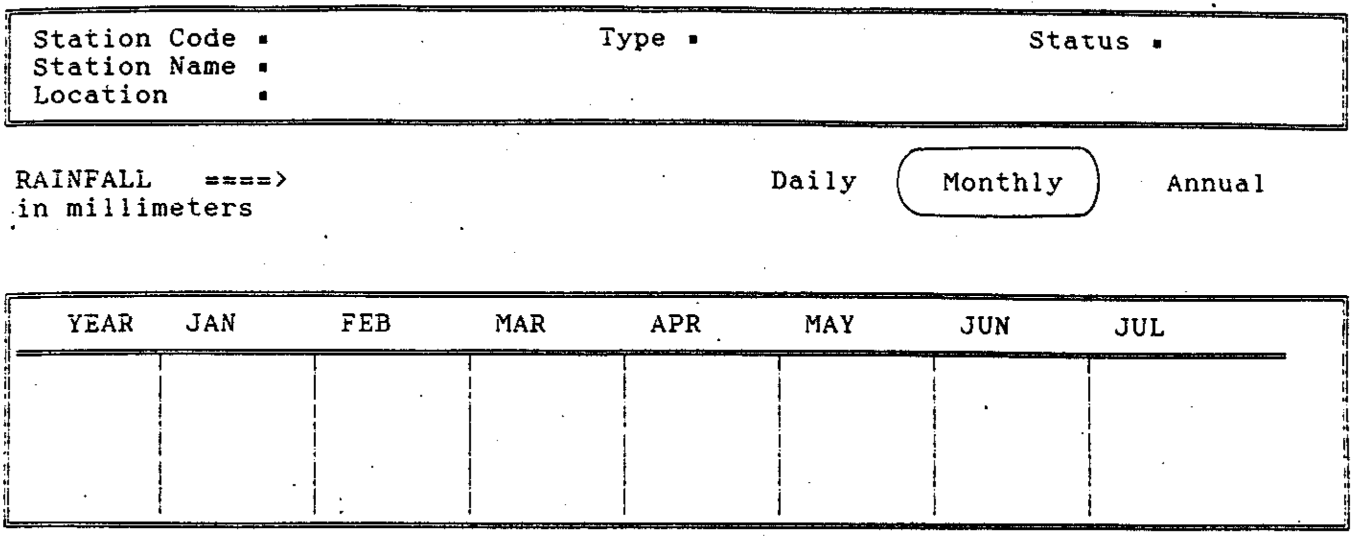
RAINFALL ====>
in millimeters

[✓ Daily] Monthly Annual

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Screen M2.2



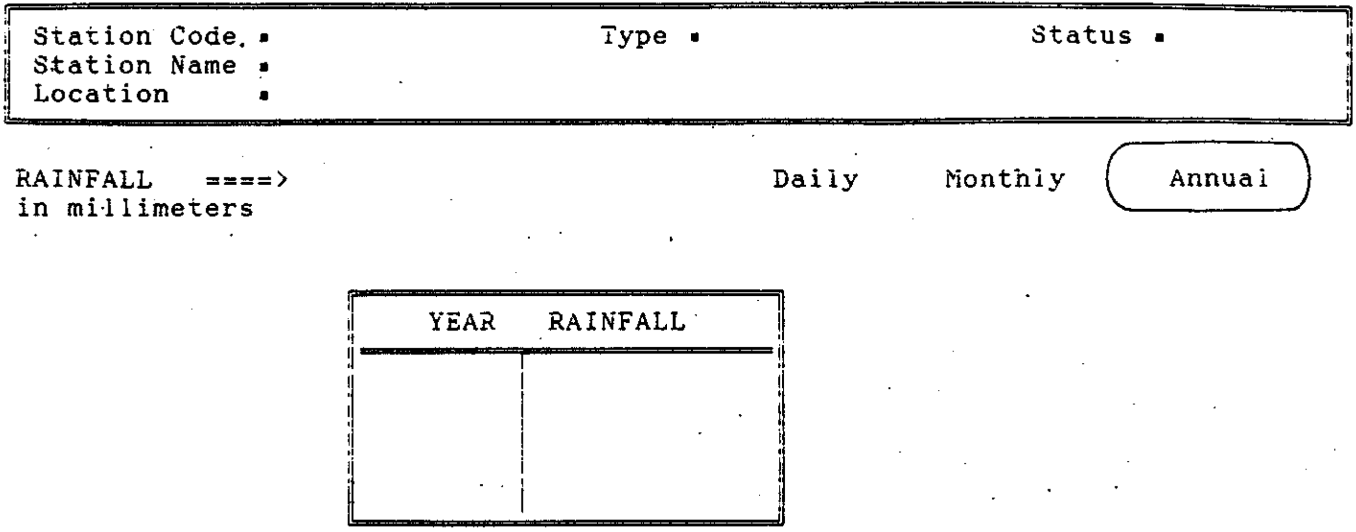
Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

RAINFALL ====>
in millimeters

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Screen M2.3



Station Code. ▪
Type ▪
Status ▪
Station Name ▪
Location ▪

RAINFALL ====>
in millimeters

Daily Monthly [✓ Annual]

YEAR	RAINFALL

Station Code • Type • Status •
Station Name •
Location •

TEMPERATURE in °C ====> [✓ Mean] Minimum Maximum

[✓ Daily] Monthly Annual

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE ====> [✓ Mean] Minimum Maximum
in °C

Daily Monthly [✓ Annual]

YEAR	TEMPERATURE

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE in °C ====> [✓ Mean] Minimum Maximum

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE ====> Mean [✓ Minimum] Maximum [✓ Daily] Monthly Annual
in °C

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE in °C ====> Mean [✓ Minimum] Maximum Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE in °C ====> Mean [✓ Minimum] Maximum Daily Monthly [✓ Annual]

YEAR	TEMPERATURE

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE ====> Mean Minimum [✓ Maximum] [✓ Daily] Monthly Annual
in °C
YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code ▪
Station Name ▪
Location ▪

Type ▪

Status ▪

TEMPERATURE in °C ====> Mean Minimum [✓ Maximum]

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

TEMPERATURE ====> Mean Minimum [✓ Maximum]
in °C Daily Monthly [✓ Annual]

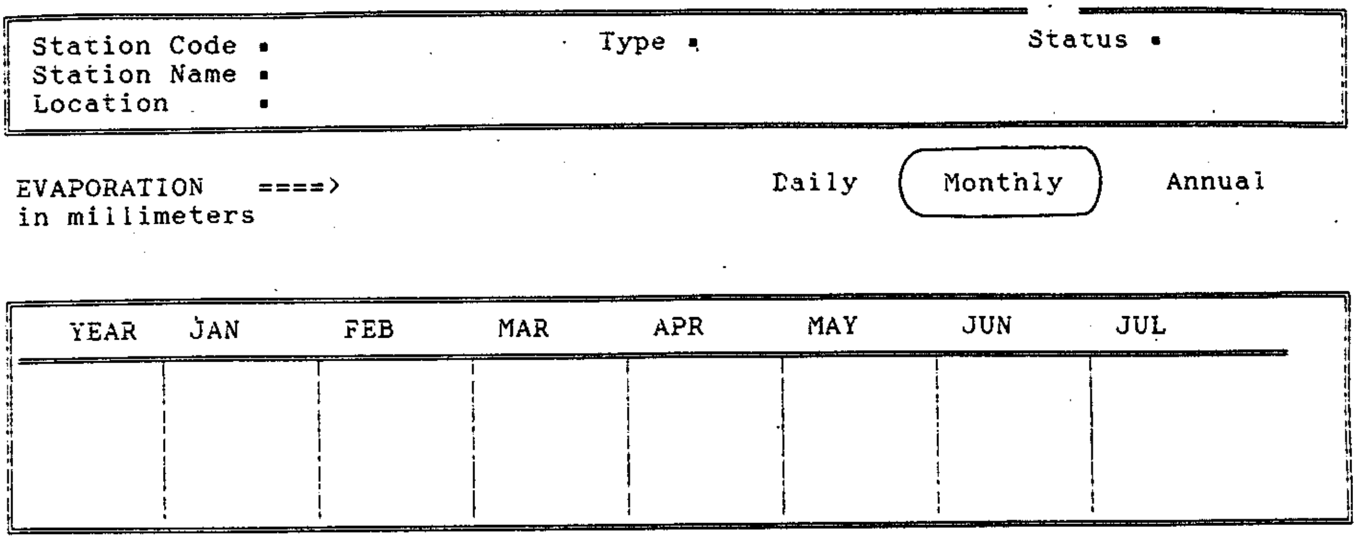
YEAR	TEMPERATURE

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

EVAPORATION ====> [✓ Daily] Monthly Annual
in milimeters

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							



Station Code ▪
Station Name ▪
Location ▪

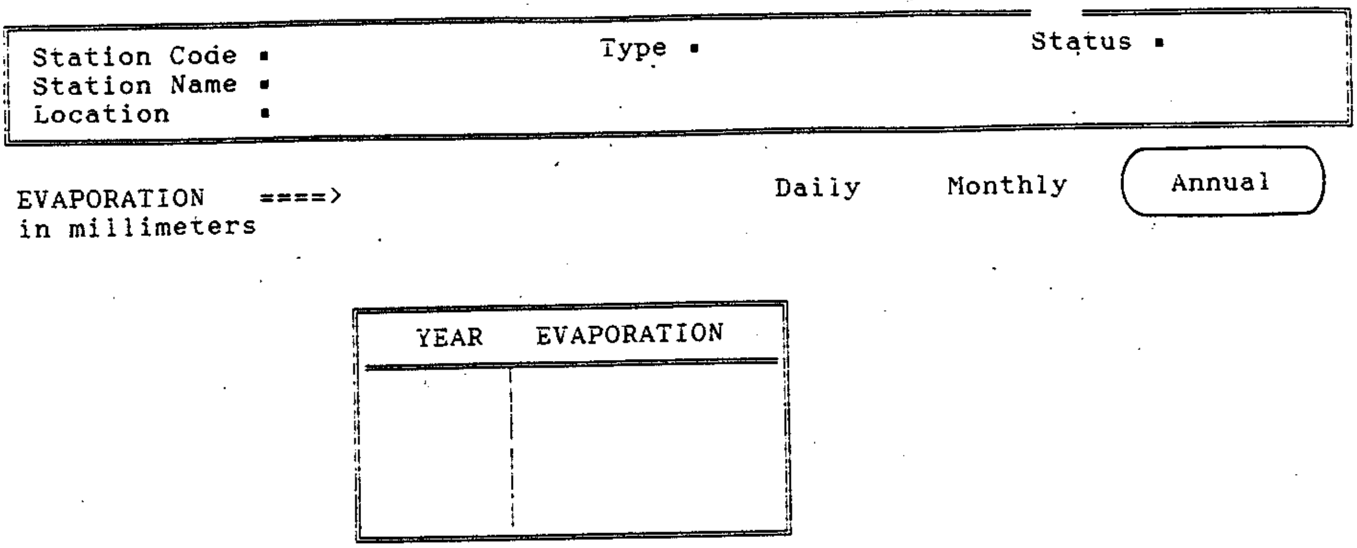
Type ▪

Status ▪

EVAPORATION ====>
in millimeters

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL



Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

EVAPORATION ====>
in millimeters

Daily Monthly [✓ Annual]

YEAR	EVAPORATION

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

HUMIDITY ====> [✓ Daily] Monthly Annual
in percent

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

HUMIDITY ====> Daily [✓ Monthly] Annual
in percent

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

HUMIDITY ====>
in percent

Daily Monthly [✓ Annual]

YEAR	HUMIDITY

Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

SUNSHINE DURATION ====> [✓ Daily] Monthly Annual
in hours

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code :
Station Name :
Location :

Type :

Status :

SUNSHINE DURATION ====>
in hours

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Station Code •
Station Name •
Location •

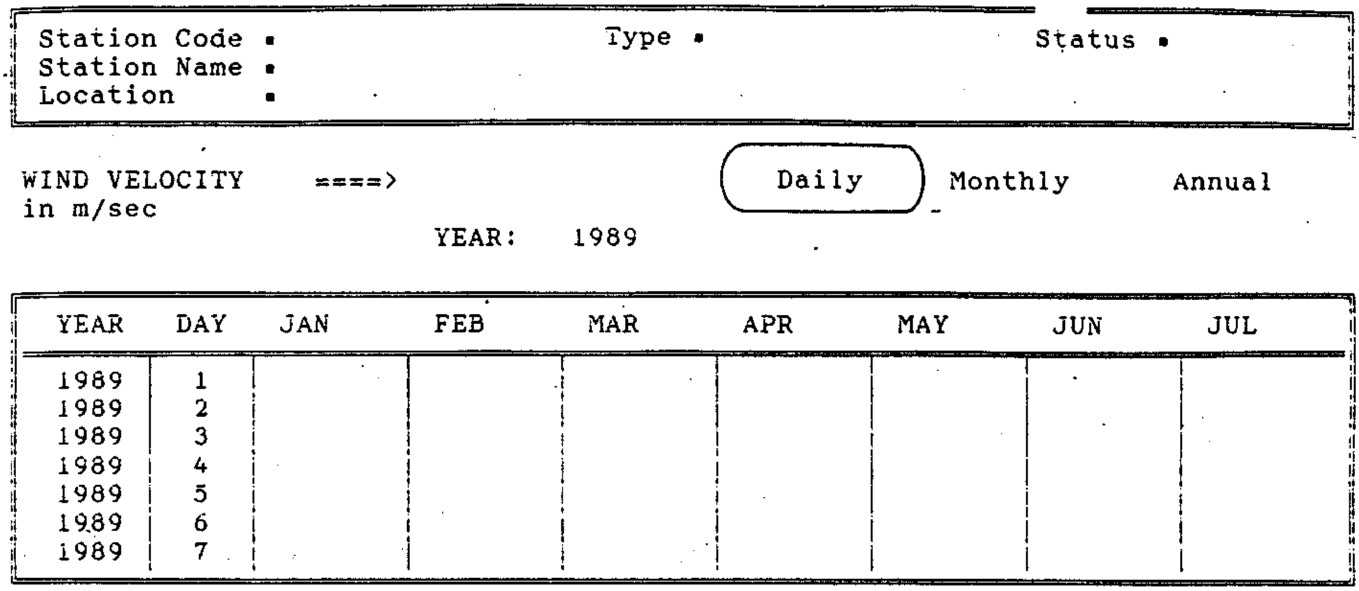
Type •

Status •

SUNSHINE DURATION ====>
in hours

Daily Monthly [✓ Annual]

YEAR	SUNSHINE DURATION



Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

WIND VELOCITY ====> [✓ Daily] Monthly Annual
in m/sec

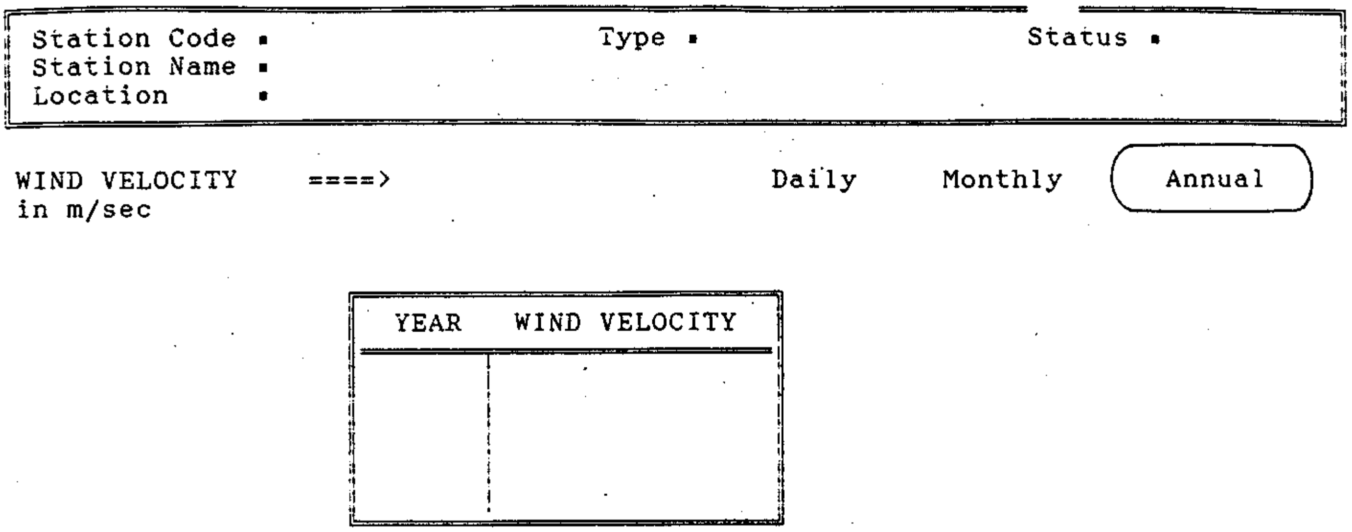
YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							
1989	6							
1989	7							

Station Code : Type : Status :
Station Name :
Location :

WIND VELOCITY ====> Daily [✓ Monthly] Annual
in m/sec

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

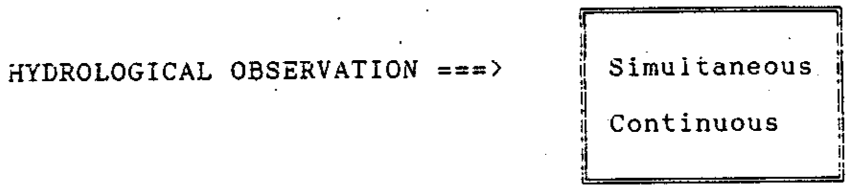


Station Code ▪ Type ▪ Status ▪
Station Name ▪
Location ▪

WIND VELOCITY ====> Daily Monthly Annual
in m/sec

YEAR	WIND VELOCITY

Screen H1



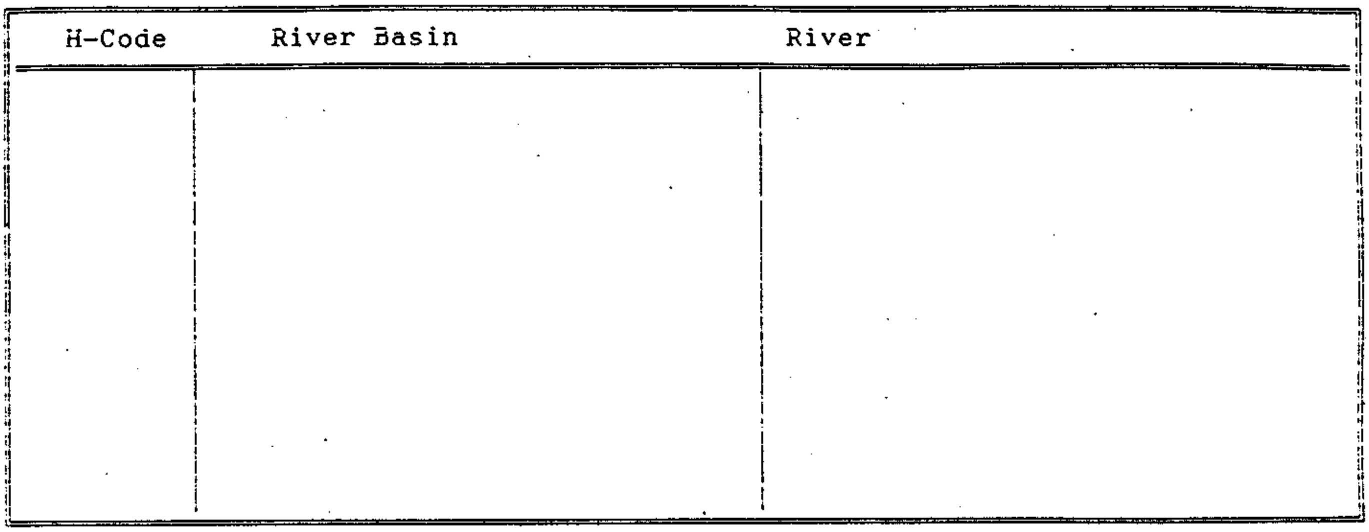
HYDROLOGICAL OBSERVATION ===>

Simultaneous

Continuous

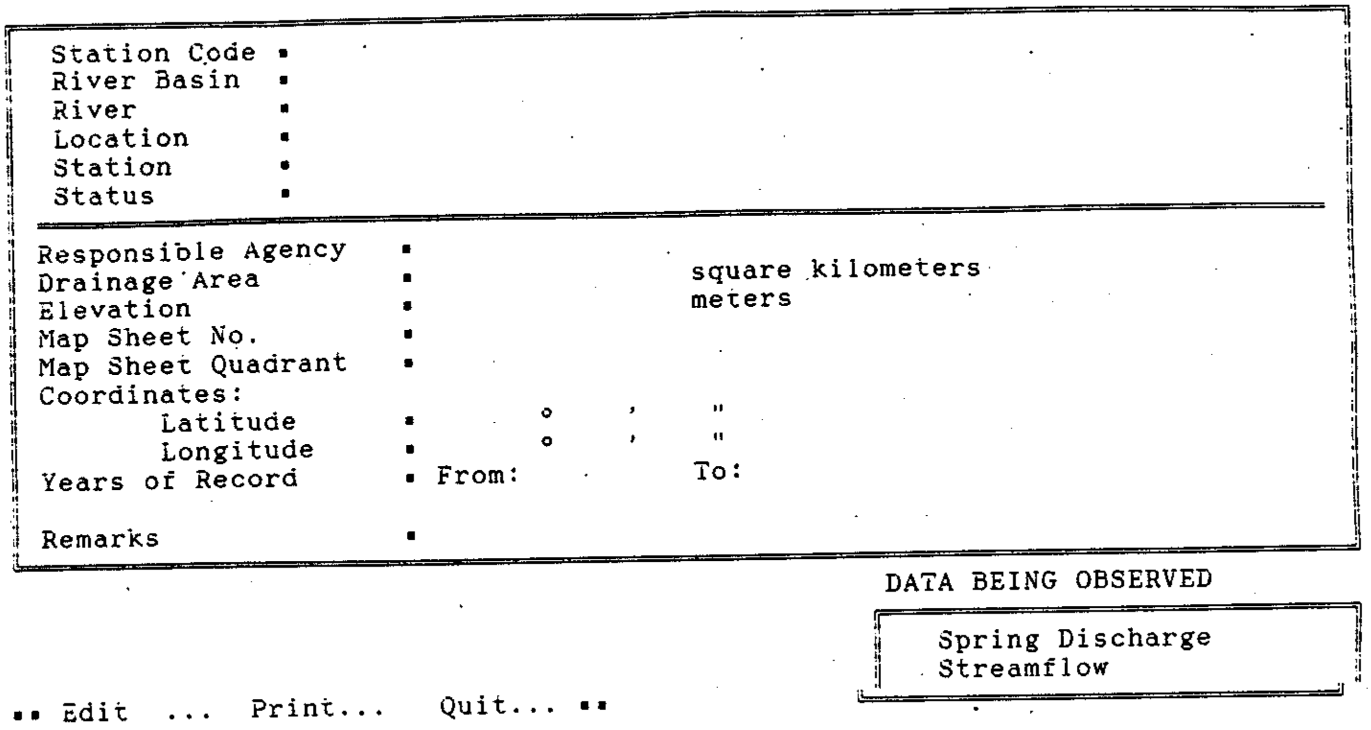
Screen H2

*** HYDROLOGICAL SIMULTANEOUS OBSERVATION ***



H-Code	River Basin	River

Screen H2.1



```
 Station Code •
 River Basin  •
 River        •
 Location     •
 Station      •
 Status       •
------------------------------------------------------------------
Responsible Agency  •                  square kilometers
Drainage Area       •                  meters
Elevation           •
Map Sheet No.       •
Map Sheet Quadrant  •
Coordinates:
      Latitude      •       o    ,    "
      Longitude     •       o    ,    "
Years of Record     • From:        To:

Remarks             •
                                              DATA BEING OBSERVED

                                                 Spring Discharge
                                                 Streamflow
•• Edit  ...  Print...  Quit... ••
```

Screen H2.1.1

Station Code :
River Basin :
River :
Location :
Station :
Status :

*** SPRING DISCHARGE SIMULTANEOUS OBSERVATION ***

Discharge, in LPS	Date Measured	Time Measured	Remarks

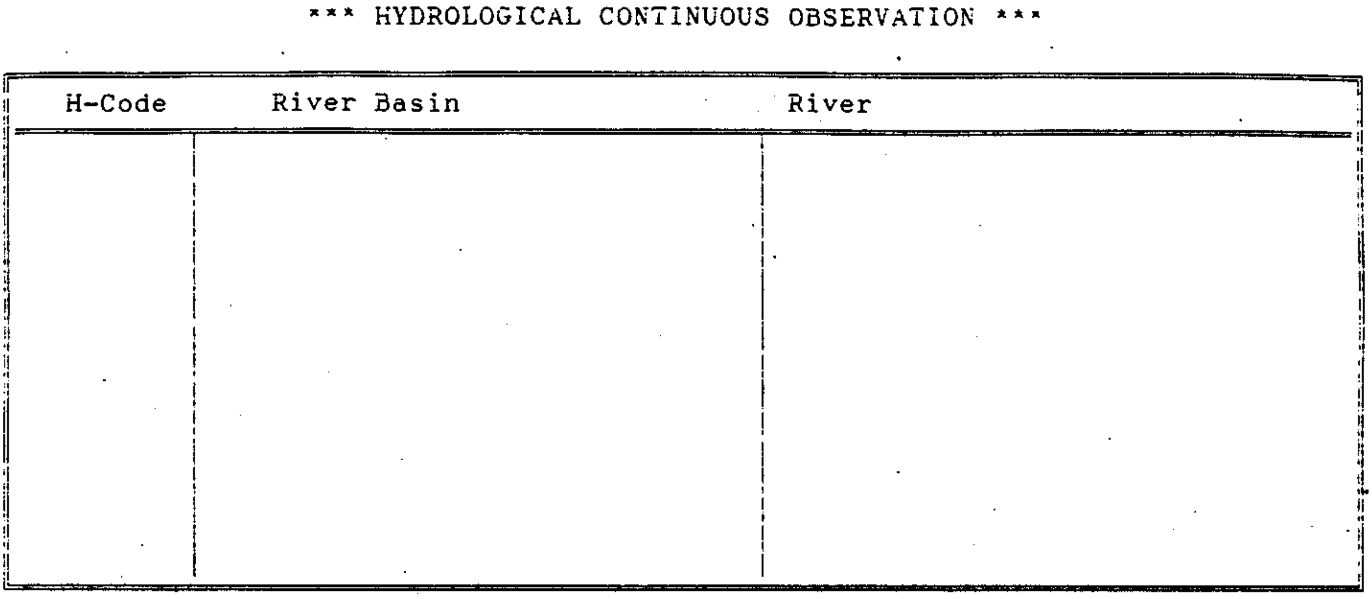
Screen H2.1.2

Station Code ▪
River Basin ▪
River ▪
Location ▪
Station ▪
Status ▪

*** STREAMFLOW DISCHARGE SIMULTANEOUS OBSERVATION ***

Discharge, in LPS	Date Measured	Time Measured	Remarks

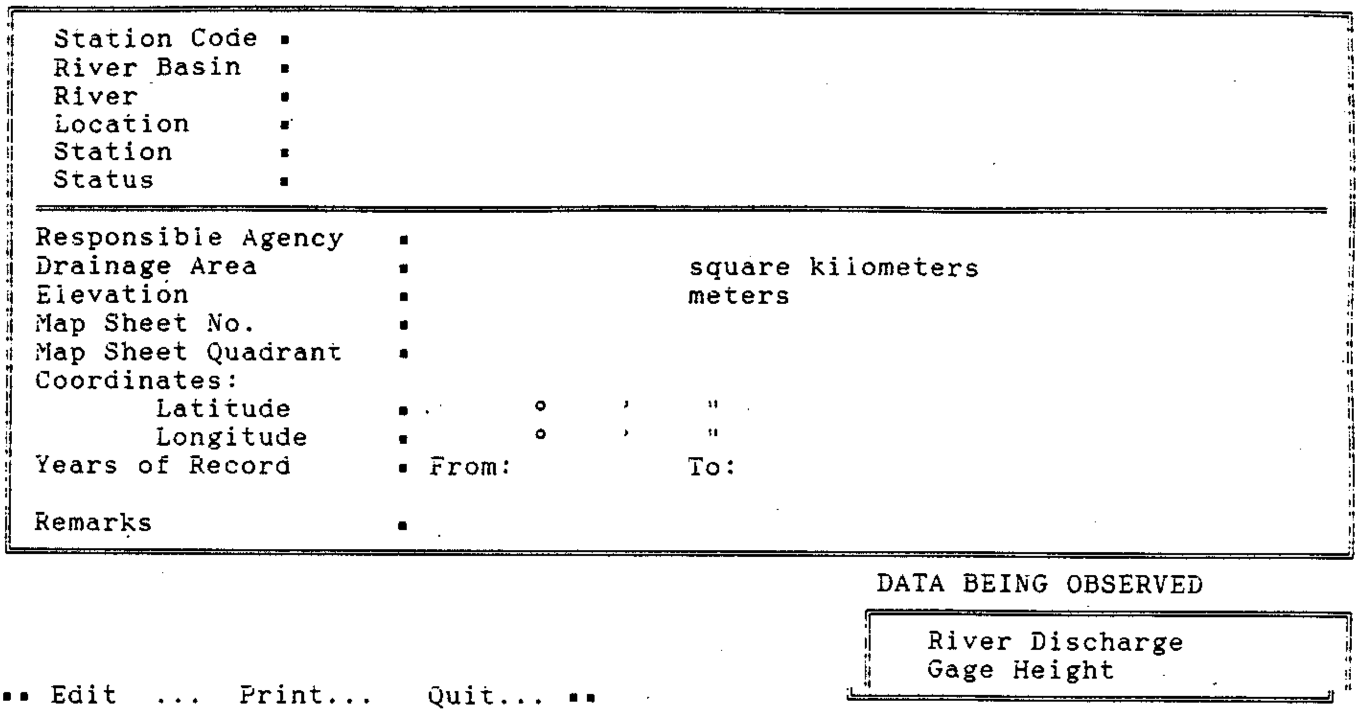
Screen H3



*** HYDROLOGICAL CONTINUOUS OBSERVATION ***

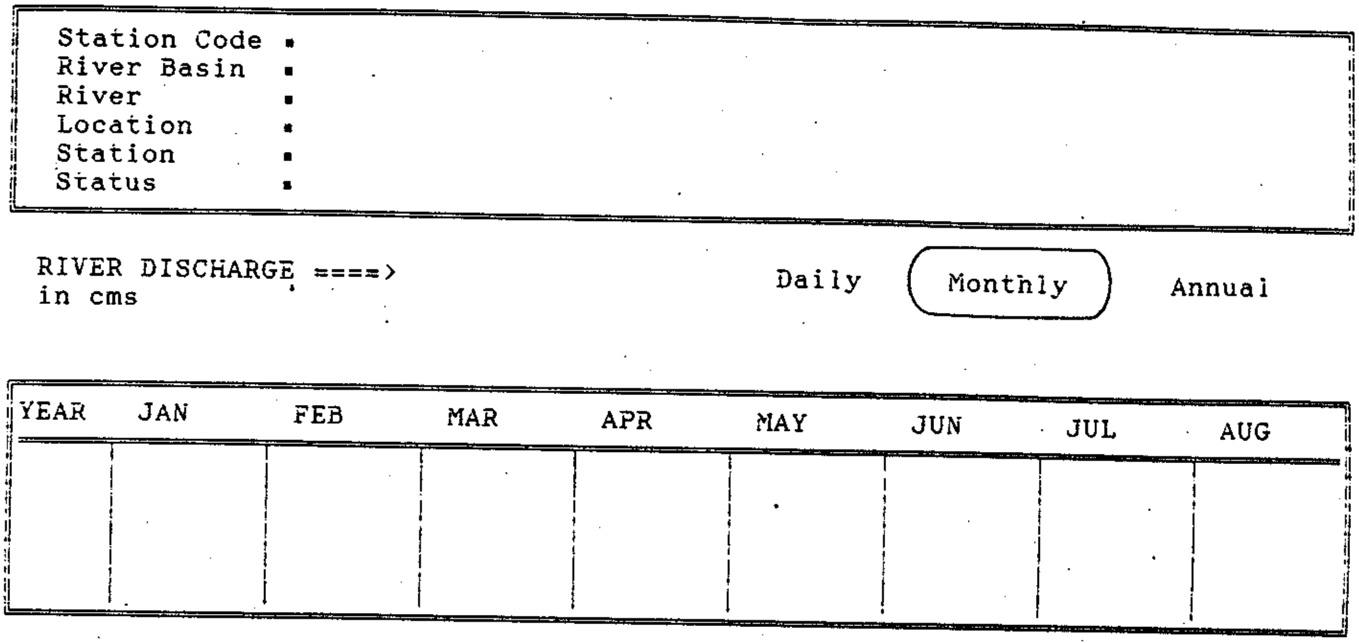
H-Code	River Basin	River

Screen H3.1



```
  Station Code ▪
  River Basin  ▪
  River        ▪
  Location     ▪
  Station      ▪
  Status       ▪

Responsible Agency   ▪
Drainage Area        ▪                 square kilometers
Elevation            ▪                 meters
Map Sheet No.        ▪
Map Sheet Quadrant   ▪
Coordinates:
       Latitude      ▪       °    '    "
       Longitude     ▪       °    '    "
Years of Record      ▪ From:           To:

Remarks              ▪

                                                 DATA BEING OBSERVED

                                                    River Discharge
                                                    Gage Height
▪▪ Edit   ...  Print...   Quit... ▪▪
```

Screen H3.1.1



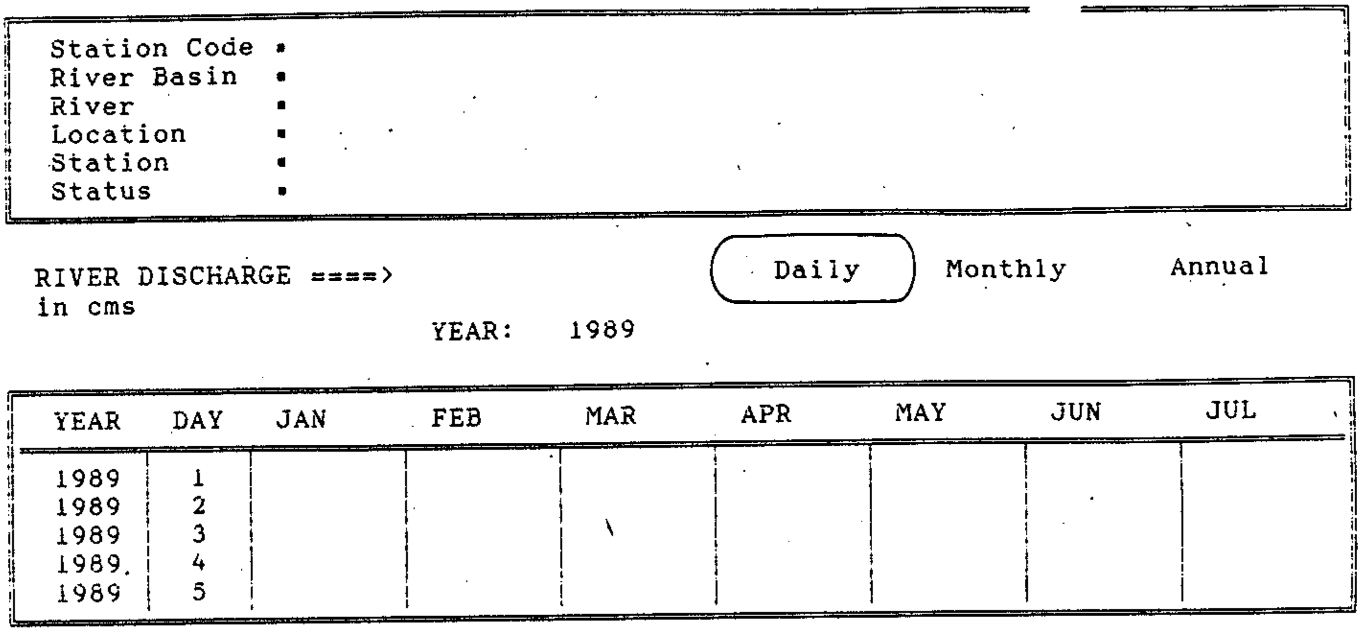
Station Code :
River Basin :
River :
Location :
Station :
Status :

RIVER DISCHARGE ====>
in cms

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

Screen H3.1.2



Station Code :
River Basin :
River :
Location :
Station :
Status :

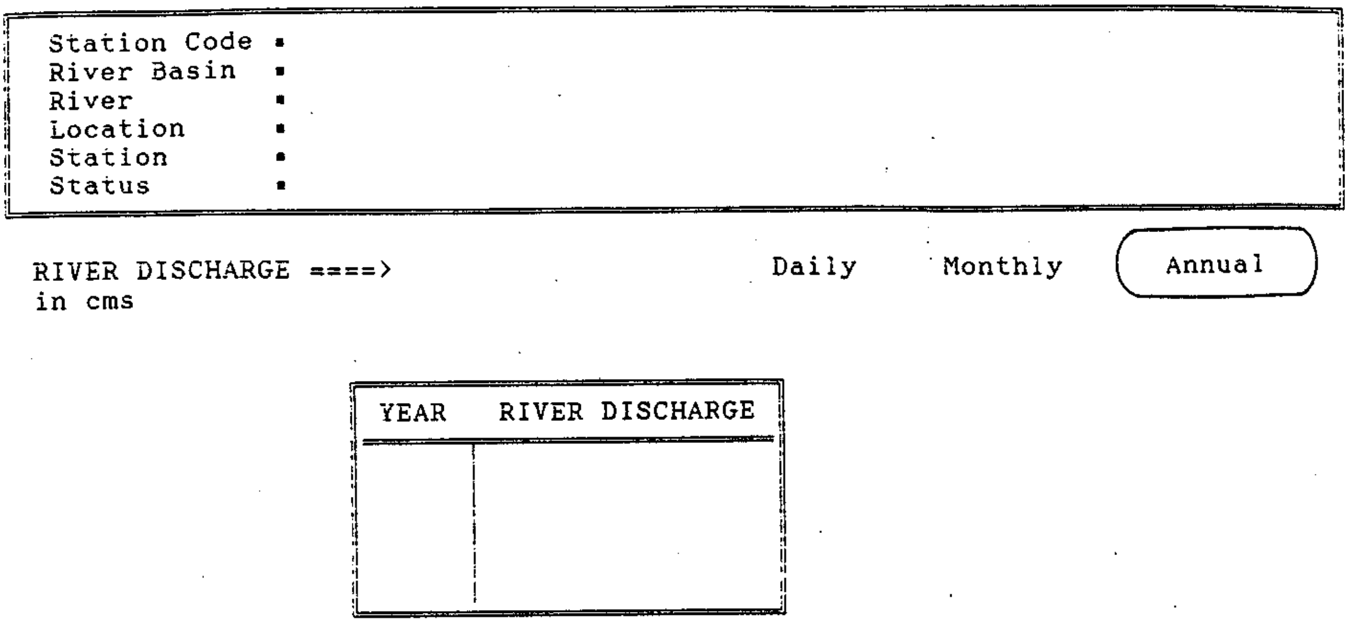
RIVER DISCHARGE ====>
in cms

[✓ Daily] Monthly Annual

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							

Screen H3.1.3



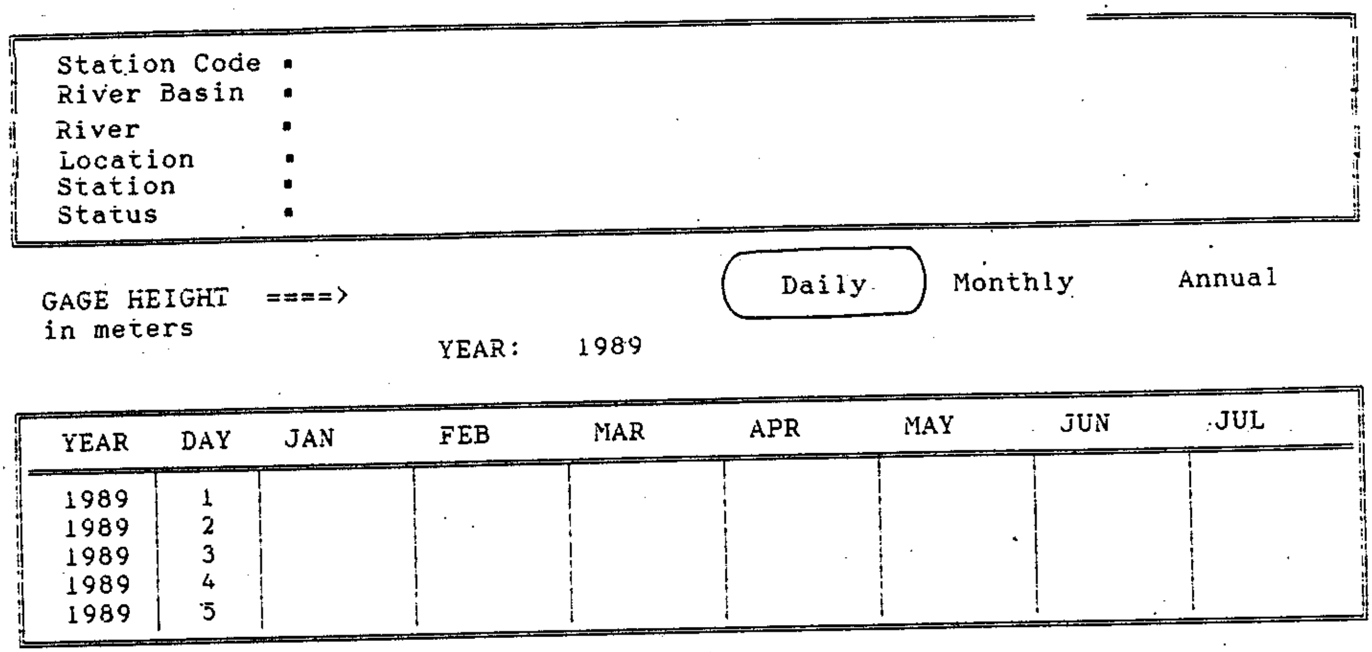
Station Code ▪
River Basin ▪
River ▪
Location ▪
Station ▪
Status ▪

RIVER DISCHARGE ====>
in cms

Daily Monthly [✓ Annual]

YEAR	RIVER DISCHARGE

Screen H3.1.4



Station Code :
River Basin :
River :
Location :
Station :
Status :

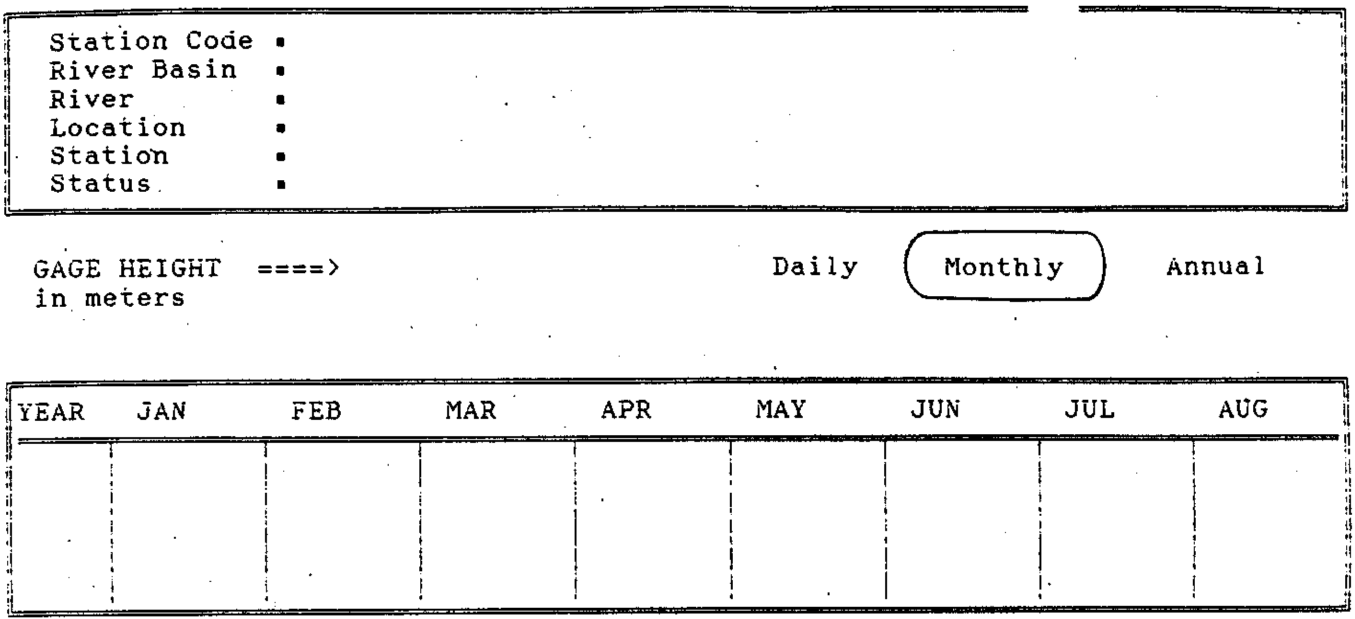
GAGE HEIGHT ====>
in meters

[✓ Daily] Monthly Annual

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							

Screen H3.1.5



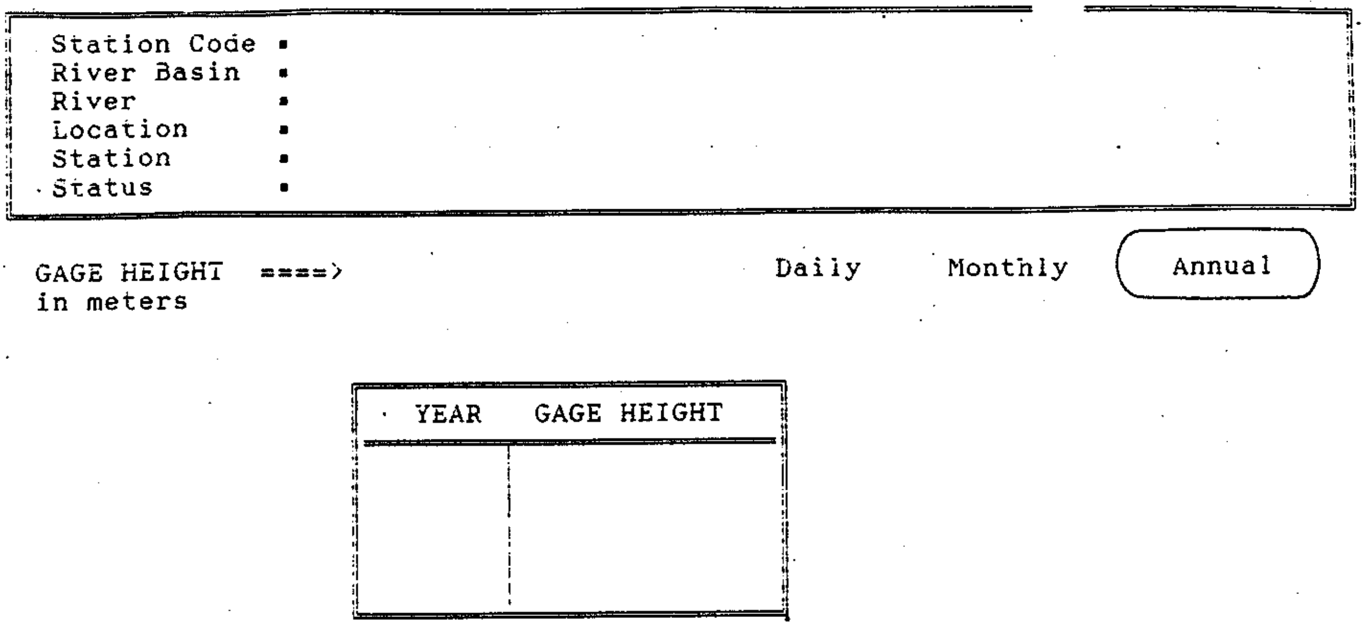
Station Code ▪
River Basin ▪
River ▪
Location ▪
Station ▪
Status ▪

GAGE HEIGHT ====>
in meters

Daily [✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

Screen H3.1.6



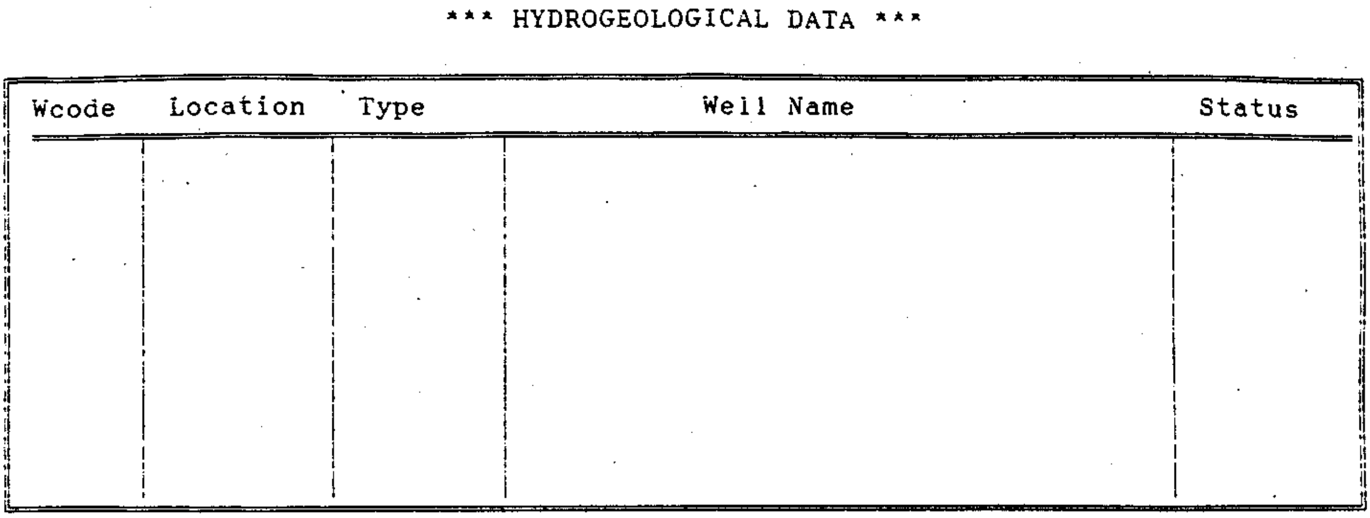
Station Code ▪
River Basin ▪
River ▪
Location ▪
Station ▪
Status ▪

GAGE HEIGHT ====>
in meters

Daily Monthly [✓ Annual]

YEAR	GAGE HEIGHT

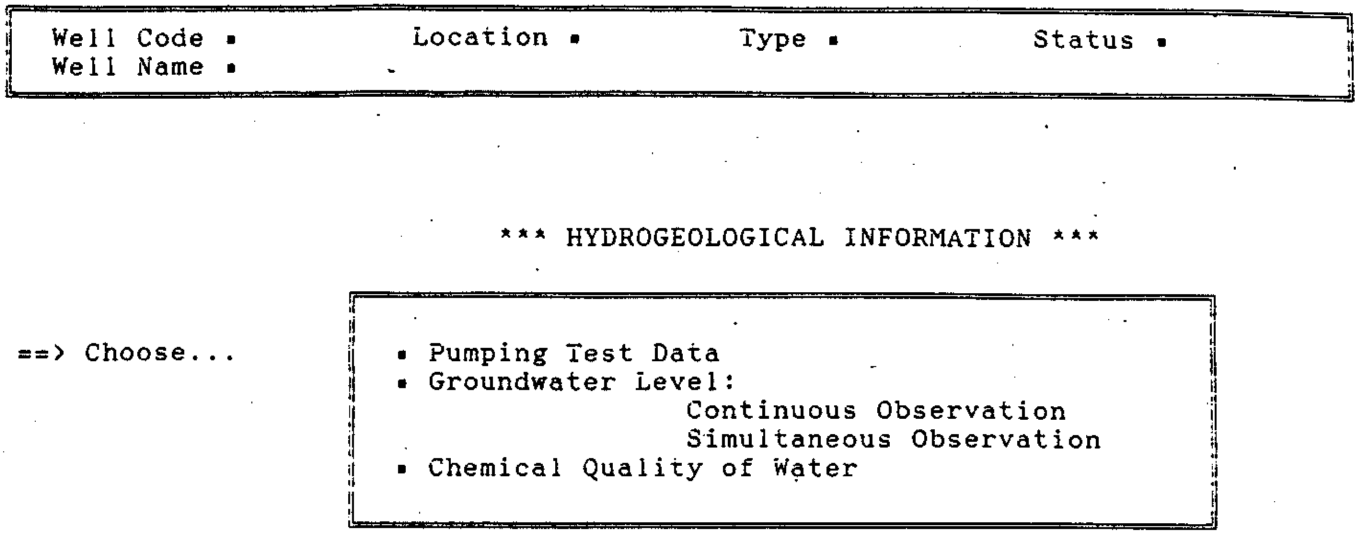
Screen G1



*** HYDROGEOLOGICAL DATA ***

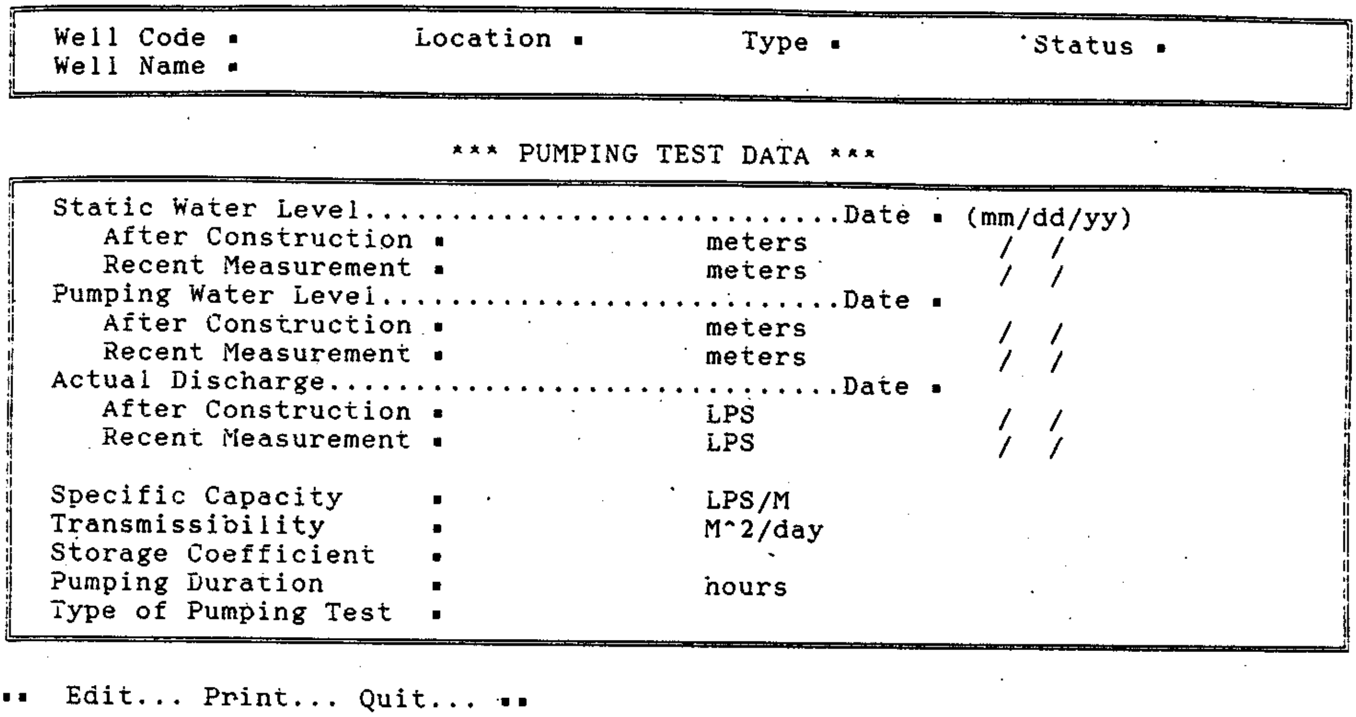
Wcode	Location	Type	Well Name	Status

Screen G2



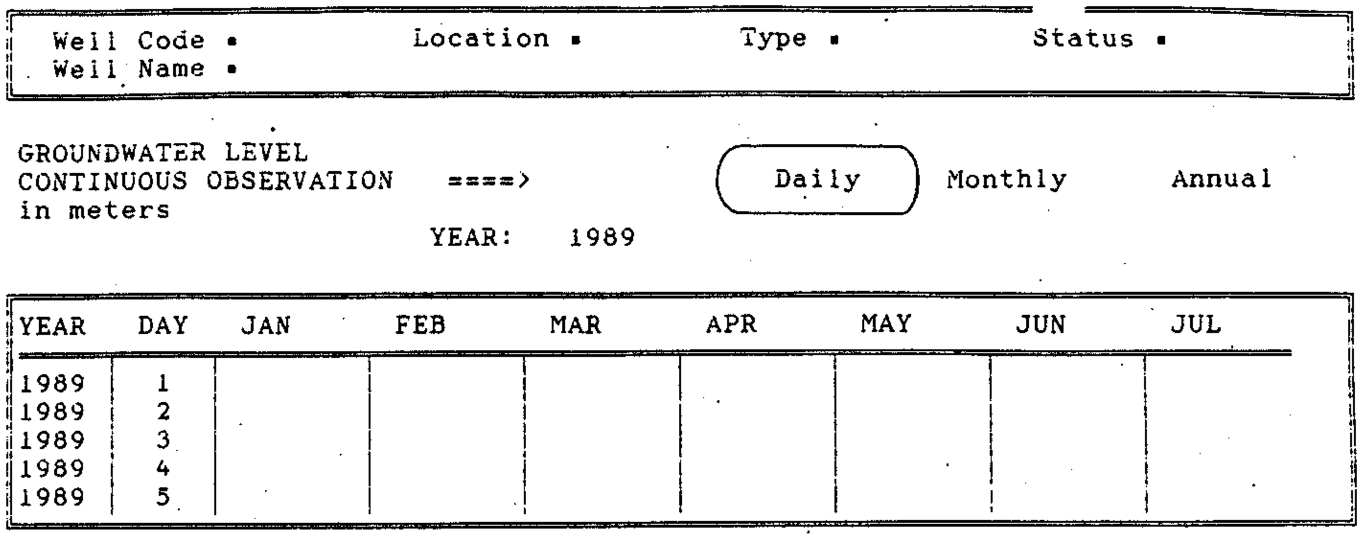
```
 Well Code ▪           Location ▪          Type ▪           Status ▪
 Well Name ▪


                         *** HYDROGEOLOGICAL INFORMATION ***

==> Choose...          ▪ Pumping Test Data
                       ▪ Groundwater Level:
                                       Continuous Observation
                                       Simultaneous Observation
                       ▪ Chemical Quality of Water
```

Screen G3



```
Well Code ▪             Location ▪          Type ▪             Status ▪
Well Name ▪

                       *** PUMPING TEST DATA ***

Static Water Level............................Date ▪ (mm/dd/yy)
   After Construction ▪              meters             /  /
   Recent Measurement ▪              meters             /  /
Pumping Water Level...........................Date ▪
   After Construction ▪              meters             /  /
   Recent Measurement ▪              meters             /  /
Actual Discharge..............................Date ▪
   After Construction ▪              LPS                /  /
   Recent Measurement ▪              LPS                /  /

Specific Capacity      ▪             LPS/M
Transmissibility       ▪             M^2/day
Storage Coefficient    ▪
Pumping Duration       ▪             hours
Type of Pumping Test   ▪

▪▪  Edit... Print... Quit... ▪▪
```

Screen G4.1



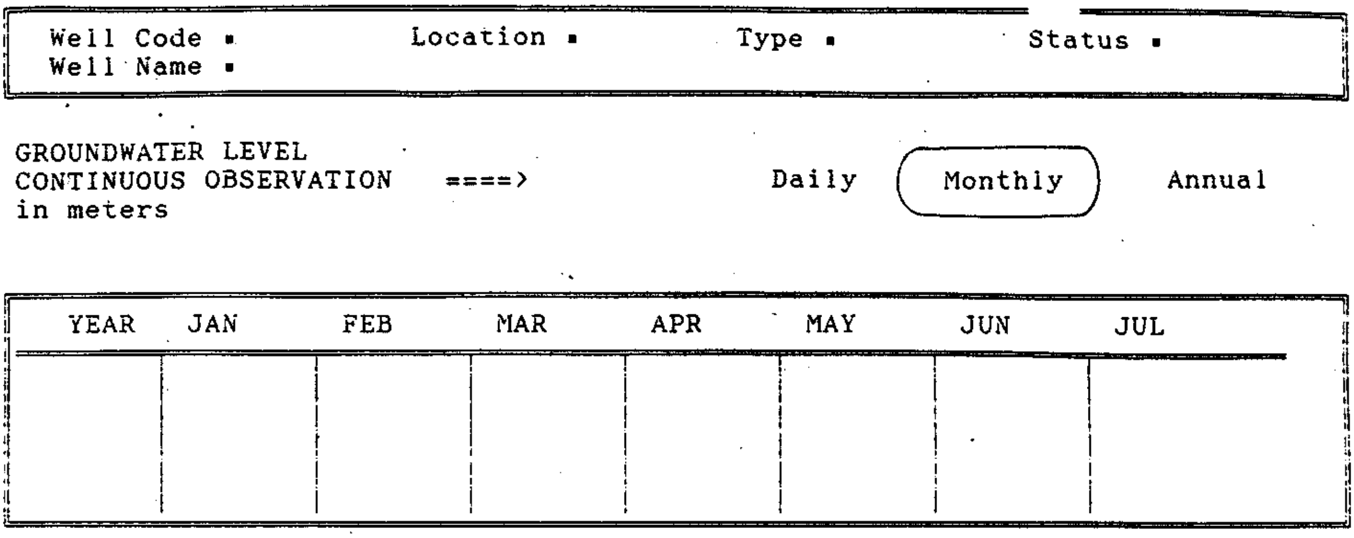
Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

GROUNDWATER LEVEL
CONTINUOUS OBSERVATION ====> [✓ Daily] Monthly Annual
in meters

YEAR: 1989

YEAR	DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL
1989	1							
1989	2							
1989	3							
1989	4							
1989	5							

Screen G4.2

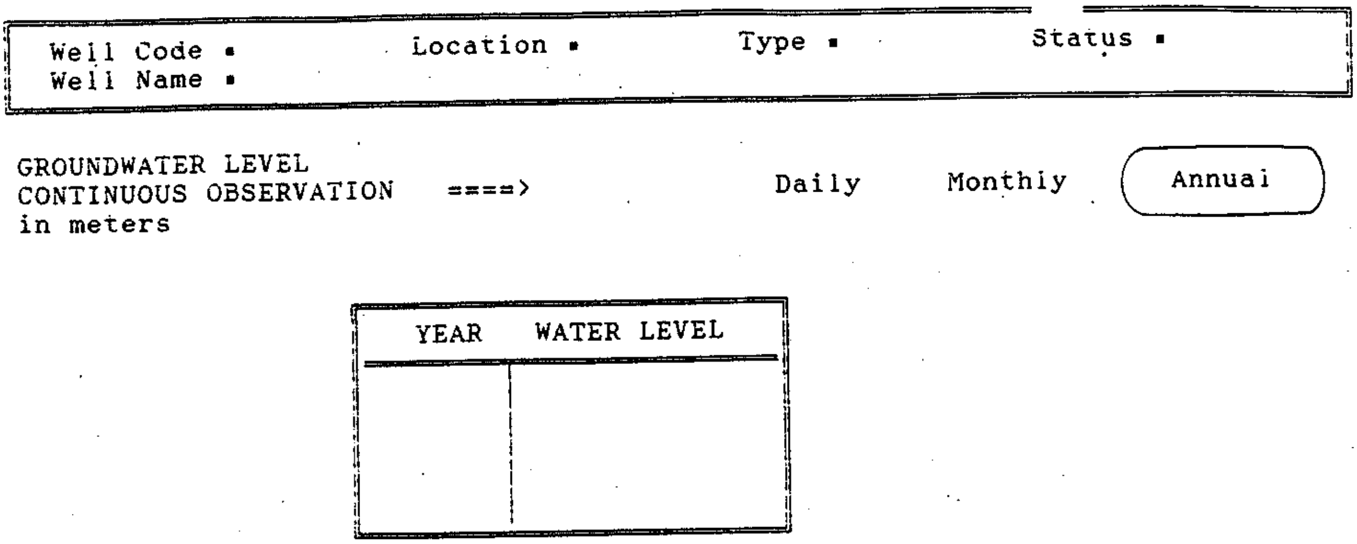


Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

GROUNDWATER LEVEL
CONTINUOUS OBSERVATION ====> Daily [✓ Monthly] Annual
in meters

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL

Screen G4.3



Well Code ▪

Well Name ▪

Location ▪

Type ▪

Status ▪

GROUNDWATER LEVEL
CONTINUOUS OBSERVATION ====>
in meters

Daily Monthly [✓ Annual]

YEAR	WATER LEVEL

Screen G5

Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

*** GROUNDWATER LEVEL SIMULTANEOUS OBSERVATION ***

C-No.	C-Diam.	C-Top	H2O-Below C-Top	Water Level	Ground Elevation

C-Diam., in centimeters
C-Top, in ma/bgs
H2O-Below C-Top, in mbgs

Water Level, in mbgs
Ground Elevation, in masl
Piezo Level, in ma/bsl

Screen 65

Well Code ▪ Location ▪ Type ▪ Status ▪
Well Name ▪

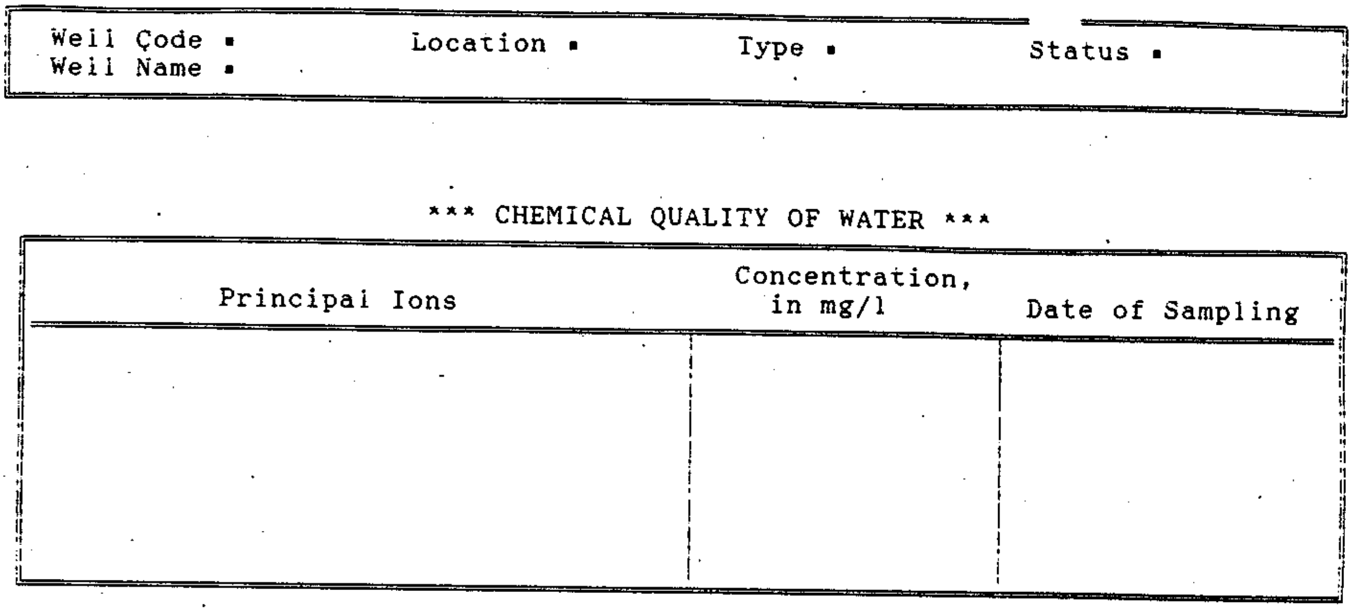
*** GROUNDWATER LEVEL SIMULTANEOUS OBSERVATION ***

Piezo Level	Water Quality	Date Measured	Time Measured

C-Diam., in centimeters
C-Top, in ma/bgs
H2O-Below C-Top, in mbgs

Water Level, in mbgs
Ground Elevation, in masl
Piezo Level, in ma/bsl

Screen G6

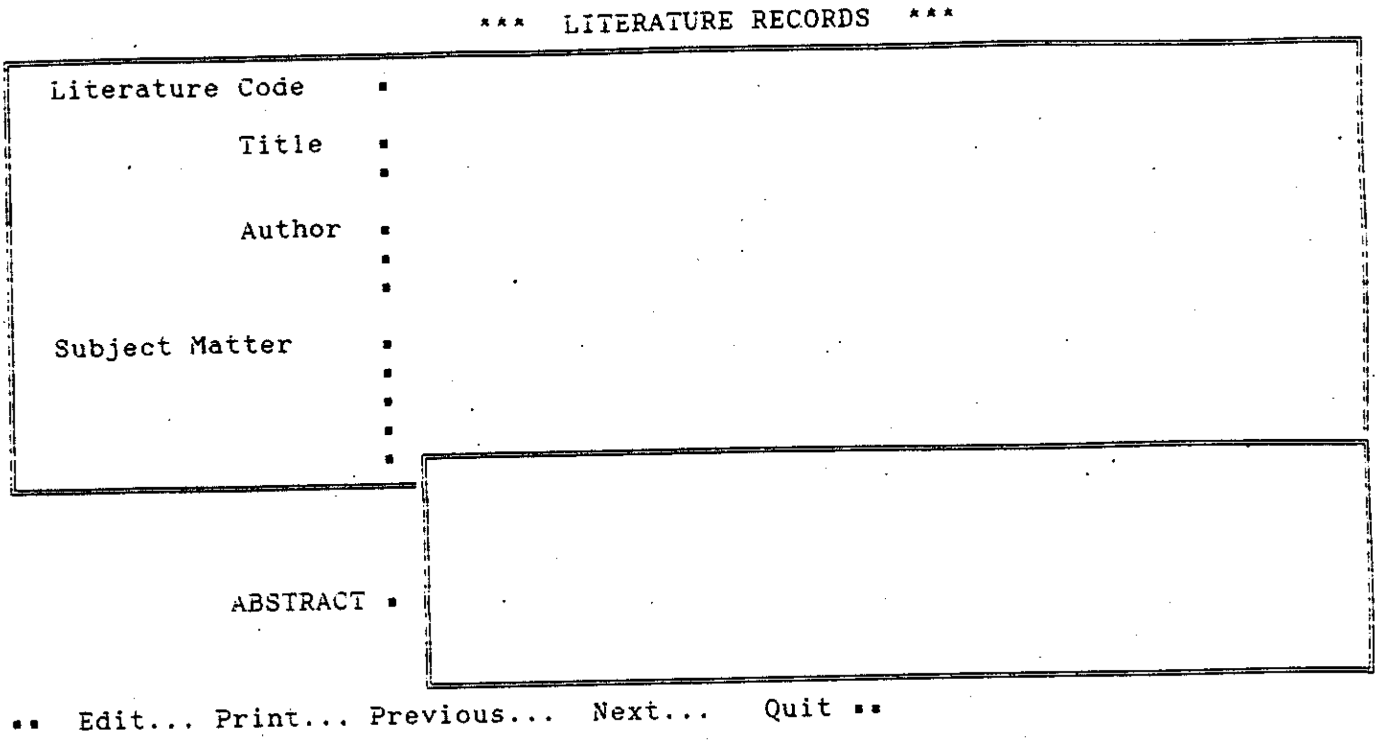


Well Code ▪
Well Name ▪
Location ▪
Type ▪
Status ▪

*** CHEMICAL QUALITY OF WATER ***

Principal Ions	Concentration, in mg/l	Date of Sampling

Screen L1



*** LITERATURE RECORDS ***

Literature Code ■

Title ■
■

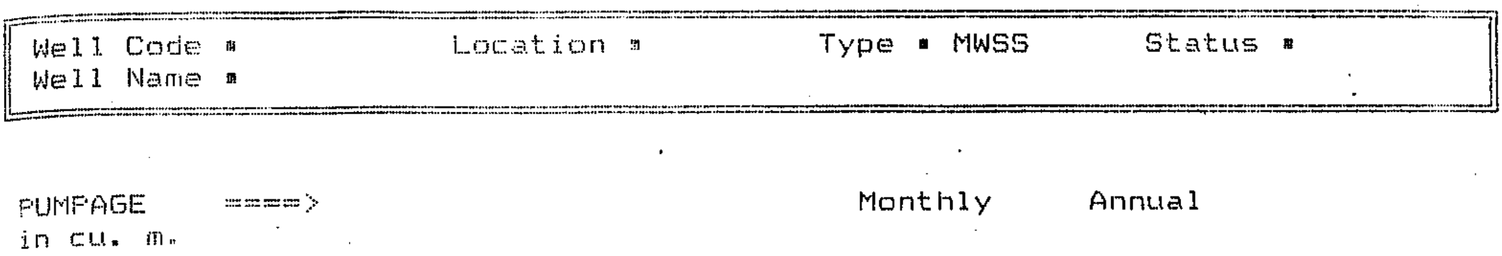
Author ■
■
■

Subject Matter ■
■
■
■
■

ABSTRACT ■

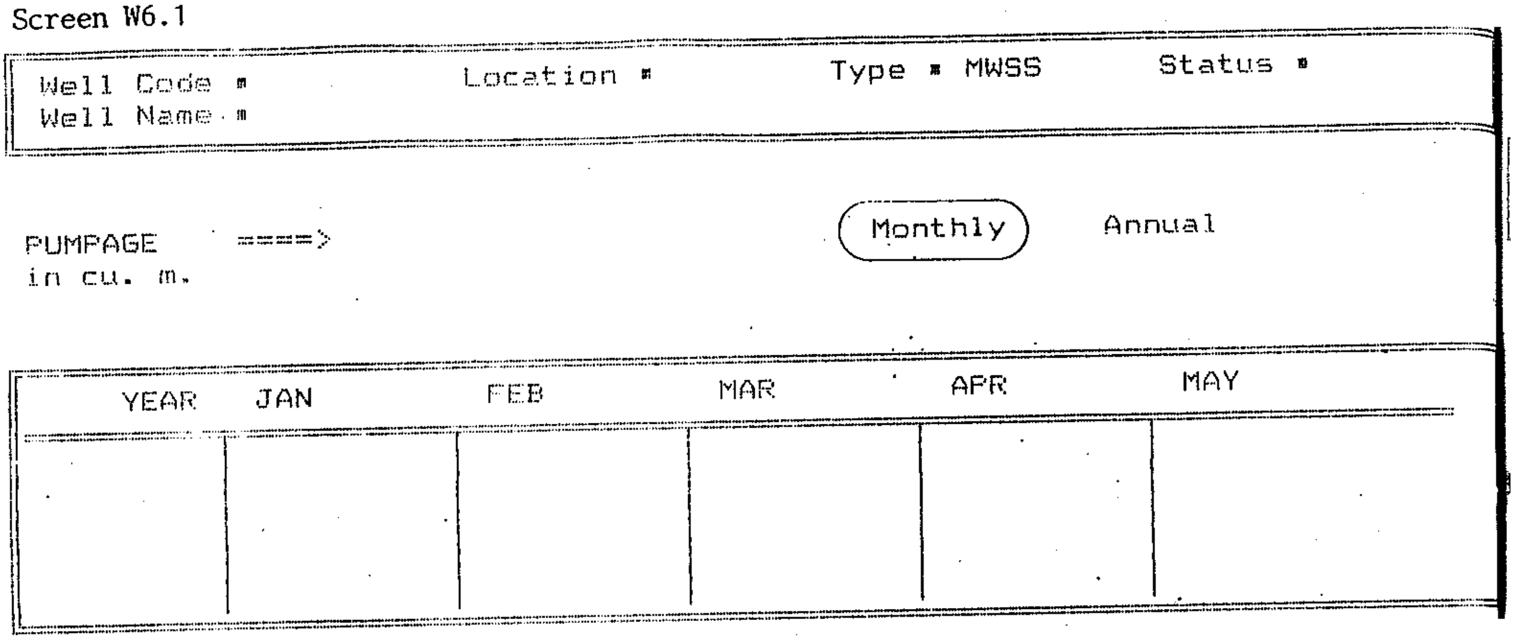
■■ Edit... Print... Previous... Next... Quit ■■

Screen W6



```
 Well Code ▪              Location ▪              Type ▪ MWSS        Status ▪
 Well Name ▪

PUMPAGE     ====>                                  Monthly      Annual
in cu. m.
```

Screen W6.1



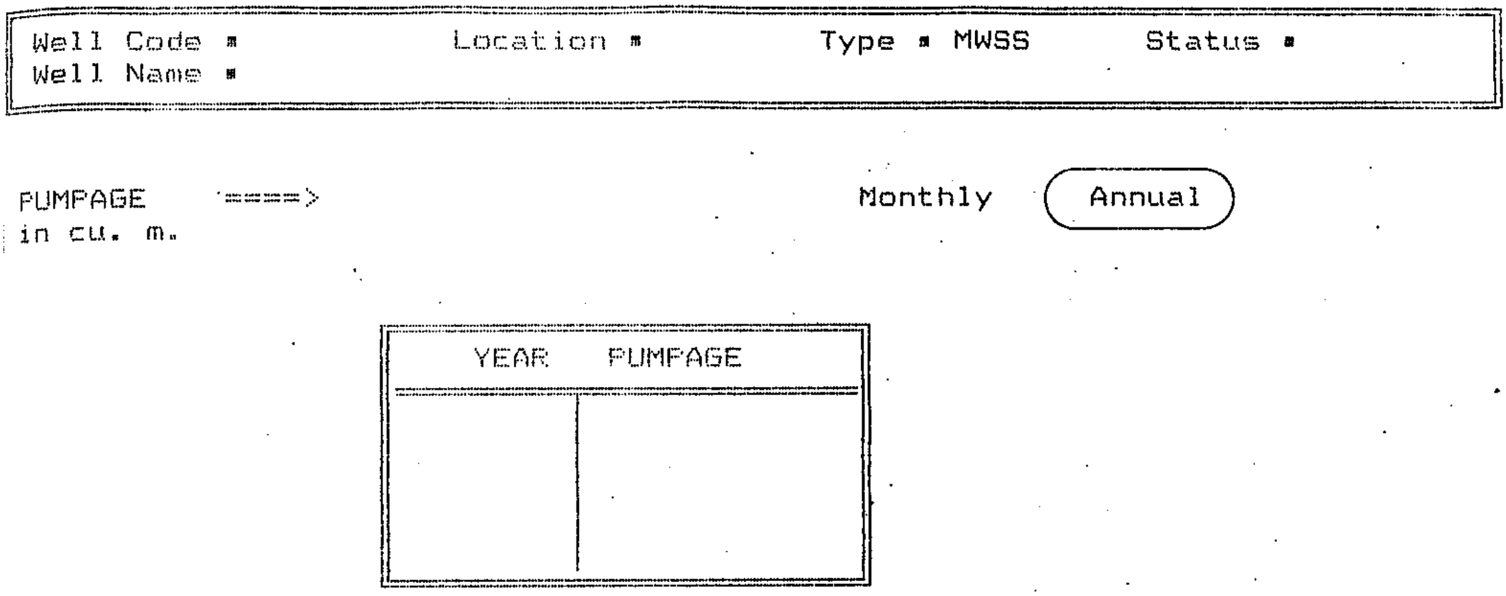
Well Code ■
Well Name ■
Location ■
Type ■ MWSS
Status ■

PUMPAGE ====>
in cu. m.

[✓ Monthly] Annual

YEAR	JAN	FEB	MAR	APR	MAY

Screen W6.2

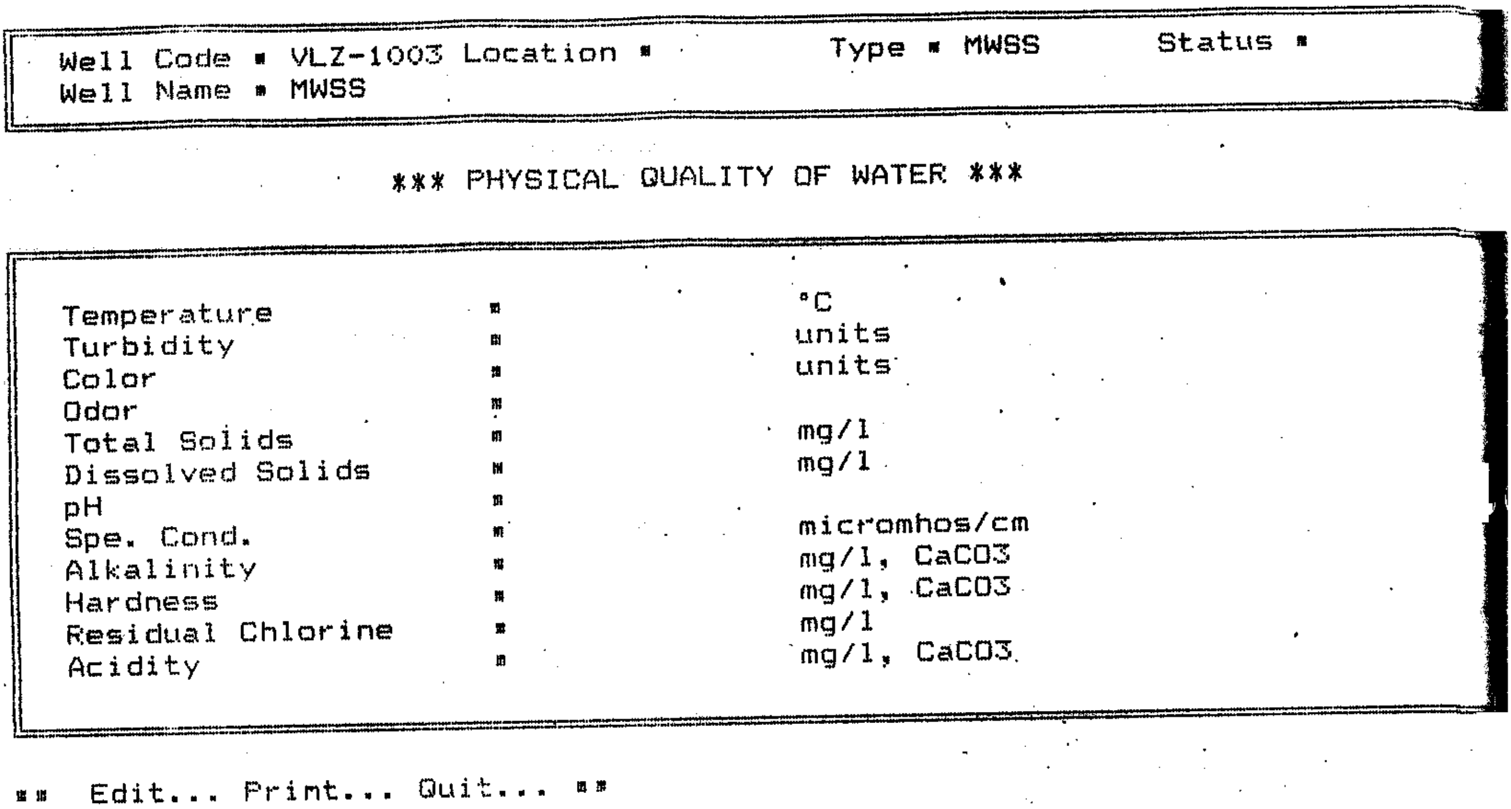


Well Code ■ Location ■ Type ■ MWSS Status ■
Well Name ■

PUMPAGE ====> Monthly [✓ Annual]
in cu. m.

YEAR	PUMPAGE

Screen G7



```
Well Code ■ VLZ-1003 Location ■          Type ■ MWSS        Status ■
Well Name ■ MWSS

                 *** PHYSICAL QUALITY OF WATER ***

Temperature             ■                  °C
Turbidity               ■                  units
Color                   ■                  units
Odor                    ■
Total Solids            ■                  mg/l
Dissolved Solids        ■                  mg/l
pH                      ■
Spe. Cond.              ■                  micromhos/cm
Alkalinity              ■                  mg/l, CaCO3
Hardness                ■                  mg/l, CaCO3
Residual Chlorine       ■                  mg/l
Acidity                 ■                  mg/l, CaCO3

■■  Edit... Print... Quit... ■■
```

APPENDIX A

DATA FILE STRUCTURE

APPENDIX A.1

DATA FILE STRUCTURE
WELL INVENTORY DATABASE

1. Filename: WELLDATA. DBF
(contains Well Data; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code
W_LOC	Character	2		Location: 01 - Antipolo (ATP) 02 - Bacoor (BCR) 03 - Caloocan-A (CLA) 04 - Cainta (CTA) 05 - Cavite City (CVC) 06 - IMUS (IMS) 07 - Kawit (KWT) 08 - Las Pinas (LPS) 09 - Makati (MKT) 10 - Malabon (MLB) 11 - Mandaluyong (MDL) 12 - Manila (MNL) 13 - Marikina (MRK) 14 - Montalban (Rodriguez)(MTB) 15 - Muntinlupa (MTL) 16 - Navotas (NAV) 17 - Noveleta (NOV) 18 - Paranaque (PRN) 19 - Pasay City (PSC) 20 - Pasig (PSG) 21 - Pateros (PTR) 22 - Quezon City (QCT) 23 - Rosario (ROS) 24 - San Juan (SJN) 25 - San Mateo (SMT) 26 - Taguig (TGG) 27 - Taytay (TYY) 28 - Valenzuela (VLZ) 29 - Caloocan-B (CLB) 30 - Angono (AGN) 31 - Baras (BRS) 32 - Binangonan (BNG) 33 - Cardona (CDN) 34 - Jala-Jala (JLJ) 35 - Morong (MRN) 36 - Pilillia (PLL) 37 - Tanay (TNY) 38 - Teresa (TRS)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_TYPE	Character	1		Well Type: 1 - MWSS 2 - Private
W_STATUS	Character	1		Well Status: 1 - Active 2 - Inactive 3 - Abandoned
W_NAME	Character	36		Well Name
W_ADDR1	Character	50		Well Address
W_ADDR2	Character	50		Well Address (continuation)
OWNER	Character	60		Owner of the well
F_OWNER	Character	60		Former Owner of the well
NEW_NO	Character	5		New No.
OLD_NO	Character	5		Old No.
MAP_NO	Character	5		Map Sheet No.
ELEVATION	Numeric	10		Ground Elevation, in meters
X	Character	2		X coordinate
Y	Character	2		Y coordinate
LAT_DEGR	Numeric	3		Latitude, in degrees
LAT_MIN	Numeric	3		Latitude, in minutes
LAT_SEC	Numeric	3		Latitude, in seconds
LONG_DEGR	Numeric	3		Longitude, in degrees
LONG_MIN	Numeric	3		Longitude, in minutes
LONG_SEC	Numeric	3		Longitude, in seconds
W_DEPTH	Numeric	10	2	Well Depth, in meters
RISER_PIPE	Numeric	10	2	Diameter of Riser Pipe, in centimeters
AQUI_TYPE	Character	1		Aquifer Type: 1 - Upper Guadalupe 2 - Lower Guadalupe 3 - Basement
DRILLER	Character	35		Well Driller
				Completion Date:
COMP_MM	Character	2		Month (1-12)
COMP_DD	Character	2		Day (1-31)
COMP_YY	Character	2		Year (1900-...)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
GW_USE	Character	1		Groundwater Use: 1 - Public: Domestic 2 - Public: Institution 3 - Commercial 4 - Industrial: Food/Beverages 5 - Industrial: Chemicals 6 - Industrial: Leather 7 - Industrial: Textile, Paper & Pulp 8 - Industrial: Others
RPC_OLD	Numeric	5	2	Rated Pump Capacity: Old,in LPS
RPC_NEW	Numeric	5	2	Rated Pump Capacity: New,in LPS
TDH_OLD	Numeric	6	2	Total Developed Head: Old,in m.
TDH_NEW	Numeric	6	2	Total Developed Head: New,in m.
MHP_OLD	Numeric	6	2	Motor HP Rating: Old
MHP_NEW	Numeric	6	2	Motor HP Rating: New
PSET_OLD	Numeric	10	2	Pump Setting: Old, in meters
PSET_NEW	Numeric	10	2	Pump Setting: New, in meters
SWL_AC	Numeric	10	2	Static water level - After construction
SWL_RM	Numeric	10	2	Static water level - Recent measurement
SWL_MM	Character	2		Month: SWL-AC (1-12)
SWL_DD	Character	2		Day: SWL-AC (1-31)
SWL_YY	Character	2		Year: SWL-AC (1900-...)
SWL1_MM	Character	2		Month: SWL-RM (1-12)
SWL1_DD	Character	2		Day: SWL-RM (1-31)
SWL1_YY	Character	2		Year: SWL-RM (1900-...)
PWL_AC	Numeric	10	2	Pumping Water Level: Old, in m.
PWL_RM	Numeric	10	2	Pumping Water Level: New, in m.
PWL_MM	Character	2		Month: PWL-AC (1-12)
PWL_DD	Character	2		Day: PWL-AC (1-31)
PWL_YY	Character	2		Year: PWL-AC (1900-...)
PWL1_MM	Character	2		Month: PWL-RM (1-12)
PWL1_DD	Character	2		Day: PWL-RM (1-31)
PWL1_YY	Character	2		Year: PWL-RM (1900-...)
YLD_AC	Numeric	10	2	Yield-After construction,in LPS
YLD_RM	Numeric	10	2	Yield-Recent Measurement,in LPS
YLD_MM	Character	2		Month: YLD-AC (1-12)
YLD_DD	Character	2		Day: YLD-AC (1-31)
YLD_YY	Character	2		Year: YLD-AC (1900-...)
YLD1_MM	Character	2		Month: YLD-RM (1-12)
YLD1_DD	Character	2		Day: YLD-RM (1-31)
YLD1_YY	Character	2		Year: YLD-RM (1900-...)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
ST_COEFF	Numeric	10	5	Storage Coefficient
TRANSMISS	Numeric	10	5	Transmissibility, in M^2/D
P_DURATION	Numeric	5		Pumping Duration, in hours/day
SPCF_CPCTY	Numeric	10	5	Specific Capacity, in LPS/M
PTEST_TYPE	Character	1		Type of Pumping Test: 1 - Step Drawdown 2 - Constant Rate Discharge
DAT_SOURCE	Character	30		Source of Data

2. Filename: WCASING.DBF
(contains Well Casing Schedule; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
CASING_NO	Numeric	2		Casing No.
DIAMETER	Numeric	8	2	Casing Diameter, in centimeters
DEPTH_FROM	Numeric	8	2	Casing Depth: From, in meters
DEPH_TO	Numeric	8	2	Casing Depth: To, in meters

3. Filename: WSCREEN.DBF
(contains Well Screen Section; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
SCR_NO	Numeric	1		Screen No.
SCR_TYPE	Character	1		Type of Screen: 1 - Johnson (continuous-slot) 2 - Slotted 3 - Wedge Wire Wound 4 - Louvered 5 - Perforated
DIAMETER	Numeric	10	2	Screen Diameter, in centimeters
DEPTH_FROM	Numeric	10	2	Screen Depth Below Ground: From, in meters
DEPTH_TO	Numeric	10	2	Screen Depth Below Ground: To, in meters

4. Filename: WSTRATUM.DBF
(contains Well Log Record; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
STR_NO	Numeric	2		Stratum No.
DEPTH_FROM	Numeric	8	2	Stratum Depth Below Ground: From, in meters
DEPTH_TO	Numeric	8	2	Stratum Depth Below Ground: To, in meters
STR_DESC1	Character	50		Description of Stratum
STR_DESC2	Character	25		Description of Stratum (continuation)

APPENDIX A.2

DATA FILE STRUCTURE
METEOROLOGICAL DATABASE

1. Filename: MSTATION.DBF
(contains data on Meteorological Stations)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
M_CODE	Character	8		Meteorological Station Code
M_NAME	Character	40		Name of the Station
M_TYPE	Character	1		Type of Station: 1 - Official Rainfall 2 - Climatological/Cooperative Rainfall 3 - Agrometeorological 4 - Synoptic Station
M_STATUS	Character	1		Status of the Station: 1 - Operational 2 - Abandoned
M_LOC	Character	30		Location of the Station
M_AGENCY	Character	1		Responsible Agency: 1 - MWSS 2 - PAGASA 3 - BRS 4 - NWRB 5 - MGB 6 - EMB 7 - Private Drilling Company
M_ELEV	Numeric	10	2	Elevation, in meters above MSL
R_BASIN	Character	3		River Basin
M_MAPNO	Character	5		Map Sheet No.
M_MQUAD	Character	2		Map Sheet Quadrant: NE - North East NW - North West SW - South West SE - South East

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
MLAT_DEGR	Numeric	3		Latitude, in degrees
MLAT_MIN	Numeric	2		Latitude, in minutes
MLAT_SEC	Numeric	2		Latitude, in seconds
MLONG_DEGR	Numeric	3		Longitude, in degrees
MLONG_MIN	Numeric	2		Longitude, in minutes
MLONG_SEC	Numeric	2		Longitude, in seconds
FROM_REC	Numeric	4		Year of Record: From
TO_REC	Numeric	4		Year of Record: To
TIME_REC	Character	30		Time Measurement
M_REMARKS	Character	45		Remarks

2. Filename:RAIN_D.DBF (Daily Rainfall Data; sorted by M_CODE)
3. TMAV_D.DBF (Daily Mean Temperature; sorted by M_CODE)
4. TMIN_D.DBF (Daily Minimum Temperature; sorted by M_CODE)
5. TMAX_D.DBF (Daily Maximum Temperature; sorted by M_CODE)
6. EVAP_D.DBF (Daily Evaporation; sorted by M_CODE)
7. HUMID_D.DBF (Daily Humidity; sorted by M_CODE)
8. SUN_D.DBF (Daily Sunshine Duration; sorted by M_CODE)
9. WIND_D.DBF (Daily Wind Velocity; sorted by M_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
M_CODE	Character	8		Meteorological Code (same as in MSTATION.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
DAY	Numeric	2		Day Observed (1-31)
JAN	Numeric	9	4	Measurement: * 0.0000 - No Data * 0.0001 - Zero - Rainfall, in mm - Temperature, in ^{o}C - Evaporation, in mm - Humidity, in percent - Sunshine Duration, in hours - Wind Velocity, in m/sec for DAY and month JAN (January)
FEB	Numeric	9	4	.... (February)
MAR	Numeric	9	4	.... (March)
APR	Numeric	9	4	.... (April)
MAY	Numeric	9	4	.... (May)
JUN	Numeric	9	4	.... (June)
JUL	Numeric	9	4	.... (July)
AUG	Numeric	9	4	.... (August)
SEP	Numeric	9	4	.... (September)
OCT	Numeric	9	4	.... (October)
NOV	Numeric	9	4	.... (November)

DEC	Numeric	9	4	.... (December)

10. Filename:RAIN_M.DBF (Monthly Rainfall Data; sorted by M_CODE)
11. TMAV_M.DBF (Monthly Mean Temperature; sorted by M_CODE)
12. TMIN_M.DBF (Monthly Minimum Temperature;sorted by M_CODE)
13. TMAX_M.DBF (Monthly Maximum Temperature;sorted by M_CODE)
14. EVAP_M.DBF (Monthly Evaporation; sorted by M_CODE)
15. HUMID_M.DBF (Monthly Humidity; sorted by M_CODE)
16. SUN_M.DBF (Monthly Sunshine Duration; sorted by M_CODE)
17. WIND_M.DBF (Monthly Wind Velocity; sorted by M_CODE)

Note: Data are computed.

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
M_CODE	Character	8		Meteorological Station Code (same as in MSTATION.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
				Measurement (same as in daily data) for the month of:
JAN	Numeric	9	4	... January
FEB	Numeric	9	4	... February
MAR	Numeric	9	4	... March
APR	Numeric	9	4	... April
MAY	Numeric	9	4	... May
JUN	Numeric	9	4	... June
JUL	Numeric	9	4	... July
AUG	Numeric	9	4	... August
SEP	Numeric	9	4	... September
OCT	Numeric	9	4	... October
NOV	Numeric	9	4	... November
DEC	Numeric	9	4	... December
YDATA	Numeric	10	2	... Yearly data

APPENDIX A.3

DATA FILE STRUCTURE
HYDROLOGICAL DATABASE

1. Filename: HSTATION.DBF
(contains information on Hydrological Stations)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
H_CODE	Character	8		Hydrological Station Code
H_STATION	Character	30		Name of the Station
H_OBS	Character	1		Type of Observation: 1 - Simultaneous 2 - Continuous
H_STAT	Character	15		Status of the Station: 1 - Operational 2 - Abandoned
H_LOC	Character	30		Location of the Station
R_BASIN	Character	30		River Basin
R_NAME	Character	30		River
H_AGENCY	Character	1		Responsible Agency: 1 - MWSS 2 - PAGASA 3 - BRS 4 - NWRB 5 - MGB 6 - EMB 7 - Private Drilling Company
H_DRAIN	Numeric	10	2	Drainage Area, in sq. kms.
H_ELEV	Numeric	10	2	Elevation, in meters above MSL
H_MAPNO	Character	5		Map Sheet No.

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
H_MQUAD	Character	2		Map Sheet Quadrant: NE - North East NW - North West SW - South West SE - South East
				Coordinates:
HLAT_DEGR	Numeric	3		Latitude, in degrees
HLAT_MIN	Numeric	2		Latitude, in minutes
HLAT_SEC	Numeric	2		Latitude, in seconds
HLONG_DEGR	Numeric	3		Longitude, in degrees
HLONG_MIN	Numeric	2		Longitude, in minutes
HLONG_SEC	Numeric	2		Longitude, in seconds
FROM_REC	Numeric	4		Year of Record: From
TO_REC	Numeric	4		Year of Record: To
H_REMARKS	Character	45		Remarks

2. Filename: RDIS_D.DBF (Daily River Discharge; sorted by H_CODE)
3. GAGE_D.DBF (Daily Gage Height; sorted by H_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
H_CODE	Character	8		Hydrological Code (same as in HSTATION.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
DAY	Numeric	2		Day Observed (1-31)
JAN	Numeric	9	4	Measurement: *0.0000 - No Data *0.0001 - Zero - River Discharge,in m^3 - Gage Height, in meters for DAY and month JAN (January)
FEB	Numeric	9	4	.... (February)
MAR	Numeric	9	4	.... (March)
APR	Numeric	9	4	.... (April)
MAY	Numeric	9	4	.... (May)
JUN	Numeric	9	4	.... (June)
JUL	Numeric	9	4	.... (July)
AUG	Numeric	9	4	.... (August)
SEP	Numeric	9	4	.... (September)
OCT	Numeric	9	4	.... (October)
NOV	Numeric	9	4	.... (November)
DEC	Numeric	9	4	.... (December)

4. Filename: RDIS_M.DBF (Monthly River Discharge; sorted by H_CODE)
5. GAGE_M.DBF (Monthly Gage Height; sorted by H_CODE)

Note: Data are computed.

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
H_CODE	Character	8		Hydrological Station Code (same as in HSTATION.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
				Measurement (same as in daily data) for the month of:
JAN	Numeric	9	4	... January
FEB	Numeric	9	4	... February
MAR	Numeric	9	4	... March
APR	Numeric	9	4	... April
MAY	Numeric	9	4	... May
JUN	Numeric	9	4	... June
JUL	Numeric	9	4	... July
AUG	Numeric	9	4	... August
SEP	Numeric	9	4	... September
OCT	Numeric	9	4	... October
NOV	Numeric	9	4	... November
DEC	Numeric	9	4	... December
YDATA	Numeric	10	2	... Yearly data

6. Filename: SPRING.DBF (Spring Discharge, sorted by H_CODE)
7. STREAM.DBF (Streamflow, sorted by H_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
H_CODE	Character	4		Hydrological Station Code (same as in HSTATION.DBF)
DISCHARGE	Numeric	8	2	Spring Discharge, in LPS/ Streamflow, in LPS
DATE_M	Character	8		Date Measured
TIME_M	Character	8		Time Measured
REMARKS	Character	45		Remarks

APPENDIX A.4

DATA FILE STRUCTURE
HYDROGEOLOGICAL DATABASE

1. Filename: HGEO.DBF
(contains Pumping Test data; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (Same as in WELLDATA.DBF)
W_LOC	Character	2		Location (Same as in WELLDATA.DBF)
W_TYPE	Character	1		Well Type (Same as in WELLDATA.DBF)
W_NAME	Character	36		Well Name (Same as in WELLDATA.DBF)
W_STATUS	Character	1		Well Status (Same as in WELLDATA.DBF)
SWL_AC	Numeric	10	2	Static Water level - After construction
SWL_RM	Numeric	10	2	Static Water level - Recent measurement
SWL_MM	Character	2		Month: SWL-AC (1-12)
SWL_DD	Character	2		Day: SWL-AC (1-31)
SWL_YY	Character	2		Year: SWL-AC (1900-...)
SWL1_MM	Character	2		Month: SWL-RM (1-12)
SWL1_DD	Character	2		Day: SWL-RM (1-31)
SWL1_YY	Character	2		Year: SWL-RM (1900-...)
PWL_AC	Numeric	10	2	Pumping Water Level: Old, in meters
PWL_RM	Numeric	10	2	Pumping Water Level: New, in meters
PWL_MM	Character	2		Month: PWL-AC (1-12)
PWL_DD	Character	2		Day: PWL-AC (1-31)
PWL_YY	Character	2		Year: PWL-AC (1900-...)
PWL1_MM	Character	2		Month: PWL-RM (1-12)
PWL1_DD	Character	2		Day: PWL-RM (1-31)
PWL1_YY	Character	2		Year: PWL-RM (1900-...)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
YLD_AC	Numeric	10	2	Yield - After Construction, in LPS
YLD_RM	Numeric	10	2	Yield - Recent Measurement, in LPS
YLD_MM	Character	2		Month: YLD-AC (1-12)
YLD_DD	Character	2		Day: YLD-AC (1-31)
YLD_YY	Character	2		Year: YLD-AC (1900-...)
YLD1_MM	Character	2		Month: YLD-RM (1-12)
YLD1_DD	Character	2		Day: YLD-RM (1-31)
YLD1_YY	Character	2		Year: YLD-RM (1900-...)
ST_COEFF	Numeric	10	5	Storage Coefficient
TRANSMISS	Numeric	10	5	Transmissibility, in M^2/D
P_DURATION	Numeric	5		Pumping Duration, in hours/day
SPCF_CPCTY	Numeric	10	5	Specific Capacity, in LPS/M
PTEST_TYPE	Character	1		Type of Pumping Test 1 - Step Drawdown 2 - Constant Rate Discharge

2. Filename: WGWS.DBF
(contains Groundwater Level Simultaneous Observation; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (Same as in WELLDATA.DBF)
CASING_NO	Character	2		Casing No.
CASING_D	Numeric	5	2	Casing Diameter, in centimeters
CASING_T	Numeric	5	2	Top of Casing, ma/bgs
WL_BT	Numeric	5	2	Water Below Casing Top, in mbgs
WL	Numeric	5	2	Water Level, in mbgs
GR_EL	Numeric	5	2	Ground Elevation, in masl
PIEZO	Numeric	5	2	Piezo Level, in ma/bsl
W_QUALITY	Character	30		Water Quality
DATE_M	Character	8		Date Measured
TIME_M	Character	8		Time Measured
REMARKS	Character	45		Remarks

3. Filename: WGWC_D.DBF
(contains Daily Groundwater Level Continuous Observation; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
DAY	Numeric	2		Day Observed (1-31)
JAN	Numeric	9	4	Water Level Observation, in meters, for DAY and month JAN (January) *0.0000 - No Data *0.0001 - Zero
FEB	Numeric	9	4	.... (February)
MAR	Numeric	9	4	.... (March)
APR	Numeric	9	4	.... (April)
MAY	Numeric	9	4	.... (May)
JUN	Numeric	9	4	.... (June)
JUL	Numeric	9	4	.... (July)
AUG	Numeric	9	4	.... (August)
SEP	Numeric	9	4	.... (September)
OCT	Numeric	9	4	.... (October)
NOV	Numeric	9	4	.... (November)
DEC	Numeric	9	4	.... (December)

4. Filename:WGWC_M.DBF
(contains Monthly Groundwater Level Continuous Observation; sorted by W_CODE)

Note: Data are computed.

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
YEAR	Numeric	4		Year Observed (1900-...)
				Water Level Observation for the Month of: (in meters)
JAN	Numeric	9	4	January
FEB	Numeric	9	4	February
MAR	Numeric	9	4	March
APR	Numeric	9	4	April
MAY	Numeric	9	4	May
JUN	Numeric	9	4	June
JUL	Numeric	9	4	July
AUG	Numeric	9	4	August
SEP	Numeric	9	4	September
OCT	Numeric	9	4	October
NOV	Numeric	9	4	November
DEC	Numeric	9	4	December
YDATA	Numeric	10	2	Yearly data

5. Filename: WCHEM.DBF
(contains the Chemical Quality of Water; sorted by W_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
W_CODE	Character	8		Well Code (same as in WELLDATA.DBF)
IONS	Character	2		Principal Ions 01 - Ca: Calcium (++) 02 - Na: Sodium (+) 03 - HCO3: Bicarbonate (-) 04 - Cl: Chloride (-) 05 - F: Flouride (-) 06 - Fe: Iron (++,+++) 07 - Mg: Magnesium (++) 08 - K: Potassium (+) 09 - SO4: Sulfate (--) 10 - NO3: Nitrate (-) 11 - TDS: Dissolved solids
CONCENT	Numeric	6	2	Concentration, in mg/l
DATE_S	Character	8		Date of Sampling

APPENDIX A.5

DATA FILE STRUCTURE
LITERATURE DATABASE

1. Filename: LITR.DBF
(contains Literature Records; sorted by LIT_CODE)

FIELD NAME	TYPE	WIDTH	DECIMAL	DESCRIPTION
LIT_CODE	Character	4		Literature Code
LIT_NAME1	Character	50		Literature Title
LIT_NAME2	Character	50		Literature Title (continuation)
AUTHOR1	Character	30		Author-1
AUTHOR2	Character	30		Author-2
AUTHOR3	Character	30		Author-3
SUBJ1	Character	2		Subject Matter: 01 - Hydrogeological Study 02 - Regional Develeopment Study 03 - Test Drilling and/or Pumping Test 04 - Geographical Prospecting 05 - Chemical Quality Test 06 - Water Level Observation 07 - Discharge Observation 08 - Groundwater Potential 09 - Water Supply System Design
SUBJ2	Character	2		Subject Matter-2
SUBJ3	Character	2		Subject Matter-3
SUBJ4	Character	2		Subject Matter-4
SUBJ5	Character	2		Subject Matter-5
ABSTRACT				Literature Abstract

APPENDIX B

COMMAND AND FUNCTION KEYS

APPENDIX B

COMMAND AND FUNCTION KEYS

Browsing

<u>Browse keys:</u>

a. Right, left, up or down arrow key

Moves the highlighted bar from one record or from one data item to another on the screen. A record which is highlighted is called the active record.

b. Home

Moves the highlighted bar to the first data item of the active record displayed on the screen.

c. End

Moves the highlighted bar to the last data item of the active record displayed on the screen.

d. Page-up

Scrolls the screen up.

e. Page-down

Scrolls the screen down.

f. Ctrl+Right arrow key

Scrolls one screen to the right.

g. Ctrl+Left arrow key

Scrolls one screen to the left.

h. Ctrl+Home

Moves the highlighted bar to the first data item of the active record.

i. Ctrl+End

Moves the highlighted bar to the last data item of the active record.

j. Ctrl+Page-up

Brings the user to the beginning of the list.

k. Ctrl+Page-down

Brings the user to the end of the list.

Adding

To add new record(s), press the Ins-key or Ctrl+V. The cursor moves to the end of the list and the computer automatically generates blank space for data to be inputted.

Editing

To change the system to the edit mode, select the data item on the screen using the browse keys and press the Enter key. "EDIT" appears at the bottom left-corner of the screen. The system is now ready to accept information from the keyboard.

Note: Pressing Enter key a second time, changes the system to the browse mode and moves the cursor to the next data item to the right. Pressing the <Esc> key aborts the editing and brings the user back to the browse mode.

Edit keys:

a. Del or Ctrl+G

Deletes the character where the cursor is.

b. Ins or Ctrl+V

Inserts a character before the cursor.

c. Ctrl+T

Deletes a word after the cursor.

d. Backspace

Deletes a character before the cursor.

Deleting

To delete a record,

a. Move the highlighted bar to the record to be deleted.

b. Press Del key or Ctrl+G.

The "Delete" remark is displayed at the bottom right of the screen.

c. To undo deletion, press F1 key.

d. To save the file excluding all records marked "Delete", press Ctrl+Q.

   Be careful. Deleted records can no longer be retrieved.

e. To save the file including all records marked "Delete", press Esc key.

Printing

To print data displayed on the screen,

- Press F4.

  A message below appears at the bottom of the screen:

  "SET THE PRINTER ON... Press any key when ready"

  Pressing Esc key aborts the print option.

Important:

a. Turn the printer ON before pressing any key.

b. Set your printer in condensed mode.

JICA

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CONTENTS OF APPENDICES

APPENDIX A COMPUTER PROGRAM AND RELATED DATA FOR Q3P MODEL

APPENDIX B COMPUTER PROGRAM AND RELATED DATA FOR MOC MODEL

1. INTRODUCTION

Computer simulation techniques were used to understand the dynamic behavior of groundwater flow and to evaluate the groundwater resources in the Metro Manila. The quasi three-dimensional flow model (Q3P model) was applied to the Antipolo groundwater basin and the Metro Manila groundwater basin. The two-dimensional solute transport model (MOC model) revealed the mechanism of saltwater intrusion in Las Pinas area. The model studies have helped design future groundwater use plans as well as prognose some remedial measures.

In recent years, digital computer models have gained wider acceptance as they foster more efficient groundwater resources management. For example, using a properly constructed groundwater model, it is possible to test various management schemes and to predict the effects of certain actions.

Of course, the validity of the model predictions will depend on how well the model approximates field conditions. Good field data are essential when using a model for predictive purposes. However, it is difficult to obtain adequate field data due to several constraints. Further, as natural aquifer systems are inherently complex and uncertain, construction of the model always requires the making of assumptions and simplifications. It is very important to keep this awareness about the model, even though sophisticated numerical techniques and high-speed computers have already been developed.

The instructions for using the computer models used in the study are described in detail in this manual. It is assumed that the user is familiar with the operation of the computer and its peripherals and understands the Disk Operating System manual supplied with the computer. The user is also expected to have a working knowledge of hydrogeology and have read books on groundwater hydrology and modeling.

2. SYSTEM REQUIREMENTS

2.1 HARDWARE

Followings are required hardware to run the computer models:

IBM Personal Computer or IBM Compatible Personal Computer.
640K RAM.
Intel 8087, 80287 or 80387 Numerical Co-processor
Hard disk.
Dot matrix printer with 132 column capability.

The Study Team used following hardware:

TOSHIBA J-3100SGX (with 100MB hard disk and 3.5" floppy disk drive).
Additional memory cards (2MB x 2 = 4MB).
Numerical co-processor (Intel 80387-20).
TOSHIBA Dual Mode Printer 4.

2.2 SOFTWARE

Followings are required software to run the computer models:

PC-DOS or MS-DOS Version 3.0 or higher.
FORTRAN 77 Compiler.
BASIC Compiler or Interpreter (for graphics).
LOTUS 123 or similar commercial program (for graphics).

The Study Team used following software:

MS-DOS Version 3.2.
Pro FORTRAN-77 Compiler.
Japanese MS-DOS Version 3.10 (for graphics).
TOSHIBA BASIC Interpreter Version 3.2 (for graphics).
LOTUS 123 (for graphics).

3. GROUNDWATER FLOW MODEL

3.1 MODEL ABSTRACT

The computer model used for the study is a quasi three-dimensional groundwater flow model (Q3P model). The original Q3P model was constructed by Fujisaki (1982) and modified by KOKUSAI KOGYO Co., Ltd. Its basic concept is that the groundwater in the main confined aquifer is supplied by lateral flow through the aquifer and by a vertical flow through the aquitard from the overlying phreatic aquifer (Figure 3.1).

Q3P solves the groundwater flow equation using a finite-element approximation. The model is based on a rectangular finite-element grid. The model is applicable to two-dimensional or three-dimensional problems even in multi-aquifer systems involving steady-state or nonsteady-state flow.

The model computes changes in piezometric heads over time caused by changes in groundwater pumpage and groundwater recharge. If future plans of groundwater pumpage are inputted to the model, it can calculate future piezometric heads.

The model assumes that geohydrologic parameters such as transmissivity, storage coefficient and leakance are not affected by changes of piezometric heads. Also, the model needs to assume that those parameters and boundary conditions do not change over time. The phreatic water levels are assumed to be constant over time.

The model must be calibrated before starting actual calculations. The main procedure of model calibration is to specify boundary conditions and to identify some poor reliable hydrogeologic parameters. Generally the model is verified by the comparison of calculated piezometric heads with actual piezometric heads. Figure 3.2 shows the general flow of model calibration.

After all parameters and boundary conditions are fixed, the model can compute future piezometric heads based on future groundwater pumpage plans and future recharge estimates.

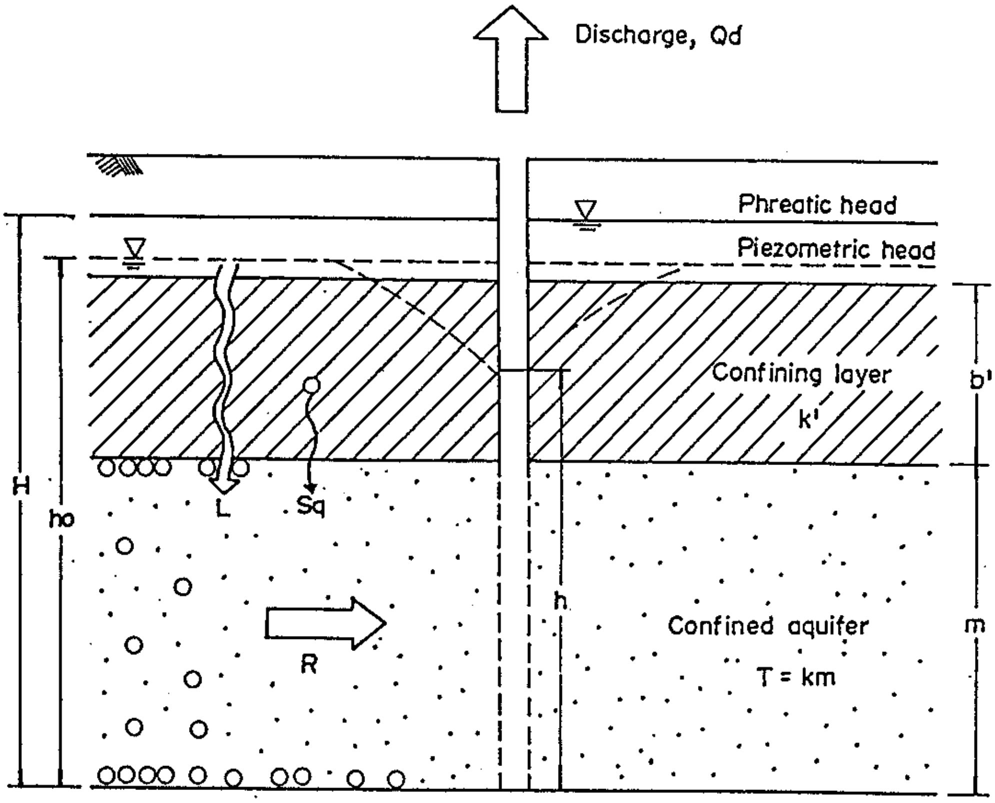

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Figure 3. 1

SCHEMATIC CROSS-SECTION OF THE QUASI 3-DIMENSIONAL MODEL

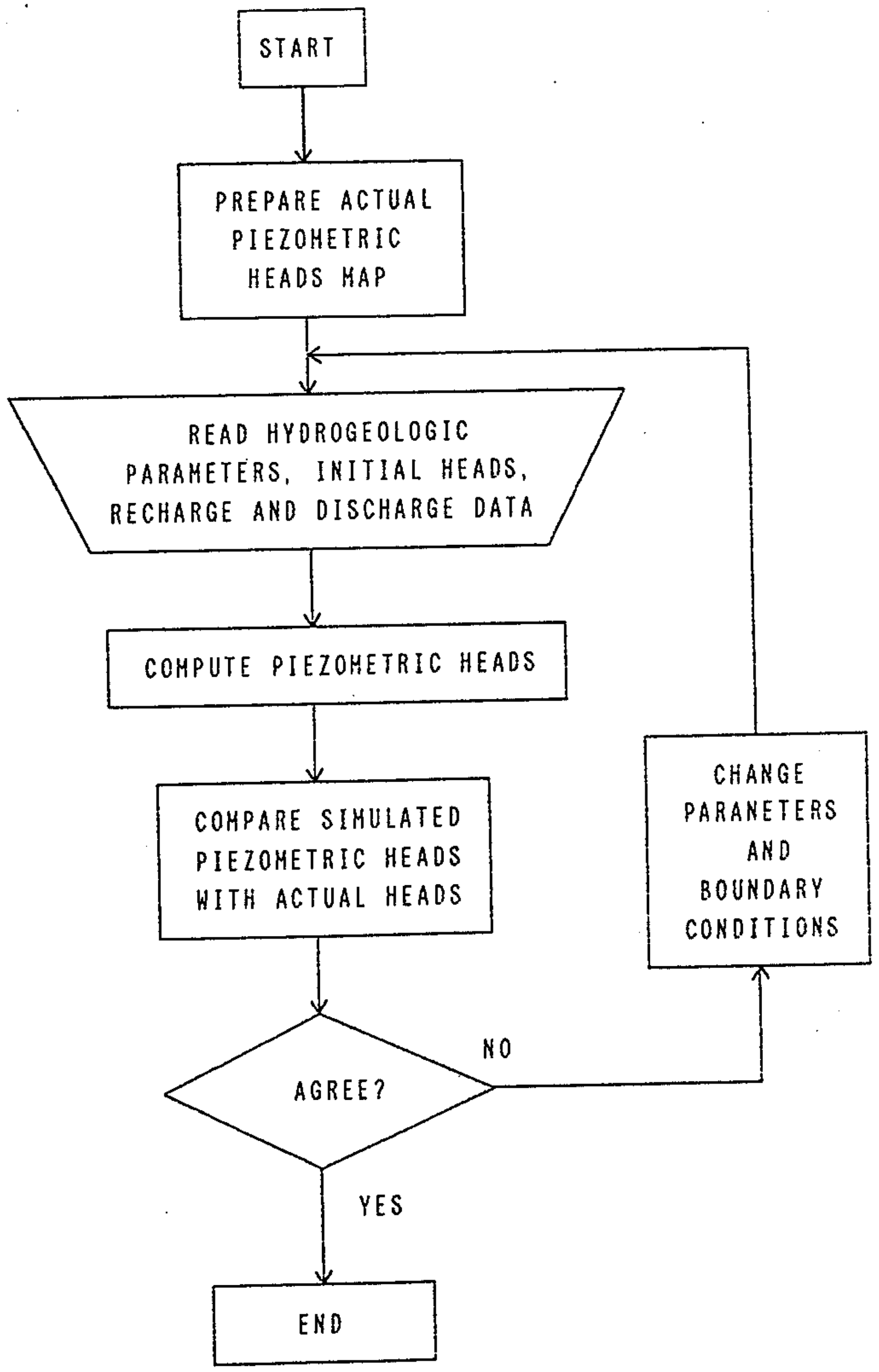

Figure 3.2 General Flow Chart of Model Calibration

This model can be applied to a wide variety of field problems. However, the user should first become aware of the assumptions and limitations inherent in the model. The computer program presented in this report is offered as a basic working tool that may have to be modified by the user for efficient application to specific field problems. The program is written in FORTRAN 77 and is compatible with most high-speed computers.

The groundwater flow model was applied to the Antipolo groundwater basin and the Metro Manila groundwater basin in the study.

3.2 MODEL FRAMEWORK

A rectangular finite-element grid should be constructed based on objectives of groundwater modeling, hydrogeological conditions and memory capacity of the computer. The grid spacing of each cell should be uniform. The original Q3P program presented here is written to allow a grid having up to 900 elements or 990 nodes.

Q3P model can be applied to two-dimensional single aquifer problem, quasi three-dimensional single aquifer problem and quasi three-dimensional double aquifer problem. All geohydrologic parameters should be prepared by the x- and y-coordinates.

3.2.1 Column Number and Row Number

Column numbers are given from left to right in x-direction and row numbers are given from top to bottom in y-direction. Figure 3.3 shows the finite-element grid used to model the Metro Manila groundwater basin. In the FORTRAN programs I and J represent the row number and the column number, respectively.

3.2.2 Element Number

After fixing the finite element grid, element numbers should be given from the top left element to the bottom right element in the modeled domain in ascending order (see Figure 3.4). The number of the elements located out of the modeled domain should be assigned as 0.

3.2.3 Nodal Number

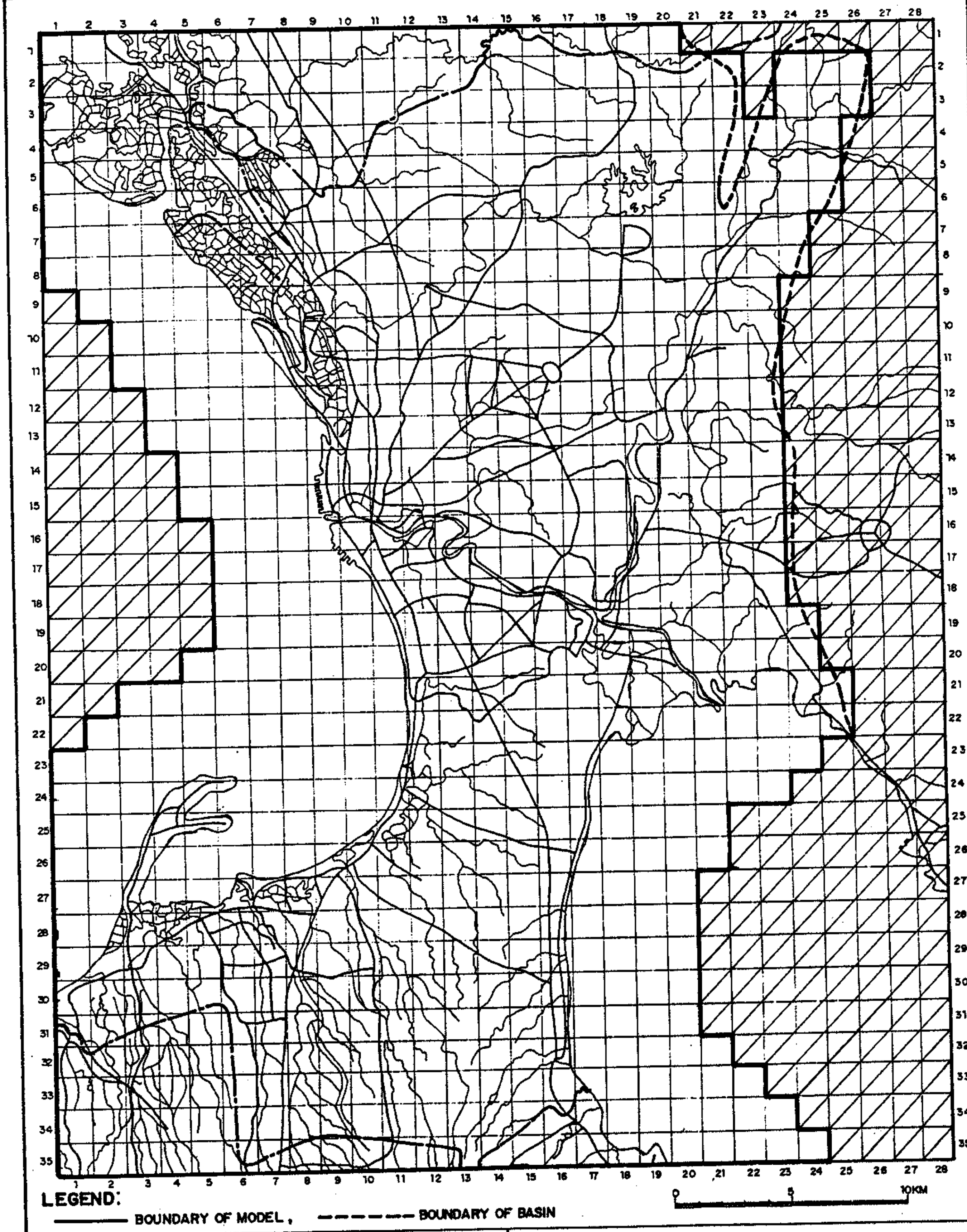

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Figure 3.3 FINITE-ELEMENT GRID USED TO MODEL METRO MANILA BASIN

Nodal numbers should be assigned at each node from the top left node to the bottom right node in the domain in ascending order (see Figure 3.5). The number of the nodes located out of the domain should be assigned as 0.

3.3 INPUT DATA

A simplified flow chart of Q3P model is given in Figure 3.6. Q3P needs following input data files.

ELE.DAT : element data.
NOD.DAT : node data.
NOP.DAT : data for element specification by nodes.
HBOUND.DAT : constant-head boundary data.
KYOKAI.LAB : labels of modeled domain, direct recharge and leakage recharge area.
T_03.IND : transmissivity.
B.IND : thickness of confining layer.
S.IND : storage coefficient.
KD_03.LAB : permeability of confining layer.
PRM_03.DAT : generated data file by PARAC (unformatted).
INI_03.DAT : initial piezometric heads (unformatted).
H.IND : water levels of phreatic aquifer.
QIN30.DAT : discharge data.
RIN30.DAT : direct recharge data.
OBSH63_2.DAT: observation points.
BLOCK.DAT : block data for water balance calculation.
Q3PSIM2.PAR : model control card.

Each data file should be prepared as follows. The names of variables shown below are used in Q3P program or data generating program named PARAC. The formats are written in FORTRAN expression. The sample data given in figures were used in the simulation of Metro Manila groundwater basin.

(1) ELE.DAT

Variables: NR(I,J)

where I is the row number, J is the column number.

Format: (nI4)
where n is the total number of columns in x-direction.

The element numbers should be given from the top left element to the bottom right element in the modeled domain in ascending order (see Figure 3.4). The element numbers located out of the modeled domain should be assigned as 0.

(2) NOD.DAT

Variables: NNO(I,J)
where I is the grid line number in y-direction and J is the grid line number in x-direction.

Format: (nI4)
where n is the total number of grid lines in x-direction.

The nodal numbers should be given from the top left node to 0the bottom right node in the modeled domain involving the perimeters in ascending order (see Figure 3.5). The nodal numbers located out of the modeled domain should be assigned as 0.

(3) NOP.DAT

Variables: (NOP(I,J), J=1,4)
where I is the element number. J represents nodal identification number to the corresponding element.

Format: (8(4I4))

Each element has 4 (four) nodes. This data file defines each element number by corresponding 4 (four) nodal numbers from the lower left node counterclockwise shown as follows:

```
4     3
 +---+
 I   I
 +---+
1     2
```

Figure 3.7 shows the data sequence of NOP.DAT used in the Metro Manila model.

(4) HBOUND.DAT

Variables: NNC, (NOHC(I,1), I=1,NNC)
HC(I,J)

Format: (I4, nI4)
where n is the total number of constant-head nodes.
(10F8.2)

NNC is a total number of constant-head nodes. NOHC(I,J) is the nodal number assigned as constant-head boundary. HC(I,J) is constant piezometric head of confined aquifer J (J=1 or 2) at node I. The data sequence of HC(I,J) locates from the next line of NOHC(I,1) data sequence. If the model is applied to a quasi 3-D two-confined aquifer model, the boundary conditions of the second confined aquifer are the same with first aquifer (NOHC(I,2) = NOHC(I,1)). The data sequence of HBOUND.DAT is shown in Figure 3.8.

(5) KYOKAI.LAB

Variables: KY(I,J)
where I and J are the row number and the column number, respectively.

Format: (nI1)
where n is the total number of columns in x-direction.

KY(I,J) is the label for recharge type identification at element (I,J); 0 indicates leakage recharge, 1 indicates direct recharge, and 9 means out of the modeled domain (see Figure 3.9).

(6) T_03.IND

Variables: IT(I,J)
where I and J are the row number and the column number, respectively.

Format: (nI4)
where n is the total number of columns in x-direction.

IT(I,J) is local value of transmissivity (m^2/d) at element (I,J). 9999 should be assigned at elements located out of the modeled area (see Figure 3.10).

(7) B.IND

Variables: IB(I,J)
where I and J are the row number and the column number, respectively.

Format: (nI4)
where n is the total number of columns in x-direction.

IB(I,J) is thickness of the confining layer (m) overlying the first confined aquifer at element (I,J). 9999 should be assigned at elements located out of the modeled area (see Fifure 3.11).

(8) S.IND

Variables: IS(I,J)
where I and J are the row number and the column number, respectively.

Format: (nI4)

where n is the total number of columns in x-direction.

Storage coefficient at element (I,J) can be computed as 1x10^(-IS(I,J)/10.). The unit of storage coefficient is dimensionless. 9999 should be assigned at elements located out of the modeled domain (see Figure 3.12).

(9) KD_03.LAB

Variables: DK(I,L)
where I is the number of leakance label for confined aquifer L (L=1 or 2).
LK(I,J)
where I and J are the row number and the column number, respectively.

Format: (8F8.0)
(nA1)
where n is the total number of columns in x-direction.

DK(I,L) is permeability of confining layer (m/d) underlain by the confined aquifer L. As many as 16 (sixteen) different values of permeability can be assigned to the elements. There are 16 (sixteen) labels (LK(I,J)) to specify each element viz. 0,1,2,3,4,5,6,7,8,A,B,C,D,E, and F. The first line of DK(I,L) sequence corresponds to the labels from 0 to 7, and the second line corresponds to the labels from 8 to F, respectively (see Figure 3.13).

(10) PRM_03.DAT

Variables: BD(I,J)
T(I,J)
S(I,J)
HF(I,J)
where I is the element number. J (J=1 or 2) is the aquifer number.

Format: Unformatted.

FORTRAN program PARAC generates a geohydrologic parameters file (PRM_03.DAT) from B.IND, KD_03.LAB, T_03.IND, S.IND and H.IND using ELE.DAT, NOD.DAT and KYOKAI.LAB. BD(I,J) is leakance (1/d) at each element which is computed by DK(I,L)/IB(I,J). The units of T(I,J), S(I,J) and HF(I,J) are m^2/d, dimensionless and masl, respectively. In addition, PRL_03.LST is also generated by PARAC to check input data.

(11) INI_03.DAT

Variables: HN(I,J)
where I is the nodal number. J (J=1 or 2) is the aquifer number.

Format: Unformatted

HN(I,J) is an initial piezometric head at each node. INI_03.DAT can be generated from INIH.IND using FORTRAN program MINIH or obtained from the output file (INI_30.DAT) of Q3P.

The variables and format of INIH.IND are as follows:

Variables: INIH(I,J)
where I is the grid line number in y-direction and J is the grid line number in x-direction, respectively.

Format: (nF5.0)
where n is the total number of grid lines in x-direction.

INIH(I,J) is a piezometric head (masl) at node (I,J). 9999. should be assigned at nodes located out of the modeled domain.

(12) H.IND

Variables: IH(I,J)

where I and J are the row number and the column number, respectively.

Format: (nI4)
where n is the total number of columns in x-direction.

IH(I,J) is water level of phreatic aquifer (masl) at element (I,J). 9999 should be assigned at elements located out of the modeled area (see Figure 3.14). H.IND is used to generate PRL_03.DAT by FORTRAN program PARAC.

(13) QIN30.DAT

Variables: (Q(I,J), I=1,NE), J=1,IL
where I is the element number. NE is the total number of elements. J (J=1 or 2) is the aquifer number.

Format: (10F10.0)

Q(I,J) is discharge (m^3/d) from element number I extracted from aquifer J. In case of nonsteady-state simulation, a sequence of discharge data in each time-step should be prepared and jointed in the same file.

(14) RIN30.DAT

variables: R(I), I=1,NE
where I is the element number. NE is the total number of elements.

Format: (10F10.0)

R(I) is direct recharge (m^3/d) to element number I. In case of non-steady-state simulation, a sequence of direct recharge data in each time-step should be prepared and jointed in the same file.

(15) OBSH63_2.DAT

Variables: NS(I), NW(I), (CN(I,N),N=1,3), SVAL(I), EVAL(I),
NWOUT(I), OBS(I,J,K)
where I is observation point number. J is aquifer number. K is time-step.

Format: (I4,I2,3A8,2F10.4,I1)
(/8X,12F6.2)

The data sequence of OBSH63_2.DAT is shown in Figure 3.15. As many as 70 (seventy) observation points can be located in the modeled domain. Each observation point should be located at a particular node NS(I). Piezometric changes of aquifer NW(I) can be observed in each time-step. CN(I,N) is the name of an observation point. A hydrograph at each point can be drawn between minimum level SVAL(I) and maximum level EVAL(I). A hydrograph of the observation point I shall be printed if NWOUT(I) is 1. OBS(I,J,K) is actual piezometric head (masl) of aquifer J at observation point I in time-step K. Q3P can draw hydrographs of both actual and simulated piezometric changes.

(16) BLOCK.DAT

Variables: LBL(I)
I is the element number.
NL(I)
I is the line number.
NLE(I,K),NLP(I,K)
I is the line number. K is the segment number of a line.

Format: (40I1)
(20I4)
(10(I4,I2))

BLOCK.DAT is a control data file for water balance quantification in each block. LBL(I) shows a block label of each element. NL(I) is the number of segments consisting line I. NLE(I,K) is the element number at which segment K of line I touches. NLP(I,K) indicates position of the side which is defined as follows.

```
        1
    +------+
    I      I
  4 I      I 2
    +------+
       3
```

(17) Q3PSIM2.PAR

Variables: TITLE
NP, NE, NBAND, IDENT, NSTEPS, IROW, JCOL
DT, X1, Y1
NC(1), NC(2)
KQIN, KHOUT, KHIN, IPP, KPRI
NWEL, IHO
VIND
NBK, NLL
NPRINT
RRR

Format: (A32)
(7I5)
(3F10.5)
(2I5)
(4I1,I5)
(2I5)
(F10.5)
(2I5)
(I4)
(F5.2)

Q3PSIM2.PAR has various parameters for the model control. Its data sequence is shown in Figure 3.16. Meanings of the variables are as follows:

TITLE: Title of the simulation.
NP : Number of nodes in the modeled domain.
NE : Number of elements in the modeled domain.
NBAND: Band width for finite-element matrix.

IDENT: Type of analysis

- 1: horizontal 2-D 1 aquifer
- 2: quasi 3-D 1 aquifer
- 3: quasi 3-D 2 aquifers

NSTEP: Number of time-steps.

IROW : Number of elements in y-direction.

JCOL : Number of elements in x-direction.

DT : Duration of one time-step (day).

X1 : Grid spacing in x-direction (m).

Y1 : Grid spacing in y-direction (m).

NC(1): Number of constant-head nodes in 1st aquifer.

NC(2): Number of constant-head nodes in 2nd aquifer.

KQIN : Option for type of simulation (1: steady-state, 2: nonsteady-state).

KHOUT: Option for generating a file of simulated piezometric heads (1: last time-step, 2: every time-step).

KHIN : Option for file type of initial piezometric heads (0: formatted, 1: unformatted).

IPP : Option for printing input data list (0: do not print, 1: print).

KPRI : Number of time-steps in which simulated piezometric maps to be printed.

NWEL : Number of observation points.

IHO : Option for printing actual piezometric changes (0: data not available, 1: print).

VIND : Spacing for printing simulated piezometric changes.

NBK : Number of blocks for quantifying water balance.

NLL : Number of lines for quantifying water balance.

NPRI : The number of time-step in which simulated piezometric heads to be printed.

RRR : Magnification of recharge intensity.

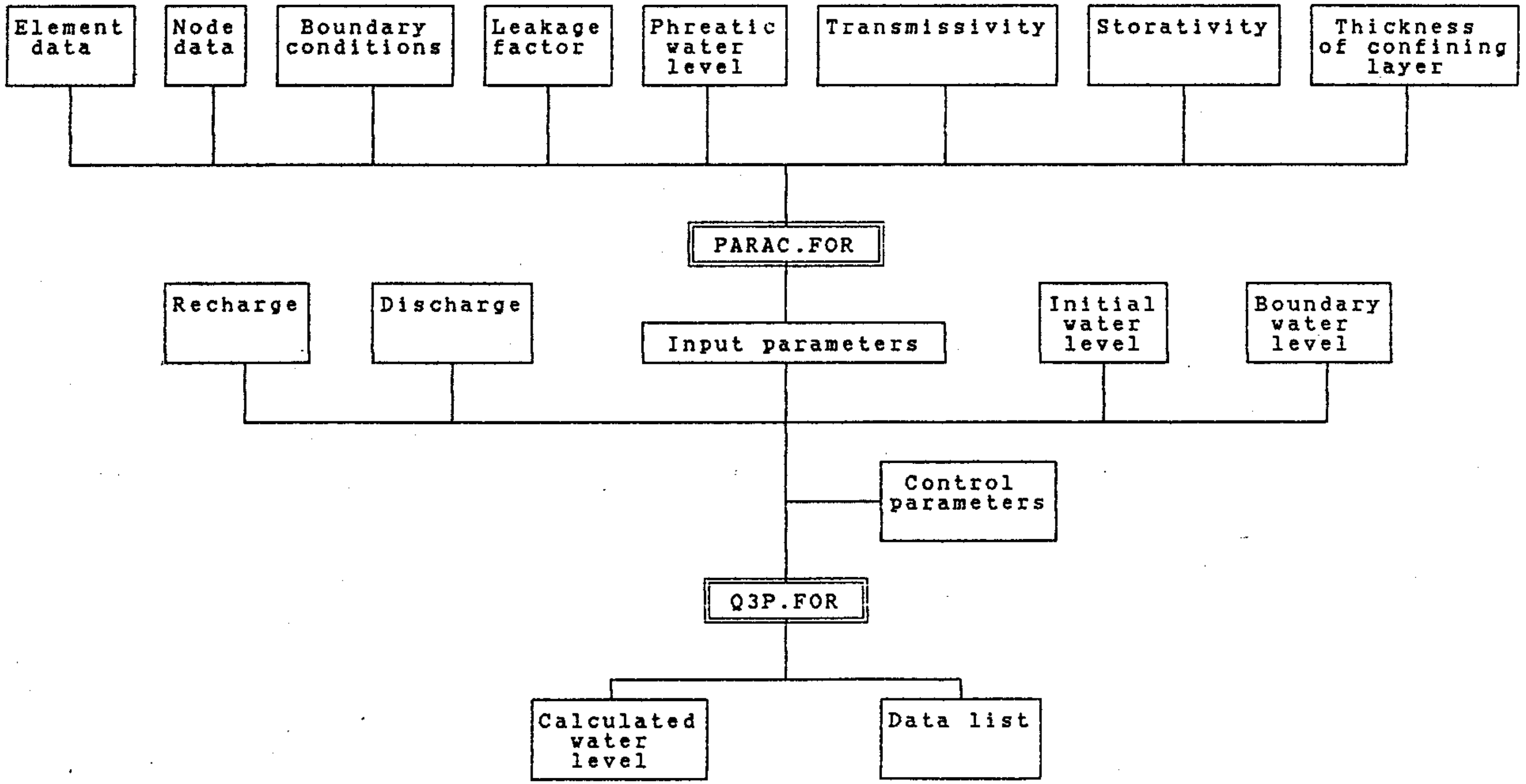
```
                                                                                                      1         1
   0        1         2         3         4         5         6         7         8         9         0         1
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
 1|   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20   0   0   0   0   0   0   0   0| 1
 2|  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42   0  43  44  45   0   0| 2
 3|  46  47  48  49  50  51  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67   0  68  69  70   0   0| 3
 4|  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91  92  93  94  95   0   0   0| 4
 5|  96  97  98  99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120   0   0   0| 5
 6| 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145   0   0   0| 6
 7| 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169   0   0   0   0| 7
 8| 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193   0   0   0   0| 8
 9|   0 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215   0   0   0   0   0| 9
10|   0   0 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236   0   0   0   0   0| 10
11|   0   0 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257   0   0   0   0   0| 11
12|   0   0   0 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277   0   0   0   0   0| 12
13|   0   0   0 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297   0   0   0   0   0| 13
14|   0   0   0   0 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316   0   0   0   0   0| 14
15|   0   0   0   0 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335   0   0   0   0   0| 15
16|   0   0   0   0   0 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353   0   0   0   0   0| 16
17|   0   0   0   0   0 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371   0   0   0   0   0| 17
18|   0   0   0   0   0 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389   0   0   0   0   0| 18
19|   0   0   0   0   0 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408   0   0   0   0| 19
20|   0   0   0   0 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428   0   0   0   0| 20
21|   0   0 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451   0   0   0| 21
22|   0 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475   0   0   0| 22
23| 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499   0   0   0   0| 23
24| 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522   0   0   0   0   0| 24
25| 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543   0   0   0   0   0   0   0| 25
26| 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564   0   0   0   0   0   0   0| 26
27| 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584   0   0   0   0   0   0   0   0| 27
28| 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604   0   0   0   0   0   0   0   0| 28
29| 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624   0   0   0   0   0   0   0   0| 29
30| 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644   0   0   0   0   0   0   0   0| 30
31| 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664   0   0   0   0   0   0   0   0| 31
32| 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685   0   0   0   0   0   0   0| 32
33| 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707   0   0   0   0   0   0| 33
34| 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730   0   0   0   0   0| 34
35| 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754   0   0   0   0| 35
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
   0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                      1         1
```

Figure 3.4 ELE.DAT for the Metro Manila Groundwater Basin Model

```
                                                                                                      1         1
   0        1         2         3         4         5         6         7         8         9         0         1
   12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456
 1    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21   0   0   0   0   0   0   0   0  1
 2   22  23  24  25  26  27  28  29  30  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48   0   0  2
 3   49  50  51  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71  72  73  74  75   0   0  3
 4   76  77  78  79  80  81  82  83  84  85  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100 101 102   0   0  4
 5  103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128   0   0   0  5
 6  129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154   0   0   0  6
 7  155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180   0   0   0  7
 8  181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205   0   0   0   0  8
 9  206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230   0   0   0   0  9
10    0 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253   0   0   0   0   0 10
11    0   0 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275   0   0   0   0   0 11
12    0   0 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297   0   0   0   0   0 12
13    0   0   0 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318   0   0   0   0   0 13
14    0   0   0 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339   0   0   0   0   0 14
15    0   0   0   0 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359   0   0   0   0   0 15
16    0   0   0   0 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379   0   0   0   0   0 16
17    0   0   0   0   0 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398   0   0   0   0   0 17
18    0   0   0   0   0 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417   0   0   0   0   0 18
19    0   0   0   0   0 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437   0   0   0   0 19
20    0   0   0   0 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458   0   0   0   0 20
21    0   0 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482   0   0   0 21
22    0 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507   0   0   0 22
23  508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533   0   0   0 23
24  534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558   0   0   0   0 24
25  559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582   0   0   0   0   0 25
26  583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604   0   0   0   0   0   0   0 26
27  605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626   0   0   0   0   0   0   0 27
28  627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647   0   0   0   0   0   0   0   0 28
29  648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668   0   0   0   0   0   0   0   0 29
30  669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689   0   0   0   0   0   0   0   0 30
31  690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710   0   0   0   0   0   0   0   0 31
32  711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732   0   0   0   0   0   0   0 32
33  733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755   0   0   0   0   0   0 33
34  756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779   0   0   0   0   0 34
35  780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804   0   0   0   0 35
36  805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829   0   0   0   0 36

   12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456
   0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                      1         1
```

Figure 3.5 NOD.DAT for the Metro Manila Groundwater Basin Model



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.6
Simplified flow chart of the Quasi Three-Dimensional FEM Flow Model (Q3P)

```
                                                                                                      1         1         1
   0        1         2         3         4         5         6         7         8         9         0         1         2
   12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678
   --------------------------------------------------------------------------------------------------------------------------------
 1|  22  23   2   1  23  24   3   2  24  25   4   3  25  26   5   4  26  27   6   5  27  28   7   6  28  29   8   7  29  30   9   8|  1
 2|  30  31  10   9  31  32  11  10  32  33  12  11  33  34  13  12  34  35  14  13  35  36  15  14  36  37  16  15  37  38  17  16|  2
 3|  38  39  18  17  39  40  19  18  40  41  20  19  41  42  21  20  49  50  23  22  50  51  24  23  51  52  25  24  52  53  26  25|  3
 4|  53  54  27  26  54  55  28  27  55  56  29  28  56  57  30  29  57  58  31  30  58  59  32  31  59  60  33  32  60  61  34  33|  4
 5|  61  62  35  34  62  63  36  35  63  64  37  36  64  65  38  37  65  66  39  38  66  67  40  39  67  68  41  40  68  69  42  41|  5
 6|  69  70  43  42  70  71  44  43  72  73  46  45  73  74  47  46  74  75  48  47  76  77  50  49  77  78  51  50  78  79  52  51|  6
 7|  79  80  53  52  80  81  54  53  81  82  55  54  82  83  56  55  83  84  57  56  84  85  58  57  85  86  59  58  86  87  60  59|  7
 8|  87  88  61  60  88  89  62  61  89  90  63  62  90  91  64  63  91  92  65  64  92  93  66  65  93  94  67  66  94  95  68  67|  8
 9|  95  96  69  68  96  97  70  69  97  98  71  70  99 100  73  72 100 101  74  73 101 102  75  74 103 104  77  76 104 105  78  77|  9
10| 105 106  79  78 106 107  80  79 107 108  81  80 108 109  82  81 109 110  83  82 110 111  84  83 111 112  85  84 112 113  86  85| 10
11| 113 114  87  86 114 115  88  87 115 116  89  88 116 117  90  89 117 118  91  90 118 119  92  91 119 120  93  92 120 121  94  93| 11
12| 121 122  95  94 122 123  96  95 123 124  97  96 124 125  98  97 125 126  99  98 126 127 100  99 127 128 101 100 129 130 104 103| 12
13| 130 131 105 104 131 132 106 105 132 133 107 106 133 134 108 107 134 135 109 108 135 136 110 109 136 137 111 110 137 138 112 111| 13
14| 138 139 113 112 139 140 114 113 140 141 115 114 141 142 116 115 142 143 117 116 143 144 118 117 144 145 119 118 145 146 120 119| 14
15| 146 147 121 120 147 148 122 121 148 149 123 122 149 150 124 123 150 151 125 124 151 152 126 125 152 153 127 126 153 154 128 127| 15
16| 155 156 130 129 156 157 131 130 157 158 132 131 158 159 133 132 159 160 134 133 160 161 135 134 161 162 136 135 162 163 137 136| 16
17| 163 164 138 137 164 165 139 138 165 166 140 139 166 167 141 140 167 168 142 141 168 169 143 142 169 170 144 143 170 171 145 144| 17
18| 171 172 146 145 172 173 147 146 173 174 148 147 174 175 149 148 175 176 150 149 176 177 151 150 177 178 152 151 178 179 153 152| 18
19| 179 180 154 153 181 182 156 155 182 183 157 156 183 184 158 157 184 185 159 158 185 186 160 159 186 187 161 160 187 188 162 161| 19
20| 188 189 163 162 189 190 164 163 190 191 165 164 191 192 166 165 192 193 167 166 193 194 168 167 194 195 169 168 195 196 170 169| 20
21| 196 197 171 170 197 198 172 171 198 199 173 172 199 200 174 173 200 201 175 174 201 202 176 175 202 203 177 176 203 204 178 177| 21
22| 204 205 179 178 206 207 182 181 207 208 183 182 208 209 184 183 209 210 185 184 210 211 186 185 211 212 187 186 212 213 188 187| 22
23| 213 214 189 188 214 215 190 189 215 216 191 190 216 217 192 191 217 218 193 192 218 219 194 193 219 220 195 194 220 221 196 195| 23
24| 221 222 197 196 222 223 198 197 223 224 199 198 224 225 200 199 225 226 201 200 226 227 202 201 227 228 203 202 228 229 204 203| 24
25| 229 230 205 204 231 232 208 207 232 233 209 208 233 234 210 209 234 235 211 210 235 236 212 211 236 237 213 212 237 238 214 213| 25
26| 238 239 215 214 239 240 216 215 240 241 217 216 241 242 218 217 242 243 219 218 243 244 220 219 244 245 221 220 245 246 222 221| 26
27| 246 247 223 222 247 248 224 223 248 249 225 224 249 250 226 225 250 251 227 226 251 252 228 227 252 253 229 228 254 255 233 232| 27
28| 255 256 234 233 256 257 235 234 257 258 236 235 258 259 237 236 259 260 238 237 260 261 239 238 261 262 240 239 262 263 241 240| 28
29| 263 264 242 241 264 265 243 242 265 266 244 243 266 267 245 244 267 268 246 245 268 269 247 246 269 270 248 247 270 271 249 248| 29
30| 271 272 250 249 272 273 251 250 273 274 252 251 274 275 253 252 276 277 255 254 277 278 256 255 278 279 257 256 279 280 258 257| 30
31| 280 281 259 258 281 282 260 259 282 283 261 260 283 284 262 261 284 285 263 262 285 286 264 263 286 287 265 264 287 288 266 265| 31
32| 288 289 267 266 289 290 268 267 290 291 269 268 291 292 270 269 292 293 271 270 293 294 272 271 294 295 273 272 295 296 274 273| 32
33| 296 297 275 274 298 299 278 277 299 300 279 278 300 301 280 279 301 302 281 280 302 303 282 281 303 304 283 282 304 305 284 283| 33
34| 305 306 285 284 306 307 286 285 307 308 287 286 308 309 288 287 309 310 289 288 310 311 290 289 311 312 291 290 312 313 292 291| 34
35| 313 314 293 292 314 315 294 293 315 316 295 294 316 317 296 295 317 318 297 296 319 320 299 298 320 321 300 299 321 322 301 300| 35
36| 322 323 302 301 323 324 303 302 324 325 304 303 325 326 305 304 326 327 306 305 327 328 307 306 328 329 308 307 329 330 309 308| 36
37| 330 331 310 309 331 332 311 310 332 333 312 311 333 334 313 312 334 335 314 313 335 336 315 314 336 337 316 315 337 338 317 316| 37
38| 338 339 318 317 340 341 321 320 341 342 322 321 342 343 323 322 343 344 324 323 344 345 325 324 345 346 326 325 346 347 327 326| 38
39| 347 348 328 327 348 349 329 328 349 350 330 329 350 351 331 330 351 352 332 331 352 353 333 332 353 354 334 333 354 355 335 334| 39
40| 355 356 336 335 356 357 337 336 357 358 338 337 358 359 339 338 360 361 341 340 361 362 342 341 362 363 343 342 363 364 344 343| 40
41| 364 365 345 344 365 366 346 345 366 367 347 346 367 368 348 347 368 369 349 348 369 370 350 349 370 371 351 350 371 372 352 351| 41
42| 372 373 353 352 373 374 354 353 374 375 355 354 375 376 356 355 376 377 357 356 377 378 358 357 378 379 359 358 380 381 362 361| 42
43| 381 382 363 362 382 383 364 363 383 384 365 364 384 385 366 365 385 386 367 366 386 387 368 367 387 388 369 368 388 389 370 369| 43
44| 389 390 371 370 390 391 372 371 391 392 373 372 392 393 374 373 393 394 375 374 394 395 376 375 395 396 377 376 396 397 378 377| 44
45| 397 398 379 378 399 400 381 380 400 401 382 381 401 402 383 382 402 403 384 383 403 404 385 384 404 405 386 385 405 406 387 386| 45
46| 406 407 388 387 407 408 389 388 408 409 390 389 409 410 391 390 410 411 392 391 411 412 393 392 412 413 394 393 413 414 395 394| 46
47| 414 415 396 395 415 416 397 396 416 417 398 397 418 419 400 399 419 420 401 400 420 421 402 401 421 422 403 402 422 423 404 403| 47
                                                                                                                    (continued...)
```

Figure 3.7(1)   NOP.DAT for the Metro Manila Groundwater basin Model (1)

```
48  423 424 405 404 424 425 406 405 425 426 407 406 426 427 408 407 427 428 409 408 428 429 410 409 429 430 411 410 430 431 412 411  48
49  431 432 413 412 432 433 414 413 433 434 415 414 434 435 416 415 435 436 417 416 439 440 419 418 440 441 420 419 441 442 421 420  49
50  442 443 422 421 443 444 423 422 444 445 424 423 445 446 425 424 446 447 426 425 447 448 427 426 448 449 428 427 449 450 429 428  50
51  450 451 430 429 451 452 431 430 452 453 432 431 453 454 433 432 454 455 434 433 455 456 435 434 456 457 436 435 457 458 437 436  51
52  461 462 439 438 462 463 440 439 463 464 441 440 464 465 442 441 465 466 443 442 466 467 444 443 467 468 445 444 468 469 446 445  52
53  469 470 447 446 470 471 448 447 471 472 449 448 472 473 450 449 473 474 451 450 474 475 452 451 475 476 453 452 476 477 454 453  53
54  477 478 455 454 478 479 456 455 479 480 457 456 480 481 458 457 484 485 460 459 485 486 461 460 486 487 462 461 487 488 463 462  54
55  488 489 464 463 489 490 465 464 490 491 466 465 491 492 467 466 492 493 468 467 493 494 469 468 494 495 470 469 495 496 471 470  55
56  496 497 472 471 497 498 473 472 498 499 474 473 499 500 475 474 500 501 476 475 501 502 477 476 502 503 478 477 503 504 479 478  56
57  504 505 480 479 505 506 481 480 506 507 482 481 509 510 484 483 510 511 485 484 511 512 486 485 512 513 487 486 513 514 488 487  57
58  514 515 489 488 515 516 490 489 516 517 491 490 517 518 492 491 518 519 493 492 519 520 494 493 520 521 495 494 521 522 496 495  58
59  522 523 497 496 523 524 498 497 524 525 499 498 525 526 500 499 526 527 501 500 527 528 502 501 528 529 503 502 529 530 504 503  59
60  530 531 505 504 531 532 506 505 532 533 507 506 534 535 509 508 535 536 510 509 536 537 511 510 537 538 512 511 538 539 513 512  60
61  539 540 514 513 540 541 515 514 541 542 516 515 542 543 517 516 543 544 518 517 544 545 519 518 545 546 520 519 546 547 521 520  61
62  547 548 522 521 548 549 523 522 549 550 524 523 550 551 525 524 551 552 526 525 552 553 527 526 553 554 528 527 554 555 529 528  62
63  555 556 530 529 556 557 531 530 557 558 532 531 559 560 535 534 560 561 536 535 561 562 537 536 562 563 538 537 563 564 539 538  63
64  564 565 540 539 565 566 541 540 566 567 542 541 567 568 543 542 568 569 544 543 569 570 545 544 570 571 546 545 571 572 547 546  64
65  572 573 548 547 573 574 549 548 574 575 550 549 575 576 551 550 576 577 552 551 577 578 553 552 578 579 554 553 579 580 555 554  65
66  580 581 556 555 581 582 557 556 583 584 560 559 584 585 561 560 585 586 562 561 586 587 563 562 587 588 564 563 588 589 565 564  66
67  589 590 566 565 590 591 567 566 591 592 568 567 592 593 569 568 593 594 570 569 594 595 571 570 595 596 572 571 596 597 573 572  67
68  597 598 574 573 598 599 575 574 599 600 576 575 600 601 577 576 601 602 578 577 602 603 579 578 603 604 580 579 605 606 584 583  68
69  606 607 585 584 607 608 586 585 608 609 587 586 609 610 588 587 610 611 589 588 611 612 590 589 612 613 591 590 613 614 592 591  69
70  614 615 593 592 615 616 594 593 616 617 595 594 617 618 596 595 618 619 597 596 619 620 598 597 620 621 599 598 621 622 600 599  70
71  622 623 601 600 623 624 602 601 624 625 603 602 625 626 604 603 627 628 606 605 628 629 607 606 629 630 608 607 630 631 609 608  71
72  631 632 610 609 632 633 611 610 633 634 612 611 634 635 613 612 635 636 614 613 636 637 615 614 637 638 616 615 638 639 617 616  72
73  639 640 618 617 640 641 619 618 641 642 620 619 642 643 621 620 643 644 622 621 644 645 623 622 645 646 624 623 646 647 625 624  73
74  648 649 628 627 649 650 629 628 650 651 630 629 651 652 631 630 652 653 632 631 653 654 633 632 654 655 634 633 655 656 635 634  74
75  656 657 636 635 657 658 637 636 658 659 638 637 659 660 639 638 660 661 640 639 661 662 641 640 662 663 642 641 663 664 643 642  75
76  664 665 644 643 665 666 645 644 666 667 646 645 667 668 647 646 669 670 649 648 670 671 650 649 671 672 651 650 672 673 652 651  76
77  673 674 653 652 674 675 654 653 675 676 655 654 676 677 656 655 677 678 657 656 678 679 658 657 679 680 659 658 680 681 660 659  77
78  681 682 661 660 682 683 662 661 683 684 663 662 684 685 664 663 685 686 665 664 686 687 666 665 687 688 667 666 688 689 668 667  78
79  690 691 670 669 691 692 671 670 692 693 672 671 693 694 673 672 694 695 674 673 695 696 675 674 696 697 676 675 697 698 677 676  79
80  698 699 678 677 699 700 679 678 700 701 680 679 701 702 681 680 702 703 682 681 703 704 683 682 704 705 684 683 705 706 685 684  80
81  706 707 686 685 707 708 687 686 708 709 688 687 709 710 689 688 711 712 691 690 712 713 692 691 713 714 693 692 714 715 694 693  81
82  715 716 695 694 716 717 696 695 717 718 697 696 718 719 698 697 719 720 699 698 720 721 700 699 721 722 701 700 722 723 702 701  82
83  723 724 703 702 724 725 704 703 725 726 705 704 726 727 706 705 727 728 707 706 728 729 708 707 729 730 709 708 730 731 710 709  83
84  733 734 712 711 734 735 713 712 735 736 714 713 736 737 715 714 737 738 716 715 738 739 717 716 739 740 718 717 740 741 719 718  84
85  741 742 720 719 742 743 721 720 743 744 722 721 744 745 723 722 745 746 724 723 746 747 725 724 747 748 726 725 748 749 727 726  85
86  749 750 728 727 750 751 729 728 751 752 730 729 752 753 731 730 753 754 732 731 756 757 734 733 757 758 735 734 758 759 736 735  86
87  759 760 737 736 760 761 738 737 761 762 739 738 762 763 740 739 763 764 741 740 764 765 742 741 765 766 743 742 766 767 744 743  87
88  767 768 745 744 768 769 746 745 769 770 747 746 770 771 748 747 771 772 749 748 772 773 750 749 773 774 751 750 774 775 752 751  88
89  775 776 753 752 776 777 754 753 777 778 755 754 780 781 757 756 781 782 758 757 782 783 759 758 783 784 760 759 784 785 761 760  89
90  785 786 762 761 786 787 763 762 787 788 764 763 788 789 765 764 789 790 766 765 790 791 767 766 791 792 768 767 792 793 769 768  90
91  793 794 770 769 794 795 771 770 795 796 772 771 796 797 773 772 797 798 774 773 798 799 775 774 799 800 776 775 800 801 777 776  91
92  801 802 778 777 802 803 779 778 805 806 781 780 806 807 782 781 807 808 783 782 808 809 784 783 809 810 785 784 810 811 786 785  92
93  811 812 787 786 812 813 788 787 813 814 789 788 814 815 790 789 815 816 791 790 816 817 792 791 817 818 793 792 818 819 794 793  93
94  819 820 795 794 820 821 796 795 821 822 797 796 822 823 798 797 823 824 799 798 824 825 800 799 825 826 801 800 826 827 802 801  94
95  827 828 803 802 828 829 804 803                                                                                                    95

   12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678
   0        1         2         3         4         5         6         7         8         9         0         1         2
```

Figure 3.7(2)   NOP.DAT for the Metro Manila Groundwater basin Model (2)

```
0        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

  48 206 207 231 232 254 276 277 298 319 320 340 360 361 380 399 418 439 438 461
 460 459 484 483 509 508 829 804 803 779 778 755 754 732 731 710 689 668 647 625
 626 604 580 581 582 557 558 532 533
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00   (Continued..)

0        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 3.8 HBOUND.DAT for the Metro Manila Groundwater Basin Model

```
    0        1         2
    1234567890123456789012345678

 1  0000000000000011111199999999  1
 2  0000000000000011111111911199  2
 3  0000000000000001111111911199  3
 4  0000000000000001111111100999  4
 5  0000000000000001111111100999  5
 6  0000000000000001111110000999  6
 7  0000000000000000111000019999  7
 8  0000000000000000011000019999  8
 9  9000000000000000011000199999  9
10  9900000000000000000000199999 10
11  9900000000000000000000199999 11
12  9990000000000000000000199999 12
13  9990000000000000000000199999 13
14  9999000000000000000000099999 14
15  9999000000000000000000199999 15
16  9999900000000000000000099999 16
17  9999900000000000000000099999 17
18  9999900000000000000000099999 18
19  9999900000000000000000009999 19
20  9999000000000000000000009999 20
21  9900000000000000000000000999 21
22  9000000000000000000000000999 22
23  0000000000000000000000009999 23
24  0000000000000000000000099999 24
25  0000000000000000000009999999 25
26  0000000000000000000009999999 26
27  0000000000000000000099999999 27
28  0000000000000000000099999999 28
29  0000000000000000000099999999 29
30  0000000000000000000099999999 30
31  0000000000000000000099999999 31
32  0000000000111100000009999999 32
33  0000011111111100000000999999 33
34  0111111111111100000000099999 34
35  1111111111111100000000009999 35

    1234567890123456789012345678
    0        1         2
```

Figure 3.9   KYOKAI.LAB for the Metro Manila Groundwater basin Model

```
                                                                                                      1         1
   0        1         2         3         4         5         6         7         8         9         0         1
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
 1  100 100 100 100 100 100  50  45  40  35  30  25  25  50  50  50  50  50  50  5099999999999999999999999999999999  1
 2  100  55  55  55  55  55  50  45  40  35  30  25  25  50  50  50  50  50  50  50  50  509999 150 150 15099999999  2
 3  100  55  55  55  55  55  55  50  45  40  35  30  25  50  50  50  50  50  50  50  50  509999 150 150 15099999999  3
 4  100  55  55  55  55  55  55  52  45  40  35  35  35  50  50  50  50  50  50  50  50  50 150 150 150999999999999  4
 5  100  55  55  55  55  60  60  55  45  40  35  35  40  50  50  75  70  65  50  50  50  75 160 155 150999999999999  5
 6  100  50  55  55  55  60  65  60  50  40  30  30  35  40  60  95  95  90  50  50  50  65  80 125 140999999999999  6
 7   50  50  45  40  40  45  50  70  84  30  28  30  35  40  50 145 190 120  60  50  65  90  63 1209999999999999999  7
 8   50  20  50  30  30  30  27  25  56  32  29  35  40  45  53  95 160 110  75  55  70 315 120 1109999999999999999  8
 9 9999  20  20  50  30  30  32  21  25  90  30  40  50  60  75 105 120 110  85  70 306 305 11099999999999999999999  9
10 99999999  20  50  30  30  30  25  20  20  15  70  90  85 105 110 115  90  80 110 110  70  5099999999999999999999 10
11 99999999  20  20  50  30  25  20  20  20  18  65 210  90 100 105  90  80  90 170  50  35  2099999999999999999999 11
12 999999999999  20  50  30  25  20  17  20  20  50 270  12  50  75  80  90 100 150  70  30  2099999999999999999999 12
13 999999999999  20  20  50  30  25  20  25  20  11 250  40  45  55  65  75 170 200 100  80  2099999999999999999999 13
14 9999999999999999  20  50  30  30  30  25  25  22  40  30  40  60  90 170 210 180 140  75  2599999999999999999999 14
15 9999999999999999  20  20  50  30  30  30  25  25  35  35  40  60  95  95 140 130 120  90  3099999999999999999999 15
16 99999999999999999999  20  50  30  25  20  15  20  30  35  40  60  80  20  60  80 130 150  6099999999999999999999 16
17 99999999999999999999  20  50  25  20  14   8  15  20  30  40  95  40  15  10  60  70 220 20099999999999999999999 17
18 99999999999999999999  20  50  30  30  20   5  30  55  50  25  40  30  20  15  60  80 164 23299999999999999999999 18
19 99999999999999999999  20  50  35  40  40  60 110 120  75  30  10  20  15  12  55  70 100 120  409999999999999999 19
20 9999999999999999  20  20  50  35  40  50 120 190 100  70  45  53  70  80  75  75  75  70  80  509999999999999999 20
21 99999999  20  20  20  50  35  40  45  80 140 180  85  60  40  45 100 155  90  85  80  70  60  50  20999999999999 21
22 9999  20  20  50  50  35  40  40  60 110 140 160 150  55  35  40 120  90  85  75  70  60  55  50  20999999999999 22
23  100  20  20  45  40  40  40  45  80 120 130  75 195  60  30  21 130  65  70  75  70  65 300 3009999999999999999 23
24  100 100  60 110  25  40  40  60  90 140 120  80  75  40  25  15  85  80  80 250 300 300 30099999999999999999999 24
25  100 100  80 120  25  35  42  70 110 180 110  85  90  55  30  25  80  85  90 250 3009999999999999999999999999999 25
26  100  60  75  70  55  35  40  60 121 180  90  80 110 170  60  30  70  85 250 300 3009999999999999999999999999999 26
27  100 130 130 125  90  16  59  70 210 200  90  85  95 120  70  23 150 210 250 30099999999999999999999999999999999 27
28  100 180 195 220 175 100  90  80 110  95  90  85  85  90  95 130 210 220 250 30099999999999999999999999999999999 28
29  100 185 240 210 170 125 100  90  90  90  80  80  80  85  90 150 220 220 250 30099999999999999999999999999999999 29
30  170 170 236 200 140 100  95  90  80 100 100 100  80  90 120 250 220 220 250 30099999999999999999999999999999999 30
31  120 120 110  95  90  85  80  75 100 100 100 100  80  90 120 270 220 220 250 30099999999999999999999999999999999 31
32   90  90  90  90  85  80  75 100 100 100 100 100  75  85  95 210 220 220 250 300 3009999999999999999999999999999 32
33   85  85  85  80  80  75 100 100 100 100 100 100 100  80  90 140 220 220 220 250 300 300999999999999999999999999 33
34   75  75 100 100 100 100 100 100 100 100 100 100 100 100  80  90 160 220 220 220 250 300 30099999999999999999999 34
35  100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 200 220 220 250 300 300 3009999999999999999 35
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
   0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                      1         1
```

Figure 3.10 T_03.IND for the Metro Manila Groundwater basin Model

```
                                                                                                       1         1
   0        1         2         3         4         5         6         7         8         9         0         1
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
 1   26  27  28  29  30  31  32  33  33  33  33  31  33  27  19  17  15  14  13  1399999999999999999999999999999999  1
 2   25  27  27  26  29  30  31  31  32  32  33  31  32  30  24  18  15  15  13  13  13  139999  10   9   799999999  2
 3   25  25  25  24  26  30  31  31  31  31  32  31  30  31  28  19  16  15  14  14  13  139999  12  10   999999999  3
 4   25  24  24  23  23  27  30  31  30  31  31  30  28  32  31  24  16  16  15  15  14  15  12  13  13999999999999  4
 5   24  23  23  22  22  22  28  30  28  30  31  31  27  30  32  27  17  16  15  15  15  25  16  15  15999999999999  5
 6   22  22  22  22  22  22  24  28  25  21  30  33  25  24  30  30  19  16  16  16  16  26  18  16  16999999999999  6
 7   21  21  21  21  21  21  22  22  27  13  27  33  28  21  23  27  18  16  16  17  18  24  19  199999999999999999  7
 8   22  23  22  22  21  21  22  19  21  31  19  30  26  20  17  18  17  17  18  21  25  22  22  219999999999999999  8
 9 9999  24  23  23  22  20  21  17  16  25  21  22  23  17  16  16  17  24  23  25  24  21  2599999999999999999999  9
10 99999999  25  24  24  21  19  18  16  15  22  17  16  16  15  16  17  25  27  25  23  22  2799999999999999999999 10
11 99999999  27  27  27  25  24  22  22  18  16  28  17  15  14  15  16  22  31  24  23  24  2999999999999999999999 11
12 999999999999  30  30  30  30  33  41  26  17  19  18  13  13  13  16  22  31  22  17  24  3099999999999999999999 12
13 999999999999  31  31  31  31  34  34  30  23  18  16  11  10  12  15  24  25  16  16  26  3499999999999999999999 13
14 9999999999999999  33  33  33  33  33  31  24  17  11  10  10  12  16  34  23  15  21  30  3899999999999999999999 14
15 9999999999999999  33  33  33  33  33  31  25  18  13  11  11  15  21  36  25  16  27  38  4399999999999999999999 15
16 99999999999999999999  33  33  33  32  31  27  21  16  16  15  18  25  28  24  18  31  39  5199999999999999999999 16
17 99999999999999999999  33  33  33  33  33  28  25  25  21  19  16  31  37  27  23  19  18  3699999999999999999999 17
18 99999999999999999999  33  33  33  33  33  28  28  33  25  21  15  21  28  28  32  22  16  2199999999999999999999 18
19 99999999999999999999  33  33  33  33  32  31  36  46  28  22  15  15  27  27  48  27  21  16  279999999999999999 19
20 9999999999999999  33  33  33  33  33  33  31  30  27  28  22  16  15  27  27  30  28  24  19  259999999999999999 20
21 99999999  29  30  33  33  33  33  33  33  31  27  13  18  24  18  15  25  26  26  27  24  22  25  27999999999999 21
22 9999  28  29  30  31  33  33  33  33  32  30  25  15  12  19  19  21  24  25  26  27  25  23  25  28999999999999 22
23   27  28  28  28  31  32  33  32  31  31  31  28  18  15  23  18  12  25  26  27  27  25  24  249999999999999999 23
24   27  27  28  28  30  33  33  32  31  31  25   7  16  25  22  16  15  27  27  27  27  25  2499999999999999999999 24
25   27  28  28  27  28  30  31  31  30  27  10  15  28  24  22  21  25  30  28  28  279999999999999999999999999999 25
26   27  28  30  33  28  24  22  24  22  13  10  30  30  19  23  15  39  33  30  29  289999999999999999999999999999 26
27   27  28  43  40  27  10  22  11  10  10  18  31  27  19  23  33  43  42  39  3099999999999999999999999999999999 27
28   27  53  43  39  23  10  13  10  11  13  28  30  26  19  22  39  42  42  36  3099999999999999999999999999999999 28
29   24  42  27  22  19  15  19  15  16  23  30  29  27  21  30  48  45  43  34  3099999999999999999999999999999999 29
30   18  12  16  21  21  20  23  22  25  30  31  29  25  22  31  49  46  45  34  3099999999999999999999999999999999 30
31   10  15  19  22  23  25  25  27  30  30  31  28  26  22  28  37  39  42  33  3099999999999999999999999999999999 31
32   18  19  22  24  25  26  28  31  30  31  31  29  27  23  25  28  30  33  31  30  309999999999999999999999999999 32
33   19  22  24  25  27  28  30  31  31  31  32  30  28  33  29  26  34  34  33  33  31  30999999999999999999999999 33
34   22  24  25  26  28  30  31  32  31  32  33  31  29  39  39  34  36  37  36  34  32  31  3099999999999999999999 34
35   24  25  27  28  30  31  31  32  32  33  33  31  31  40  40  37  39  39  39  37  34  33  31  309999999999999999 35
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
   0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                       1         1
```

Figure 3.11 B. IND for the Metro Manila Groundwater basin Model

```
                                                                                                      1         1
   0        1         2         3         4         5         6         7         8         9         0         1
   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
 1|   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   599999999999999999999999999999999| 1
 2|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  13  13  13  13  139999  13  13  1399999999| 2
 3|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  13  13  13  139999  13  13  1399999999| 3
 4|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  13  13  13  13  13  20  20999999999999| 4
 5|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  13  13  13  13  13  20  20999999999999| 5
 6|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  13  13  13  20  20  20  20999999999999| 6
 7|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  13  20  20  20  20  139999999999999999| 7
 8|   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  20  20  20  20  139999999999999999| 8
 9|9999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  13  13  20  20  20  1399999999999999999999| 9
10|99999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  1399999999999999999999|10
11|99999999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  1399999999999999999999|11
12|999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  1399999999999999999999|12
13|999999999999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  1399999999999999999999|13
14|9999999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  2099999999999999999999|14
15|9999999999999999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  1399999999999999999999|15
16|99999999999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  2099999999999999999999|16
17|99999999999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  2099999999999999999999|17
18|99999999999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  2099999999999999999999|18
19|99999999999999999999   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  209999999999999999|19
20|9999999999999999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  209999999999999999|20
21|99999999   0   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20999999999999|21
22|9999   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20999999999999|22
23|   0   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   0   09999999999999999|23
24|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   0   0   099999999999999999999|24
25|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   09999999999999999999999999999|25
26|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   0   09999999999999999999999999999|26
27|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   099999999999999999999999999999999|27
28|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   099999999999999999999999999999999|28
29|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   099999999999999999999999999999999|29
30|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   099999999999999999999999999999999|30
31|   0  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20  20   099999999999999999999999999999999|31
32|   0  20  20  20  20  20  20  20  20  20  13  13  13  13  20  20  20  20  20   0   09999999999999999999999999999|32
33|   0  20  20  20  20  13  13  13  13  13  13  13  13  13  20  20  20  20  20  20   0   0999999999999999999999999|33
34|   0  13  13  13  13  13  13  13  13  13  13  13  13  13  20  20  20  20  20  20  20   0   099999999999999999999|34
35|   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   59999999999999999|35

   1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
   0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                      1         1
```

Figure 3.12 S.IND for the Metro Manila Groundwater basin Model

```
0         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234

  1.0E-1  5.0E-3  2.0E-3  1.0E-3  7.0E-4  5.0E-4  2.0E-4  1.0E-4
  7.0E-5  5.0E-5  2.0E-5  1.0E-5  7.0E-6  5.0E-6  2.0E-6  1.0E-9
AAFFFFCCCCCC3111111222222222             1    KL1
AAFFFFFFCCCC3221111111111222             2
66FFFFFFFCCC4221111111111222             3
66FFFFFFFFFF5221111111111222             4
6FFFFFFFFF885221111111111222             5
666FFFFFFF736311111111111222             6
66666FFFFF335642111111111222             7
666555A767885432111111111222             8
F844444557B86555511111111222             9
FF6455A33666434AB21111222222            10
FF866F333766334AB22222222222            11
FFFAAA367873357BB54443222222            12
FFFAAA356776657643255222222             13
FFFFAA52224A8562223633222222            14
FFFFFFAA865B76722565333222222           15
FFFFFFFFFFFB55843C5311222222            16
FFFFFFFFFFFFFA454212222222222           17
FFFFFFFFFFFF5325532332211222            18
FFFFFFFFFFFF2247422388211222            19
FFFFFFFFFF5222774234885222222           20
FFFFFFFFF53334465345AAA55444            21
FFFFFFFF5444345665 5AAAA55444           22
FFAAFFFF444446668655888844444           23
FF3147FF444446422134444444444           24
FFA857FF44423522112344444444            25
FF67775445622441112244444444            26
FFFFFF75773566422224444444444           27
FFFFFFF46A722342223444444444            28
FF6333126CC113311123444444444           29
AAA1111211118801134444444444            30
AAA3111111112321124444444444            31
AAA4111111332222234444444444            32
4444444444566633334444444444            33
444444444445AAAAAA6644444444            34
44444444444AAAAAAAA444444444            35

1234567890123456789012345678901234567890123456789012345678901234
0         1         2         3         4         5         6
```

Figure 3.13 KD_03.LAB for the Metro Manila Groundwater basin Model

```
                                                                                                       1         1
    0        1         2         3         4         5         6         7         8         9         0         1
    1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
 1 |   0   0   0   0   0   1   1   2   2   2  10  12  26  20  32  42  44  52  64  8899999999999999999999999999999999| 1
 2 |   0   1   1   0   0   1   1   2   4   6  10  16  24  24  32  37  44  56  64  86  48  389999  20  18  1899999999| 2
 3 |   0   1   1   0   0   2   2   1   2   4   8   8  20  40  49  49  56  60  72  82  26  269999  18  17  1899999999| 3
 4 |   0   0   0   1   2   2   2   1   1   3   4   8  18  35  52  51  69  80  68  69  78  60  16  14  16999999999999| 4
 5 |   0   1   2   0   2   2   2   1   2   1   4  16  20  36  35  36  52  68  68  68  66  11  10  17  18999999999999| 5
 6 |   0   0   2   2   2   2   2   1   1   1   5  16  20  22  26  29  40  50  65  58  28  10  11  18  20999999999999| 6
 7 |   0   0   0   0   1   1   1   2   2   1   6  11  17  18  28  30  40  49  60  34  14  10  12  209999999999999999| 7
 8 |   0   0   0   0   0   0   1   1   1   2   9   9  10  12  19  37  43  48  58  36   8  10  15  249999999999999999| 8
 9 |9999   0   0   0   0   0   0   0   1   1   2   4   8  11  26  34  37  51  62   8   7  10  1799999999999999999999| 9
10 |99999999   0   0   0   0   0   0   1   1   2   3  14  13  20  31  37  44  42   5  10  13  2299999999999999999999|10
11 |99999999   0   0   0   0   0   0   1   2  10  15   6   7  24  33  39  52  14   4   7  16  2799999999999999999999|11
12 |999999999999   0   0   0   0   0   0   0   2  10   8  12  16  32  42  42  10   4  11  12  3499999999999999999999|12
13 |999999999999   0   0   0   0   0   0   0   2   2   5   4   8  20  38  42   6   2   8   9  2499999999999999999999|13
14 |9999999999999999   0   0   0   0   0   2   2   2   6   2   8  27  44  16   4   8   7   7  2099999999999999999999|14
15 |9999999999999999   0   0   0   0   0   1   2   2   2   2   8  16  28  10   6   6   6   7  1199999999999999999999|15
16 |99999999999999999999   0   0   0   0   2   1   1   3   3   2  12  32  11   7   5   6   6  1299999999999999999999|16
17 |99999999999999999999   0   0   0   0   1   2   1   2   1   3   8  32   7   4   2   4   6   699999999999999999999|17
18 |99999999999999999999   0   0   0   0   0   1   1   3   3   2   4   4   4   2   2   2   2   499999999999999999999|18
19 |99999999999999999999   0   0   0   0   0   2   1   2   4  10  13   4   3   2   2   2   4   4  109999999999999999|19
20 |9999999999999999   0   0   0   0   0   0   0   2   2   4  14  16   2   1   1   2   1   0   0   09999999999999999|20
21 |99999999   0   0   0   0   0   0   0   0   0   2   3   4   9   6   1   1   0   0   0   0   0   0   0999999999999|21
22 |9999   0   0   0   0   0   0   0   0   0   0   2   3  10  10   9   1   0   0   0   0   0   0   0   0999999999999|22
23 |   0   0   0   0   0   0   0   0   0   0   0   2   3   5  12  11   1   0   0   0   0   0   0   09999999999999999|23
24 |   0   0   0   0   0   0   0   0   0   0   0   1   2   6  12  20   2   0   0   0   0   0   099999999999999999999|24
25 |   0   0   0   0   0   0   0   0   0   0   2   2   2   9  16  20   1   0   0   0   09999999999999999999999999999|25
26 |   0   0   0   0   0   0   0   0   0   1   2   2   6  10  16  12   2   0   0   0   09999999999999999999999999999|26
27 |   0   0   0   0   0   0   0   1   1   3   4   6   8  14  20   8   2   0   0   099999999999999999999999999999999|27
28 |   0   0   2   2   1   1   1   1   4   6  10  14  14  16  12   2   0   0   0   099999999999999999999999999999999|28
29 |   0   0   2   2   3   3   4   5   7  10  10  18  22  23  11   2   0   0   0   099999999999999999999999999999999|29
30 |   2   2   3   5   5   8   8   9   9  14  14  15  30  24  10   2   0   0   0   099999999999999999999999999999999|30
31 |   5   5   5   7  10  10  12  12  16  19  24  20  32  28  16   2   0   0   0   099999999999999999999999999999999|31
32 |   8  10  10  11  13  14  18  18  22  30  30  36  30  27  17   2   0   0   0   0   09999999999999999999999999999|32
33 |  12  14  15  17  17  22  27  28  32  32  36  36  41  28  15   4   0   0   0   0   0   0999999999999999999999999|33
34 |  14  16  20  24  24  30  32  35  44  52  50  48  49  32  19   6   0   0   0   0   0   0   099999999999999999999|34
35 |  20  27  28  30  35  41  42  40  40  64  68  68  59  34  19   7   1   0   0   0   0   0   0   09999999999999999|35
    1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
    0        1         2         3         4         5         6         7         8         9         0         1
                                                                                                       1         1
```

Figure 3.14   H.IND for the Metro Manila Groundwater basin Model

```
 263 1CLC                           -150.0    -50.01
 290 1QCT                            -50.0     50.01
 412 1PSG                           -100.0      0.01
 448 1MKT                           -100.0      0.01
 564 1CVC                           -100.0      0.01
 574 1PRN                           -100:0      0.01
 615 1LPS                            -50.0     50.01
QCT
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
VLZ
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
TYY
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
MKT
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
CVC
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
LPS
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
MTL
        999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99999.99999.99999:99999.99999.99999.99
        999.99999.99999.99999.99999.99999.99
```

Figure 3.15 OBSH63_2.DAT for the Metro Manila Groundwater Basin Model

```
0         1         2         3         4
12345678901234567890123456789012345678901234567

  MSA NONSTEADY-STATE,30STEPS
  829  754   30    1   30   35   28
      365.     1350.     1380.
   48   48
2211     1   ! TEI=1110     1  HITEI=2210     1
    7    1
       5.0
    2    4   !!!NBK,NLL
  30
 0.30

12345678901234567890123456789012345678901234567
0         1         2         3         4
```

Figure 3.16 Q3PSIM2.PAR for the Metro Manila Groundwater Basin Model

3.4 MODEL OPERATION

General flow of the model operation is shown in Figure 3.17. Data preparation and model calibration are the most important works for using the model.

Input data files mentioned above should be carefully prepared. Several FORTRAN programs are needed for data processing. The user should pay attention to data formats, units of values , miss-typing, file name, etc.

If the user creates/modified FORTRAN programs, the user must compile and link those programs using a FORTRAN Compiler to create executable (*.EXE) files. Then the user can run those programs. If the user uses Pro FORTRAN-77 Compiler, source programs are compiled and linked in the following manner:

1. Specify source program name as '*.FOR' ('*' is the program name).
2. Confirm 'PATH=C:\PROFORT', where Pro FORTRAN-77 Compiler exists.
3. Create *.OBJ file. Type 'F77 *' and press <ENTER>.
4 Change dirctory to PROFORT. (Type 'CD C:\PROFORT' and press <ENTER>).
5. Create *.EXE file. Type 'PROLINK C:\###*, F77LIB7B/S' and press <ENTER> (### is the subdirectory name where the source program exists).
6. Change directory to ### (Type 'CD C:\###' and press <ENTER>).
7. Find *.EXE file and run the program (Type '*' and press <ENTER>).

The study team prepared several FORTRAN programs to process and arrange data (see APPENDIX). All these programs can be run in Batch Files (*.BAT). The user is recommended to use Batch Files so as to save time and avoid mistakes during complicated operation procedure.

Some of the less reliable geohydrologic parameters are modified/identified during model calibrations. The main procedure of the model calibration is to specify boundary conditions and to identify some poor reliable hydrogeologic parameters. Generally the model is verified by the comparison of calculated piezometric heads with actual piezometric heads. Sometimes this work is repeated more than 100 times until the computed heads show a good agreement with the actual heads.

After the calibration, the model can be used to predict future piezometric heads. Based on the future groundwater use plans and future recharge estimates, several discharge data and direct recharge data are prepared using same formats as QIN_30.DAT and RIN_30.DAT. The actual piezometric heads at present are generally used as the initial heads for future simulation.

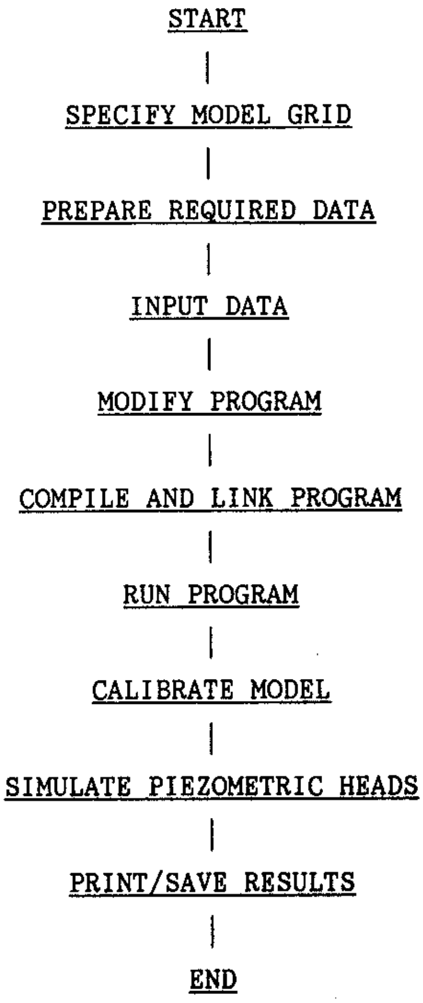


Figure 3.17 General Flow of Model Operation

3.5 OUTPUT DATA

Q3P generates several output files. Followings are essential output files involving results of calculation.

Q3P_30.LST
INI_30.DAT
BLOCK.OUT

Q3P_30.LST is the most important output file. It involves simulated piezometric heads in each time-step and piezometric changes at observation points as well as those hydrographs. If IPP is 1, lists of input data are also generated in this file.

INI_30.DAT is an unformatted file of piezometric heads in the last time-step of simulation. This file is useful when the calculated piezometric heads are employed as initial heads for subsequent simulation. For example, if the data of actual heads are not available at the beginning stage of nonsteady-state simulation, INI_30.DAT obtained from the preceding steady-state simulation can be used as estimated initial piezometric heads for the nonsteady-state simulation.

Results of water balance computation in the fixed blocks are generated in BLOCK.OUT. The water balance components viz. direct recharge, leakage recharge, discharge, lateral inflow/outflow and change of storage in selected blocks are given in the output tables.

INI_30.DAT and Q3P_30.LST are used for graphics.

3.6 GRAPHICS

Computer graphic technique helps immediate graphical understanding of the results of simulation. Also the user can easily compare the results with other results obtained from different data input because the graphical representations are drawn in the same form.

Two types of graphic techniques are presented in this manual. One is the representation of piezometric changes at observation points. The other is the drawing of equipotential contours (or isolines) of piezometric heads.

3.6.1 Piezometric Heads Changes

The output file Q3P_30.LST contains the piezometric heads changes throughout the simulation period at the observation points selected in OBSH63_2.DAT. Though this output file shows the simulated piezometric heads changes using simplified graphics, it is recommended to use other graphic software.

The study team used LOTUS-123 to draw simulated hydrographs at the observation points. LOTUS-123 is one of the most common and useful software of worksheet which involves graphic functions. It is assumed that the user has already understood basic operations of the LOTUS-123.

A FORTRAN program FOBS has been made to find computed piezometric heads data from Q3P_30.LST. Q3P_30.PRN is generated from the program. The sequences of piezometric heads values are arranged in the file. The LOTUS-123 can retrieve Q3P_30.PRN as a text file. Then using the graphic commands of LOTUS-123, beautiful hydrographs can easily be drawn.

If the user defines necessary parameters of the graphic functions and saves this LOTUS data file, then the user can utilize this LOTUS data file and draw hydrographs in the same format from next time.

3.6.2 Contour Map

Two programs for drawing contours have been prepared. The programs are written in BASIC because the BASIC language has various graphic functions. The study teams executed the programs using TOSHIBA BASIC Interpreter Ver. 3.2 under Japanese MS-DOS Ver.3.1. The TOSHIBA BASIC is following the Microsoft BASIC so that user can easily modify the programs into other BASIC Interpreters/Compilers such as IBM PC BASIC or GWBASIC which can be run under the English MS-DOS.

Followings are the contour map programs used for the Metro Manila groundwater basin model.

MSAPLTS.BAS : draw small scale contour map.

MSAPLTL.BAS : draw large scale contour map.
CONXYZ.MAP : draw contour map with locations of observation points.

The original program of MSAPLTS.BAS and MSPLTL.BAS is shown in Kinzelbach (1986) as SAMPLE PROGRAM 5. The original program of CONXYZ.MAP is shown in Shiono et al. (1988) as XYZCON.MAP. Those original programs were modified by the Study Team for the TOSHIBA BASIC Interpreter.

The programs can draw simulated piezometric contour maps in Metro Manila. The contour intervals, minimum and maximum values etc. can be specified from the keyboard.

The graphic programs require following input data files.

MSAPLTS.BAS : CALS.PLT
MSAPLTL.BAS : CALD1.PLT (for northern map)
CALD2.PLT (for southern map)
CONXYZ.MAP : HDN.OUT (for northern map)
HDS.OUT (for southern map)
CONT.LOC (observation points data)

The input data files mentioned above except CONT.LOC are produced by the following data input programs written in FORTRAN. These programs produce the input data files from INI_30.DAT, which are obtained from Q3P program.

MPRO5DS : Generate input data file for MSAPLTS.BAS
MPRO5DL : Generate input data files for MSAPLTL.BAS
MCONT : Generate input data files for CONXYZ.MAP

The user should modify dimension sizes and some parameters in the programs depending upon the user's problems.

4. SOLUTE TRANSPORT MODEL

4.1 MODEL ABSTRACT

The two-dimensional solute transport and dispersion model (MOC model) used in the study was originally devised by L. F. Konikow and J. D. Bredehoeft in 1978.

MOC is a two-dimensional model for the simulation of non-conservative solute transport in saturated groundwater systems. It computes changes in the spatial concentration distribution over time caused by convective transport, hydrodynamic dispersion, mixing or dilution from recharge, and chemical reactions.

The chemical reactions include first-order irreversible rate reaction (such as radioactive decay), reversible equilibrium-controlled absorption with linear, Fruendlich or Langmuir isotherms, and reversible equilibrium-controlled ion exchange for monovalent or divalent ions.

The model assumes that fluid density variations, viscosity changes and temperature gradients do not affect the velocity distribution. MOC does allow modeling heterogeneous and/or anisotropic aquifers.

MOC couples the groundwater flow equation with the non-conservative solute transport equation. The computer program uses the Alternating Direction Implicit (ADI) procedure or Strongly Implicit Procedure (SIP) to solve the finite difference approximation of the groundwater flow equation. The SIP procedure for solving the groundwater equation is most useful when aerial discontinuities in transmissivity exist or when the ADI solution does not converge.

MOC uses the method of characteristics to solve the solute transport equation. It uses a particle tracking method to represent convective transport and a two-step explicit procedure to solve the finite difference equation that describes the effects of hydrodynamic dispersion, fluid sources or sinks, and divergence of velocity.

The explicit procedure is subject to stability criteria, but the program automatically determines and implements the time-step limitations necessary to satisfy the stability criteria.

MOC uses a rectangular, block-centered, finite-difference grid for flow and transport calculations. The grid size for flow calculations is limited to 40 rows and 40 columns. The grid size for transport calculations is limited to 20 rows and 20 columns which can be assigned to any area of the flow grid.

The program allows spatially varying diffuse recharge or discharge, saturated thickness, transmissivity, boundary conditions, initial heads and initial concentrations and unlimited number of injection or withdrawal wells.

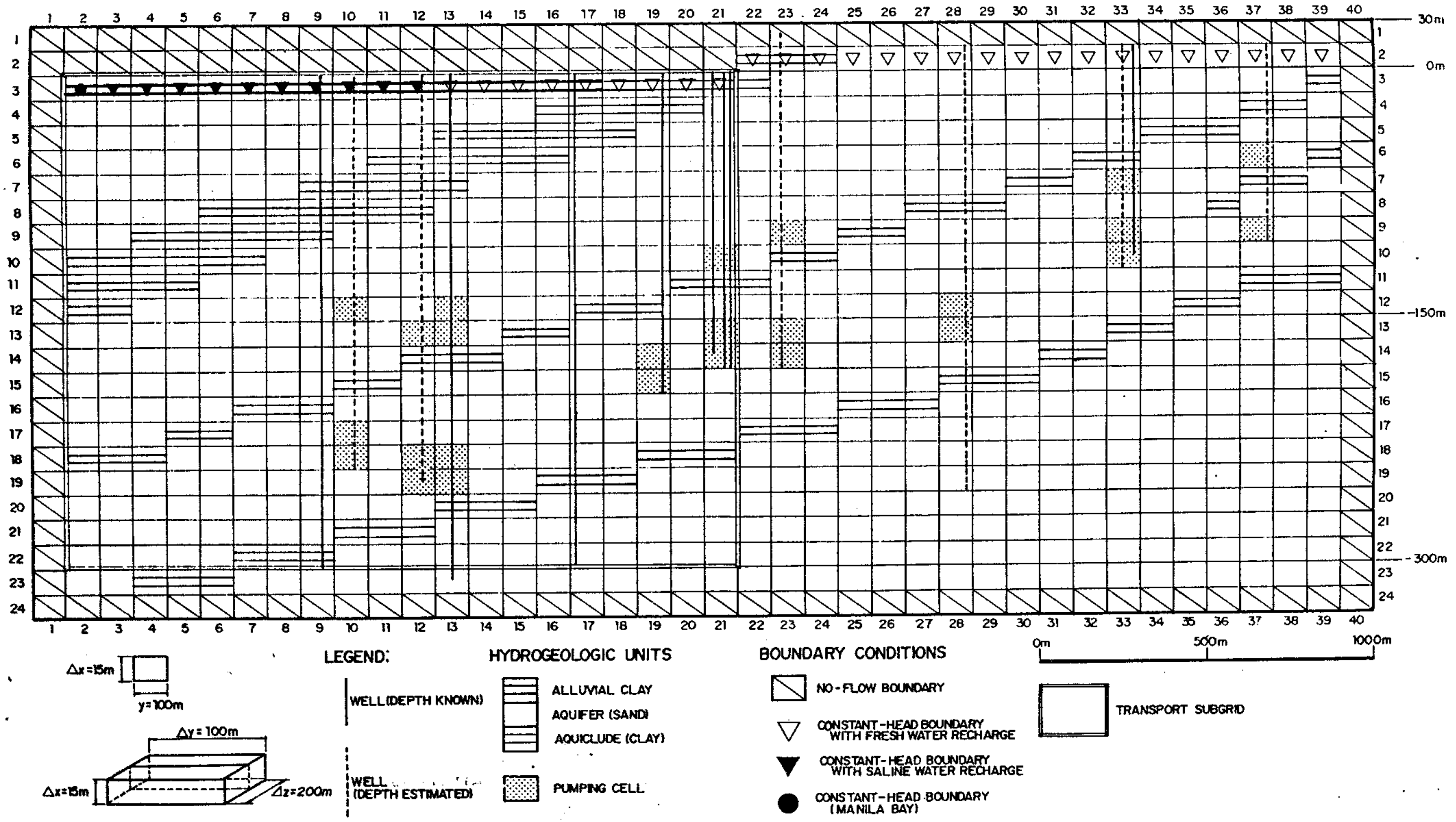
MOC model can be applied to one- or two-dimensional problems involving steady-state or transient flow. The solute transport model was originally developed for plain two-dimensional problem, but it was applied to the vertical two-dimensional multiple aquifer system in Las Pinas area to reveal the mechanism of saline water intrusion (see Figure 4.1).

4.2 MODEL FRAMEWORK

A rectangular, block-centered, finite-difference grid should be constructed depending on the objectives of solute transport modeling, hydrogeological conditions and the limitations of grid size for both flow calculation and transport calculation. The original MOC program presented here is written to allow a flow grid having up to 40 rows and 40 columns in which a transport grid can be located up to the size of 20 rows and 20 columns.

If both the transport equation and the flow equation are solved on the same grid, the number of nodes in the x- and y-directions, NX and NY, respectively are restricted to 20.

The transport equation may be solved on a smaller grid than the grid on which the flow equation is solved. This may yield savings in computation time and storage for problems in which the hydraulic gradients within the area of interest for transport are influenced by hydraulic stresses and/or boundary conditions outside of the area in which solute transport



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JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 4.1
VERTICAL TWO-DIMENSIONAL GRID FOR THE SOLUTE TRANSPORT AND DISPERSION MODEL IN LAS PIÑAS

is occurring.

The approach is to define a primary finite-difference grid for the flow model. A smaller, secondary subgrid for transport is then defined within the coordinates of the primary grid.

To specify different grid size for the transport and flow grids, specify NX as a negative value greater than -40. Then enter a positive value for NY in the range (1 to 40). The program will then prompt for four additional inputs: MX, MY, MMX and MMY. MX and MY are, respectively, the x- and y-coordinates within the primary grid of the upper-left node of the transport subgrid. MMX and MMY are the respective grid coordinates of the lower-right node of the transport subgrid.

For example, if the primary grid is 20 by 20 (that is, NX = -20 and NY = 20) , and if the subgrid for transport was to be 10 by 10, with the upper-left node of the subgrid corresponding to node (3,4) of the primary grid, then the following specifications would be made: MX = 3, MY = 4, MMX = 12 and MMY = 13.

It is noted that the "window" for the transport subgrid can overlap all or any part of the primary grid, but cannot extend beyond it. Also note that unless the subgrid overlaps the first or last row or column of the primary grid, which are no-flow boundaries, then all nodes of the subgrid can be "active" nodes.

Finally, the subgrid should be located so that there will not be a significant amount of convective transport across the subgrid boundary, or else the accuracy of the solution will be adversely affected.

4.3 DATA INPUT

An input processor MOCINP was provided in the MOC package. MOCINP is used to create or modify the data file required by MOCADI or MOCSIP.

The user should become familiar with the inputs required by MOC prior to using MOCINP. The USGS MOC reports and associated MOC Computer Program Updates Note (see Appendix) describes all inputs. MOCINP provides convenient means for producing the input data files required by MOC.

4.3.1 MOCINP and MOC

The preprocessor MOCINP is written to enable its user to prepare data set for the model USGS-2D-TRANSPORT/MOC. The functional relationship between the preprocessor and the model is illustrated in Fifure 4.2. After preparing a data file using MOCINP, you will run MOC separately.

```
                   manually prepared
                           ¦
                           V
+----------+        +------------+    +-------+     +----------+
¦          ¦<-------¦            ¦    ¦       ¦     ¦          ¦
¦  MOCINP  ¦        ¦  DATA SET  ¦---->¦  MOC  ¦---->¦  OUTPUT  ¦
¦          ¦------->¦            ¦    ¦       ¦     ¦          ¦
+----------+        +------------+    +-------+     +----------+
preprocessor           data file        model       output file
```

Figure 4.2 Relationship between MOCINP and MOC

The model will use the data file as if it were prepared manually. Thus the preprocessor remains transparent to the model.

```
                 +-----------------------------+
                 ¦                             ¦     ________
  ____________   ¦                             ¦    /        \
 /            \  ¦ input  +----------+   read  ¦    ¦\________/¦
 ¦    Your    ¦--+------->¦ Internal ¦<--------+----¦ Disk     ¦¦
 ¦interaction ¦  ¦        ¦   data   ¦         ¦    ¦  data    ¦¦
 ¦____________¦<-+------->¦ storage  ¦---------+--->¦  file    ¦¦
 /. .. . . . .\  ¦  edit  +----------+  write  ¦     \________/
/______________\ ¦                             ¦
                 +-----------------------------+
```

Figure 4.3 Functions of MOCINP

The preprocessor has four major functions. They are: 1. prepare a fresh data set; 2. modify current (internal) data; 3. read data from a disk file; and 4. write data to a file. As illustrated in Figure 4.3, an internal storage space is used to perform these functions.

4.3.2 MOCINP Usage

MOCINP has following files:

MOCINP.EXE : MOC input processor
MOCINPD.TXT : Text file containing MOC menus

The user can run MOCINP to create or modify the data file from TECSOFT menu. Then the user can input data as following procedure.

1) Main Menu

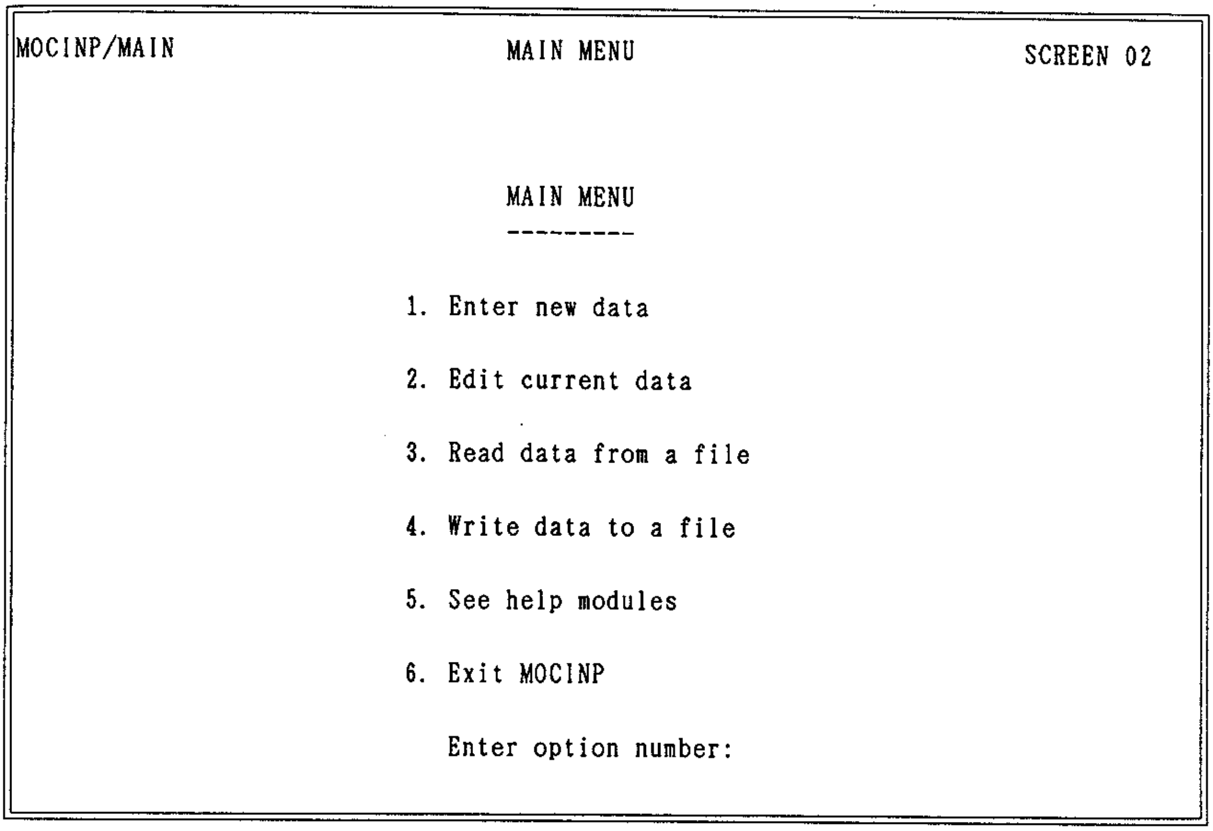
Example uses of MOCINP are:

1. User prepares a data set (option 1), edits it (option 2) to correct any mistake, saves it on a disk file (option 4), and exits (option 6).

2. User reads an existing disk file (option 3), modifies the data using MOCINP editor (option 2), saves it on the same (or another) disk file (option 4), and exits (option 6).

3. User reads an existing file (option 3), views it using the editor (option 2) without making any corrections, and exits (option 6).

4. User reads a manually-prepared data file (option 3) just to see if the format is correct, and exits (option 6). Running MOCINP to check the format of data files, precludes the need to run the model to do the same.



```
MOCINP/MAIN                    MAIN MENU                    SCREEN 02


                               MAIN MENU
                               ---------

                           1. Enter new data

                           2. Edit current data

                           3. Read data from a file

                           4. Write data to a file

                           5. See help modules

                           6. Exit MOCINP

                              Enter option number:
```

Figure 4.4 Main Menu of MOCINP

Sometimes, the user may inadvertently choose to exit MOCINP forgetting to save the current data set. This may result in a loss of your valuable time. To prevent such accidental termination of a session, MOCINP keeps track to see if the latest version of data has been saved on a disk file. If not, it issues a 'reminder' message at the time of termination. You may then ignore the message and choose option 6 to exit, or save the data (option 4) and then exit.

The four options, input, edit, read, and write are chosen from a MAIN MENU screen shown below. At the end of each option, you are brought back to the main menu.

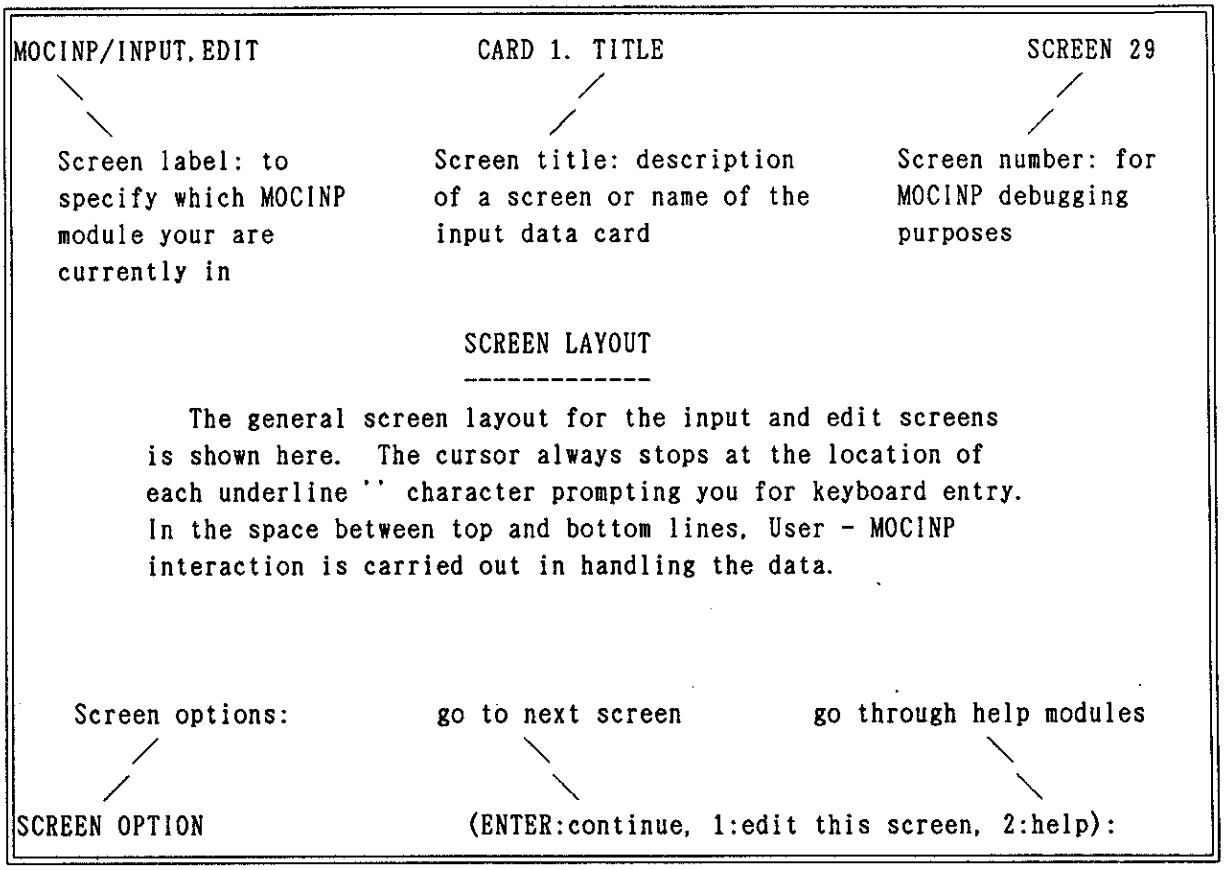
2) Cards and Screen

The variables of MOCINP are grouped together in the same manner as it is done in the MOC input data instruction. Cards 1 through 3, and data sets 1 through 10 are identical to their representation in the model documentation. These cards and data sets will be referred hereafter as just 'cards.'

During inputting, reading or writing options, the variables are handled in the same order as they appear in the MOC input data instruction. For editing, however, a card may be accessed at will.

While you are inputting or editing data, a single card is handled at any time. A separate screen is allotted for each card. For clarity, some cards are allotted more than one screen.

The general screen layout for the input and edit screens is shown in Figure 4.5. The cursor always stops at the location of each underline '_' character prompting you for keyboard entry. In the space between top and bottom lines, User - MOCINP interaction is carried out in handling the data.



MOCINP/INPUT.EDIT
CARD 1. TITLE
SCREEN 29

Screen label: to specify which MOCINP module your are currently in

Screen title: description of a screen or name of the input data card

Screen number: for MOCINP debugging purposes

SCREEN LAYOUT

The general screen layout for the input and edit screens is shown here. The cursor always stops at the location of each underline '' character prompting you for keyboard entry. In the space between top and bottom lines, User - MOCINP interaction is carried out in handling the data.

Screen options:
go to next screen
go through help modules

SCREEN OPTION
(ENTER:continue, 1:edit this screen, 2:help):

Figure 4.5 General Screen Layout of MOCINP

3) Input Procedure

A fresh data file for MOC can be prepared using MOCINP input option. Once this option is chosen, you are taken through all the input screens in sequence. Steps involved in preparing data for each card are:

step 1. The text screen corresponding to the card is shown.

step 2. Cursor stops at each inquiry and prompts for a value. You should type the value and hit <ENTER>. MOCINP checks this value against acceptable values. If invalid, the cursor prompts for another value. If valid, the cursor moves to the next inquiry. Acceptable values for the variables are tabulated in the help module, 'MOC Input Variables.'

step 3. At the bottom of the screen, you are given option toredo any variable's value on the screen. The help module, 'Screen Editing' describes this procedure. If the values entered are satisfactory, you should hit <ENTER> to go to next screen.

For assigning values to two-dimensional array variables, a special procedure is used. This procedure is described in the help module, 'Block Assignment for Arrays.'

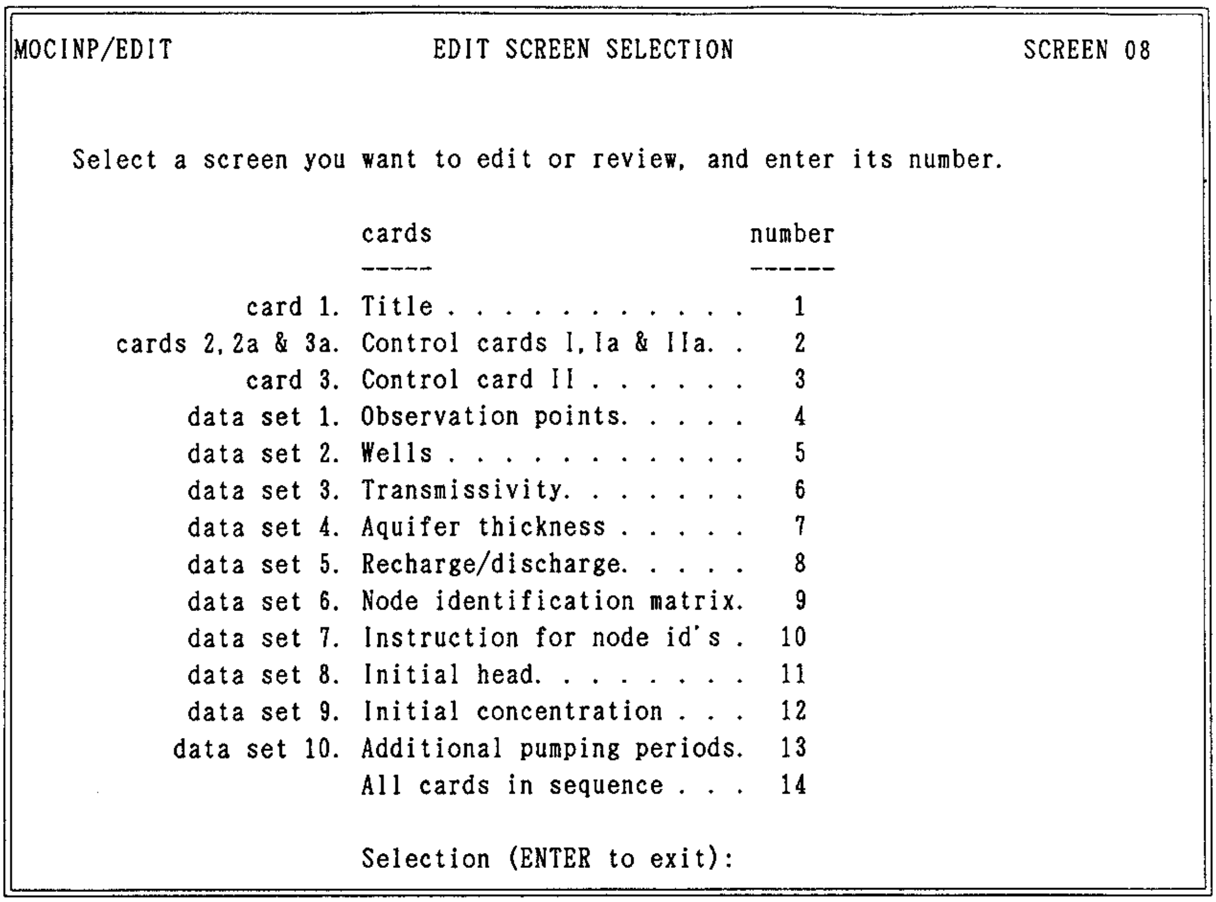
The screens used during input option may also be accessed using the MOCINP editor. Therefore, any mistake in the input data can be corrected later using the edit option.

4) Edit Procedure

The MOCINP editor may be used to review, and modify if necessary, the data entered using input option or data read from a disk file.

The steps involved are:

step 1. A menu screen containing names of all the data cards are shown to you first (Figure 4.6). The cards are given identification numbers 1 through 13. Any of the cards may be accessed by



```
MOCINP/EDIT                    EDIT SCREEN SELECTION                    SCREEN 08


    Select a screen you want to edit or review, and enter its number.

                                   cards                      number
                                   -----                      ------
                     card 1.  Title . . . . . . . . . . .        1
          cards 2,2a & 3a.  Control cards I,Ia & IIa. .        2
                     card 3.  Control card II . . . . . .        3
               data set 1.  Observation points. . . . .        4
               data set 2.  Wells . . . . . . . . . . .        5
               data set 3.  Transmissivity. . . . . . .        6
               data set 4.  Aquifer thickness . . . . .        7
               data set 5.  Recharge/discharge. . . . .        8
               data set 6.  Node identification matrix.        9
               data set 7.  Instruction for node id's .       10
               data set 8.  Initial head. . . . . . . .       11
               data set 9.  Initial concentration . . .       12
              data set 10.  Additional pumping periods.       13
                            All cards in sequence . . .       14

                            Selection (ENTER to exit):
```

Figure 4.6 Menu Screen for Screen Selection

entering the corresponding id number. Just hitting <ENTER> (equivalent to typing 0 and hitting <ENTER>) at this point will take you back to MOCINP main menu.

step 2. For each card accessed, the corresponding text screen is shown first.

step 3. The current values of variables on the screen are then displayed.

step 4. At the bottom of the screen, you are given option to modify any value on the screen. This procedure is described in the help module, 'Screen Editing.' If the values on screen are satisfactory you should hit <ENTER> to go to editor menu.

Using the procedure described above, you can access only one card at a time. Sometimes, it may be necessary to review all the 13 cards. To do this, an identification number of 14 is provided in the editor menu. By choosing this option you can go through all cards in sequence along with their current data, and modify any card if necessary.

As with the input option, array variables are edited using the special procedure which is described in the help module, 'Block Assignment for Arrays.'

5) Screen Editing

Screen editing procedure is used to modify the data currently on screen. The steps involved are:

1. Once this option is chosen, the cursor goes to the first data value and prompts.

2. If the value is OK, just hit <ENTER> key. This is equivalent to entering a zero. The cursor goes to next value and prompts.

3. If you want to modify the value, type the new value and hit <ENTER> key. MOCINP checks this value against acceptable values. If it is valid the new value is printed on screen, and the cursor goes to next value. If it is invalid cursor stays at the same location.

NOTE: If the new value you want to enter is 0, type a letter in the alphabet (ex: Z) first and hit <ENTER>. The cursor stays on. Now type 0 and hit <ENTER>.

The following example illustrates the procedure. The location of cursor at any point is shown by a '^' character under the location. Let us assume that the user wants to leave NX as it is and change NY to 18.

1. First cursor prompts at NX value.

```
NX                             No. of nodes in x-direction:    15
                                                       ^

NY                             No. of nodes in y-direction:    20
```

2. NX value of 15 is OK; therefore user hits <ENTER>. Cursor goes to

next variable NY and prompts.

```
NX                             No. of nodes in x-direction:    15
                                                       ^

NY                             No. of nodes in y-direction:    20
```

3. NY should be changed to 18. User types in 18 and hits <ENTER>.

```
NY                             No. of nodes in y-direction: 18 20
                                                         ^
```

4. Acceptable values for NY are 3 to 20. Therefore, the value 18 is assigned to NY and printed. Cursor goes to next variable.

```
NY                             No. of nodes in y-direction:    18
```

ZERO VALUE ENTRY: To change value of S to 0, user types 'Z' and hits <ENTER>. Cursor stays on. Now user enters a 0 and hits <ENTER>.

```
S Storage coefficient (set 0 for steady flow problems): Z 0.1E-04

S Storage coefficient (set 0 for steady flow problems): Z 0.1E-04
                                                    ^

S Storage coefficient (set 0 for steady flow problems): 0 0.1E-04

S Storage coefficient (set 0 for steady flow problems):   0.0E+00
```

Some screens (eg. data set 2. Wells) will contain data in a tabular form. Modifying individual values on these screens is similar to that for other screens as explained before. Adding or deleting an entry from the table is not so direct. It is described here with a simple example. Let us say that there is a table of values for an array variable VAR. NVAR represents the number of entries of this variable in the table.

```
         NVAR      Number of entries of VAR: 3

                   Serial No.    VAR
                   ----------    -------
                       1          37
                       2          21
```

3	15
–	–
–	–

To ADD an entry to the table:

The value of NVAR must be increased by 1. In general, NVAR is specified in a different card. Therefore, you must first access the screen containing NVAR, and modify its value to 4. When you come back to the screen containing table of VAR, it would look like this:

NVAR Number of entries of VAR: 4

Serial No.	VAR
1	37
2	21
3	15
4	0
–	–

Notice that VAR(4) is assigned a value of 0. Now use screen editing procedure to change VAR(4) to the new value.

To DELETE an entry from the table:

Let us say you want to delete entry number 1. Using the screen editor modify value VAR(1) to that of VAR(2), and value of VAR(2) to that of VAR(3). Leave value of VAR(3) as it is. The table before and after this editing is shown below.

NVAR Number of entries of VAR: 3

BEFORE EDITING		AFTER EDITING	
Serial No.	VAR	Serial No.	VAR
1	37	1	21
2	21	2	15

```
3          15               3          15
```

Now go back to the control card specifying the value of NVAR and modify NVAR to 2.

If the aquifer is nonhomogeneous with respect to a parameter, such as transmissivity, aquifer thickness, etc., the value of the parameter must be specified at each node. If many nodes share a common value for the parameter, it will be easier to assign a single value to a block of nodes rather than assigning values to them individually.

In the illustration, box ABCD represents the aquifer and box EFGH is a block of zone where nodal values of a parameter are the same.

AD is column 1; BC is column NC; AB is row 1; and DC is row NR; where, NC and NR represent the number of columns and rows in the aquifer, respectively.

```
  col 1 . . .          NC
row 1 A----------------B
    . ¦                ¦
    . ¦     E------F   ¦
      ¦     ¦      ¦   ¦
      ¦     ¦      ¦   ¦
      ¦     H------G   ¦
      ¦                ¦
   NR D----------------C
```

The block EFGH is bound by columns EH and FG, and rows EF and HG. To specify EFGH these two columns and rows must be given by the user.

Many possible block structures exist. A block may have only one column (eg. block AB), one row (eg. block CD), or one node (eg. X). Some blocks may overlap (eg. blocks EFGH and IJKL). If block IJKL is specified after EFGH, the value specified for IJKL will replace that for EFGH for nodes common between these two blocks. Therefore, the order in which the blocks are specified is important.

```
+------------------------------------------------------------+
|                                                            |
|   A                         E-------------------F          |
|   |    C-------D            |                   |          |
|   |                         |       I----------------J     |
|   |                         |       |                |     |
|   |        X                |       L----------------K     |
|   B                         |                   |          |
|                             H-------------------G          |
|                                                            |
+------------------------------------------------------------+
```

6) Block Assignment for Arrays

Screen Layout:

The nodal value of the parameter is displayed in the middle of the screen in a matrix form. For clarity, a zero value of the parameter at any node is represented by the character '.' instead of the number 0. Above this matrix, values assigned to multiplication factor for the parameter, and the size of the array are displayed.

Only 15 columns and 10 rows of nodes can be displayed at any time on screen. If the parameter array is larger than this size, it is divided into blocks of 15X10 which are referred as windows.

You may scroll to next window at any time by typing -1 for a prompt. Scrolling is done left to right, and then top to bottom.

```
    1          15             NC
   1+----------+---------------+
    |          |               |
    |  window  |               |
    |          |               |
  10+----------+               |
    |                          |
    |                          |
    |                          |
  NR+--------------------------+
```

Procedure:

The block assignment procedure is the same for both input and edit options. The text screen is displayed first, and currently available information for the parameter is filled in. To specify columns, rows and value for block assignment, the following line is displayed on the screen.

COLUMNS (begin: _ ,end: _) ROWS (begin: _ ,end: _) VALUE: _

Choosing edit screen option, you may specify rows and columns of block and the parameter value in that block. Type -1 for a row or a column prompt to scroll to the next window.

The values you entered are checked then for possibility of forming a block. For 'line' blocks, either columns or rows will have the same beginning and ending values. If a block is possible, the value is assigned to nodes within the block, and the display is altered accordingly.

7) Read Option

Using the read option you can read the contents of a data file for MOC. MOCINP reads the data file in the same manner as MOC does. If MOCINP and MOC are compiled using the same FORTRAN compiler, their interpretation of the input data format will be identical.

Procedure:

In the first read option screen, you will enter the name of the disk file to read. MOCINP checks to see if the file exists. If not, it prompts you for another file name.

A monitoring feature is provided in the next screen. The names of all data cards are displayed first. When a card is read successfully, a character 'X' appears next to the card name on this screen. The monitoring process is useful while reading data that was prepared using a text editor. If there is a format error on a card, MOCINP stops reading and displays an error message at the bottom of the screen. You should note down the erroneous card, exit MOCINP, and edit the data file using a text editor.

8) Write Option

The write option is used to prepare an input data file for MOC with the current data in MOCINP.

Procedure:

If you have read a data file prior to using this option, you may choose to replace the same file with the modified data. Otherwise, you will be asked to enter a new file name. As in the read option, a monitor screen is then displayed to indicate the cards prepared in the disk file.

An important step in this procedure is specification of the file name. If the FORTRAN compiler used on this computer allows error trapping while opening disk files, this feature would have been incorporated in MOCINP. Otherwise, if error condition occurs while opening a disk file, it may result in loss of your data.

A brief discussion of file names is presented next.

4.3.3 MOC Input Variables

The range of values an input variable can have is set at the time of programming MOCINP. It is based on one or more of the following:

1. Definition of the variable.
2. Allocation of storage space for the variable, especially if it is an array.
3. Format identifier used by MOC to read the value of the variable.
4. Format identifier used by MOCINP to write the value in a data file.

The ranges set for this version of MOCINP are given in Table 4.1. The variables are listed in alphabetical order. For clarity, the array variables are grouped together and are listed at the end of the table.

Table 4.1 MOC Input Variables

variable	type	range of values	output format
ANFCTR	real number	0.0 <= ANFCTR	F5.2
BETA	real number	0.0 <= BETA	F5.0
CELDIS	real number	1E-20 <= CELDIS <= 1.0	F5.0
CNRECH	real number	none	G8.2
DLTRAT	real number	0.0 <= DLTRAT <= 1.0	F5.2
FCTR1	real number	none	F10.2
FCTR2	real number	none	F10.2
FCTR3	real number	none	F10.2
ICHK	integer	0 <= ICHK <= 1	I1
ICODE	integer	1 <= ICODE <= 9	I2
INPUT	integer	0 <= INPUT <= 1	I1
IX	integer	2 <= IX <= NX-1	I2
IXOBS	integer	2 <= IXOBS <= NX-1	I2
IY	integer	2 <= IY <= NY-1	I2
IYOBS	integer	2 <= IYOBS <= NY-1	I2
ITMAX	integer	100 <= ITMAX <= 200	I4
NCODES	integer	0 <= NCODES <= 10	I4
NITP	integer	4 <= NITP <= 10	I4
NPDELC	integer	0 <= NPDELC <= 1	I4
NPMAX	integer	1 <= NPMAX <= 6400	I4
NPMP	integer	1 <= NPMP	I4
NPNCHV	integer	0 <= NPNCHV <= 2	I4
NPNT	integer	1 <= NPNT	I4
NPNTD	integer	0 <= NPNTD <= 2	I4
NPNTMV	integer	0 <= NPNTMV	I4
NPNTVL	integer	0 <= NPNTVL <= 2	I4
NPTPND	integer	1 <= NPTPND <= 16	I4
NREC	integer	0 <= NREC	I4
NTIM	integer	1 <= NTIM <= 100	I4
NUMOBS	integer	0 <= NUMOBS <= 5	I4
NX	integer	-40 <= NX <= 20	I4
NY	integer	3 <= NY <= 40	I4
OVERRD	integer	0 <= OVERRD <= 99	I2
PINT	real number	0.0 <= PINT	F5.1

POROS	real number	0.01 <= POROS <= 0.99	F5.2
REC	real number	none	G8.2
S	real number	.0001 <= S < 1.0 or S = 0.0	F5.4
TIMX	real number	1.0 <= TIMX <= 2.0	F5.2
TINIT	real number	0.0 <= TINIT	F5.0
TITLE	character array	maximum 80 characters	20A4
TOL	real number	1E-10 <= TOL <= 1.0	F5.4
XDEL	real number	1E-20 <= XDEL	F5.0
YDEL	real number	1E-20 <= YDEL	F5.0

ARRAYS

Array variables are dimensioned as ARRAY(NX,NY) where NX=40, and NY=40. Because of the number of columns allocated in input FORMAT statements of MOC, the precision with which one can specify their values is limited. It is further restricted by the rules governing output FORMAT descriptors of MOCINP. In most cases these restrictions may be overcome by carefully choosing a multiplication factor FCTR (which does not have any FORMAT-based restriction on its range) for each array variable.

Table 4.2 specifies the range and precision of the each array. In terms of precision, a range of -99. to 999. does not include the values 1.23 or 0.4.

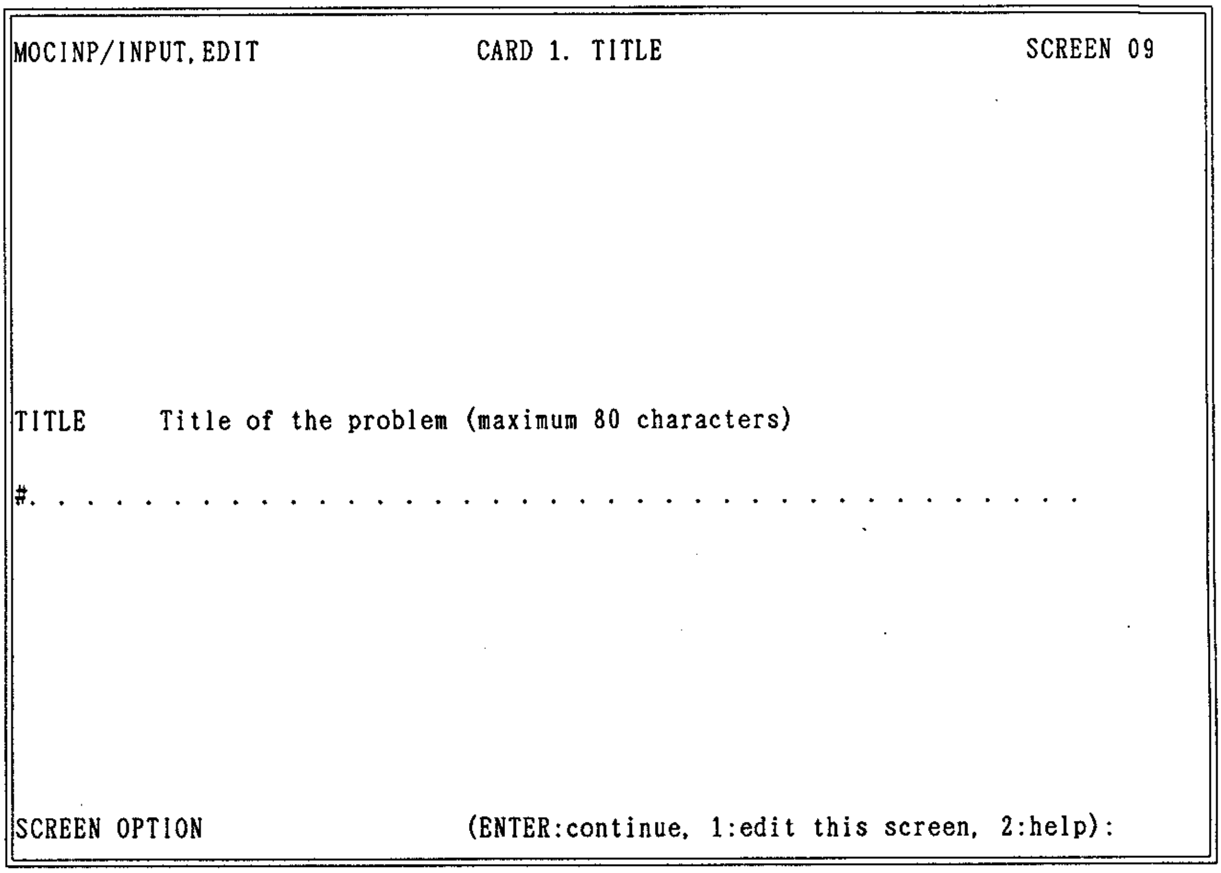
Table 4.2 MOC Input Arrays

variable.	type	range of values	output format
CONC	real array	-99. <= CONC <= 999.	20F4.0
NODEID	integer array	0 <= NODEID <= 9	20I1
RECH	real array	-99. <= RECH <= 999.	20F4.0
THCK	real array	-9. <= THCK <= 99.	20F3.0
VPRM	real array	-99. <= VPRM <= 999.	20F4.0
WT	real array	-99. <= WT <= 999.	20F4.0
NREACT	integer	-1 <= NREACT <= 7	I4
MX	integer	1 <= MX <= 40	FREE
MY	integer	1 <= MY <= 40	FREE

MMX	integer	1 <= MY <= 40	FREE
MMY	integer	1 <= MY <= 40	FREE
DK	real number	0 <= DK	FREE
RHOB	real number	0 <= RHOB	FREE
THALF	real number	0 <= THALF	FREE
CEC	real number	0 <= CEC	FREE
CTOT	real number	0 <= CTOT	FREE
EK	real number	0 <= EK	FREE
EKF	real number	0 <= EKF	FREE
EKL	real number	0 <= EKL	FREE

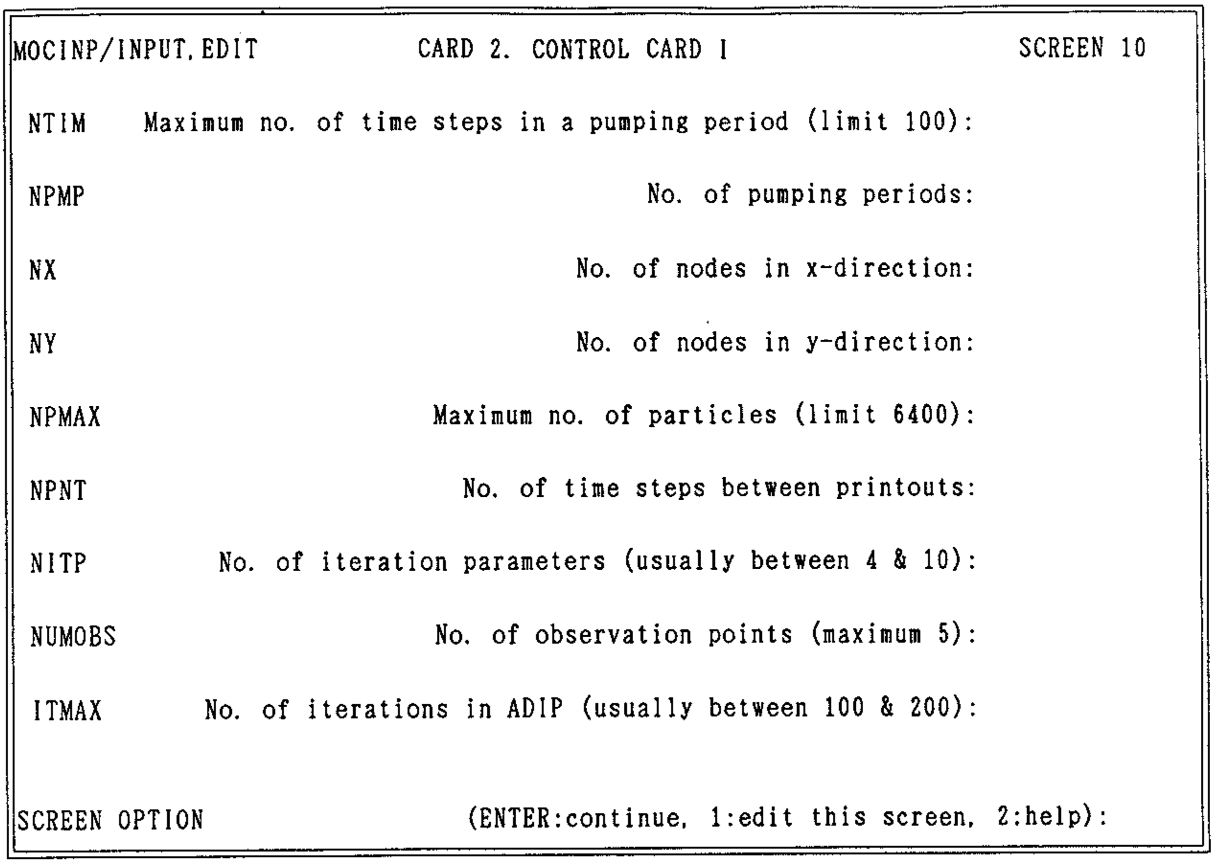
4.3.4 MOCINP Screen

The user can input/modify data following the MOCINP Screens shown in Figures 4.7 to 4.24.



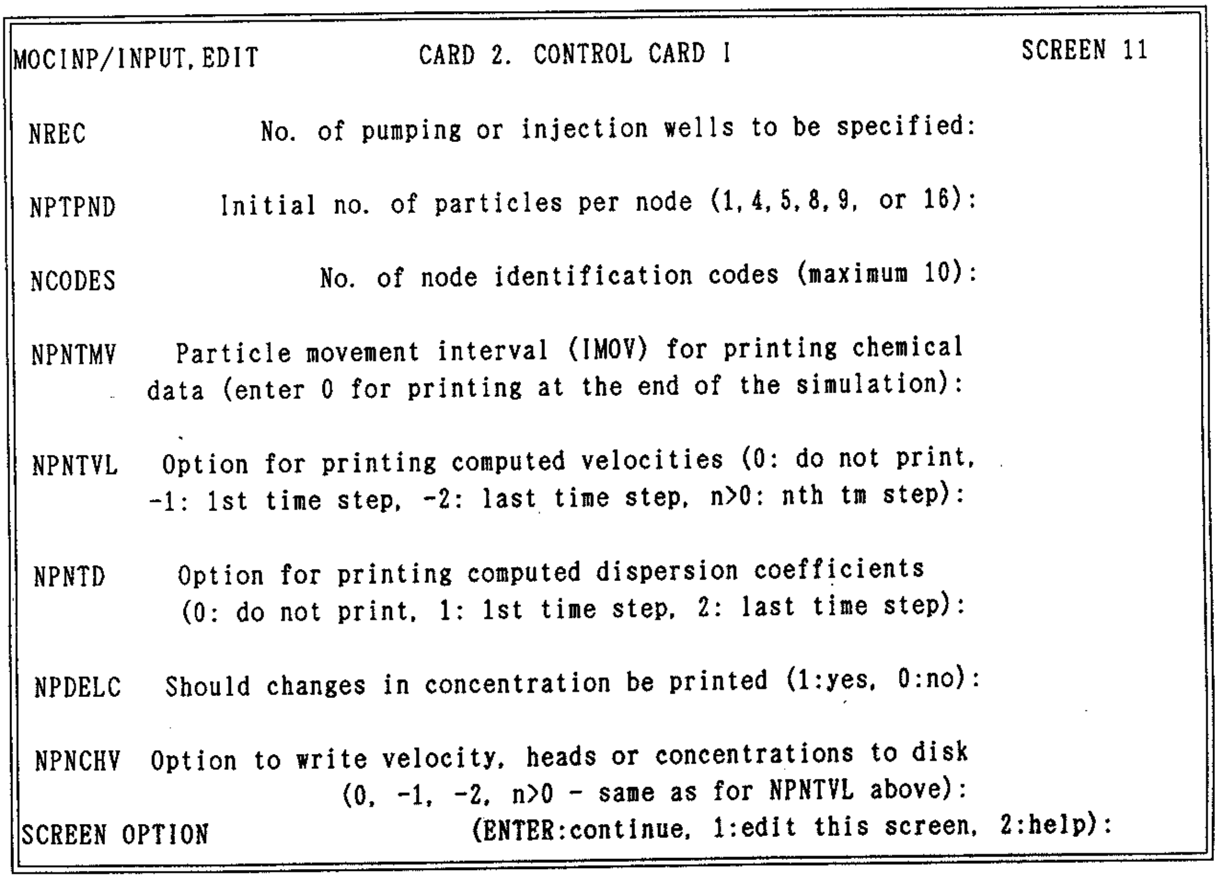
```
MOCINP/INPUT.EDIT                CARD 1. TITLE                      SCREEN 09










TITLE     Title of the problem (maximum 80 characters)

#. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .








SCREEN OPTION                     (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.7 MOCINP Screen for CARD 1. TITLE



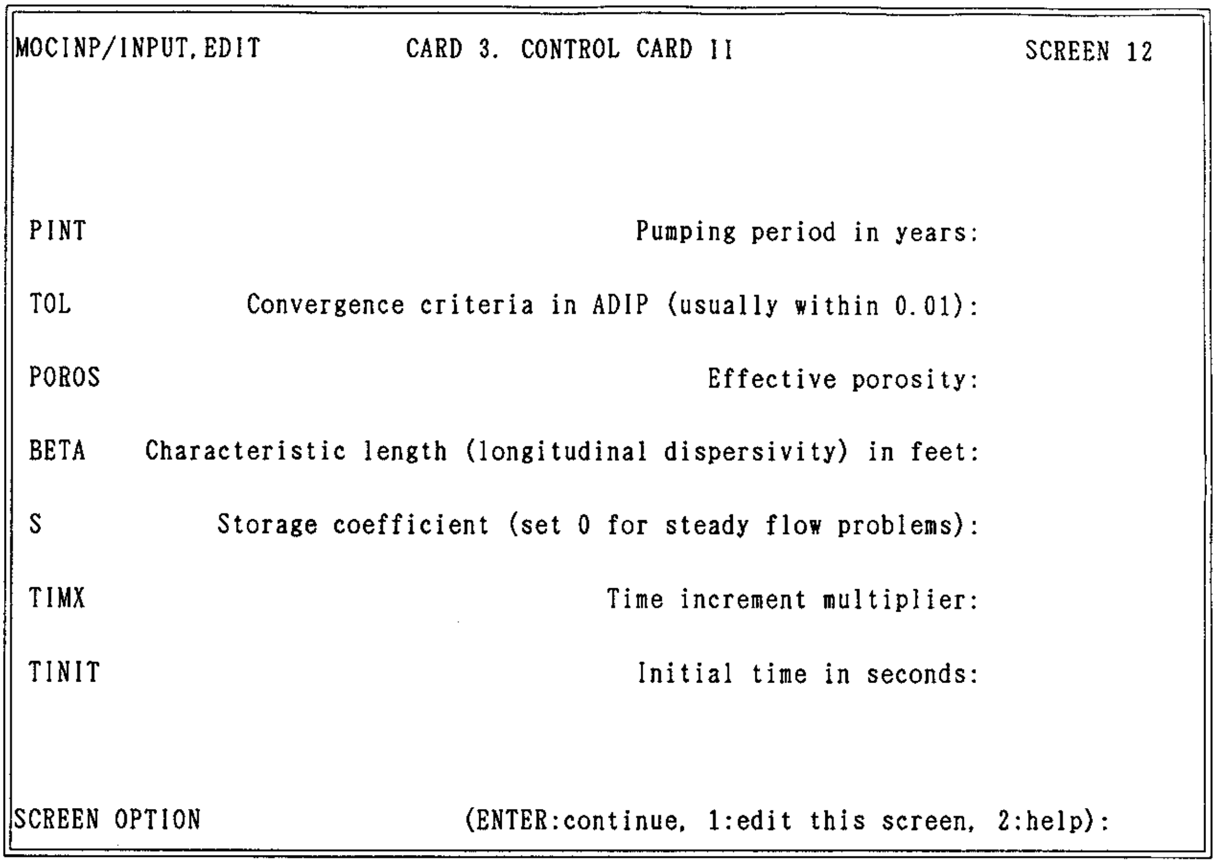
```
MOCINP/INPUT.EDIT            CARD 2. CONTROL CARD I                    SCREEN 10

 NTIM    Maximum no. of time steps in a pumping period (limit 100):

 NPMP                                          No. of pumping periods:

 NX                                         No. of nodes in x-direction:

 NY                                         No. of nodes in y-direction:

 NPMAX                          Maximum no. of particles (limit 6400):

 NPNT                               No. of time steps between printouts:

 NITP         No. of iteration parameters (usually between 4 & 10):

 NUMOBS                         No. of observation points (maximum 5):

 ITMAX       No. of iterations in ADIP (usually between 100 & 200):


SCREEN OPTION                     (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.8 MOCINP Screen for CARD 2. CONTROL CARD I(1)



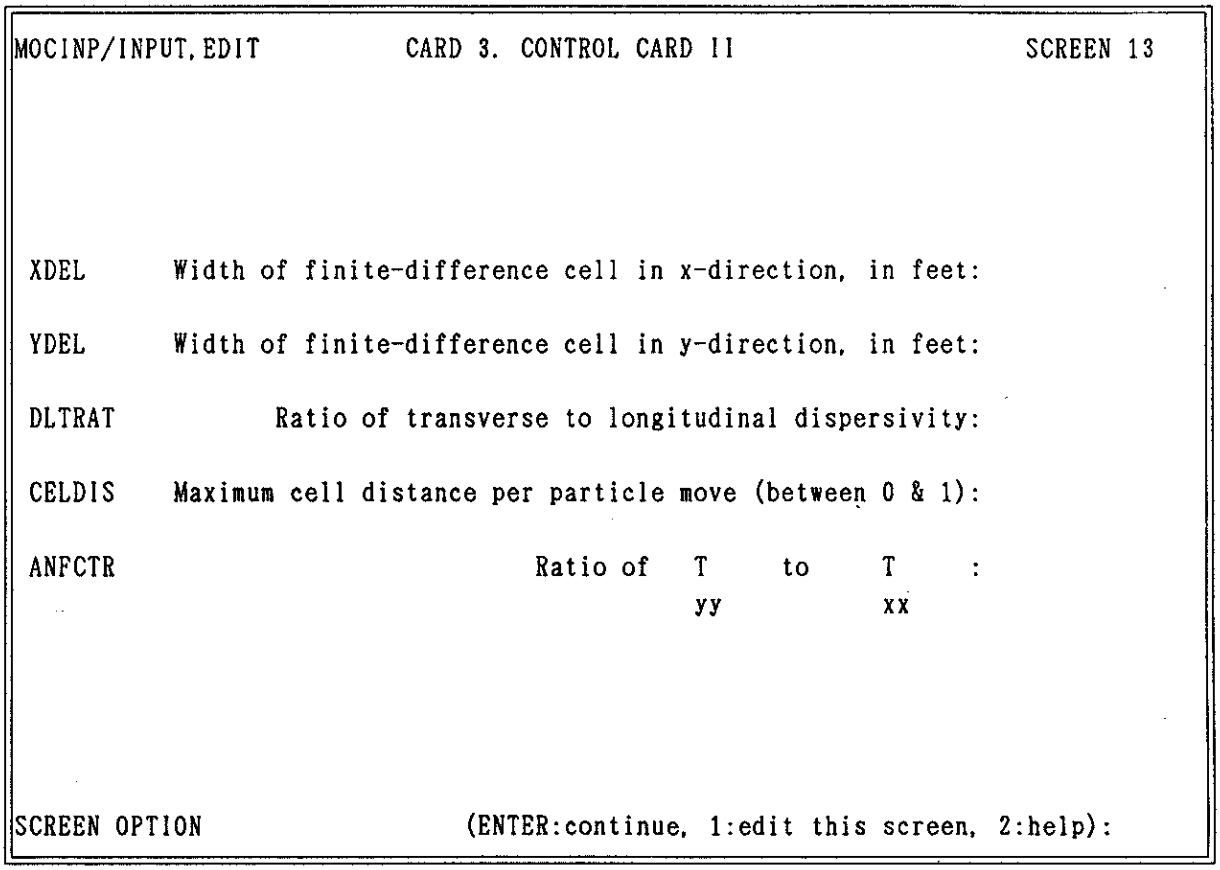
```
MOCINP/INPUT.EDIT            CARD 2. CONTROL CARD I                    SCREEN 11

 NREC             No. of pumping or injection wells to be specified:

 NPTPND       Initial no. of particles per node (1,4,5,8,9, or 16):

 NCODES                 No. of node identification codes (maximum 10):

 NPNTMV    Particle movement interval (IMOV) for printing chemical
          data (enter 0 for printing at the end of the simulation):

 NPNTVL   Option for printing computed velocities (0: do not print,
          -1: 1st time step, -2: last time step, n>0: nth tm step):

 NPNTD     Option for printing computed dispersion coefficients
            (0: do not print, 1: 1st time step, 2: last time step):

 NPDELC   Should changes in concentration be printed (1:yes, 0:no):

 NPNCHV  Option to write velocity, heads or concentrations to disk
                          (0, -1, -2, n>0 - same as for NPNTVL above):
SCREEN OPTION                     (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.9 MOCINP Screen for CARD 2. CONTROL CARD I(2)



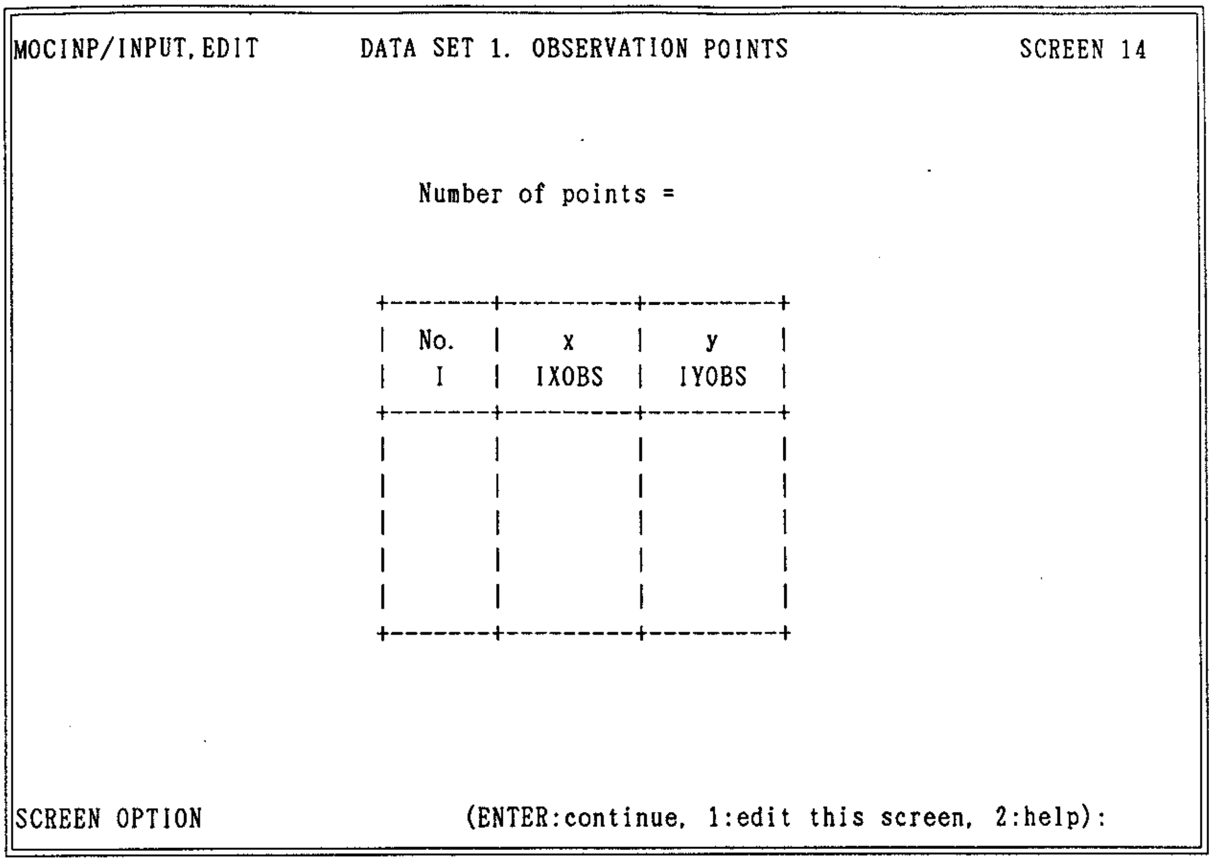
```
MOCINP/INPUT.EDIT          CARD 3. CONTROL CARD II                 SCREEN 12



 PINT                                           Pumping period in years:

 TOL             Convergence criteria in ADIP (usually within 0.01):

 POROS                                              Effective porosity:

 BETA    Characteristic length (longitudinal dispersivity) in feet:

 S             Storage coefficient (set 0 for steady flow problems):

 TIMX                                        Time increment multiplier:

 TINIT                                         Initial time in seconds:


SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.10 MOCINP Screen for CARD 3. CONTROL CARD II(1)



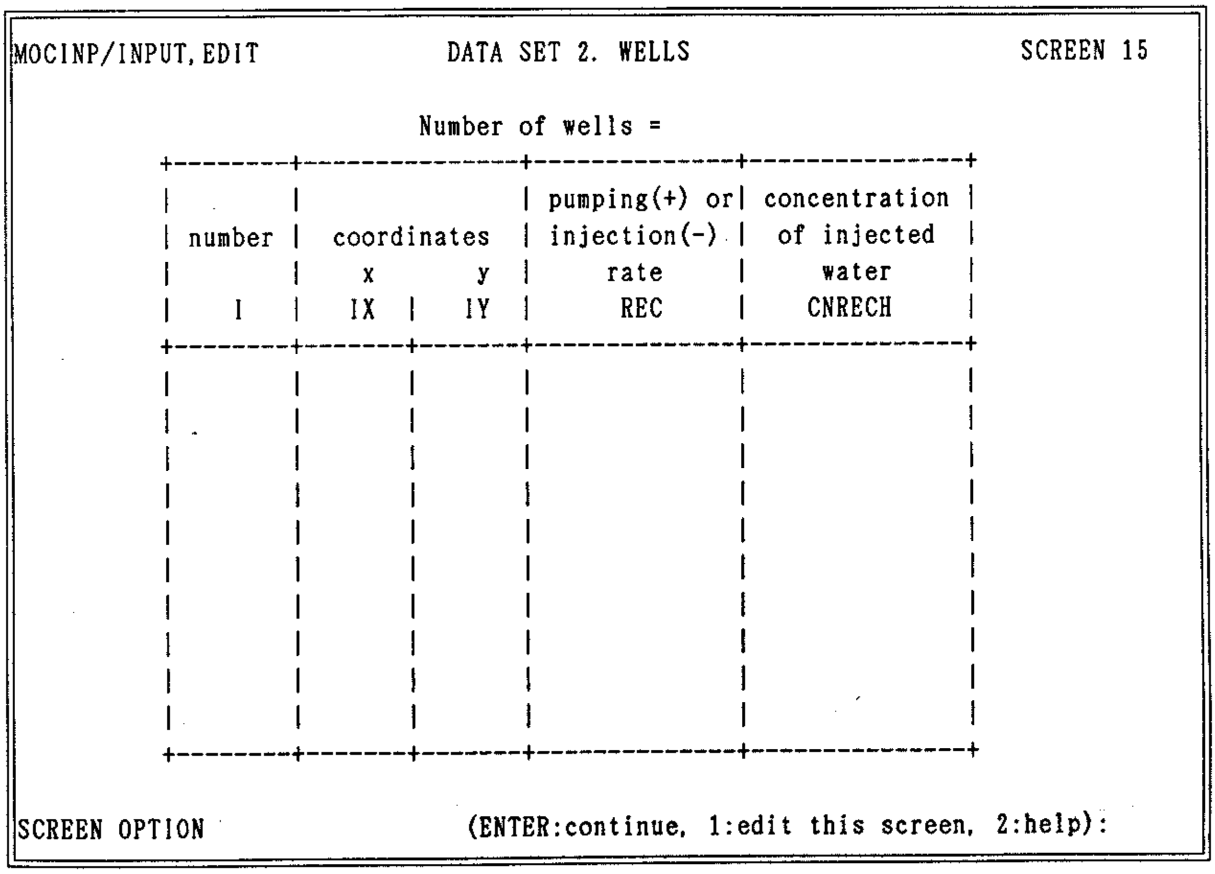
```
MOCINP/INPUT.EDIT          CARD 3. CONTROL CARD II                 SCREEN 13




 XDEL      Width of finite-difference cell in x-direction, in feet:

 YDEL      Width of finite-difference cell in y-direction, in feet:

 DLTRAT              Ratio of transverse to longitudinal dispersivity:

 CELDIS    Maximum cell distance per particle move (between 0 & 1):

 ANFCTR                               Ratio of  T      to     T     :
                                                yy            xx




SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.11 MOCINP Screen for CARD 2. CONTROL CARD II(2)



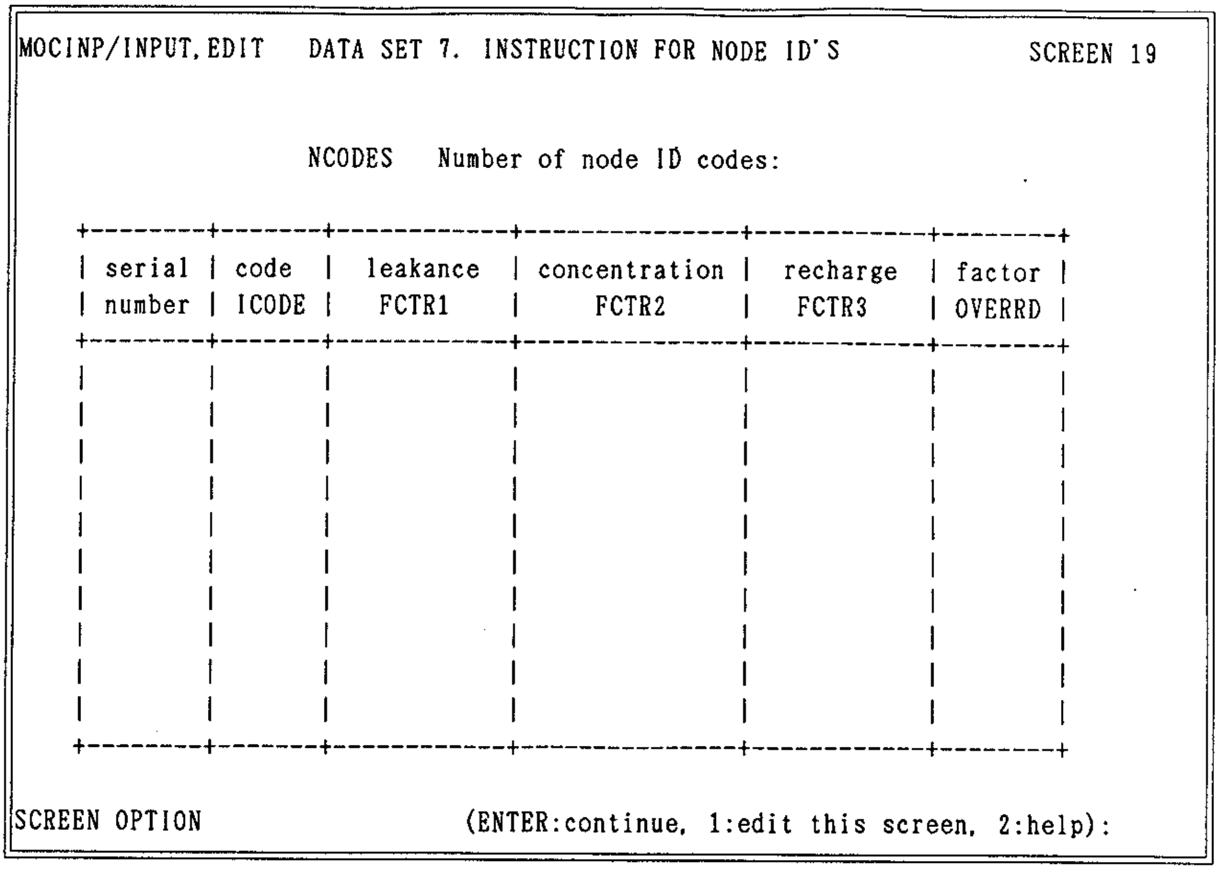
```
MOCINP/INPUT,EDIT        DATA SET 1. OBSERVATION POINTS              SCREEN 14


                            Number of points =


                        +-------+---------+---------+
                        |  No.  |    x    |    y    |
                        |   I   |  IXOBS  |  IYOBS  |
                        +-------+---------+---------+
                        |       |         |         |
                        |       |         |         |
                        |       |         |         |
                        |       |         |         |
                        |       |         |         |
                        +-------+---------+---------+



SCREEN OPTION                 (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.12 MOCINP Screen for DATA 1. OBSERVATION POINTS



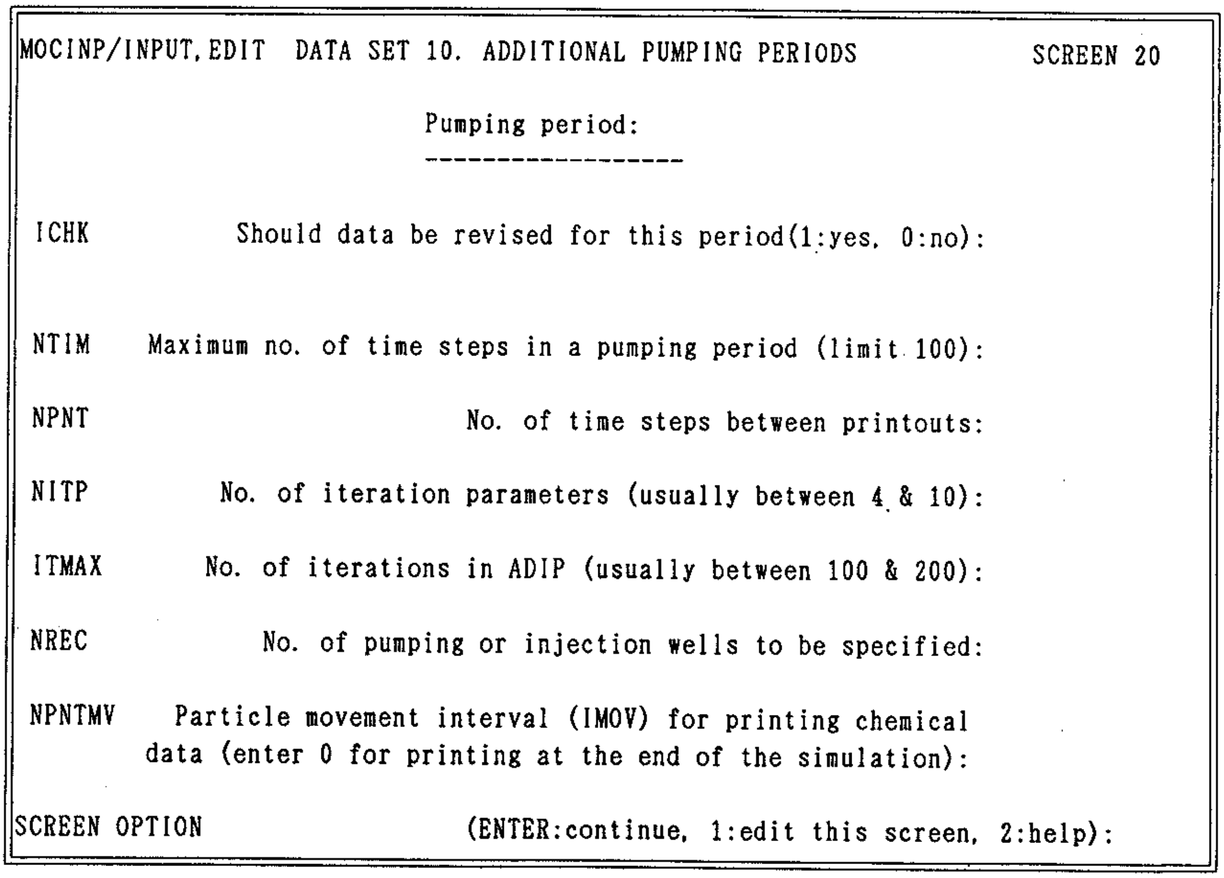
```
MOCINP/INPUT,EDIT              DATA SET 2. WELLS                     SCREEN 15

                              Number of wells =
        +--------+---------------+--------------+---------------+
        |        |               | pumping(+) or| concentration |
        | number |  coordinates  | injection(-) |  of injected  |
        |        |    x       y  |     rate     |     water     |
        |    I   |   IX  |   IY  |      REC     |    CNRECH     |
        +--------+-------+-------+--------------+---------------+
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        |        |       |       |              |               |
        +--------+-------+-------+--------------+---------------+

SCREEN OPTION                 (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.13 MOCINP Screen for DATA SET 2. WELLS



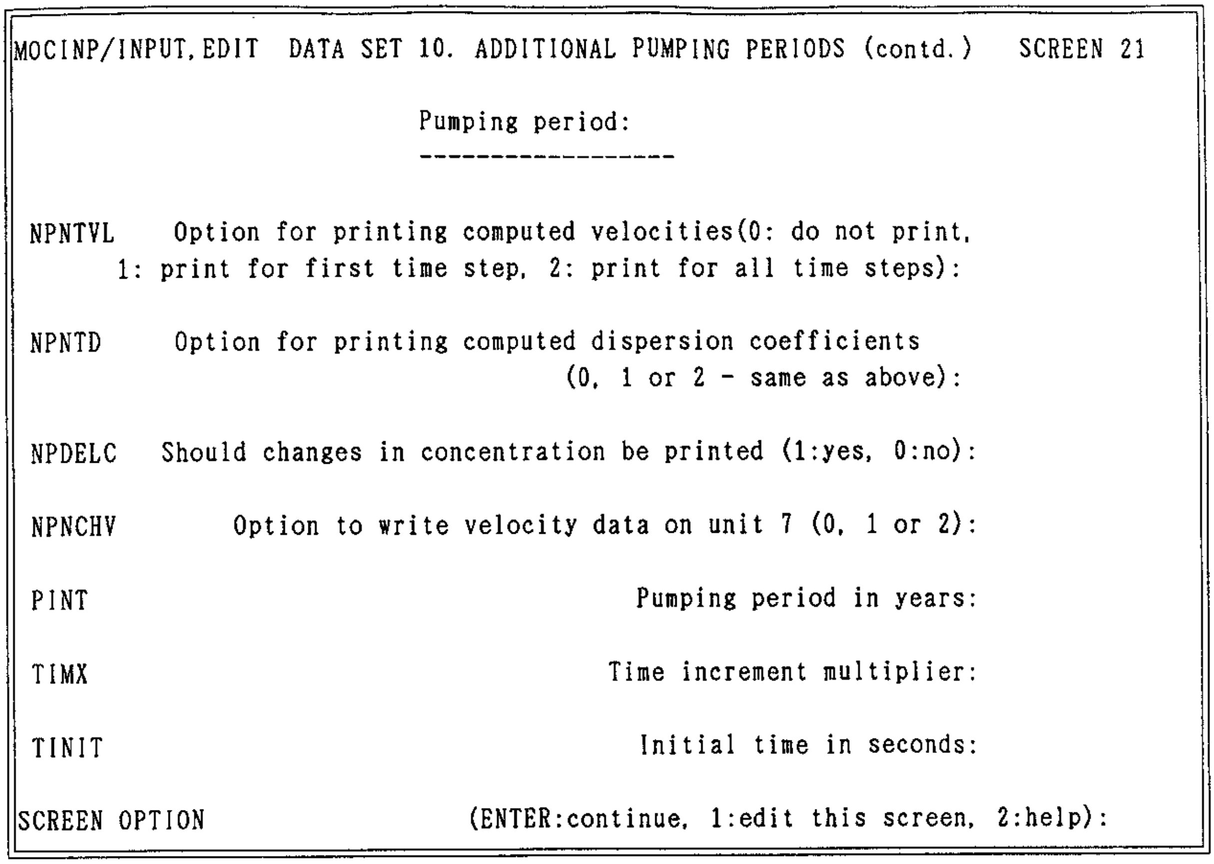
```
MOCINP/INPUT.EDIT   DATA SET 7. INSTRUCTION FOR NODE ID'S         SCREEN 19


                        NCODES   Number of node ID codes:

    +---------+-------+------------+---------------+------------+--------+
    | serial  | code  |  leakance  | concentration |  recharge  | factor |
    | number  | ICODE |   FCTR1    |     FCTR2     |   FCTR3    | OVERRD |
    +---------+-------+------------+---------------+------------+--------+
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    |         |       |            |               |            |        |
    +---------+-------+------------+---------------+------------+--------+

SCREEN OPTION                (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.14 MOCINP Screen for DATA SET 7. INSTRUCTION FOR NODE ID'S



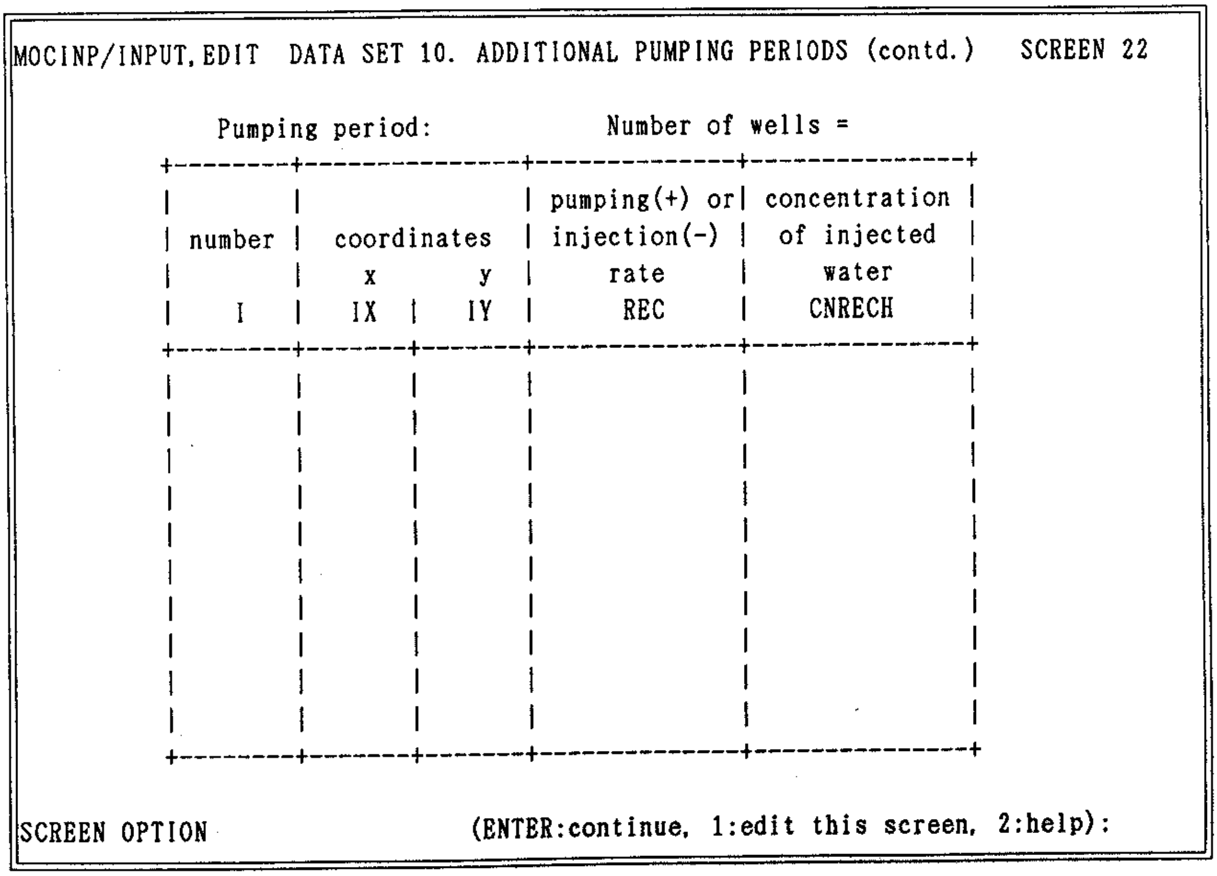
```
MOCINP/INPUT.EDIT  DATA SET 10. ADDITIONAL PUMPING PERIODS        SCREEN 20

                              Pumping period:
                              ------------------

 ICHK          Should data be revised for this period(1:yes, 0:no):


 NTIM    Maximum no. of time steps in a pumping period (limit 100):

 NPNT                              No. of time steps between printouts:

 NITP          No. of iteration parameters (usually between 4 & 10):

 ITMAX        No. of iterations in ADIP (usually between 100 & 200):

 NREC               No. of pumping or injection wells to be specified:

 NPNTMV    Particle movement interval (IMOV) for printing chemical
          data (enter 0 for printing at the end of the simulation):

SCREEN OPTION                (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.15 MOCINP Screen for DATA SET 10. ADDITIONAL PUMPING PERIOD(1)



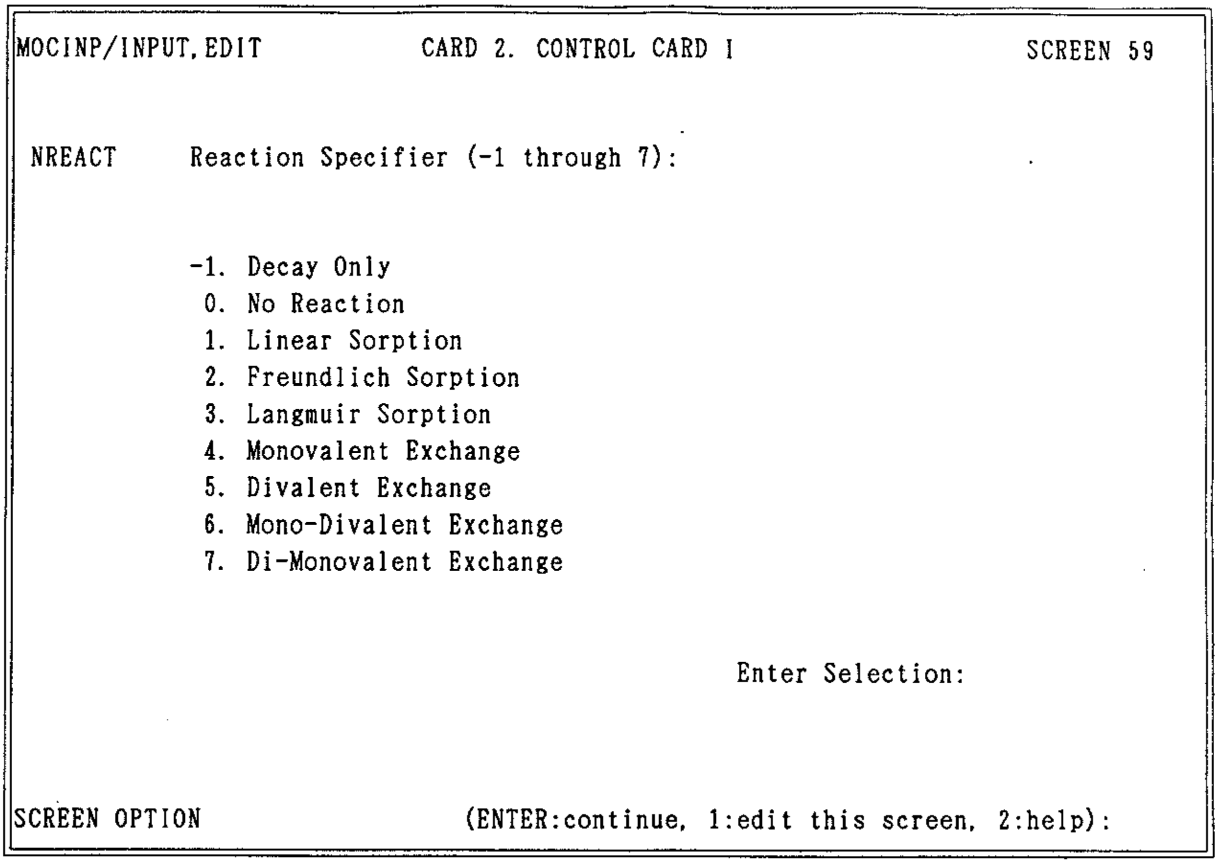
```
MOCINP/INPUT.EDIT  DATA SET 10. ADDITIONAL PUMPING PERIODS (contd.)   SCREEN 21

                             Pumping period:
                             ------------------

 NPNTVL    Option for printing computed velocities(0: do not print,
       1: print for first time step, 2: print for all time steps):

 NPNTD     Option for printing computed dispersion coefficients
                                           (0, 1 or 2 - same as above):

 NPDELC   Should changes in concentration be printed (1:yes, 0:no):

 NPNCHV        Option to write velocity data on unit 7 (0, 1 or 2):

 PINT                                         Pumping period in years:

 TIMX                                       Time increment multiplier:

 TINIT                                         Initial time in seconds:

SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.16 MOCINP Screen for DATA SET 10. ADDITIONAL PUMPING PERIOD(2)



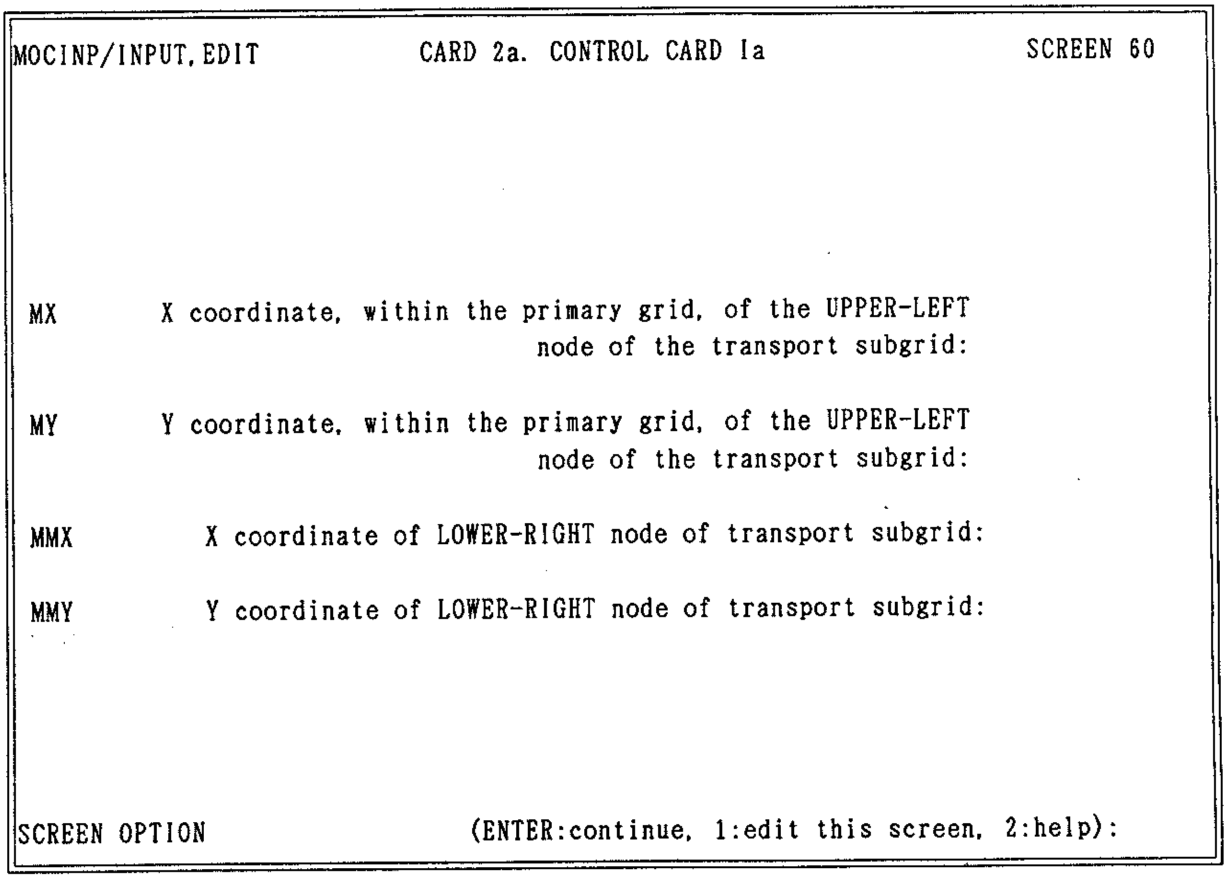
```
MOCINP/INPUT.EDIT  DATA SET 10. ADDITIONAL PUMPING PERIODS (contd.)   SCREEN 22

              Pumping period:            Number of wells =
          +--------+----------------+--------------+---------------+
          |        |                | pumping(+) or| concentration |
          | number |  coordinates   | injection(-) |  of injected  |
          |        |   x        y   |     rate     |     water     |
          |   I    |   IX   |   IY  |     REC      |    CNRECH     |
          +--------+--------+-------+--------------+---------------+
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          |        |        |       |              |               |
          +--------+--------+-------+--------------+---------------+

SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.17 MOCINP Screen for DATA SET 10. ADDITIONAL PUMPING PERIOD(3)



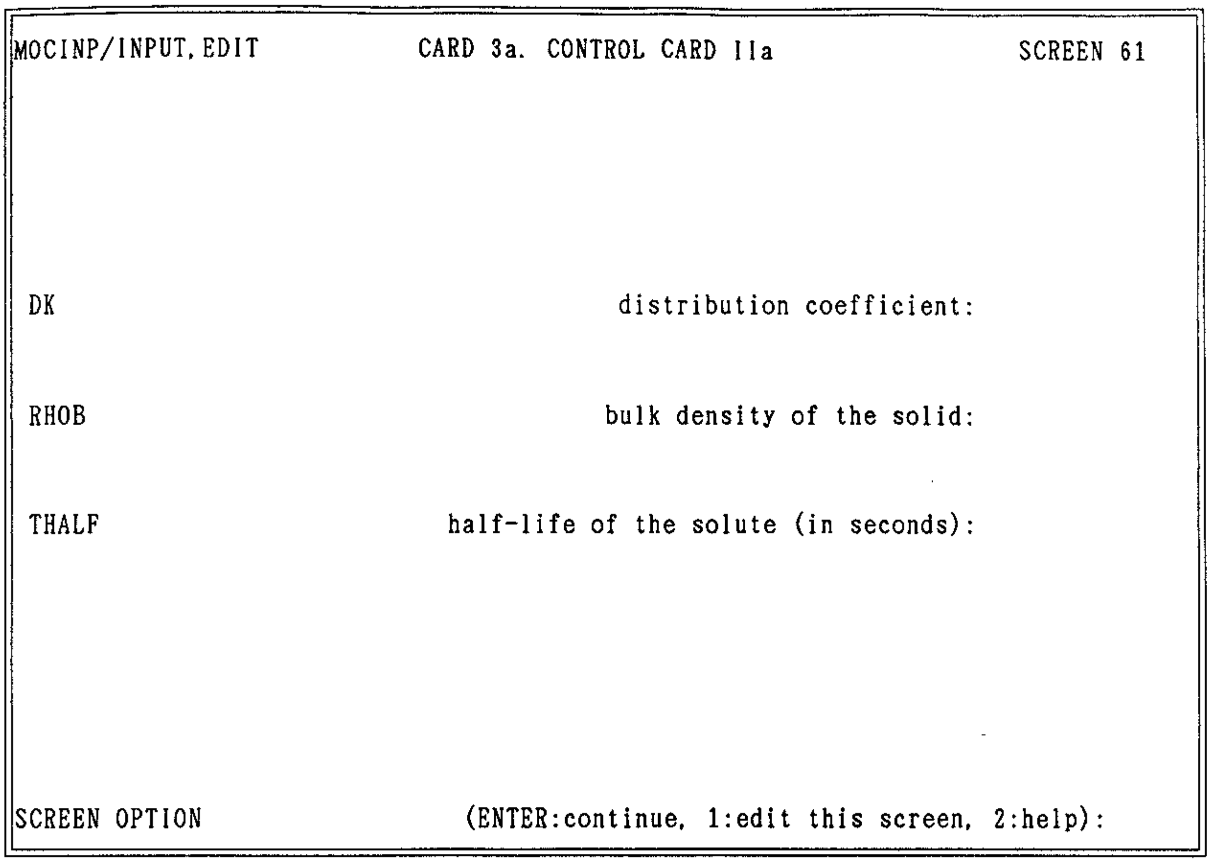
```
MOCINP/INPUT.EDIT           CARD 2. CONTROL CARD I                  SCREEN 59


 NREACT     Reaction Specifier (-1 through 7):


           -1. Decay Only
            0. No Reaction
            1. Linear Sorption
            2. Freundlich Sorption
            3. Langmuir Sorption
            4. Monovalent Exchange
            5. Divalent Exchange
            6. Mono-Divalent Exchange
            7. Di-Monovalent Exchange


                                                  Enter Selection:



SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.18 MOCINP Screen for CARD 2. CONTROL CARD I



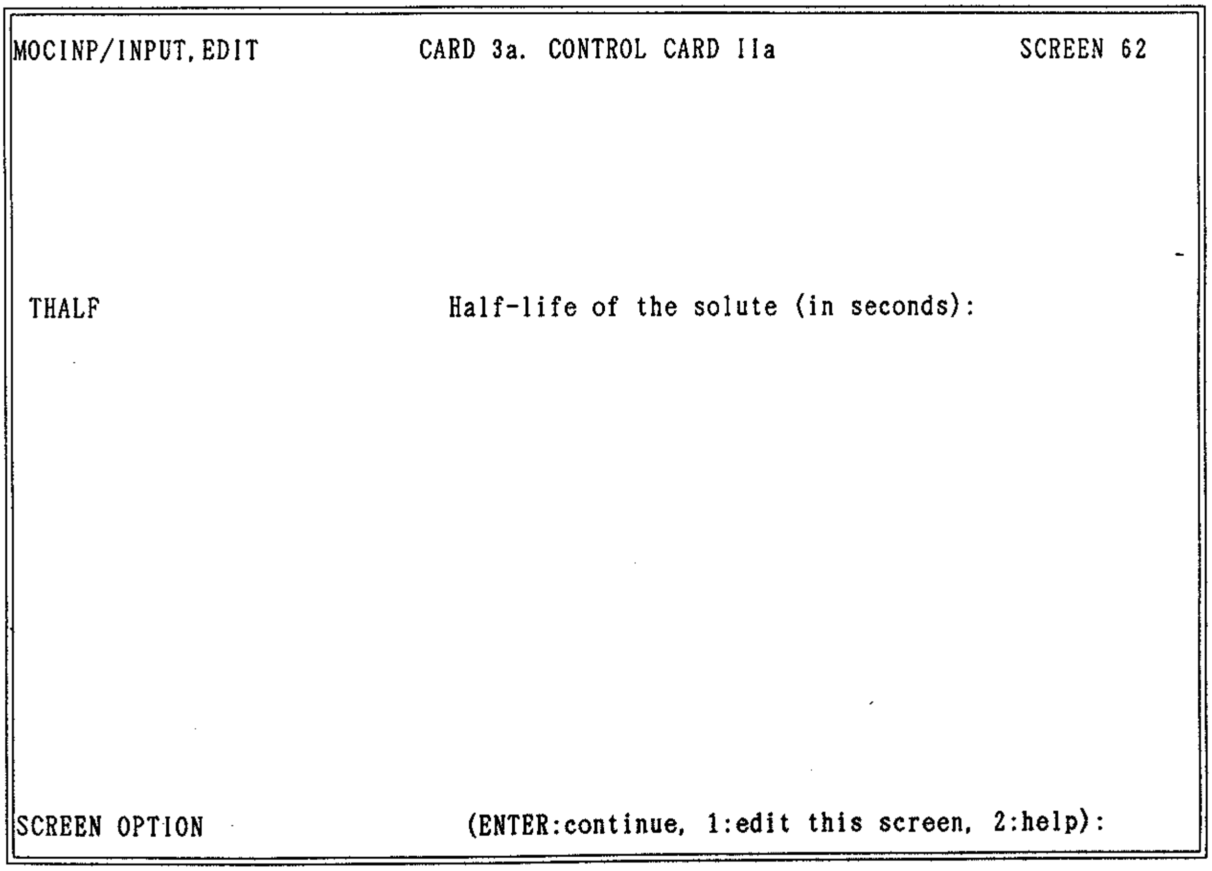
```
MOCINP/INPUT.EDIT           CARD 2a. CONTROL CARD Ia                SCREEN 60






 MX        X coordinate, within the primary grid, of the UPPER-LEFT
                                          node of the transport subgrid:

 MY        Y coordinate, within the primary grid, of the UPPER-LEFT
                                          node of the transport subgrid:

 MMX          X coordinate of LOWER-RIGHT node of transport subgrid:

 MMY          Y coordinate of LOWER-RIGHT node of transport subgrid:





SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.19 MOCINP Screen for CARD 2a. CONTROL CARD Ia



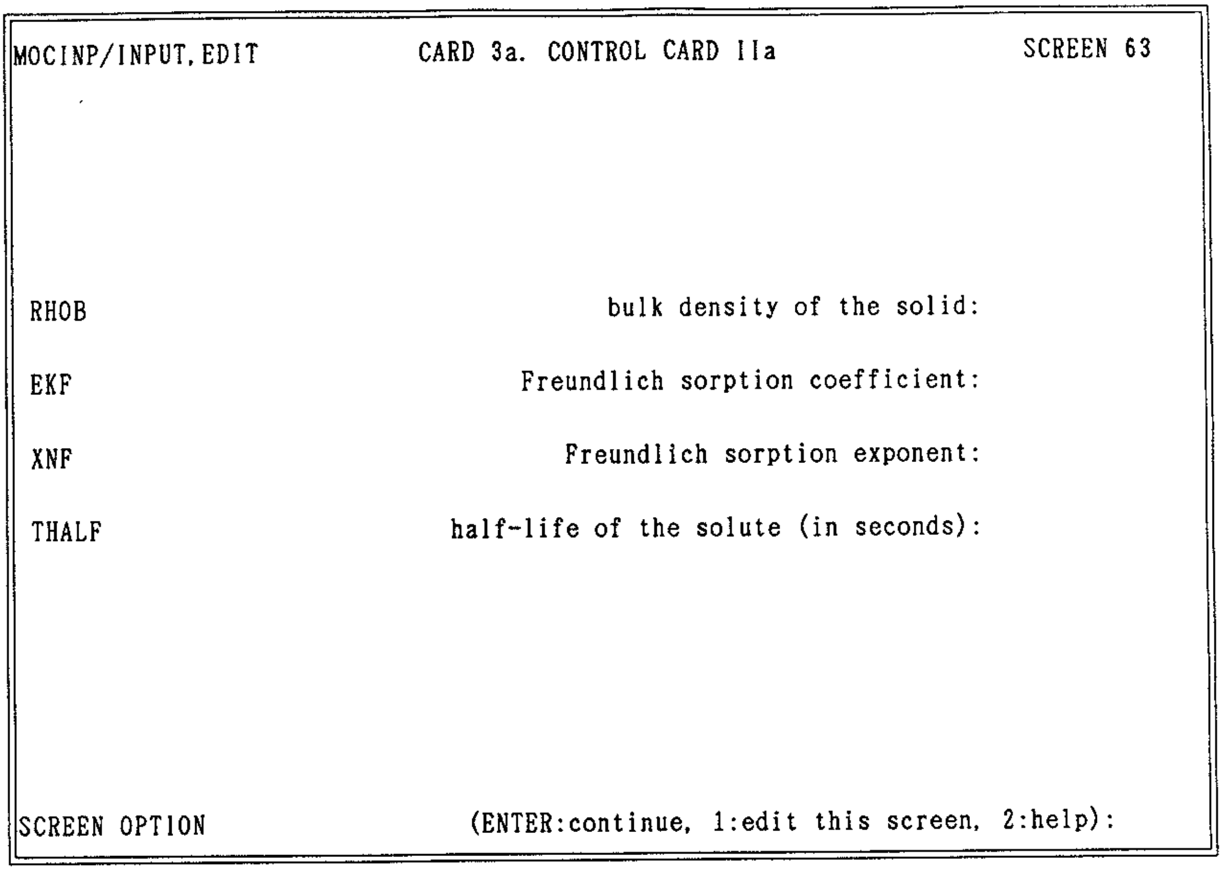
```
MOCINP/INPUT,EDIT            CARD 3a.  CONTROL CARD IIa                 SCREEN 61

 DK                                          distribution coefficient:

 RHOB                                       bulk density of the solid:

 THALF                            half-life of the solute (in seconds):

SCREEN OPTION                   (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.20 MOCINP Screen for CARD 3a. CONTROL CARD IIa(1)



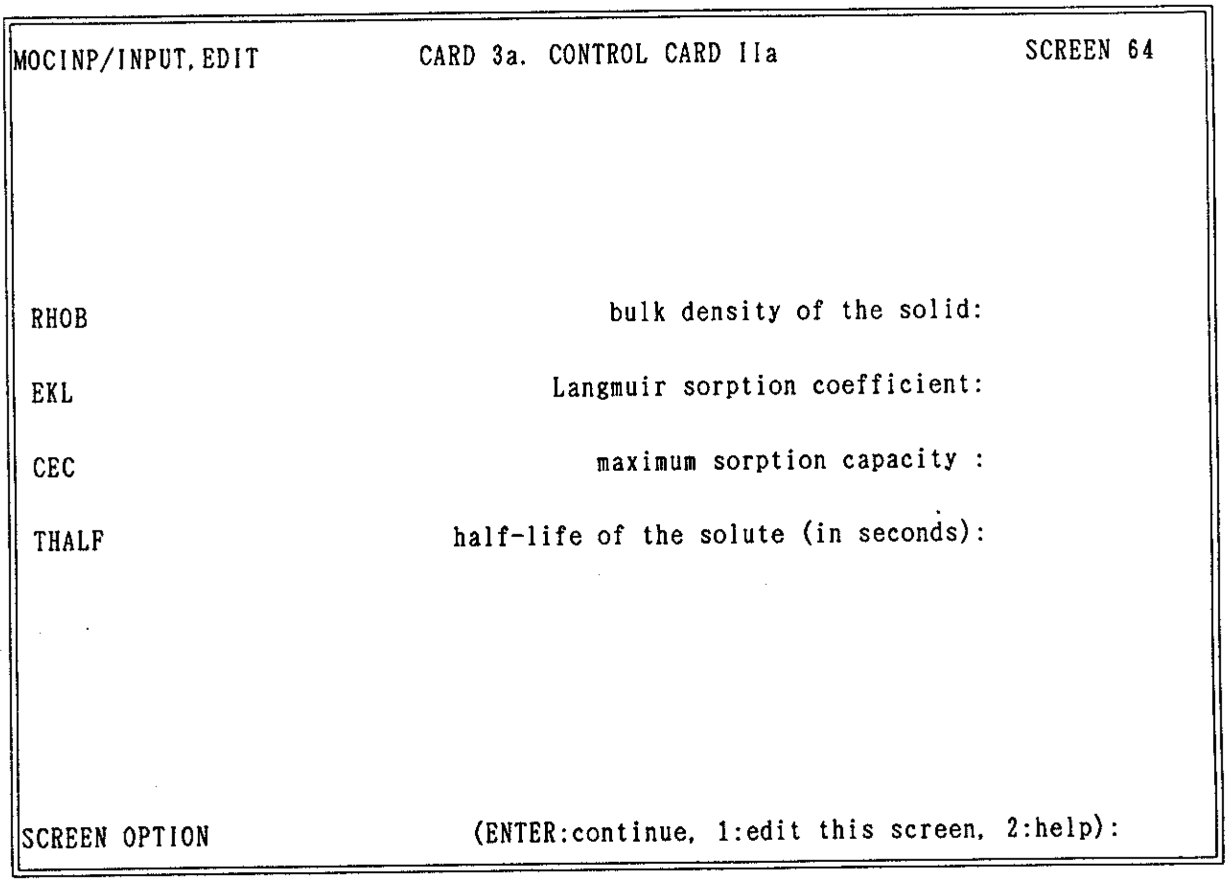
```
MOCINP/INPUT,EDIT            CARD 3a.  CONTROL CARD IIa                 SCREEN 62

 THALF                            Half-life of the solute (in seconds):

SCREEN OPTION                   (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.21 MOCINP Screen for CARD 3a. CONTROL CARD IIa(2)



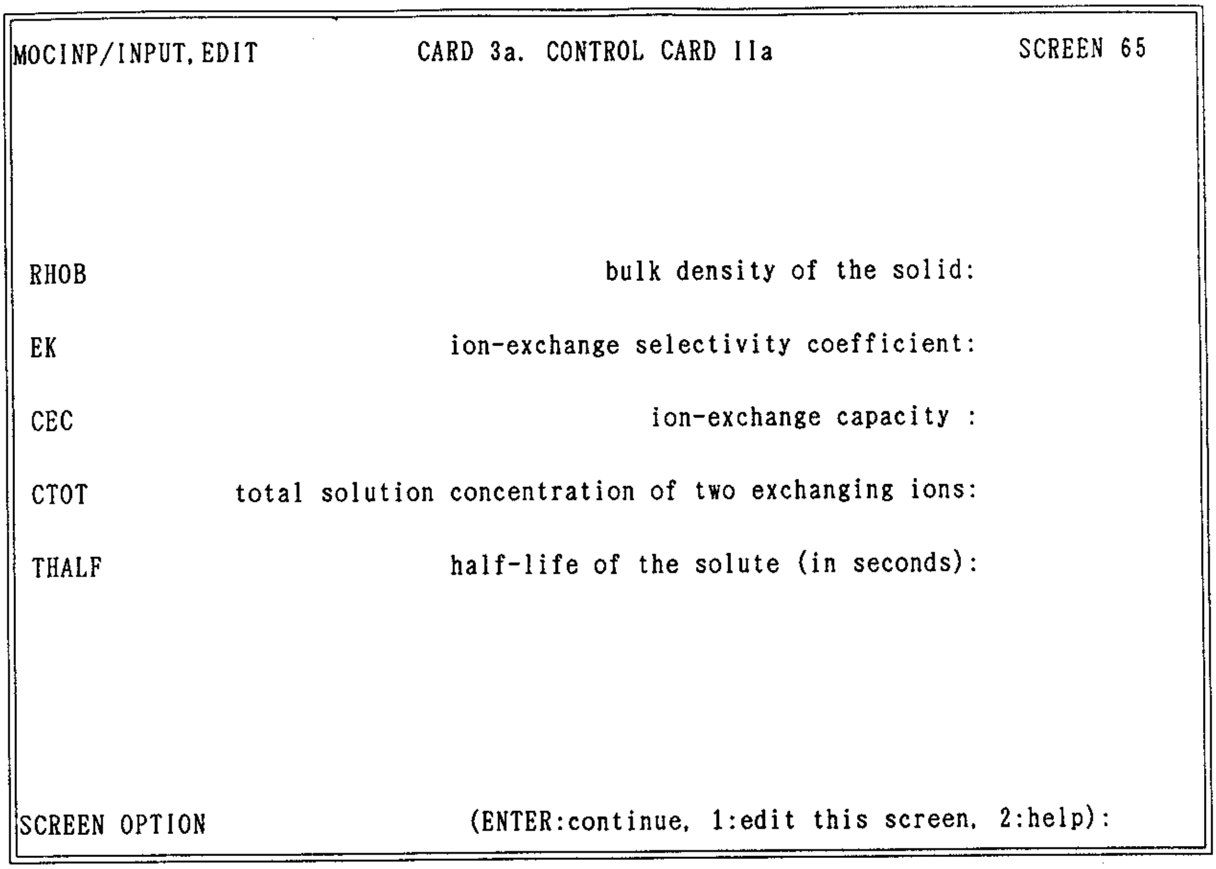
```
MOCINP/INPUT,EDIT          CARD 3a. CONTROL CARD IIa                SCREEN 63



 RHOB                                          bulk density of the solid:

 EKF                                     Freundlich sorption coefficient:

 XNF                                        Freundlich sorption exponent:

 THALF                                half-life of the solute (in seconds):




SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.22 MOCINP Screen for CARD 3a. CONTROL CARD IIa(3)



```
MOCINP/INPUT,EDIT          CARD 3a. CONTROL CARD IIa                SCREEN 64



 RHOB                                          bulk density of the solid:

 EKL                                       Langmuir sorption coefficient:

 CEC                                        maximum sorption capacity :

 THALF                                half-life of the solute (in seconds):




SCREEN OPTION                  (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.23 MOCINP Screen for CARD 3a. CONTROL CARD IIa(4)



```
MOCINP/INPUT.EDIT          CARD 3a. CONTROL CARD IIa                SCREEN 65



 RHOB                                       bulk density of the solid:

 EK                               ion-exchange selectivity coefficient:

 CEC                                             ion-exchange capacity :

 CTOT        total solution concentration of two exchanging ions:

 THALF                           half-life of the solute (in seconds):




SCREEN OPTION                (ENTER:continue, 1:edit this screen, 2:help):
```

Figure 4.24 MOCINP Screen for CARD 3a. CONTROL CARD IIa(5)

4.4 MODEL OPERATION

MOC executes in a batch environment system designed by TECSOFT INC. In the response to the system prompt C:>TECSOFT, type TECSOFT and press <ENTER>, then the following TECSOFT ACCESS MENU will appear on the screen. Select MOC from the menu and press <ENTER>. Enter the default data drive where all data is read or written. If the user is using the hard disk, the drive name is C (or D).

MOCINP is selected when the user creates or modifies data files required by MOC as described in the previous chapter.

The batch processing environment is initiated by selecting MOC from the menu. The four (4) major functions within the batch shell are FILES, SELECT, EXECUTE and QUIT.

Help is available for most functions within the shell by pressing the <F1> function key while highlighting that function. Exit help by pressing the <ESC> key.

4.4.1 FILES

FILES permits the creation (CREATE) or modification (MODIFY) of batch files necessary for execution. The default extension for the batch files is 'MCB'. Any number of MOC batch files may exist concurrently. Prior to execution, a batch file must be selected.

To execute, MOC requires various files:

1. A data file must be provided for each simulation. This file is created and/or modified using MOCINP.
2. The name of Hardcopy Output File must be specified. This file will contain all output generated during the simulation.
3. If Binary Concentration/Head/Drawdown data is to be saved, the name of the file in which it will be saved must be also be specified.

Rather than enter the file names manually during MOC execution, a batch file is selected prior to execution. The Batch File contains all filenames required for MOC execution. Batch Files may be created or modified by the program. It is noted that the Batch Files described are internal to the TECSOFT version of MOC and have no relation to DOS batch files.

(1) CREATE

In the Create Batch File process, the program prompts for two file types:

1. Specified Files (Hardcopy Output, Binary Concentration/Head/Velocity Vectors and Batch Files).
2. Selected File (MOC Data File).

The Specified Files are created during MOC execution. The default extensions for the Specified Files are:

OUT (Hardcopy Output File)
BIN (Binary File - Concentration/Head/Velocity)

MCB (MOC Batch File)

The MOC Data File was previously created using MOCINP and is selected from a picklist when creating the batch File. The default extension for the MOC Data File is .DAT. A group of files may also be selected by using a different mask.

For example, to select all files with a .NAM extension, enter *.NAM for the mask. Wild card characters may be used. All files in current directory may be displayed by using the mask (*.*).

To change the pick directory, select the entry at the top of the list. The desired directory may now be selected. To select a specific file, merely type the name (up to 63 characters).

(2) MODIFY

In the Modify Batch File process, the Batch File to be modified is selected. The program sequentially displays the filenames read from the Batch File and modifications may be made. The name of the Batch Files containing the modifications is specified.

The Specified File names may be edited or overridden. The default extensions for the Specified Files are the same as mentioned above.

(3) Specify File

Enter a pathname of up to 63 characters or a filename of up to 12 characters. The format is:

```
[C]:[\dirname][\dirname]...[\]filename[.ext]
```

A sophisticated line editor with Wordstar compatibility is included for use when entering the name of the file.

4.4.2 SELECT

This option selects an existing MOC Batch File prior to MOC execution. MOC will not execute if a selection has not been made. The Batch File may be created or modified prior to selection.

The Batch File may be selected by entering a specific file name or choosing from a picklist. If entering a specific file name, a pathname may consist of up to 63 characters. The filename itself may consist of up to 12 characters. The format is:

```
[c]:[\dirname][\dirname]...[\]filename[.ext]
```

After the Batch File is selected, Specified Files are checked for path existence and the data File is checked for existence prior to MOC execution.

4.4.3 EXECUTE

Execute MOC using the Selected Batch File. The appropriate solver (MOCADI or MOCSIP) must be selected. MOCADI solves MOC using the Alternating Direction Implicit method. MOCSIP solves MOC using the Strongly Implicit Procedure method.

For most problems, MOCADI should be used. However, for steady-state cases when grid nodes have zero transmissivity and for cases in which the transmissivity is highly anisotropic, MOCSIP should be used.

If a Batch File was not selected prior to execution, an error message is reported.

MOC errors, which normally result in program abortion, are reported and appropriate action can be taken.

4.4.4 QUIT

This option is to terminate the MOC program. It is recommended that the user should move the cursor to QUIT and press <ENTER> key immediately after Executing to avoid losing created data files.

4.5 OUTPUT PROCESSOR

MOC generates a Hardcopy Output File and a Binary File which may contain concentrations, heads and velocity vectors.

MOCREC was provided in the MOC package to remove carriage control characters and replace with appropriate ASCII control characters, if desired.

An output processor MOCOUT was also provided in the package. MOCOUT takes as input the binary file from MOCADI (or MOCSIP) and outputs an ASCII file. Binary data may have been saved for all simulation time steps (NPNCHV=1). Rather than process all of this data with MOCGRAF, when only a subset is required. MOCOUT gives the user an opportunity to thin out the data while converting to ASCII.

The four (4) major functions such as FILES, INPUTS, EXECUTE and QUIT are used in the MOCOUT program.

Help is available for most functions within the shell by pressing the <F1> function key while highlighting that function. Exit help by pressing the <ESC> key.

4.5.1 FILES

Select all inputs and output files required by MOCOUT.
The input file is:

- The Binary File which may contain concentrations, heads and velocity vectors.

This is the only required input file for MOCOUT. If this file has not been specified prior to execution of MOCOUT, the execution will abort.

The Binary File may be selected by entering a specific filename or choosing from a picklist. The picklist default is *.BIN for the Binary File.

The output files are:

- The ASCII MOCGRAF Data File
- The Hardcopy Output File

These are the required output files for MOCOUT. If either of these files has not been specified prior to execution of MOCOUT, the execution will abort.

The ASCII MOCGRAF data file is the file containing ASCII Concentration/Head/Velocity Vector data which will be input to MOCGRAF. This file may contain all or a subset of the data contained in the original binary file. This file will be used by MOCGRAF to produce contours of concentrations and heads and, opptionally, velocity vectors. A pathname of up to 63 characters or a file name of up to 12 characters must be entered. The format is:

```
[C]:[\dirname][\dirname]...[\]filename[.ext]
```

The Default file extension is [.MCG]

4.5.2 INPUTS

This option is used to select a required input other than a file name. The input which will be selected is:

- Output ASCII File Format

4.5.3 EXECUTE

The MOCOUT program converts binary (Concentration/Heads/ Velocity Vector) files generated by MOC to ASCII files which may be read and contoured by MOCGRAF. Each binary file may contain numerous sets of data. Each set corresponds to a particular time step and pumping period from the MOC simulation.

In addition to converting from binary to ASCII, MOCOUT affords the opportunity to view the time step, pumping period and total elapsed time corresponding to each set of binary data read and to determine whether that set of data shall be converted to ASCII and saved in a file.

All or part of the original binary file may be converted and saved. The original binary files are neither destroyed nor modified in the conversion process.

Three options exist for saving ASCII data:

1) Save all ASCII data in one file for use with MOCGRAF.
2) Save each set of ASCII data in TECKON format.
3) Save each set of ASCII data in general XYZ format.

(1) Option (1)

In addition to offering simplicity by using a single ASCII file, Option (1) (MOCGRAF option) is easiest to use. It eliminates the book-keeping and possible confusion associated with the use of multiple files and requires minimal intervention.

MOCGRAF is a graphic module designed specially for use with the MOC model. MOCGRAF requires relatively little user intervention and is extremely easy to use. It uses sophisticated algorithms to produce high resolution graphics on a variety of graphics devices.

(2) Option (2)

Although Option (2) requires the use of individual ASCII files, it permits the use of TKON2R and TKON3D, 2-D and 3-D contouring by TECSOFT. TKON2R and TKON3D are powerful modules offering a wide selection of contouring options and customizing capability.

(3) Option (3)

This option produces general XYZ ASCII files. The Binary File is a file created by MOC and may contain any or all of the following data types:

- Concentration
- Head
- Velocity Vector

Each set corresponds to a specific time step and pumping period of the MOC simulation. The Binary file is converted to one or more ASCII files by MOCOUT.

As each set of binary data is read, the data may be written to an ASCII file or discarded. In any event, the binary file is not modified. Since ASCII files usually require much more disk space than binary files containing equivalent data, if disk space is concern, only the data of immediate interest need be saved as ASCII.

4.5.4 QUIT

This option is to terminate the MOCOUT program. It is recommended that the user should move the cursor to **QUIT** and press Enter key immediately after Executing to avoid losing created data files.

4.6 GRAPHICS

MOCGRAF is a program provided in the TECSOFT package. MOCGRAF is used to contour heads and concentrations and to generate velocity vectors which may be superimposed on the contours or drawdown stand-alone. MOCGRAF reads and processes the ASCII file from MOCOUT.

TECSOFT's TRANSLATE program is required to process the plot files generated by MOCGRAF and output the graphics.

4.6.1 MOCGRAF

The batch processing environment is initiated by selecting MOCGRAF from the TECSOFT menu. The four (4) major functions within the batch shell are **FILES**, **SELECT**, **EXECUTE** and **QUIT**.

Help is available for most functions within the shell by pressing the <F1> function key while highlighting that function. Exit help by pressing the <ESC> key.

(1) FILES

To Execute, MOCGRAF requires a Batch File. The Batch File contains specific (numeric and text) inputs required to execute MOCGRAF, in addition to input/output files. The Batch Files may be created or modified by the package prior to MOCGRAF execution. The following filenames are contained in the Batch Files:

1. An ASCII Data File produced by MOCOUT which contains concentration, head and velocity vector data.

2. The name of the Plot File which will be created by MOCGRAF and which contains graphics information which will be input to TRANSLATE.

3. The name of a Hardcopy Output File which will contain all output generated during MOCGRAF execution. This file is optional.

It is noted that the Batch Files described above are internal to the MOCGRAF package and have no relation to DOS batch files.

The data associated with the creation of head and/or concentration contours and, optionally, the superposition of velocity vectors is entered through a series of seven (7) possible menus. The program scans the Input Data File and sequentially displays the appropriate set of menus for each set of data. <PgUp> key and <PgDn> key are used to select the various menus.

a) Menu 1 -- Graphics Options

This menu displays the ordinal number of the current data set and indicates whether head, concentration and velocity vector data are present. Also displayed are the Time Step, Pumping Period and Total Elapsed Time. The times are displayed in years.

The user may select this set of data for contouring. If both head and concentration data are present, the user may choose to contour either or both. If neither is to be contoured, the program skips to read the next set. If the head and/or concentration data is selected for contouring and if velocity vector data is present, the user is prompted to specify whether velocity vectors will be superimposed on the contours.

b) Menu 2 -- Aspect Ratio

The aspect ratio is defined as:

(Length of Y-axis) / (Length of X-axis)

The program scans the current set of data, computes the aspect ratio and displays the computed value. The user is prompted to enter the aspect ration and, thus, may override the computed value.

c) Menu 3 -- Contour Section Types

Contour levels may be selected in one of three (3) ways:

1. Computer Selects Contour Levels (Default)
2. User Selects Maximum, Minimum and Increment
3. User Selects Specific Contour Levels

If the computer (program) selects the contour levels, the data set is scanned and a set of pleasing, evenly spaced levels is chosen. If both head and concentration data are present in the current data set, contour levels may be selected in a different manner for each.

d) Menu 4 -- Contour Incrementand Bounds

This menu is displayed only if the user selects the minimum and maximum contour levels and increment. The program scans the data set and computes the minimum and maximum values of the data to be contoured and computes an interval based on ten (10) contour levels. The data is then displayed. The user may override these computed values with his/her own selections.

e) Menu 5 -- Selected Contour Levels

This menu is displayed only if the user selects specific contour levels. The program scans the data and computes the minimum and maximum values of the data to be contoured. The data is displayed. The user specifies the number of contour levels which will be selected. The maximum allowable number is 50.

f) Menu 6 -- Selected Contour Levels

This menu is only displayed only if the user selects specific contour levels. The desired contour levels are entered through this menu.

g) Menu 7 -- Title/Label Options

Title, X-axis and Y-axis labels for heads and/or concentration data may be entered through this menu. Each may consist of a string of up to 40 alpha-numeric characters.

Menus 1 through Menu 7 repeat for each set of data processed.

(2) SELECT

This option selects an existing MOCGRAF Batch File prior to MOCGRAF execution. MOCGRAF will not execute if a selection has not been made. The Batch File may be created or modified prior to selection.

The batch File may be selected by entering a specific file name or choosing from a picklist. The picklist default is *.GCB. If entering a specific file name, a pathname may consist of up to 63 characters. The filename itself may consist of up to 12 characters.

After the Batch File is selected, Specified Files are checked for path existence and Selected Files are checked for file existence prior to MOCGRAF execution.

(3) EXECUTE

Execute MOCGRAF using the Selected Batch File. If a Batch File was not selected prior to execution, an error message is reported. MOCGRAF errors, which normally result in program abortion, are reported and appropriate action can be taken.

(4) QUIT

This option is to terminate the MOCGRAF program.

4.6.2 TRANSLATE

TRANSLATE produces high quality screen, dot matrix printer and vector plotter graphics on a wide variety of devices by translating a graphics metacode file (previously generated by a TECSOFT application program such as MOCGRAF). Among the devices supported are: CGA, EGA, Hercules, AT&T (normal & high resolution) screen graphics; IBM graphics printer, Epson and Comrex printers; Hewlett-Packard, Houston Instruments, IBM, Calcomp, Roland, Sweet Pea and other vector plotters.

The graphics files may contain up to 500 pictures (plots) stacked sequentially as pictures in camera. TRANSLATE permits selective slipping or plotting of specific pictures. Re-translation for another device is possible without exiting from the program. Paper size (A, B, C, D, E) may be selected through the program for applicable plotters. Serial port (plotters, printers), parallel port (printers) and baud rate (plotters) are also selected.

The procedure for running the program is to set the system to the drive and directory where the program resides. Type TECSOFT and press <ENTER>. Select TRANSLATE from the TECSOFT ACCESS MENU and press <ENTER>. Enter the default drive. This is the drive where all data is read or written. The TRANSLATE introductiry menu appears. The user is prompted for program inputs through a series of menus. Press any key to invoke the Metacode Graphics File menu.

The usage of the program is mentioned below:

(1) METACODE PLOT FILE NAME

ENTER PLOT FILE NAME:
Enter the name of the metacode graphics file to be translated. This is a graphics file created by a TECSOFT program.

It is noted that the metacode graphics file name may consist of up to 61 characters (including optional path designation). A drive letter must never be appended to the file name since it is specified in the TECSOFT ACCESS MENU and is automatically concatenated to the name. If a path designation is used, the file name appears as:

\subdir1\subdir2\...\filename.

(2) SELECT FUNCTION

<1> TRANSLATE A FILE
<2> CREATE Hewlett-Packard HPGL FILE(S)
<3> CREATE AutoCAD (.DXF) FILE(S)
<R> RETURN TO PREVIOUS MENU
<E> EXIT TO TECSOFT ACCESS MENU.

Selection <1> reads a metacode graphics file and selectively produces plots on the selected device (plotter, printer or screen). No additional files are saved.

Selection <2> reads a metacode graphics file and selectively converts plots to HPGL (Hewlett-Packard Graphics Language), an ASCII graphics code, and saves the results in specified files. Once a plot has been converted to HPGL and saved, That file may later be incorporated directly into many popular word processors and desktop publishing packages to produce professional looking reports with graphics.

Selection <3> reads a metacode graphics file and selectively creates AutoCAD DXF files. DXF files are ASCII files written in a format recognizable to AutoCAD, ProDesign II and other CAD packages. Once input to a CAD package supporting the DXF convention, a file can be saved as a working drawing. This selection is available only with the DXF version of TRANSLATE.

ENTER SELECTION:
Enter Selection 1,2,3,R or E.

(3) SELECT GRAPHICS TYPE

<1> VECTOR PLOTTER
<2> SCREEN GRAPHICS
<3> PRINTER GRAPHICS
<4> RETURN TO PREVIOUS MENU
<5> EXIT TO TECSOFT ACCESS MENU

This menu appears only if translating a file (Selection <1>) is selected.

ENTER GRAPHICS SELECTION
Enter selection (1,2 or 3).

(3.1) VECTOR PLOTTER

ENTER SERIAL PORT#(1,2):
Enter the serial port (1 or 2) to which the plotter is connected.

ENTER BAUD RATE 1 2 3 4 5 6:
Enter selection (1,2,3,4,5 or 6). These correspond to baud rates of 300, 600, 1200, 2400, 4800 and 9600, respectively.

The plotter currently supported are:

- HEWLETT PACKARD 7440 ColorPro, 7470, 7475, 7550 DraftPro, 7580, 7585, 7595 DraftMaster
- HOUSTON INSTRUMENTS DMP29, DMP40, DMP41, DMP42, DMP51, DMP52, 595, 695
- CALCOMP 945, 965, 1040, 1070
- IBM 7371, 7372
- ROLAND 880, 980
- SWEET PEA 100, 600
- FACIT 4550, 4551
- GOULD 6120, 6320, TAXAN 710
- WESTERN GRAPHTEC MP1000, MP2000

Select the brand of plotter, the specific model and paper size, if applicable. Choose an option by entering the appropriate character.

(3.2) SCREEN GRAPHICS

The Screen Graphics types aurrently supported include:

- CGA (640x200)
- EGA (640x350)

- Hercules (720x345)
- AT&T normal and high resolution (640x200, 640x400)

(3.3) PRINTER GRAPHICS

ENTER PORT TYPE (SERIAL OR PARALLEL)(S/P):

A printer may be connected to either a serial or parallel port. Enter Selection (S or P).

If 'S" is selected, enter the serial port number (1 or 2).
If 'P' is selected, enter the parallel port number (1,2 or 3).

The Printer Graphics types currently supported include:

- IBM PC Graphics Printer
- EPSON FX, LX, RX, MX series (single or double density)
- EPSON LQ series (single or double density)
- COMREX 420
- HP LaserJet Series II

Select the brand of printer and specific model. Choose an option by selecting the appropriate character.

(4) TRANSLATOR OPTIONS

<P> PLOT THIS PICTURE
<S> SKIP THIS PICTURE
<R> RESELECT FUNCTION

If <P> is selected, the metacode file is read and the current picture is plotted on the selected plotter.

If <S> is selected, the metacode file is read and the current picture will be skipped.

Choosing <R> will return for selection of another device. The metacode graphics file is automatically rewound and another graphics device (screen, printer or vector plotter) may be selected.

This menu appears only if translating a file (Selection <1>) is selected.

(5) HEWLETT PACKARD - HPGL

<1> HP7470, HP7440 ColorPro
<2> HP7475
<3> HP7550
<4> HP7570 DraftPro
<5> HP7580
<6> HP7585
<7> HP7595 DraftMaster

ENTER SELECTION:
Enter selection (1,2,3,4,5,6 or 7).

A prompt for paper size (A,B,C,D or E) will also appear, if applicable. The HPGL files will vary slightly between plotter models. Although most HPGL commands apply to all HP plotters, a few commands do not apply to all of the plotter models.

This menu appears only if Creating HPGL Files (Selection <2>) is selected.

(6) HPGL OPTION MENU

<W> WRITE HPGL FILE FOR THIS FRAME
<S> SKIP THIS PICTURE
<R> RETURN TO PREVIOUS MENU
<E> EXIT TO TECSOFT ACCESS MENU

If Selection <W> is made, the metacode file is read, and an HPGL file will be written. The following prompt appears:

ENTER HPGL FILE NAME:
The HPGL file names may consist of up to 61 characters.

If Selection <F> is made, the metacode file will be read but an HPGL file will not be written.

<R> returns for selection of another function.

The HPGL OPTION MENU appears only if Creating HPGL Files (Selection <2>) is selected.

(7) AutoCAD OPTION MENU

<B> BUILD DXF FILE FOR THIS FRAME
<S> SKIP THIS FRAME
<R> RETURN TO PREVIOUS MENU
<E> EXIT TO TECSOFT ACCESS MENU

If Selection <B> is made, the metacode file is read, and a DXF file will be written. The following prompt appears:

ENTER DXF FILE NAME:

If Selection <B> is made, the metacode file is read, and a DXF file will be written. The following prompt appears:

ENTER DXF FILE NAME:

The DXF file names may be consist of up to 61 characters.

If Selection <S> is made, the metacode file will be read but a DXF file will not be written.

The AutoCAD OPTION MENU appears only if Creating DXF Files (Selection <3> is chosen.

APPENDIX A

COMPUTER PROGRAMS AND RELATED DATA FOR Q3P MODEL

```
C     ********************************************
C     *                                          *
C     * TWO-DIMANSIONAL/QUASI THREE DIMENSIONAL  *
C     * GROUNDWATER FLOW MODEL (Q3P MODEL)       *
C     * FOR METRO MANILA GROUNDWATER BASIN       *
C     ********************************************
C
C     *** VARIABLES, ARRAY ***
C       HN(I,1)   = PHREATIC WATER LEVEL (M)
C       HN(I,2)   = HEAD OF CONFINED AQUIFER-1
C       HN(I,3)   = HEAD OF CONFINED AQUIFER-2
C       IDENT     = MODEL SPECIFICATION
C                   (0: PLAIN 2-D MODEL FOR SINGLE AQUIFER)
C                   (1: QUASI 3-D MODEL FOR SINGLE AQUIFER)
C                   (2: QUASI 3-D MODEL FOR DOUBLE AQUIFER)
C       T         = TRANSMISSIVITY(M**2/D)
C       S         = STORAGE COEFFICIENT
C       X,Y       = X- AND Y-COORDINATES
C       BD        = LEAKANCE(1/M)
C       SS        = SPECIFIC STORAGE(1/M) OF AQUICLUDE
C       Q         = DISCHARGE(M**3/D)
C       DT        = DURATION OF 1-TIME STEP (D)
C       NSTEPS    = NUMBER OF STEPS
C       NINTER    = NUMBER OF DIVIDE IN ONE CALSULATION STEP
C       NP        = NUMBER OF NODES
C       NE        = NUMBER OF ELEMENTS
C       NBAND     = WIDTH OF BAND
C       NC(I)     = NUMBER OF CONSTANT-HEAD NODEL IN AQUIFER-I
C       KQIN      = 1:STEADY-STATE 2:NONSTEADY-STATE
C       KOUT      = 1:OUTPUT ALL STEPS 2:OUTPUT FINAL STEP
C       KHIN      = INPUT INITIAL HEADS
C                   (0:FROM FILE-5)
C                   (1:FROM FILE-3)
C       KPRI      = NUMBER OF OUTPUT STEPS
C       NPRINT(I) = STEP NUMBER FOR PRINT OUT
C       DX,DY     = SCALE FOR MAP PRINT OUT
C     *** INPUT  ***
C       FILE-1  : DISCHARGE DATA
C       FILE-3  : INITIAL HEADS
C       FILE-5  : CONTROL DATA
C       FILE-7  : AQUIFER PARAMETERS
C     *** OUTPUT ***
C       FILE-2  : COMPUTED HEADS
C       FILE-6  : LIST OF RESULTS
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      COMMON /BK4/R(900)
      COMMON /BK8/LBL(900),NBK,NLL,NL(15),NLE(15,100),NLP(15,100),
     *             H0(990,2)
      INTEGER*2   NOP,NOHC,NPRINT,NNO,NL,NLE,NLP,LBL
      CHARACTER*8 TITLE,CN
C==FILE SPECIFICATION==========================================
      OPEN(UNIT=1,FILE='\MSA\DAT\QIN30.DAT',STATUS='OLD')
      OPEN(UNIT=19,FILE='\MSA\DAT\RIN30.DAT',STATUS='OLD')
      OPEN(UNIT=5,FILE='\MSA\DAT\Q3PSIM2.PAR',STATUS='OLD')
      OPEN(UNIT=7,FILE='\MSA\DAT\PRM_03.DAT',STATUS='OLD',
     *FORM='UNFORMATTED')
      OPEN(UNIT=4,FILE='\MSA\DAT\NOP.DAT',STATUS='OLD')
      OPEN(UNIT=13,FILE='\MSA\DAT\NOD.DAT',STATUS='OLD')
      OPEN(UNIT=3,FILE='\MSA\DAT\INI_08.DAT',STATUS='OLD',
     *FORM='UNFORMATTED')
      OPEN(UNIT=8,FILE='\MSA\DAT\HBOUND.DAT',STATUS='OLD')
      OPEN(UNIT=14,FILE='\MSA\DAT\OBSH63_2.DAT',STATUS='OLD')
      OPEN(UNIT=15,FILE='\MSA\DAT\BLOCK.DAT',STATUS='OLD',
     *BLANK='ZERO')
C=================================================================
      OPEN(UNIT=6,FILE='\MSA\OUT\Q3P_30.LST',STATUS='NEW')
C     OPEN(UNIT=2,FILE='\MSA\OUT\CAL_30.DAT',STATUS='NEW',
C    *FORM='UNFORMATTED')
      OPEN(UNIT=20,FILE='\MSA\OUT\INI_30.DAT',STATUS='NEW',
     *FORM='UNFORMATTED')
```

```
C     OPEN(UNIT=22,FILE='\MSA\OUT\HBU_30.DAT',STATUS='NEW',
C    *FORM='UNFORMATTED')
      OPEN(UNIT=24,FILE='\MSA\OUT\FOR024.DAT',STATUS='NEW',
     *FORM='UNFORMATTED')
      OPEN(UNIT=30,FILE='\MSA\OUT\FOR030.DAT',STATUS='NEW')
      OPEN(UNIT=28,FILE='\MSA\OUT\BLOCK.OUT',STATUS='NEW')
C==================================================================
C==================================================================
C     **********  ZERO CLEAR   ********************
      CALL CLEAR
C     **********  DATA INPUT  ********************
      CALL GDATA(IL)
C     **********  ESTABLISH MATRIX   **************
      DO 10 ID=1,IL
      CALL FORMK(ID)
   10 CONTINUE
C     **********  START CALCULATION ************
      IF(KQIN.EQ.1) READ(1,101) ((Q(I,J),I=1,NE),J=1,IL)
      IF(KQIN.EQ.1) READ(19,101) (R(I),I=1,NE)
  101 FORMAT(10F10.0)
      KT=1
      WRITE(*,192)
  192 FORMAT(///19X,2X,'STEP')
C
      DO 200 KY=1,NSTEPS
      WRITE(*,191)KY
  191 FORMAT(1H+,15X,I3)
      IF(KQIN.EQ.2) READ(1,101) ((Q(I,J),I=1,NE),J=1,IL)
      IF(KQIN.EQ.2) READ(19,101) (R(I),I=1,NE)
      DO 20 J=1,IL
      K=NC(J)
      READ(8,102) (HC(I,J),I=1,K)
   20 CONTINUE
  102 FORMAT(10F8.2)
C
C     **********  CREATE BASIC VECTOR *************
      CALL RIGHT(1)
      GO TO (300,301),IL
  301 CALL RIGHT(2)
      CALL RIGHT(2)
      CALL RIGHT(1)
C     **********  PRINT OUT RESULTS ***************
  300 IF(NWEL.NE.0) THEN
      DO 30 I=1,NWEL
      IW=NS(I)
      DO 40 J=1,2
      CAL(I,J,KY)=HN(IW,J)
   40 CONTINUE
   30 CONTINUE
      ENDIF
C     IF(KHOUT.GE.2) WRITE(2) ((HN(I,J),I=1,NP),J=1,IL)
C     IF(NPRINT(KT).EQ.KY) THEN
                  CALL PRINT(KY)
                  CALL OUTPUT(1,KY)
      IF(IL.EQ.2) CALL OUTPUT(2,KY)
C     WRITE(22)KY,((HN(I,J),I=1,NP),J=1,IL)
   21 KT=KT+1
C     ENDIF
  200 CONTINUE
      IF(KHOUT.GE.1) WRITE(20) ((HN(I,J),I=1,NP),J=1,IL)
C     ********** OUTPUT OBSERVED HEADS ***
      IF(NWEL.EQ.0)  GO TO 900
      DO 800 N=1,NWEL
      WRITE(24)((CAL(N,J,KY),KY=1,NSTEPS),J=1,IL)
      IF(NWOUT(N).NE.0)CALL WELPRI(N)
  800 CONTINUE
  900 STOP
      END
      SUBROUTINE CLEAR
C
C     ************************************
C     *                                  *
C     * ZERO CLEAR                       *
C     *                                  *
C     ************************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
```

```
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
      DO 20 ID=1,2
      DO 10 I=1,990
      DO 10 J=1,30
      SK(I,J,ID)=0.0
   10 CONTINUE
      DO 15 I=1,900
      T(I,ID)    =0.0
      S(I,ID)    =0.0
   15 BD(I,ID)   =0.0
   20 CONTINUE
      RETURN
      END
      SUBROUTINE GDATA(IL)
C
C     ***********************************
C     *                                 *
C     * DATA INPUT                      *
C     *                                 *
C     ***********************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      COMMON /BK8/LBL(900),NBK,NLL,NL(15),NLE(15,100),NLP(15,100),
     *            H0(990,2)
      INTEGER*2   NOP,NOHC,NPRINT,NNO,NL,NLE,NLP,LBL
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
C     **********  INPUT DATA   ********************
C     ***  << TITLE & CONTROL DATA>> **************
      READ(5,501) (TITLE(I),I=1,4),NP,NE,NBAND,IDENT,NSTEPS,IROW,JCOL,
     *            DT,X1,Y1,(NC(I),I=1,2),KQIN,KHOUT,KHIN,IPP,
     *            KPRI,NWEL,IHO,VIND,NBK,NLL
      READ(5,511) (NPRINT(I),I=1,KPRI)
  501 FORMAT(4A8/7I5/3F10.5/2I5/4I1,I5/2I5/F10.5/2I5)
  511 FORMAT(20I4)
      IL=2
      IF(IDENT.LE.1) IL=1
C     ***  << ELEMENT NUMBERING >> **************
      READ(4,503) ((NOP(I,J),J=1,4),I=1,NE)
  503 FORMAT(32I4)
      DO 10 I=1,IROW+1
      READ(13,512) (NNO(I,J),J=1,JCOL+1)
   10 CONTINUE
  512 FORMAT(30I4)
C     *** ERROR CHECK ******************************
      CALL ERCHK
C     *** <<BLOCK LABEL >> *************************
      IF(NBK.NE.0) READ(15,589) (LBL(I),I=1,NE)
      IF(NLL.NE.0) THEN
      READ(15,591) (NL(I),I=1,NLL)
      DO 11 I=1,NLL
      J=NL(I)
      READ(15,590) (NLE(I,K),NLP(I,K),K=1,J)
   11 CONTINUE
      ENDIF
  589 FORMAT(40I1)
  590 FORMAT(10(I4,I2))
  591 FORMAT(20I4)
C     *** << LEAKANCE >> ***************************
      IF(IDENT.EQ.0) GO TO 41
      DO 20 J=1,IL
   20 READ(7) (BD(I,J),I=1,NE)
C
      WRITE(*,507)(BD(I,1),I=1,NE)
  505 FORMAT(10F8.6)
C     *** << TRANSMISSIVITY & STORAGE COEFFICIENT >> ***
```

```
      DO 51 J=1,IL
   51 READ(7) (T(I,J),I=1,NE)
      DO 50 J=1,IL
   50 READ(7) (S(I,J),I=1,NE)
  507 FORMAT(10F8.7)
C     *** << PHREATIC WATER LEVEL >> **********
      IF(IDENT.GE.1) READ(7) (HF(I),I=1,NE)
C     *** << INITIAL HEADS >> *****************
      IF(KHIN.EQ.0) THEN
      DO 55 J=1,IL
   55 READ(7) (HN(I,J),I=1,NP)
  510 FORMAT(10F8.2)
      ELSE
      READ(3) ((HN(I,J),I=1,NP),J=1,IL)
      ENDIF
  100 CONTINUE
  508 FORMAT(10F8.0)
C     ***  << CONSTANT-HEAD BOUNDARY >> *******
   41 CONTINUE
      READ(8,506)NNC, (NOHC(I,1),I=1,NNC)
      NC(1)=NNC
      NC(2)=NNC
      DO 12 I=1,NNC
      NOHC(I,2)=NOHC(I,1)
   12 CONTINUE
  506 FORMAT(20I4)
   40 CONTINUE
      READ(5,543)RRR
  543 FORMAT(F5.2)
C     *** << OBSERVED HEADS >> ****************
      IF(NWEL.EQ.0) GO TO 90
      DO 93 I=1,NWEL
   93 READ(14,542) NS(I),NW(I),(CN(I,J),J=1,3),SVAL(I),EVAL(I),NWOUT(I)
  542 FORMAT(I4,I2,3A8,2F10.4,I1)
      IF(IHO.EQ.0)  GO TO 90
      DO 91 I=1,NWEL
      N=NW(I)
      DO 91 J=1,N
      READ(14,541)
   91 READ(14,541)(OBS(I,J,K),K=1,NSTEPS)
  541 FORMAT(8X,12F6.2)
   90 CONTINUE
C     ********** DATA PRINT OUT **************
      IF(IPP.NE.0) CALL DPRINT(DT,KPRI)
      IF(IL.EQ.2) DT=DT/2.0
      DO 30 J=1,IL
      DO 30 I=1,NE
      S(I,J)=X1*Y1*S(I,J)/DT/36.0
      BD(I,J)=X1*Y1*BD(I,J)/36.0
   30 CONTINUE
      DO 13 I=1,NP
      DO 14 J=1,IDENT
      HO(I,J)=HN(I,J)
   14 CONTINUE
   13 CONTINUE
      RETURN
      END
      SUBROUTINE DPRINT(DT,KPRI)
C
C     ***********************************
C     *                                 *
C     * DATA PRINT OUT                  *
C     *                                 *
C     ***********************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
C
      WRITE(6,601) (TITLE(I),I=1,4),NP,NE,NBAND,IDENT,NSTEPS,
     *             (NC(I),I=1,2),DT,X1,Y1,KQIN,KHOUT,KHIN,
```

```
     *            KPRI,NWEL,IHO,VIND,IROW,JCOL
  601 FORMAT(1H1///10X,4A8//16X,'NP =',I5/16X,'NE =',
     *I5/13X,'NBAND =',I5/13X,'IDENT =',I5/
     *13X,'NSTEPS =',I5/13X,'NC(1) =',I5/
     *13X,'NC(2) =',I5/16X,'DT =',F5.0/16X,'X1 =',
     *F7.1/16X,'Y1 =',F7.1/14X,'KQIN =',
     *I5/13X,'KHOUT =',I5/14X,'KHIN =',I5/14X,'KPRI =',I5/
     *14X,'NWEL =',I5/15X,'IHO =',I5/
     *13X,'VIND =',F10.4///14X,'IROW =',I5/14X,'JCOL =',I5///)
      WRITE(6,608) (NPRINT(I),I=1,KPRI)
  608 FORMAT(10X,' =22 3A@^< =C/L_'/(10X,10I5))
C
      DO 60 I=1,NE
      IF(MOD(I,50).EQ.1) WRITE(6,604)
      WRITE(6,605) I,(NOP(I,J),J=1,4),(T(I,J),J=1,2),(S(I,J),J=1,2),
     *             (BD(I,J),J=1,2),HF(I),I
  604 FORMAT(//10X,'NOP(I,J),TRANS.,STORAGE COFF.,LEAKANCE '//5X,
     *       'I',9X,'NOP(I,J)',10X,'T(1)',4X,'T(2)',5X,'S(1)',5X,
     *       'S(2)',5X,'K/B(1)',3X,'K/B(2)',7X,'HF',5X,'I'/)
  605 FORMAT(3X,I4,1X,4I5,1X,2F8.1,1X,2F9.6,1X,2F9.6,1X,F9.2,2X,I4)
   60 CONTINUE
C
                  CALL OUTPUT(1,KY)
      IF(IDENT.EQ.2) CALL OUTPUT(2,KY)
  200 CONTINUE
      RETURN
      END
      SUBROUTINE ERCHK
C
C     **********************************
C     *                                *
C     * NOP, COODINATES ERROR CHECK    *
C     *                                *
C     **********************************
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
C     *** ERROR CHECK ******************************
      DO 5 N=1,NE
      I=NOP(N,1)
      J=NOP(N,2)
      K=NOP(N,3)
      L=NOP(N,4)
      MA=MAX0(I,J,K,L)
      MI=MIN0(I,J,K,L)
      NB=MA-MI+1
    5 IF(NB.GT.NBAND)  WRITE(6,610) N,I,J,K
  610 FORMAT(/10X,'ERROR  BAND WIDTH  NO. =',4I4)
      RETURN
      END
      SUBROUTINE FORMK(ID)
C
C     **********************************
C     *                                *
C     * ESTABLISH WHOLE MATRIX         *
C     *                                *
C     **********************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
      DIMENSION   E(4,4)
C     ********** OVERLAP ELEMENT MATRIX TO WHOLE MATRIX****
      DO 100 N=1,NE
      P1=Y1*T(N,ID)/X1/6.0
```

```
      P2=X1*T(N,ID)/Y1/6.0
      P3=BD(N,ID)
      IF(ID.EQ.1) P3=P3+BD(N,ID+1)
      P4=S(N,ID)
      E(1,1)=2.0*P1+2.0*P2+4.0*P3+4.0*P4
      E(2,2)=E(1,1)
      E(3,3)=E(1,1)
      E(4,4)=E(1,1)
      E(1,2)=-2.0*P1+P2+2.0*P3+2.0*P4
      E(3,4)=E(1,2)
      E(2,1)=E(1,2)
      E(4,3)=E(1,2)
      E(1,3)=-P1-P2+P3+P4
      E(2,4)=E(1,3)
      E(3,1)=E(1,3)
      E(4,2)=E(1,3)
      E(1,4)=P1-2.0*P2+2.0*P3+2.0*P4
      E(2,3)=E(1,4)
      E(3,2)=E(1,4)
      E(4,1)=E(1,4)
      DO 300 I=1,4
      II=NOP(N,I)
      DO 300 J=1,4
      JJ=NOP(N,J)
      LL=JJ-II+1
      IF(LL) 300,300,320
  320 SK(II,LL,ID)=SK(II,LL,ID)+E(I,J)
  300 CONTINUE
  100 CONTINUE
C     ********** CONSTANT-HEAD BOUNDARY **************
      NNC=NC(ID)
      IF(NNC.EQ.0) GO TO 20
      DO 10 N=1,NNC
      I=NOHC(N,ID)
      SK(I,1,ID)=SK(I,1,ID)*(10.**8.)
   10 CONTINUE
C     ********** FORWARD ELIMINATION OF MATRIX *******
   20 CALL SOLVE1(ID)
      RETURN
      END
      SUBROUTINE RIGHT(NN)
C
C     ********************************
C     *                              *
C     * CREATE BASIC VECTOR          *
C     *                              *
C     ********************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      COMMON /BK4/R(900)
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
C     ********** ZERO CLEAR *************************
      DO 10 N=1,990
   10 F(N)=0.0
      N1=NN-1
      N2=NN+1
C     ********** CREATE VECTOR **********************
      DO 200 N=1,NE
      I=NOP(N,1)
      J=NOP(N,2)
      K=NOP(N,3)
      L=NOP(N,4)
      SS=S(N,NN)
C     ********** COMPUTE STORAGE CHANGE *************
      F(I)=F(I)+SS*(HN(I,NN)*4.0+HN(J,NN)*2.0+HN(K,NN)
     1                                       +HN(L,NN)*2.0)
      F(J)=F(J)+SS*(HN(I,NN)*2.0+HN(J,NN)*4.0+HN(K,NN)*2.0
     1                                       +HN(L,NN)    )
      F(K)=F(K)+SS*(HN(I,NN)    +HN(J,NN)*2.0+HN(K,NN)*4.0
     1                                       +HN(L,NN)*2.0)
```

```
      F(L)=F(L)+SS*(HN(I,NN)*2.0+HN(J,NN)    +HN(K,NN)*2.0
     1                                       +HN(L,NN)*4.0)
      FI1=F(I)
      FJ1=F(J)
      FK1=F(K)
      FL1=F(L)
C     ********** LEAKAGE FROM UPPER AQUIFER    ******
      IF(IDENT.EQ.0)     GO TO 400
      GO TO (30,20),NN
   20 IF(BD(N,NN).EQ.0.) GO TO 300
      BB=BD(N,NN)
C
      F(I)=F(I)+BB*(HN(I,N1)*4.0+HN(J,N1)*2.0+HN(K,N1)
     1                                       +HN(L,N1)*2.0)
      F(J)=F(J)+BB*(HN(I,N1)*2.0+HN(J,N1)*4.0+HN(K,N1)*2.0
     1                                       +HN(L,N1)    )
      F(K)=F(K)+BB*(HN(I,N1)    +HN(J,N1)*2.0+HN(K,N1)*4.0
     1                                       +HN(L,N1)*2.0)
      F(L)=F(L)+BB*(HN(I,N1)*2.0+HN(J,N1)    +HN(K,N1)*2.0
     1                                       +HN(L,N1)*4.0)
  300 CONTINUE
      GO TO 400
C     ********** LEAKAGE FROM LOWER AQUIFER **********
   30 IF(BD(N,N2).EQ.0)    GO TO 400
      BB=BD(N,N2)
      CC=HF(N)*BD(N,NN)*9.0
      F(I)=F(I)+BB*(HN(I,N2)*4.0+HN(J,N2)*2.0+HN(K,N2)
     1                                   +HN(L,N2)*2.0)+CC
      F(J)=F(J)+BB*(HN(I,N2)*2.0+HN(J,N2)*4.0+HN(K,N2)*2.0
     1                                   +HN(L,N2)    )+CC
      F(K)=F(K)+BB*(HN(I,N2)    +HN(J,N2)*2.0+HN(K,N2)*4.0
     1                                   +HN(L,N2)*2.0)+CC
      F(L)=F(L)+BB*(HN(I,N2)*2.0+HN(J,N2)    +HN(K,N2)*2.0
     1                                   +HN(L,N2)*4.0)+CC
  400 CONTINUE
      FI2=F(I)-FI1
      FJ2=F(J)-FJ1
      FK2=F(K)-FK1
      FL2=F(K)-FL1
      FLEAK=FI2+FJ2+FK2+FL2
C     WRITE(28,777)FLEAK
777   FORMAT(10F15.0)
C     ********** DISCHARGE****************************
      QQ=Q(N,NN)/4.0
      IF(NN.EQ.1) QQ=QQ-R(N)*RRR/4.0
      F(I)=F(I)-QQ
      F(J)=F(J)-QQ
      F(K)=F(K)-QQ
      F(L)=F(L)-QQ
  500 CONTINUE
  200 CONTINUE
C     ********** CONSTANT-HEAD NODE   ****************
      NNC=NC(NN)
      IF(NNC.NE.0) THEN
      DO 41 NO=1,NNC
      I=NOHC(NO,NN)
      F(I)=SK(I,1,NN)*HC(NO,NN)
   41 CONTINUE
      ENDIF
C     ********** COMPUTE NEXT STEP   **************
   35 CALL SOLVE2(NN)
C     ********** CHANGE COMPUTED HEADS ***************
      DO 40 I=1,NP
      HN(I,NN)=F(I)
   40 CONTINUE
      RETURN
      END
      SUBROUTINE SOLVE1(ID)
C
C     ***************************************
C     *                                     *
C     * FORWARD ELIMINATION PROGRAM         *
C     *                                     *
C     ***************************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
```

```
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
C
      DO 300 N=1,NP
      I=N
      DO 290 L=2,NBAND
      I=I+1
      IF(I.GT.NP) GO TO 290
      IF(SK(N,L,ID)) 240,290,240
  240 C=SK(N,L,ID)/SK(N,1,ID)
      J=0
      DO 270 K=L,NBAND
      J=J+1
      IF(SK(N,K,ID)) 260,270,260
  260 SK(I,J,ID)=SK(I,J,ID)-C*SK(N,K,ID)
  270 CONTINUE
      SK(N,L,ID)=C
  290 CONTINUE
  300 CONTINUE
      RETURN
      END
      SUBROUTINE SOLVE2(ID)
C
C     *******************************
C     *                             *
C     * BACKWARD SUBSTITUTION       *
C     *                             *
C     *******************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
C
      DO 300 N=1,NP
      I=N
      DO 290 L=2,NBAND
      I=I+1
      IF(I.GT.NP) GO TO 290
      F(I)=F(I)-SK(N,L,ID)*F(N)
  290 CONTINUE
  300 F(N)=F(N)/SK(N,1,ID)
C
      N=NP
  350 N=N-1
      IF(N) 500,500,360
  360 L=N
      DO 400 K=2,NBAND
      L=L+1
      IF(L.GT.NP) GO TO 400
      IF(SK(N,K,ID)) 370,400,370
  370 F(N)=F(N)-SK(N,K,ID)*F(L)
  400 CONTINUE
      GO TO 350
  500 RETURN
      END
      SUBROUTINE OUTPUT(KH,NS)
C
C     *******************************
C     *                             *
C     * PRINT OUT MAPS              *
C     *                             *
C     *******************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
```

```
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN,HU
      CHARACTER*5 HP(38,30),BLK
      DATA BLK/'     '/
      DATA HU/'KEISAN H'/
C
      DO 10 I=1,IROW+1
      DO 20 J=1,JCOL+1
      K=NNO(I,J)
      IF(K.NE.0) THEN
      REWIND 30
      WRITE(30,111)HN(K,KH)
      REWIND 30
      READ(30,191)HP(I,J)
  191 FORMAT(A5)
      ELSE
      HP(I,J)=BLK
      ENDIF
   20 CONTINUE
   10 CONTINUE
  111 FORMAT(F5.1)
      M=1
C     ********** PRINT OUT MAPS **************************
      CALL OUT(HP,KH,NS,TITLE,HU,IROW+1,JCOL+1)
C      WRITE(6,601) (TITLE(I),I=1,4),NS,KH,M
  601 FORMAT(1H1///10X,'***',4A8,'***',10X,I3,'STEP_',2X,'NO.',I1,
     *       'AQUIF.',20X,'PAGE',I1//)
      RETURN
      END
      SUBROUTINE WELPRI(IW)
C
C     ******************************
C     *                            *
C     * PRINT OUT SIMULATED HEADS  *
C     * AND LAND SUBSIDENCE        *
C     *                            *
C     ******************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      INTEGER*2   NOP,NOHC,NPRINT,NNO
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
      CHARACTER*1 CO(3),CC(3),BLNK,IBND,PLUS,MINS,AP(101),BP(101)
      DATA CO,CC,BLNK,IBND,PLUS/'A','B','C','+','X','*',' ','I','+'/
      DATA MINS/'-'/
      ETRC=.4999999
      VINT=(EVAL(IW)-SVAL(IW))*0.01
      DO 100 I=2,100
  100 BP(I)  =MINS
      BP(1)  =PLUS
      BP(101)=PLUS
      VVVV=VIND/VINT
      PPT=1.0+VVVV
      IPPT=INT(PPT)
  110 BP(IPPT)=PLUS
      PPT=PPT+VVVV
      IPPT=INT(PPT)
      IF(IPPT.LT.101) GO TO 110
      NNW=NW(IW)
      IF(NSTEPS.GT.60)WRITE(6,600)
  600 FORMAT(1H1/)
      DO 120 N=1,NNW
  120 WRITE(6,601) CO(N),CN(IW,N)
      DO 125 N=1,2
  125 WRITE(6,621) CC(N),N
      WRITE(6,604) SVAL(IW),EVAL(IW)
      WRITE(6,607) (BP(I),I=1,101)
      DO 200 N=1,NSTEPS
      DO 205 I=2,100
  205 AP(I)  =BLNK
      AP(1)  =IBND
      AP(101)=IBND
```

```
      DO 206 J=1,2
      IPPT=1+INT((CAL(IW,J,N)-SVAL(IW))/VINT+ETRC)
      IF(IPPT.LT.1)   IPPT=1
      IF(IPPT.GT.101) IPPT=101
  206 AP(IPPT)=CC(J)
C      WRITE(6,605) N,(CAL(IW,J,N),J=1,2),(OBS(IW,J,N),J=1,3),
C      *             (AP(I),I=1,101)
      IF(IHO.EQ.0) GO TO 203
C      DO 201 I=1,101
C  201 AP(I)=BLNK
      DO 202 M=1,NNW
      IPPT=1+INT((OBS(IW,M,N)-SVAL(IW))/VINT+ETRC)
      IF(IPPT.LT.1)   IPPT=1
      IF(IPPT.GT.101) IPPT=101
  202 AP(IPPT)=CO(M)
      WRITE(6,605) N,(CAL(IW,J,N),J=1,2),(OBS(IW,J,N),J=1,3),
     *             (AP(I),I=1,101)
C      WRITE(6,606) (AP(I),I=1,101)
  203 CONTINUE
  200 CONTINUE
      WRITE(6,607) (BP(I),I=1,101)
      WRITE(6,608) SVAL(IW),EVAL(IW)
  601 FORMAT(30X,'OBSVAL',A1,2X,A8)
  604 FORMAT(/2X,'N',2X,'CA1',2X,'CA2',2X,
     *       'OB1',2X,'OB2',2X,'OB3',1X,F5.1,91X,F5.1)
  621 FORMAT(30X,'CMPVAL',A1,' NO.',I1,'AQUIFER')
  607 FORMAT(31X,101A1)
  605 FORMAT(1X,I3,F6.1,4F5.1,2X,101A1)
  606 FORMAT(1H+,31X,101A1)
  608 FORMAT(31X,F5.0,91X,F5.0)
      RETURN
      END
      SUBROUTINE PRINT(NT)
C
C     *********************************
C     *                               *
C     * COMPUTE FLUX                  *
C     *                               *
C     *********************************
C
      COMMON TITLE(4),NBAND,NSTEPS,KQIN,KHOUT,IROW,JCOL,RRR
      COMMON NP,X1,Y1,HF(900),NNO(38,29)
      COMMON NE,NOP(900,4),T(900,2),S(900,2),Q(900,2)
      COMMON SK(990,30,2),F(990),HN(990,2),BD(900,2)
      COMMON NC(2),HC(30,2),NOHC(30,2),NPRINT(30)
      COMMON /BK3/NWEL,EVAL(70),SVAL(70),VIND,CN(70,3),NWOUT(70),
     *       OBS(70,3,30),CAL(70,2,30),NW(70),NS(70),IHO
      COMMON /BK4/R(900)
      COMMON /BK8/LBL(900),NBK,NLL,NL(15),NLE(15,100),NLP(15,100),
     *            HO(990,2)
      INTEGER*2   NOP,NOHC,NPRINT,NNO,NL,NLE,NLP,LBL
      CHARACTER*8 TITLE,CN
      COMMON /BK1/IDENT
      DIMENSION QB(10,2),DD(10,2),RB(10,2),FB(15,2),DRB(10,2)
C
 1000 IF(NBK.EQ.0) GO TO 900
      DO 10 I=1,2
      DO 11 J=1,10
      QB(J,I)=0.0
      RB(J,I)=0.0
      DRB(J,I)=0.0
   11 DD(J,I)=0.0
      DO 12 J=1,15
   12 FB(J,I)=0.0
   10 CONTINUE
C
      DO 500 N=1,NE
      I=NOP(N,1)
      J=NOP(N,2)
      K=NOP(N,3)
      L=NOP(N,4)
      J1=LBL(N)
      IF(J1) 500,500,501
  501 CONTINUE
      DO 510 M=1,IDENT
      QB(J1,M)=QB(J1,M)-Q(N,M)
      HH=S(N,M)*(HO(I,M)+HO(J,M)+HO(K,M)+HO(L,M)-HN(I,M)
     *                      -HN(J,M)-HN(K,M)-HN(L,M))*4.5
```

```
      DD(J1,M)=DD(J1,M)+HH
      IF(M.EQ.1) THEN
C     RB(J1,M)=RB(J1,M)+R(N)
      DRB(J1,M)=DRB(J1,M)+R(N)
      RB(J1,M)=RB(J1,M)+36.0*BD(N,1)*(HF(N)-(HN(I,1)+HN(J,1)+
     *                      HN(K,1)+HN(L,1))/4.0)
C     RB(J1,M)=RB(J1,M)-DRB(J1,M)
      ELSE
      RB(J1,M)=RB(J1,M)+9.0*BD(N,2)*(HN(I,1)+HN(J,1)+HN(K,1)+
     *                  HN(L,1)-HN(I,2)-HN(J,2)-HN(K,2)-HN(L,2))
      ENDIF
  510 CONTINUE
  500 CONTINUE
      DO 600 N1=1,NLL
      LL=NL(N1)
      DO 610 N2=1,LL
      M=NLE(N1,N2)
      I=NOP(M,1)
      J=NOP(M,2)
      K=NOP(M,3)
      L=NOP(M,4)
C
C                      1
C                    +---+
C            NLP   4 I   I 2
C                    +---+
C                      3
C
      DO 615 M1=1,IDENT
      N=NLP(N1,N2)
      GO TO (621,622,623,624),N
  621 HH=HN(L,M1)+HN(K,M1)-HN(I,M1)-HN(J,M1)
      GO TO 625
  622 HH=HN(J,M1)+HN(K,M1)-HN(I,M1)-HN(L,M1)
      GO TO 627
  623 HH=HN(I,M1)+HN(J,M1)-HN(K,M1)-HN(L,M1)
      GO TO 625
  624 HH=HN(I,M1)+HN(L,M1)-HN(J,M1)-HN(K,M1)
      GO TO 627
  625 HH=T(M,M1)*HH*X1*0.5/Y1
      GO TO 630
  627 HH=T(M,M1)*HH*Y1*0.5/X1
  630 FB(N1,M1)=FB(N1,M1)+HH
  615 CONTINUE
  610 CONTINUE
  600 CONTINUE
C
      WRITE(28,110) NT
  110 FORMAT(1H1////5X,'<WATER BALANCE TABLE>  STEP ',I2/)
      WRITE(28,111)(I,I=1,NBK)
  111 FORMAT(/5X,'<DISCHARGE>'/15X,10(I2,'BLOCK',2X))
      DO 650 I=1,IDENT
  650 WRITE(28,112) I,(QB(J,I),J=1,NBK)
  112 FORMAT(/5X,'AQUIFER',I1,10F10.0)
      WRITE(28,113) (I,I=1,NBK)
      DO 33 I=1,IDENT
      WRITE(28,112) I,(DRB(J,I),J=1,NBK)
   33 CONTINUE
  113 FORMAT(/5X,'<DIRECT RECHARGE>'/15X,10(I2,'BLOCK',2X))
      WRITE(28,114) (I,I=1,NBK)
      DO 34 I=1,IDENT
      WRITE(28,112) I,(RB(J,I),J=1,NBK)
   34 CONTINUE
  114 FORMAT(/5X,'<LEAKAGE RECHARGE>'/15X,10(I2,'BLOCK',2X))
      WRITE(28,117) (I,I=1,NBK)
  117 FORMAT(/5X,'<STORAGE CHANGE>'/15X,10('BLOCK',I2,2X))
      DO 660 I=1,IDENT
  660 WRITE(28,118) I,(DD(J,I),J=1,NBK)
  118 FORMAT(5X,'AQUIFER',I1,10F10.0)
      N1=NLL
      IF(NLL.GT.10) N1=10
      WRITE(28,119) (I,I=1,N1)
  119 FORMAT(/5X,'<LATERAL FLUX>'/16X,10(I2,'LINE',5X))
      DO 665 I=1,IDENT
  665 WRITE(28,112) I,(FB(J,I),J=1,N1)
      IF(NLL.LE.10) GO TO 900
      WRITE(28,119) (I,I=11,NLL)
      DO 670 I=1,IDENT
```

```
  670 WRITE(28,112) I,(FB(J,I),J=11,NLL)
  900 CONTINUE
      DO 100 I=1,IDENT
      DO 100 J=1,NP
  100 HO(J,I)=HN(J,I)
      RETURN
      END
        SUBROUTINE OUT(NQ,KH,NS,TITLE,HU,IRR,JCC)
        CHARACTER*8 TITLE(4),HU
C
        CHARACTER*5 NQ(38,30),IA(22)
C
        IPAGE=(JCC-1)/20+1
        DO 10 IP=1,IPAGE
        LS=20*(IP-1)+1
        LE=20*IP
        IF(IP.LT.IPAGE)GO TO 15
        IF(JCC.LT.20) GO TO 11
        LS=JCC-20+1
   11   LE=JCC
C
   15   WRITE(6,600) TITLE,NS,HU,KH,IP,(J,J=LS,LE)
  600   FORMAT(1H1//30X,4A8,30X,'STEP=',I3,2X,A8,
     *      I1,'AQUIF.',8X,'PAGE=',I3//4X,20I6/)
        DO 70 I=1,IRR
        DO 75 J=LS,LE
        JJ=J-LS+1
        IA(JJ)=NQ(I,J)
   75   CONTINUE
        LE1=LE-LS+2
        REWIND 30
        WRITE(30,103)I
  103   FORMAT(I5)
        REWIND 30
        READ(30,193)IA(LE1)
  193   FORMAT(A5)
C       WRITE (6,610)
    2   WRITE(6,610)I,(IA(J),J=1,LE1)
C       WRITE(6,610)I
  610   FORMAT(2X,I2,21(1X,A5))
C
   70   CONTINUE
C
        WRITE(6,620)(J,J=LS,LE)
  620   FORMAT(/4X,20I6)
   10   CONTINUE
        RETURN
        END
```

```
C         PROGRAM                          PARAC
C
C        ** DATA FORM CHANGE **
C
         CHARACTER CHA*16,C1*1,LK(40,30)
         DIMENSION H(40,30),DD(1000),DK(16,2),ND(30)
         INTEGER*2 NR(40,30),NP(40,30),KY(40,30)
C
         DATA    CHA/'0123456789ABCDEF'/
C
         OPEN(UNIT=1,FILE='\MSA\DAT\PRM_03.DAT',STATUS='NEW',
     *   FORM='UNFORMATTED')
         OPEN(UNIT=2,FILE='\MSA\DAT\ELE.DAT',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=3,FILE='\MSA\DAT\NOD.DAT',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=4,FILE='\MSA\DAT\KD_03.LAB',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=5,FILE='\MSA\DAT\KYOKAI.LAB',STATUS='OLD',
     *   BLANK='ZERO')
         OPEN(UNIT=11,FILE='\MSA\DAT\H.IND',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=12,FILE='\MSA\DAT\T_03.IND',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=13,FILE='\MSA\DAT\B.IND',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=14,FILE='\MSA\DAT\S.IND',STATUS='OLD',BLANK='ZERO')
         OPEN(UNIT=6,FILE='\MSA\DAT\PRL_03.LST',STATUS='NEW')
C
         IR=35
         JC=28
         NNE=754
         NNP=829
C
         DO 10 I=1,IR
         READ(2,200)(NR(I,J),J=1,JC)
         READ(5,210)(KY(I,J),J=1,JC)
         READ(3,200)(NP(I,J),J=1,JC+1)
   10    CONTINUE
         READ(3,200)(NP(IR+1,J),J=1,JC+1)
  200    FORMAT(30I4)
  210    FORMAT(40I1)
C
C        LEAK
C
C        DO 11 L=1,2
         L=1
         READ(4,220)(DK(I,L),I=1,16)
  220    FORMAT(8F8.0)
C   11    CONTINUE
C
C        DO 12 L=1,2
         L=1
C
         DO 13 K=1,NNE
         DD(K)=0.
   13    CONTINUE
C
         WRITE(6,610)(J,J=1,28)
  610    FORMAT(1H1//4X,30I4)
         DO 14 I=1,IR
         READ(4,500)(LK(I,J),J=1,JC)
   14    CONTINUE
C
500      FORMAT  (28A1)
C
         DO 15 I=1,IR
         READ(13,100)(H(I,J),J=1,JC)
  100    FORMAT(30F4.0)
C
         DO 16 J=1,JC
         K=NR(I,J)
           IF (K.GT.0) THEN
           C1=LK(I,J)
           LL=INDEX(CHA,C1)
           IF (LL.EQ.0) LL=1
           DD(K)=DK(LL,L)
           IF (H(I,J).GT.0) DD(K)=DK(LL,L)/H(I,J)
           ND(J)=INT(DD(K)*1000000.)+1
             IF(L.EQ.1.AND.KY(I,J).EQ.1)THEN
             DD(K)=0.
             ND(J)=-1
             END IF
           ELSE
```

```
            ND(J)=9999
            END IF
   16   CONTINUE
C
        WRITE(6,600)I,(ND(J),J=1,JC),I
  600   FORMAT(2X,30I4)
   15   CONTINUE
C
        WRITE(1)(DD(K),K=1,NNE)
        WRITE(*,300)(DD(K),K=1,NNE)
  300   FORMAT(8F10.8)
C  12   CONTINUE
C
C       T
C
C       DO 17 L=1,2
        L=1
        DO 18 K=1,NNE
        DD(K)=0.
   18   CONTINUE
C
        WRITE(6,610)(J,J=1,28)
        DO 19 I=1,IR
        READ(12,100)(H(I,J),J=1,JC)
C
        DO 20 J=1,JC
        K=NR(I,J)
        ND(J)=9999
        IF(K.GT.0)THEN
                DD(K)=H(I,J)
                ND(J)=H(I,J)
                END IF
   20   CONTINUE
        WRITE(6,600)I,(ND(J),J=1,JC),I
   19   CONTINUE
C
        WRITE(1)(DD(K),K=1,NNE)
  310   FORMAT(10F8.0)
C  17   CONTINUE
C
C       S
C
C       DO 21 L=1,2
        L=1
        DO 22 K=1,NNE
        DD(K)=0.
   22   CONTINUE
C
        WRITE(6,610)(J,J=1,28)
        DO 23 I=1,IR
        READ(14,100)(H(I,J),J=1,JC)
C
        DO 24 J=1,JC
        K=NR(I,J)
        ND(J)=9999
        IF(K.GT.0)THEN
                R=-H(I,J)*0.1
                DD(K)=10**R
                ND(J)=H(I,J)
                END IF
   24   CONTINUE
        WRITE(6,600)I,(ND(J),J=1,JC),I
   23   CONTINUE
C
        WRITE(1)(DD(K),K=1,NNE)
  340   FORMAT(10F8.6)
C  21   CONTINUE
C
C       H
C
        DO 25 K=1,NNE
        DD(K)=0.
   25   CONTINUE
C
        DO 26 I=1,IR
        READ(11,110)(H(I,J),J=1,JC)
  110   FORMAT(30F4.0)
C
```

```
      DO 27 J=1,JC
      K=NR(I,J)
      IF(K.GT.0)DD(K)=H(I,J)
   27 CONTINUE
   26 CONTINUE
C
      WRITE(1)(DD(K),K=1,NNE)
      L=1
C     DO 28 L=1,2
      WRITE(1)(DD(K),K=1,NNP)
  360 FORMAT(10F8.2)
C  28 CONTINUE
C
      STOP
      END
```

AN EXAMPLE BATCH FILE (Q3PSCN1.BAT) USED FOR THE METRO MANILA MODEL

```
ECHO ON
CD C:\MSA\DAT
DIR PR*.*
PAUSE Delete these files?
DEL PR*.*
DEL RIN30.DAT
TYPE T_03.IND
PAUSE Confirmed?
TYPE S.IND
PAUSE Confirmed?
TYPE KD_03.LAB
PAUSE Confirmed?
CD C:\MSA\OUT
DIR
PAUSE Delete these files?
DEL *.*
CD C:\MSA\EXE
MR30IN
PARAC
COPY C:\MSA\DAT\INI_81AV.DAT C:\MSA\DAT\INI_03.DAT
COPY C:\MSA\DAT\Q3PSIM2.NSS C:\MSA\DAT\Q3PSIM2.PAR
COPY C:\MSA\DIS\CASE\SCNR01\QIN30.DAT C:\MSA\DAT\QIN30.DAT
TYPE C:\MSA\DAT\Q3PSIM2.PAR
Q3PF
MPRO5DS
MPRO5DL
FOBS
HELE
HN10C90C
MCONT
HDCONT
cd c:\MSA\OUT
dir
COPY *.* C:\MSA\OUT\SCN1
TYPE Q3P_30.PRN
```

PROGRAM LIST OF CONXYZ.MAP TO DRAW CONTOURS

```
10 '*******PROGRAM CONXYZ.MAP********
20 '
30 '
40 '
50 KEY OFF
60 DEFINT I-N
70 MXGR=100
80 DIM XG(MXGR) , YG(MXGR) , F(MXGR,MXGR)
90 MXDT=250
100 DIM XD(MXDT),YD(MXDT),ZD(MXDT)
110 'CONSOL ,,0
120 SCREEN 3 : CLS
130 COLF=1
140 VNULL=1E+09
150 '
160 '----------(1) READ GRID DATA-------------------------
170 '
180 GOSUB 3040                                       'GOSUB *GRID.IN
190 IF IFLG<>0 THEN 400
200     FOR I=1 TO NX : XG(I)=XMIN+(I-1)*DX : NEXT
210     FOR J=1 TO NY : YG(J)=YMIN+(J-1)*DY : NEXT
220 GOSUB 3340                                       'GOSUB *OBSDAT.IN
230 IF IFLG<>0 THEN 400
240 '
250 '----------(2)DISPLAY AND AXES------------------------
260 '
270 COMMENT$="GRID DATA="+NFGI$+" ["+CMNTG$+"]"
280 GOSUB 1560                                     'GOSUB *SCREEN.FULL
290 '
300 GOSUB 3620                                     'GOSUB XYZ.PAR
310 GOSUB 3850                                     'GOSUB XYZ.DRW
320 '----------(3)CONTOR MAP--------------------------------
330 'CLS
340 GOSUB 490                                     'GOSUB *CONTOUR
350 GOSUB 2290                                     'GOSUB *LABEL.DRAW
360 GOSUB 3850
370 LCOPY
380 '----------(4)NEXT OPERATION----------------------------
390 'LOCATE 10,60
400 PRINT
410 PRINT "-------NEXT OPERATION------------"
420 PRINT "  ADD MORE CONTOR                -->1"
430 PRINT "  REWRITE USING SAME DATA        -->2"
440 PRINT "  INPUT NEW DATA                 -->3"
450 PRINT "                                 END"
460 INPUT "        PLEASE SELECT?           -->",NW
470 ON NW GOTO 340,270,180
480 END
490 '
500 '---------SUBROUTINE *CONTOUR--------------------------------
510 '       DRAWING CONTOUR LINES
520 '       NULL VALUES NOT BE DRAWN
530 '  [REQUIRED DATA]  GRID POINTS : XG(I),YG(I)
540 '                   VALUES      : F(I,J) (I=1-NX,J=1-NY)
550 '  [REQUIRED SUBROUTINE] *STATG.F  *DRAW.CONT
560 '-----------------------------------------------------------
570 '
580 '*CONTOUR
590 '                                  [MAX. AND MIN. OF F(I,J)]
600 GOSUB 1420                                 'GOSUB *STATG.F
610 DELTAF=(FMX-FMN)*.000001
620 '                                  [PARAMETERS OF CONTOUR]
630 PRINT "---------------------------------"
640 PRINT "   MIN. VALUE    Fmin =";FMN
650 PRINT "   MAX. VALUE    Fmax =";FMX
660 PRINT "  ***SPECIFICATION****"
670 INPUT "       START VALUE  =",CST
680 INPUT "       END VALUE    =",CEN
690            IF CST>CEN THEN SWAP CST ,CEN
700            IF CST>FMX OR CEN<FMN THEN RETURN :' RETURN
710 INPUT "       INTERVAL     =",CIN
720            CIN=ABS(CIN)
```

```
730           IF CIN<(FMX-FMN)/1000 THEN 630
740 INPUT "         COLOUR         =",COL
750 IF COL>0 THEN LN=&HFFFF ELSE LN=&H5555
760 COL=ABS(COL)
770 GOSUB 790        'GOUSUB *DRAW.CONT
780 RETURN       'GOTO 630
790 CLS
800 '------------------SUBROUTINE *DRAW.CONT------------------
810 '*DRAW.CONT
820 FOR I=1 TO NX-1
830     I1=I+1
840     XP(1)=XG(I) : XP(2)=XG(I1) : XP(3)=XG(I1) : XP(4)=XG(I)
850   FOR J=1 TO NY-1
860       J1=J+1
870       YP(1)=YG(J) : YP(2)=YG(J)  : YP(3)=YG(J1)  : YP(4)=YG(J1)
880       FP(1)=F(I,J): FP(2)=F(I1,J): FP(3)=F(I1,J1): FP(4)=F(I,J1)
890 '
900 '            [CONTORS OF ICS TO ICE PASS IN THE CELL]
910          FBOT=FP(1) : FTOP=FP(1)
920          FOR K=2 TO 4
930            IF FP(K)<FBOT THEN FBOT=FP(K)
940            IF FP(K)>FTOP THEN FTOP=FP(K)
950          NEXT
960          IF FTOP>VNULL THEN 1390           :'  [SKIP AT NULL]
970            IF FBOT<CST THEN FLBT=CST ELSE FLBT=FBOT
980            ICS=INT((FLBT-CST)/CIN+.9999)
990            IF FTOP>CEN THEN FLTP=CEN ELSE FLTP=FTOP
1000            ICE=INT((FLTP-CST)/CIN+.0001)
1010          IF ICS>ICE THEN 1390
1020 '
1030 '
1040   FOR IC=ICS TO ICE
1050     CON=CST+CIN*IC
1060       FOR K=1 TO 4
1070         FC(K)=FP(K)-CON
1080         IF FC(K)=0 THEN FC(K)=FC(K)+DELTAF
1090       NEXT
1100 '
1110     KC=0
1120       IF FC(1)*FC(2)>0 THEN 1160 ELSE KC=KC+1
1130       XR(KC)=XP(1)-FC(1)*DX/(FC(2)-FC(1))
1140       YR(KC)=YP(1)
1150 '
1160       IF FC(2)*FC(3)>0 THEN 1200 ELSE KC=KC+1
1170       XR(KC)=XP(2)
1180       YR(KC)=YP(2)-FC(2)*DY/(FC(3)-FC(2))
1190 '
1200       IF FC(3)*FC(4)>0 THEN 1240 ELSE KC=KC+1
1210       XR(KC)=XP(3)+FC(3)*DX/(FC(4)-FC(3))
1220       YR(KC)=YP(3)
1230 '
1240       IF FC(4)*FC(1)>0 THEN 1280 ELSE KC=KC+1
1250       XR(KC)=XP(4)
1260       YR(KC)=YP(4)+FC(4)*DY/(FC(1)-FC(4))
1270 '
1280       IF KC<2 THEN 1380
1290       IF KC=2 THEN 1370
1300          D1=(XR(1)-XR(2))^2+(YR(1)-YR(2))^2
1310          D2=(XR(1)-XR(4))^2+(YR(1)-YR(4))^2
1320          IF D1<D2 THEN 1360
1330             LINE (XR(1),-YR(1))-(XR(4),-YR(4)),COL,,LN
1340             LINE (XR(2),-YR(2))-(XR(3),-YR(3)),COL,,LN
1350          GOTO 1380
1360             LINE (XR(3),-YR(3))-(XR(4),-YR(4)),COL,,LN
1370             LINE (XR(1),-YR(1))-(XR(2),-YR(2)),COL,,LN
1380       NEXT
1390    NEXT
1400 NEXT
1410 RETURN
1420 '
1430 '----------------SUBROUTINE *STATG.F-------------------------
1440 '       MAX. AND MIN. VALUES OF F(I,J)
1450 '-------------------------------------------------------------
1460 '*STATG.F
1470 FMX=-VNULL : FMN=VNULL
1480   FOR I=1 TO NX
1490     FOR J=1 TO NY
1500       IF F(I,J)>VNULL THEN 1530
```

```
1505       IF F(I,J)<-9999 THEN 1530
1510       IF FMX<F(I,J) THEN FMX=F(I,J)
1520       IF FMN>F(I,J) THEN FMN=F(I,J)
1530     NEXT
1540   NEXT
1550 RETURN
1560 '
1570 '---------------SUBROUTINE *SCREEN.FULL--------------------
1580 '            SET UP DISPLAY AND AXES
1590 '----------------------------------------------------------
1600 '*SCREEN.FULL
1610     SCREEN 3 : CLS 1
1620     XMAX=XMIN+(NX-1)*DX
1630     YMAX=YMIN+(NY-1)*DY
1640 '                                               [WINDOW]
1650 PRINT
1660 PRINT "--------SET UP DISPLAY---------"
1670 INPUT " FULL(1) OR WITH MARGIN (2) ";LD
1680    IF LD=1 THEN SCALE=0 ELSE SCALE=.5
1690    GOSUB 1760                            'GOSUB *WINDOW.FULL
1700 '                                              [AXES]
1710    GOSUB 1960                            'GOSUB *LABEL.PARAMETER
1720    GOSUB 2290                            'GOSUB *LABEL.DRAW
1730 INPUT " RESET ? (Y/N) ";A$
1740 IF A$="Y"OR A$="y" THEN 1610
1750 RETURN
1760 '
1770 '--------------SUBROUTINE *WINDOW.FULL--------------------
1780 '          DEFINE WINDOW
1790 DIM KANJI(141)
1800 '       IF VIEW IS (0,0)-(639,399) THEN
1810 '       DOMAIN : XMIN=<X=<XMAX,  YMIN=<Y=<YMAX
1820 '       MARGIN : REMAIN SCALEx100% AT FOUR SIDES
1830 '---------------------------------------------------------
1840 '*WINDOW.FULL
1850 WX=(XMAX-XMIN)/1.6
1860 WY=YMAX-YMIN
1870 IF WX<WY THEN WW=WY ELSE WW=WX
1880 XW1=XMAX-1.6*(1+SCALE)*WW
1890 XW2=XMAX+1.6*SCALE*WW
1900 YW1=-YMAX-SCALE*WW
1910 YW2=-YMAX+(1+SCALE)*WW
1920 'WINDOW SCREEN (XW1,YW1)-(XW2,YW2)
1930 VIEW (0,0)-(639,399)
1940 WINDOW (XW1,YW1)-(XW2,YW2)
1950 RETURN
1960 '
1970 '--------------SUBROUTINE *LABEL.PARAMETER-----------------
1980 '          AXES AND INPUT FILE INFORMATION
1990 '          LD = 1 [ONLY SCALE], LD=2  [WITH COMMENT]
2000 '----------------------------------------------------------
2010 '*LABEL.PARAMETER
2020     XWD=XMAX-XMIN
2030     YWD=YMAX-YMIN
2040 PRINT "----------AXES-----------"
2050 INPUT " Auto(A) OR Manual(M)  ";LA$
2060 IF LA$="M" OR LA$="m" THEN 2170
2070 '                                               [AUTO]
2080 IF XWD>YWD THEN WD=XWD ELSE WD=YWD
2090     NP=INT(LOG(WD)/LOG(10))
2100     WP=10^(NP-1)
2110     WSTEP=10^NP
2120 IF WD/WSTEP<2 THEN WSTEP=WSTEP/5
2130    XSTART=INT(XMIN/WSTEP+.0001)*WSTEP
2140    YSTART=INT(YMIN/WSTEP+.0001)*WSTEP
2150 RETURN
2160 '                                               [MANUAL]
2170 PRINT "Xmin=";XMIN;" Xmax=";XMAX;" DIF. =";XWD
2180 PRINT "Ymin=";YMIN;" Ymax=";YMAX;" DIF. =";YWD
2190 INPUT "  INTERVAL   =",WSTEP
2200 '   IF WSTEP<XWD/20 OR WSTEP<YWD/20 THEN 2170
2210 INPUT " START POINT OF x-AXIS =",XSTART
2220 INPUT " START POINT OF y-AXIS =",YSTART
2230 IF LD=1 THEN RETURN
2240     NP=INT(LOG(WSTEP)/LOG(10))
2250     WP=10^NP
2260 PRINT " [ SCALE    = ABOUT";WP;"]"
2270 INPUT "   SCALE    =",WP
```

```
2280 RETURN
2290 '
2300 '-------------SUBROUTINE *LABEL.DRAW-------------------------
2310 '      DRAW AXES AND INPUT FILE INFORMATION
2320 '      LD(1) = 1 [ONLY SCALE],   LD(2) = 2 [WITH COMMENT]
2330 '----------------------------------------------------------
2340 '*LABEL.DRAW
2350 JC=0 : KMIN=10 : CLH=1
2360 LINE (XMIN,-YMIN)-(XMAX,-YMAX),COLF,B
2370 '                                            [x-AXIS]
2380   FOR WXP=XSTART TO XMAX STEP WSTEP
2390     IF WXP<XMIN THEN 2470
2400     LINE (WXP,-YMIN-WW/60)-(WXP,-YMIN),COLF
2410     LINE (WXP,-YMAX+WW/60)-(WXP,-YMAX),COLF
2420     IF LD=1 THEN 2470
2430     WYP=YMIN-WW/200 : WXPP=WXP/WP
2440     IF WXPP>32767 THEN 2470
2450     IV=INT(WXP/WP+.01) : KN$=STR$(IV)
2460     GOSUB 2700                           'GOSUB *VDRAW.GRP
2470   NEXT
2480   IF WP=1 OR LD=1 THEN 2530
2490      WXP=XMAX-WW/20 : WYP=YMIN-WW/30
2500      KN$="x"+STR$(WP)
2510      GOSUB 2700                          'GOSUB *VDRAW.GRP
2520 '                                           [y-AXIS]
2530 JC=1
2540   FOR WYP=YSTART TO YMAX STEP WSTEP
2550      IF WYP<YMIN THEN 2630
2560       LINE (XMIN,-WYP)-(XMIN+WW/60,-WYP),COLF
2570       LINE (XMAX-WW/60,-WYP)-(XMAX,-WYP),COLF
2580       IF LD=1 THEN 2630
2590       WXP=XMAX : WYPP=WYP/WP
2600       IF ABS(WYPP)>32767 THEN 2630
2610       IV=INT(WYPP+.01) : KN$=STR$(IV)
2620       GOSUB 2700                         'GOSUB *VDRAW.GRP
2630   NEXT
2640   IF LD=1 THEN RETURN
2650      KMIN=80
2660      WXP=XMIN : WYP=YMAX+WW/30
2670      KN$=COMMENT$
2680      GOSUB 2700                          'GOSUB *VDRAW.GRP
2690 RETURN
2700 '
2710 '-----------SUBROUTIBE *VDRAW.GRP------------------------------
2720 '       TYPE CHARACTERS(KN$) ON DISPLAY
2730 '       ORIGIN     : (WXP,WYP)   <---  WORLD
2740 '       JC=0  -----> DRAW UNDER ORIGIN
2750 '       JC=1  -----> DRAW RIGHT OF ORIGIN
2760 '        KMIN  : NUMBERS OG CHAECTERS
2770 '       CLH        : COLOUR
2780 '--------------------------------------------------------------
2790 '*VDRAW.GRP
2800 'DIM A%(250)
2810 KL=LEN(KN$)
2820    IF LEFT$(KN$,1)<>" " THEN 2840
2830    KL=KL-1 : KN$=RIGHT$(KN$,KL)
2840 IF KL>KMIN THEN KL=KMIN
2850    KSXO=PMAP(WXP,0)+7
2860    IF JC=0 THEN KSXO=KSXO-4*KL-6
2870    KSY=PMAP(-WYP,1)+6-9*JC
2880    IF (KSY-2)*(KSY-391)=>0 THEN RETURN
2890    FOR IK=1 TO KL
2900      MKL=ASC(MID$(KN$,IK,1))
2910      KSX=KSXO+7*(IK-1)
2920      KSY=PMAP(-WYP,1)+4-7*JC
2930        IF (KSX-2)*(KSX-631)=>0 THEN 2970
2940 LOCATE 1,1:PRINT CHR$(MKL)
2950 'GET(0,0)-(20,20),A%
2960 '    PUT (KSX,KSY),A%,XOR
2970 NEXT
2980 RETURN
2990 '
3000 '
3010 '
3020 '
3030 '
3040 '--------SUBROUTINE *GRID.IN--------------
3050 '    READ X-Y CORDINATES DATA FROM FILE
```

```
3060 '    (IF FILE NAME="NO", GOTO RETURN)
3070 '----------------------------------------
3080 '*GRID.IN
3090 IFLG=1
3100 PRINT
3110 PRINT "-----INPUT GRID DATA--------"
3120 PRINT "FILE NAME : NO: NO READING"
3130 PRINT "RETURN KEY: FILES 2"
3140 INPUT "GRID DATA FILE NAME ->",NFGI$
3150       IF NFGI$=""THEN FILES 2:GOTO 3100
3160       IF NFGI$="NO" OR NFGI$="no" THEN RETURN
3170 IFLG=-1
3180 OPEN NFGI$ FOR INPUT AS #1
3190   IF EOF(1) THEN 3320
3200 INPUT #1,NX,NY,XMIN,YMIN,DX,DY
3210 PRINT "GRID : Nx=";NX;" Ny=";NY
3220 FOR I=1 TO NX
3230  FOR J=1 TO NY
3240    IF EOF(1) THEN 3320
3250    INPUT #1,F(I,J)
3260  NEXT
3270 NEXT
3280 IF EOF(1) THEN CMNTG$=" ":GOTO 3310
3290 INPUT #1,CMNTG$
3300 PRINT "  [";CMNTG$;"]"
3310 IFLG=0
3320 CLOSE #1
3330 RETURN
3340 '-------SUBROUTINE *OBSDAT.IN-------------------------
3350 '    READ (X,Y,Z) DATA FROM FILE
3360 '    (WHEN INPUT FILE NAME=NO, RETURN WITHOUT READING)
3370 '----------------------------------------------------
3380 '
3390 '*OBSDAT.IN
3400 IFLG=1
3410 PRINT
3420 PRINT "---------READ DATA FROM FILE---------"
3430 PRINT "      FILE NAME =NO --->NO READING"
3440 PRINT "      RETURN KEY    ---> FILES 2"
3450 INPUT "      FILE NAME ?   --->",NFDI$
3460    IF NFDI$="NO" OR NFDI$="no" THEN RETURN
3470    IF NFDI$="" THEN FILES 2 : GOTO 3410
3480       IF NFDI$="NO" OR NFGI$="no" THEN RETURN
3490 '
3500 OPEN NFDI$ FOR INPUT AS #1
3510    FOR K=1 TO MXDT
3520       IF EOF(1) THEN 3560
3530       INPUT #1,XD(K),YD(K),ZD(K)
3540       IF XD(K)>VNULL THEN 3560
3550    NEXT
3560    ND=K-1
3570    IFLG=0
3580    IF EOF(1) THEN CMNTD$=" " : GOTO 3600
3590    INPUT #1,CMNTD$
3600 CLOSE #1
3610 RETURN
3620 '-----------------SUBROUTINE *XYZ.PARAMETER-------------------
3630 '    PARAMETER TO DISPLAY OBSERVED DATA
3640 '------------------------------------------------------------
3650 '*XYZ.PARAMETER
3660 PRINT "---DISPLAY OBSERVED DATA---"
3670 JCC=0 : CLH=COLZ
3680 INPUT "-----DISPLAY VALUES? (Y/N) ";ZP$
3690 IF ZP$="n" OR ZP$="N" THEN RETURN
3700 INPUT " Auto(A) OR Manual(M)? ";SD$
3710 '                                     Zmax :MAX. OF ZD(K)
3720 ZMAX=ABS(ZD(1))
3730    FOR K=2 TO ND
3740       IF ABS(ZD(K))>ZMAX THEN ZMAX=ABS(ZD(K))
3750    NEXT
3760 '                                     SCALING OF VALUES
3770 NPZ=INT(LOG(ZMAX)/LOG(10)+.0001)
3780 WPZ=10^(NPZ-2)
3790    IF SD$="m" OR SD$="M" THEN 3800 ELSE RETURN
3800    PRINT " MAX. (Z) =";ZMAX
3810    PRINT " [SCALE = ABOUT";WPZ;"]"
3820    INPUT "  SCALE  =",WPZ
3830    INPUT "  LOCATION : (0)UNDER OR (1)RIGHT ? =",JCC
```

```
3840 RETURN
3850 '--------------SUBROUTINE *XYZ.DRAW---------------------------
3860 '      DISPLAY OBSERVED DATA ON GRAPHICS
3870 '-------------------------------------------------------------
3880 '*XYZ.DRAW
3890 '                                          DISPLAY SCALE
3900 IF ZP$="n" OR ZP$="N" THEN 3970
3910 IF WPZ=1 THEN 3970
3920 KN$="x"+STR$(WPZ)
3930 KMIN=20  : JC=0
3940 WXP=XMIN+(XMAX-XMIN)/20 : WYP=YMAX
3950 GOSUB 2700                               'GOSUB *VDRAW.GRP
3960 '                                        DISPLAY DATA
3970 KMIN=4
3980 JC=JCC
3990 DP=(XMAX-XMIN)/100
4000    FOR K=1 TO ND
4010       IF XD(K)<XMIN OR XD(K)>XMAX THEN 4100
4020       IF YD(K)<YMIN OR YD(K)>YMAX THEN 4100
4030       LINE (XD(K)+DP,-YD(K))-(XD(K)-DP,-YD(K)),1
4040       LINE (XD(K),-YD(K)-DP)-(XD(K),-YD(K)+DP),1
4050       IF ZP$="n" OR ZP$="N" THEN 4100
4060          WXP=XD(K):WYP=YD(K)
4070          IF ABS(ZD(K)/WPZ)>9999 THEN PRINT "SCALE OVER!!!": GOTO 4100
4080          KN$=STR$(CINT(ZD(K)/WPZ))
4090          GOSUB 2700                      'GOSUB *VDRAW.GRP
4100    NEXT
4110 RETURN
4120 '
4130 DIM BALL(62)
4140 KEY OFF:CLS
4150 CIRCLE(20,20),20
4160 PAINT(20,20)
4170 GET(0,0)-(40,40),BALL
4180 FOR I=1 TO 7
4190 LINE(60*I,40*I)-STEP(200,100),IMOD2,BF
4200 NEXT
4210 FOR I=1 TO 170
4220 PUT(3*I+20,2*I),BALL,XOR
4230 PUT(3*I+20,2*I),BALL,XOR
4240 NEXT
4250 END
```

APPENDIX B

COMPUTER PROGRAMS AND RELATED DATA FOR MOC MODEL

```
$LARGE
      SUBROUTINE CHMOT                                                   I  10
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE  I  20
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,    I  30
     1               HMIN,PYR,ANFCTR                                     I  32
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,     I  41
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,    I  51
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK               I  62
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),     SI  67
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                      I  68
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                 SI  91
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),          SI 101
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),    SI 111
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SI 115
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR  I 121
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                          SI 125
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040), SI 132
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS,  SI 141
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,    I 145
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                     I 151
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,    I 156R
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,     I 157R
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 I 158R
      DIMENSION IC(020)                                                  I 161
C     ***************************************************************    I 170
      TMFY=86400.0*365.25                                                I 180
      TMYR=SUMT/TMFY                                                     I 190
      TCHD=SUMTCH/86400.0                                                I 200
      TCHYR=SUMTCH/TMFY                                                  I 210
      ERR1=0.0                                                           I 212
      ERR3=0.0                                                           I 214
      IF (MOD(IMOV,NPNTMV).NE.0.AND.(IMOV.NE.NMOV.OR.                    I 221
     1   (MOD(N,NPNT).NE.0.AND.N.NE.NTIM.AND.IPRNT.EQ.0)))               I 222
     2                GO TO 100                                          I 223
C     ***************************************************************    I 230
C     ---PRINT CONCENTRATIONS---                                         I 240
      WRITE (6,160)                                                      I 250
      WRITE (6,170) N                                                    I 260
      IF (N.GT.0) WRITE (6,180) TIM(N)                                   I 270
      WRITE (6,190) SUMT                                                 I 280
      WRITE (6,450) SUMTCH                                               I 290
      WRITE (6,200) TCHD                                                 I 300
      WRITE (6,210) TMYR                                                 I 310
      WRITE (6,460) TCHYR                                                I 320
      WRITE (6,380) IMOV                                                 I 330
      WRITE (6,220)                                                      I 340
      DO 20 IY=1,NMY                                                    SI 351
      DO 10 IX=1,NMX                                                    SI 361
   10 IC(IX)=NINT(CONC(IX,IY))                                           I 371
   20 WRITE (6,240) (IC(IX),IX=1,NMX)                                   SI 381
C     ***************************************************************    I 390
      IF (N.EQ.0) GO TO 150                                              I 400
      IF (NPDELC.EQ.0) GO TO 50                                          I 410
C                                                                        I 420
C     ---PRINT CHANGES IN CONCENTRATION---                               I 430
      WRITE (6,230)                                                      I 440
      WRITE (6,170) N                                                    I 450
      WRITE (6,180) TIM(N)                                               I 460
      WRITE (6,190) SUMT                                                 I 470
      WRITE (6,450) SUMTCH                                               I 480
      WRITE (6,200) TCHD                                                 I 490
      WRITE (6,210) TMYR                                                 I 500
      WRITE (6,460) TCHYR                                                I 510
      WRITE (6,380) IMOV                                                 I 520
      WRITE (6,220)                                                      I 530
      DO 40 IY=1,NMY                                                    SI 541
      DO 30 IX=1,NMX                                                    SI 551
   30 IC(IX)=NINT(CONC(IX,IY)-CONINT(IX,IY))                             I 571
   40 WRITE (6,240) (IC(IX),IX=1,NMX)                                   SI 581
C     ***************************************************************    I 590
C     ---PRINT MASS BALANCE DATA FOR SOLUTE---                           I 600
   50 RESID=SUMIO-CSTM2+DMASS1                                           I 611R
      SUMIN=FLMIN-CMSIN                                                  I 615
      IF (SUMIN.EQ.0.0) GO TO 60                                         I 625
      ERR1=RESID*100.0/SUMIN                                             I 635
      IF (SUMIO.GT.(STORMI+SORBI)) GO TO 70                              I 637R
   60 IF (STORMI.EQ.0.0) GO TO 70                                        I 650
```

```
      ERR3=-100.0*(RESID)/(STORMI+SORBI-SUMIO)                          I 661R
   70 WRITE (6,220)                                                     I 670
      WRITE (6,250)                                                     I 680
      WRITE (6,220)                                                     I 690
      WRITE (6,260) FLMIN                                               I 700
      WRITE (6,270) FLMOT                                               I 710
      RECIN=-CMSIN                                                      I 720
      RECOUT=-CMSOUT                                                    I 730
      WRITE (6,290) RECIN                                               I 740
      WRITE (6,280) RECOUT                                              I 750
      WRITE (6,295) DMASS1                                              I 751R
      WRITE (6,296) ADSORB                                              I 752R
      WRITE (6,298) SORBI                                               I 753R
      WRITE (6,300) SUMIO                                               I 760
      WRITE (6,310) STORMI                                              I 770
      WRITE (6,320) STORM                                               I 780
      WRITE (6,330) CSTORM                                              I 790
      WRITE (6,332) CSTM2                                               I 795R
      WRITE (6,340)                                                     I 810
      WRITE (6,350) RESID                                               I 820
      WRITE (6,360) ERR1                                                I 830
   80 IF (STORMI.EQ.0.0) GO TO 100                                      I 841
      IF (SUMIN.NE.0.0.AND.SUMIO.GT.(STORMI+SORBI)) GO TO 100           I 846R
      WRITE (6,370)                                                     I 850
      WRITE (6,360) ERR3                                                I 860
C     **************************************************************   I 870
C     ---PRINT HYDROGRAPHS AFTER 50 STEPS OR END OF SIMULATION---       I 880
  100 IF (NUMOBS.LE.0) GO TO 150                                        I 921
      IF (S.GT.0.0) THEN                                                I 923
       IF (IMOV.NE.NMOV.OR.                                             I 924
     1    (MOD(N,50).NE.0.AND.N.NE.NTIM.AND.IPRNT.EQ.0)) GO TO 150      I 925
      ELSE                                                              I 926
       IF (MOD(IMOV,50).NE.0.AND.IMOV.NE.NMOV) GO TO 150                I 927
      END IF                                                            I 928
      WRITE (6,390) TITLE                                               I 931
      WRITE (6,400) INT                                                 I 940
      IF (S.GT.0.0) WRITE (6,410)                                       I 950
      IF (S.EQ.0.0) WRITE (6,420)                                       I 960
C         ---TABULATE HYDROGRAPH DATA---                                I 970
      MOZ=0                                                             I 980
      IF (S.GT.0.0) GO TO 110                                           I 990
      NTO=NMOV                                                          I1000
      IF (NMOV.GT.50) NTO=MOD(IMOV,50)                                  I1010
      GO TO 120                                                         I1020
  110 NTO=N                                                             I1031
      IF (N.GT.50) NTO=MOD(N,50)                                        I1041
  120 IF (NTO.EQ.0) NTO=50                                              I1050
      DO 140 J=1,NUMOBS                                                 I1060
      TMYR=0.0                                                          I1070
      JX=IXOBS(J)                                                      SI1074
      JY=IYOBS(J)                                                      SI1076
      WRITE (6,430) J,IXOBS(J),IYOBS(J)                                 I1080
      C1INT=0.0                                                        SI1082
      IX=JX-MX+1                                                       SI1083
      IY=JY-MY+1                                                       SI1084
      IF (JX.LT.MX.OR.JY.LT.MY.OR.JX.GT.MMX.OR.JY.GT.MMY) GO TO 125    SI1085
      C1INT=CONINT(IX,IY)                                              SI1086
      GO TO 127                                                        SI1087
  125 WRITE (6,435)                                                    SI1088
  127 WRITE (6,440) MOZ,WT(JX,JY),C1INT,                               SI1091
     1TMYR                                                              I1100
      DO 130 M=1,NTO                                                    I1110
      TMYR=TMOBS(M)/TMFY                                                I1120
  130 WRITE (6,440) M,TMWL(J,M),TMCN(J,M),TMYR                          I1130
  140 CONTINUE                                                          I1140
C     ****************************************************************  I1150
  150 RETURN                                                            I1166
C     ****************************************************************  I1170
C                                                                       I1180
C                                                                       I1190
C                                                                       I1200
  160 FORMAT (1H1,13HCONCENTRATION/)                                    I1210
  170 FORMAT (1X,23HNUMBER OF TIME STEPS = ,1I5)                        I1220
  180 FORMAT (8X,16HDELTA T        = ,1G12.5)                           I1230
  190 FORMAT (8X,16HTIME(SECONDS) = ,1G12.5)                            I1240
  200 FORMAT (3X,21HCHEM.TIME(DAYS)     = ,1E12.5)                      I1250
  210 FORMAT (8X,16HTIME(YEARS)    = ,1E12.5)                           I1260
  220 FORMAT (1H )                                                      I1270
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  230 FORMAT (1H1,23HCHANGE IN CONCENTRATION/)                           I1280
  240 FORMAT (1H0,20I5)                                                  I1290
  250 FORMAT (1H ,21HCHEMICAL MASS BALANCE)                              I1300
  260 FORMAT (8X,25HMASS IN BOUNDARIES      = ,1E12.5)                   I1310
  270 FORMAT (8X,25HMASS OUT BOUNDARIES     = ,1E12.5)                   I1320
  280 FORMAT (8X,25HMASS PUMPED OUT         = ,1E12.5)                   I1330
  290 FORMAT (8X,25HMASS PUMPED IN          = ,1E12.5)                   I1340
  295 FORMAT (8X,25HMASS LOST BY DECAY      = ,1E12.5)                   I1341R
  296 FORMAT (8X,25HMASS ADSORBED ON SOLIDS= ,1E12.5)                    I1342R
  298 FORMAT (8X,25HINITIAL MASS ADSORBED  = ,1E12.5)                    I1343R
  300 FORMAT (8X,25HINFLOW MINUS OUTFLOW   = ,1E12.5)                    I1350
  310 FORMAT (8X,25HINITIAL MASS DISSOLVED = ,1E12.5)                    I1361R
  320 FORMAT (8X,25HPRESENT MASS DISSOLVED = ,1E12.5)                    I1371R
  330 FORMAT (8X,25HCHANGE MASS DISSOLVED  = ,1E12.5)                    I1381R
  332 FORMAT (8X,25HCHANGE TOTL.MASS STORED= ,1E12.5)                    I1382R
  340 FORMAT (1H ,5X,53HCOMPARE RESIDUAL WITH NET FLUX AND MASS ACCUMULA I1390
     1TION:)                                                             I1400
  350 FORMAT (8X,25HMASS BALANCE RESIDUAL  = ,1E12.5)                    I1410
  360 FORMAT (8X,25HERROR  (AS PERCENT)    = ,1E12.5)                    I1420
  370 FORMAT (1H ,5X,55HCOMPARE INITIAL MASS STORED WITH CHANGE IN MASS  I1430
     1STORED:)                                                           I1440
  380 FORMAT (1X,23H NO. MOVES COMPLETED = ,1I5)                         I1450
  390 FORMAT (1H1,10A8//)                                                I1460
  400 FORMAT (1H0,5X,65HTIME VERSUS HEAD AND CONCENTRATION AT SELECTED O I1470
     1BSERVATION POINTS//15X,19HPUMPING PERIOD NO. ,I4////)              I1480
  410 FORMAT (1H0,16X,19HTRANSIENT  SOLUTION////)                        I1490
  420 FORMAT (1H0,15X,21HSTEADY-STATE SOLUTION////)                      I1500
  430 FORMAT (1H0,20X,22HOBS.WELL NO.    X     Y,17X,1HN,6X,40HHEAD (FT)  I1510
     1  CONC.(MG/L)    TIME (YEARS)//24X,I3,9X,I2,3X,I2//)               I1520
  435 FORMAT (1H ,3X,45H** NOTE **  THIS OBS. WELL IS LOCATED OUTSIDE/16 SI1525
     1X,24HOF THE TRANSPORT SUBGRID)                                     SI1526
  440 FORMAT (1H ,58X,I2,6X,F7.1,8X,F7.1,8X,F7.3)                         I1531
  450 FORMAT (1H ,2X,21HCHEM.TIME(SECONDS) = ,E12.5)                     I1540
  460 FORMAT (1H ,2X,21HCHEM.TIME(YEARS)   = ,E12.5)                     I1550
      END                                                                I1560-
C     ***  RETRD2  ****************************************************** K  10
C                                                                        K  20

$LARGE
      SUBROUTINE CNCON                                                   G  10
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE  G  20
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,    G  30
     1                 HMIN,PYR,ANFCTR                                   G  32
      DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV  ,                       G  35
      DOUBLE PRECISION FLW                                               G  40
      DOUBLE PRECISION DCYFCT,DCYT,DCYT2                                 G  42
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,     G  51
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,    G  61
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK               G  72
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),     SG  77
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                      G  78
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                 SG 101
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),          SG 111
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),    SG 121
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SG 125
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR  G 131
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                          SG 135
      COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                             G 140
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040), SG 152
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS,  SG 161
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,    G 165
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                     G 171
      COMMON /DIFUS/ DISP(020,020,4)                                     G 181
      COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)         SG 192
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,    G 196R
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,     G 197R
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 G 198R
      COMMON /CHMR2/ CRETRD(020,020),CRDCOF(020,020),CELDCY(020,020)     G 199R
      DIMENSION CNCNC(020,020),CNOLD(020,020),CAVG(020,020)              G 202R
C     ************************************************************       G 210
      DO 10 IX=1,NMX                                                    SG 232
      DO 10 IY=1,NMY                                                    SG 242
      CNOLD(IX,IY)=CONC(IX,IY)                                           G 250
      CAVG(IX,IY)=CONC(IX,IY)                                            G 255R
   10 CNCNC(IX,IY)=0.0                                                   G 260
      APC=0.0                                                            G 270
      NZERO=0                                                            G 280
      TVA=AREA*TIMV                                                      G 290
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      TVA2=TVA*0.5                                                       G 295R
      TMCHK=TIMV*10.0                                                    G 296R
      SRCDCY=0.0                                                         G 297R
      RFAREA=RF*AREA                                                     G 307R
C     ***************************************************************    G 310
C     ---CONC. CHANGE DUE TO:                                            G 321R
C           MIXING AT SOURCE CELLS...                                    G 322R
C           ...WITH DECAY OF RECHARGE DURING TIME INCREMENT              G 323R
      CONST=TIMV                                                         G 341R
      DCYFCT=TIMV*DECAY                                                  G 342R
      RFFCT=CONST/RF                                                     G 344R
      DCYT=1.D0                                                          G 346A
      DCYT2=1.D0                                                         G 346B
      IF(DECAY.NE.0.0) THEN                                              G 346C
       DCYT=DEXP(-DCYFCT)                                                G 346D
       DCYT2=DEXP(-DCYFCT*0.5D0)                                         G 346E
      END IF                                                             G 346F
      GO TO 70                                                           G 347R
   20 DO 60 IX=1,NMX                                                    SG 352
      DO 60 IY=1,NMY                                                    SG 362
      JX=IX+MX-1                                                        SG 366
      JY=IY+MY-1                                                        SG 367
      IF (THCK(JX,JY).EQ.0.0) GO TO 60                                  SG 371
      CALL RETRD2(CAVG(IX,IY),RF2,RDCOEF)                                G 384R
      EQFCT=RFFCT/(THCK(JX,JY)*RF2)                                     SG 385R
      C1=CAVG(IX,IY)                                                     G 401R
      IF (ABS(C1).LT.1.0E-20) C1=0.0                                    MULTICS
      C2=C1                                                              G 403R
      CLKCN=C1                                                           G 411R
      SLEAK=(HK(JX,JY)-WT(JX,JY))*VPRM(JX,JY)                           SG 421
      IF (SLEAK.GE.0.0) GO TO 25                                         G 425R
      CLKCN=CNRECH(IX,IY)*DCYT2                                          G 431A
      SRCDCY=SRCDCY+(CNRECH(IX,IY)-CLKCN)*SLEAK*TVA                      G 432R
   25 CONTINUE                                                           G 435R
      CNREC=C1                                                           G 450
      CNREC2=C1                                                          G 455
      RATE=REC(JX,JY)*ARINV                                             SG 461
      IF (RATE.GE.0.0) GO TO 27                                          G 471R
      CNREC=CNRECH(IX,IY)*DCYT2                                          G 472A
      SRCDCY=SRCDCY+(CNRECH(IX,IY)-CNREC)*RATE*TVA                       G 473R
   27 IF (RECH(JX,JY).GE.0.0) GO TO 29                                  SG 474R
      CNREC2=CNRECH(IX,IY)*DCYT2                                         G 476A
      SRCDCY=SRCDCY+(CNRECH(IX,IY)-CNREC2)*RECH(JX,JY)*TVA              SG 477R
   29 CONTINUE                                                           G 478R
      DIV=RATE+SLEAK+RECH(JX,JY)                                        SG 481
      IF (THALF.GT.TMCHK.OR.THALF.EQ.0.0) GO TO 37                       G 482R
      IF (DIV.GE.0.0) GO TO 37                                           G 484R
      IF (CNOLD(IX,IY).LE.0.0.OR.CONC(IX,IY).LE.0.0) GO TO 37            G 486R
C     NEXT CALC IS EQUIVALENT TO C1=EXP((ALOG(CNOLD)+ALOG(CONC))*0.5)    G 488A
      C1=SQRT(CNOLD(IX,IY)*CONC(IX,IY))                                  G 488B
C     IF (NPCELL(IX,IY).LE.0) C1=CNOLD(IX,IY)*DCYT2                      G 489A
   37 CONTINUE                                                           G 592R
      DELC=EQFCT*(C1*DIV-RATE*CNREC-SLEAK*CLKCN-RECH(JX,JY)*CNREC2)     SG 597
   40 CNCNC(IX,IY)=CNCNC(IX,IY)+DELC                                     G 610
C     ---CONC. CHANGE DUE TO DISPERSION FOR TIMV---                      G 621R
C        ---DISPERSION WITH TENSOR COEFFICIENTS---                       G 630
      IF (BETA.EQ.0.0) GO TO 60                                          G 635
      IF (MCHK.EQ.1) GO TO 39                                           SG 638
      X1=DISP(IX,IY,1)*(CAVG(IX+1,IY)-C2)                                G 651R
      X2=DISP(IX-1,IY,1)*(CAVG(IX-1,IY)-C2)                              G 661R
      Y1=DISP(IX,IY,2)*(CAVG(IX,IY+1)-C2)                                G 671R
      Y2=DISP(IX,IY-1,2)*(CAVG(IX,IY-1)-C2)                              G 681R
      XX1=DISP(IX,IY,3)*(CAVG(IX,IY+1)+CAVG(IX+1,IY+1)-CAVG(IX,IY-1)-CAV G 691R
     1G(IX+1,IY-1))                                                      G 701R
      XX2=DISP(IX-1,IY,3)*(CAVG(IX,IY+1)+CAVG(IX-1,IY+1)-CAVG(IX,IY-1)-C G 711R
     1AVG(IX-1,IY-1))                                                    G 721R
      YY1=DISP(IX,IY,4)*(CAVG(IX+1,IY)+CAVG(IX+1,IY+1)-CAVG(IX-1,IY)-CAV G 731R
     1G(IX-1,IY+1))                                                      G 741R
      YY2=DISP(IX,IY-1,4)*(CAVG(IX+1,IY)+CAVG(IX+1,IY-1)-CAVG(IX-1,IY)-C G 751R
     1AVG(IX-1,IY-1))                                                    G 761R
      GO TO 48                                                          SG 762
   39 X1=0.0                                                            SG 763A
      X2=0.0                                                            SG 763B
      Y1=0.0                                                            SG 763C
      Y2=0.0                                                            SG 763D
      XX1=0.0                                                           SG 763E
      XX2=0.0                                                           SG 763F
      YY1=0.0                                                           SG 763G
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      YY2=0.0                                                            SG 763H
      IF (IX.GE.NMX) GO TO 41                                            SG 763I
      X1=DISP(IX,IY,1)*(CAVG(IX+1,IY)-C2)                                SG 763J
   41 IF (IX.LE.1) GO TO 42                                              SG 763K
      X2=DISP(IX-1,IY,1)*(CAVG(IX-1,IY)-C2)                              SG 763L
   42 IF (IY.GE.NMY) GO TO 43                                            SG 763M
      Y1=DISP(IX,IY,2)*(CAVG(IX,IY+1)-C2)                                SG 763N
   43 IF (IY.LE.1) GO TO 46                                              SG 763O
      Y2=DISP(IX,IY-1,2)*(CAVG(IX,IY-1)-C2)                              SG 763P
   44 IF (IY.GE.NMY) GO TO 47                                            SG 764
      IF (IX.GE.NMX) GO TO 45                                            SG 765
      XX1=DISP(IX,IY,3)*(CAVG(IX,IY+1)+CAVG(IX+1,IY+1)-CAVG(IX,IY-1)-CAV SG 766A
     1G(IX+1,IY-1))                                                      SG 766B
   45 IF (IX.LE.1) GO TO 48                                              SG 766C
      XX2=DISP(IX-1,IY,3)*(CAVG(IX,IY+1)+CAVG(IX-1,IY+1)-CAVG(IX,IY-1)-C SG 766D
     1AVG(IX-1,IY-1))                                                    SG 766E
   46 IF (IX.LE.1) GO TO 48                                              SG 766F
      IF (IY.GE.NMY) GO TO 47                                            SG 766G
      IF (IX.GE.NMX) GO TO 48                                            SG 766H
      YY1=DISP(IX,IY,4)*(CAVG(IX+1,IY)+CAVG(IX+1,IY+1)-CAVG(IX-1,IY)-CAV SG 766I
     1G(IX-1,IY+1))                                                      SG 766J
   47 IF (IY.LE.1) GO TO 48                                              SG 766K
      IF (IX.LE.1.OR.IX.GE.NMX) GO TO 48                                 SG 766L
      YY2=DISP(IX,IY-1,4)*(CAVG(IX+1,IY)+CAVG(IX+1,IY-1)-CAVG(IX-1,IY)-C SG 766M
     1AVG(IX-1,IY-1))                                                    SG 766O
   48 CONTINUE                                                           SG 768
      CNCNC(IX,IY)=CNCNC(IX,IY)+EQFCT*(X1+X2+Y1+Y2+XX1-XX2+YY1-YY2)       G 772
   60 CONTINUE                                                            G 780
C     ****************************************************************    G 790
      GO TO 110                                                           G 820
C     ****************************************************************    G 830
C     ---CONC. CHANGE AT NODES DUE TO CONVECTION---                       G 840
C                                  ... AND DECAY---                       G 841R
   70 DO 90 IX=1,NMX                                                     SG 852
      DO 90 IY=1,NMY                                                     SG 862
      JX=IX+MX-1                                                         SG 866
      JY=IY+MY-1                                                         SG 867
      IF (THCK(JX,JY).EQ.0.0) GO TO 90                                   SG 871
      APC=NPCELL(IX,IY)                                                   G 880
      IF (APC.GT.0.0) GO TO 80                                            G 890
      IF (REC(JX,JY).NE.0.0.OR.VPRM(JX,JY).GT.0.09) GO TO 90             SG 901
      NZERO=NZERO+1                                                       G 910
      GO TO 90                                                            G 920
   80 CONC(IX,IY)=SUMC(IX,IY)/APC                                         G 930
      CAVG(IX,IY)=(CONC(IX,IY)+CNOLD(IX,IY))*0.5                          G 935R
   90 CONTINUE                                                            G 940
C         ---CHECK NUMBER OF CELLS VOID OF PTS.---                        G 950
      IF (NZERO.GT.0) WRITE (6,290) NZERO,IMOV                            G 960
      IF (NZERO.LE.NZCRIT) GO TO 20                                       G 970
      TEST=99.0                                                           G 980
      WRITE (6,300)                                                       G 990
      WRITE (6,320)                                                       G1000
      DO 100 IY=1,NMY                                                    SG1011
  100 WRITE (6,330) (NPCELL(IX,IY),IX=1,NMX)                             SG1021
      GO TO 20                                                            G1030
C     ****************************************************************    G1040
C     ---CHANGE CONCENTRATIONS AT NODES---                                G1050
  110 DO 130 IX=1,NMX                                                    SG1062
      DO 130 IY=1,NMY                                                    SG1072
      JX=IX+MX-1                                                         SG1076
      JY=IY+MY-1                                                         SG1077
      IF (THCK(JX,JY).EQ.0.0) GO TO 120                                  SG1081
      CNCPCT=0.0                                                          G1084G
      IF (CONC(IX,IY).GT.0.0) CNCPCT=CNCNC(IX,IY)/CONC(IX,IY)             G1085G
      CONC(IX,IY)=CONC(IX,IY)+CNCNC(IX,IY)                                G1090
      SUMC(IX,IY)=0.0                                                     G1110
      IF (CNCPCT.LT.0.0) SUMC(IX,IY)=CNCPCT                               G1125G
      GO TO 130                                                           G1150
  120 IF (CONC(IX,IY).GT.0.0) WRITE (6,310) JX,JY,CONC(IX,IY)            SG1161
      CONC(IX,IY)=0.0                                                     G1170
  130 CONTINUE                                                            G1180
C     ****************************************************************    G1190
C     ---CHANGE CONCENTRATION OF PARTICLES---                             G1200
      DO 180 IN=1,NP                                                      G1210
      IF (PART(1,IN).EQ.0.0) GO TO 180                                    G1220
      INX=ABS(PART(1,IN))+0.5                                             G1230
      INY=ABS(PART(2,IN))+0.5                                             G1240
      JNX=INX-MX+1                                                       SG1244
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      JNY=INY-MY+1                                                       SG1245
C     ---UPDATE CONC. OF PTS. IN SINK/SOURCE CELLS---                     G1250
      IF (REC(INX,INY).NE.0.0) GO TO 140                                  G1260
      IF (VPRM(INX,INY).LE.0.09) GO TO 150                                G1270
  140 PART(3,IN)=CONC(JNX,JNY)                                           SG1281
      GO TO 180                                                           G1290
  150 IF (CNCNC(JNX,JNY).LT.0.0) GO TO 170                               SG1301
  160 PART(3,IN)=PART(3,IN)+CNCNC(JNX,JNY)                               SG1311
      GO TO 180                                                           G1320
  170 IF (CONC(JNX,JNY).LE.0.0) GO TO 160                                SG1331
      IF (SUMC(JNX,JNY).LT.-1.0) GO TO 160                               SG1341
      PART(3,IN)=PART(3,IN)+PART(3,IN)*SUMC(JNX,JNY)                     SG1351
  180 CONTINUE                                                            G1360
      WRITE (6,280) TIM(N),TIMV,SUMTCH                                    G1370
C     ****************************************************************    G1380
C     ---COMPUTE MASS BALANCE FOR SOLUTE---                               G1390
      CSTORM=0.0                                                          G1400
      STORM=0.0                                                           G1410
      ADSORB=0.0                                                          G1411R
      ADSRB2=0.0                                                          G1412R
      DO 270 IX=1,NMX                                                    SG1422
      DO 270 IY=1,NMY                                                    SG1432
      JX=IX+MX-1                                                         SG1435
      JY=IY+MY-1                                                         SG1436
      IF (THCK(JX,JY).EQ.0.0) GO TO 270                                  SG1441
      C1=CONC(IX,IY)                                                      G1442R
      C1B=C1*THCK(JX,JY)                                                 SG1443R
      IF (DECAY.NE.0.0) THEN                                              G1445A
       DELDCY=CNOLD(IX,IY)*(1.0-DCYT)                                     G1445B
       IF (IREACT.GE.2) DELDCY=DELDCY+SORB2(CNOLD(IX,IY))*(1.0-DCYT)*C3   G1445C
      DMASS1=DMASS1-DELDCY*THCK(JX,JY)*RFAREA                            SG1447R
      END IF                                                              G1447R
      SUMC(IX,IY)=0.0                                                     G1450
      WTFCT=0.0                                                           G1455
C        ---COMPUTE MASS OF SOLUTE IN STORAGE---                          G1460
      STORM=STORM+C1B                                                     G1471A
C        ---COMPUTE MASS ADSORBED---                                      G1472R
      ADSORB=C1B+ADSORB                                                   G1474R
      IF (IREACT.GE.2) ADSRB2=ADSRB2+THCK(JX,JY)*SORB2(C1)               SG1475R
C        ---ACCOUNT FOR MASS PUMPED IN, OUT, RECHARGED, & DISCHARGED---   G1480
      IF (REC(JX,JY)) 200,210,190                                        SG1491
  190 FCT1=NPOLD(IX,IY)                                                   G1492
      FCT2=NPCELL(IX,IY)                                                  G1494
      IF (FCT2.GT.0.0) WTFCT=FCT1/FCT2                                    G1496
      CMSOUT=CMSOUT+REC(JX,JY)*TIMV*((1.0-WTFCT)*CNOLD(IX,IY)+WTFCT*C1)  SG1498R
      GO TO 210                                                           G1510
  200 CMSIN=CMSIN+REC(JX,JY)*CNRECH(IX,IY)*TIMV                          SG1521
  210 IF (RECH(JX,JY)) 230,240,220                                       SG1531
  220 CMSOUT=CMSOUT+RECH(JX,JY)*TVA2*(CNOLD(IX,IY)+C1)                   SG1538R
      GO TO 240                                                           G1550
  230 CMSIN=CMSIN+RECH(JX,JY)*CNRECH(IX,IY)*TVA                          SG1561
C     ****************************************************************    G1570
C        ---ACCOUNT FOR BOUNDARY FLOW---                                  G1580
  240 IF (VPRM(JX,JY).EQ.0.0) GO TO 265                                  SG1586
      FLW=VPRM(JX,JY)*(WT(JX,JY)-HK(JX,JY))                              SG1601
      IF (FLW.GT.0.0) GO TO 250                                           G1610
      IF (FLW.LT.0.0) GO TO 260                                           G1620
      GO TO 265                                                           G1625
C           ---MASS IN BOUNDARY DURING TIME STEP---                       G1640
  250 FLMIN=FLMIN+FLW*CNRECH(IX,IY)*TVA                                   G1650
      GO TO 265                                                           G1655
C           ---MASS OUT DURING TIME STEP---                               G1670
  260 FCT1=NPOLD(IX,IY)                                                   G1672
      FCT2=NPCELL(IX,IY)                                                  G1674
      IF (FCT2.GT.0.0) WTFCT=FCT1/FCT2                                    G1676
      FLMOT=FLMOT+FLW*TVA*((1.0-WTFCT)*CNOLD(IX,IY)+WTFCT*C1)             G1679R
  265 NPOLD(IX,IY)=NPCELL(IX,IY)                                          G1682
      NPCELL(IX,IY)=0                                                     G1684
      IF (IREACT.GE.2) THEN                                               G1686R
       CALL RETRD2(C1,CRETRD(IX,IY),CRDCOF(IX,IY))                        G1687A
       IF (DECAY.NE.0.0)                                                  G1687B
     1     CELDCY(IX,IY)=EXP(-DCYFCT*CRDCOF(IX,IY)/CRETRD(IX,IY))         G1687C
      END IF                                                              G1688R
  270 CONTINUE                                                            G1690
C           ---SUBGRID BOUNDARIES---                                     SG1692A
      IF (MCHK.EQ.0) GO TO 275                                           SG1692B
      YT=YDEL*TIMV                                                       SG1692C
      XT=XDEL*TIMV                                                       SG1692D
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```
      DO 272 IY=MY,MMY                                                  SG1694A
      IX=MX                                                             SG1694B
      JY=IY-MY+1                                                        SG1694C
      FLW=TMRX(IX-1,IY,1)*(HK(IX-1,IY)-HK(IX,IY))                       SG1694D
      IF (FLW.GT.0.0) FLMIN=FLMIN+FLW*YT*CNOLD(1,JY)*DCYT               SG1694G
      IF (FLW.LT.0.0) FLMOT=FLMOT+FLW*YT*CNOLD(1,JY)*DCYT               SG1694H
      IX=MMX                                                            SG1695A
      FLW=TMRX(IX,IY,1)*(HK(IX+1,IY)-HK(IX,IY))                         SG1695B
      IF (FLW.GT.0.0) FLMIN=FLMIN+FLW*YT*CNOLD(NMX,JY)*DCYT             SG1695E
  272 IF (FLW.LT.0.0) FLMOT=FLMOT+FLW*YT*CNOLD(NMX,JY)*DCYT             SG1695F
      DO 274 IX=MX,MMX                                                  SG1696A
      IY=MY                                                             SG1696B
      JX=IX-MX+1                                                        SG1696C
      FLW=TMRX(IX,IY-1,2)*(HK(IX,IY-1)-HK(IX,IY))                       SG1696D
      IF (FLW.GT.0.0) FLMIN=FLMIN+FLW*XT*CNOLD(JX,1)*DCYT               SG1696G
      IF (FLW.LT.0.0) FLMOT=FLMOT+FLW*XT*CNOLD(JX,1)*DCYT               SG1696H
      IY=MMY                                                            SG1697A
      FLW=TMRX(IX,IY,2)*(HK(IX,IY+1)-HK(IX,IY))                         SG1697B
      IF (FLW.GT.0.0) FLMIN=FLMIN+FLW*XT*CNOLD(JX,NMY)*DCYT             SG1697E
  274 IF (FLW.LT.0.0) FLMOT=FLMOT+FLW*XT*CNOLD(JX,NMY)*DCYT             SG1697F
  275 CONTINUE                                                          SG1698A
C     ****************************************************************   G1700
C        ---COMPUTE CHANGE IN MASS OF SOLUTE STORED---                   G1710
C        ---COMPUTE MASS LOST BY DECAY---                                G1715R
      STORM=STORM*AREA                                                   G1717
      ADSORB=(ADSORB*DK+ADSRB2)*RHOB/POROS*AREA                          G1719R
      CSTORM=STORM-STORMI                                                G1720
      CSTM2=CSTORM+ADSORB-SORBI                                          G1725R
      DMASS1=DMASS1+SRCDCY                                               G1726R
      SUMIO=FLMIN+FLMOT-CMSIN-CMSOUT                                     G1730
C     ****************************************************************   G1740
C     ---REGENERATE PARTICLES IF 'NZCRIT' EXCEEDED---                    G1750
      IF (TEST.GT.98.0) CALL GENPT                                       G1760
      TEST=0.0                                                           G1770
C     ****************************************************************   G1780
      RETURN                                                             G1790
C     ****************************************************************   G1800
C                                                                        G1810
C                                                                        G1820
C                                                                        G1830
  280 FORMAT (3H    ,11HTIM(N)    = ,1G12.5,10X,11HTIMV      = ,1G12.5,10X,  G1840
     19HSUMTCH = ,G12.5)                                                 G1850
  290 FORMAT (1H0,5X,40HNUMBER OF CELLS WITH ZERO PARTICLES  =  ,I4,5X,9  G1860
     1HIMOV  =  ,I4/)                                                    G1870
  300 FORMAT (1H0,5X,44H***   NZCRIT EXCEEDED  ---  CALL GENPT   ***/)   G1880
  310 FORMAT (1H ,5X,37H***CONC.GT.0.AND.THCK.EQ.0 AT NODE = ,2I4,4X,7HC  G1890
     1ONC = ,G10.4,4H ***)                                               G1900
  320 FORMAT (1H0,2X,6HNPCELL/)                                          G1910
  330 FORMAT (1H ,4X,20I3)                                               G1920
      END                                                                G1930-


$LARGE
      SUBROUTINE GENPT                                                  D  10
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE D  20
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,   D  30
     1                 HMIN,PYR,ANFCTR                                  D  32
      INTEGER PTID                                                      D  36
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,    D  41
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,   D  51
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK              D  62
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),    SD  67
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                     D  68
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                SD  91
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),         SD 101
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),   SD 111
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SD 115
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR  D 121
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                         SD 125
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040), SD 132
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS, SD 141
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,   D 145
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                    D 151
      COMMON /CHMP/ PTID(06400)                                         D 157
      DIMENSION RPT(16),RNT(16),RP(16),RN(16),IPT(16)                   D 161
C     ***************************************************************   D 170
      IONED=0                                                           D 172
      IF(NX.EQ.3.OR.NY.EQ.3) IONED=1                                    D 173
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      F1=0.30                                                            D 180
      F2=1.0/3.0                                                         D 190
      IF (NPTPND.EQ.4) F1=0.25                                           D 200
      IF (NPTPND.EQ.5.AND.IONED.EQ.1) F1=0.25                            D 202
      IF (NPTPND.EQ.9) F1=1.0/3.0                                        D 210
      IF (NPTPND.EQ.8.AND.IONED.NE.1) F2=0.25                            D 221
      IF (NPTPND.EQ.8.AND.IONED.EQ.1) F1=1.0/3.0                         D 222
      IF (NPTPND.EQ.16) F1=0.25                                          D 223
      IF (NPTPND.EQ.16) F2=0.125                                         D 224
      NCHK=NPTPND                                                        D 230
      IF (NPTPND.EQ.5.OR.NPTPND.EQ.9) NCHK=NPTPND-1                      D 240
      IF (TEST.GT.98.) GO TO 10                                          D 250
C     ***************************************************************    D 260
C     ---INITIALIZE VALUES---                                            D 270
      STORM=0.0                                                          D 280
      CMSIN=0.0                                                          D 290
      CMSOUT=0.0                                                         D 300
      FLMIN=0.0                                                          D 310
      FLMOT=0.0                                                          D 320
      SUMIO=0.0                                                          D 330
C     ***************************************************************    D 340
   10 DO 20 IN=1,NPMAX                                                   D 345
      PTID(IN)=0                                                         D 355
      DO 20 ID=1,3                                                       D 365
   20 PART(ID,IN)=0.0                                                    D 370
      DO 30 IA=1,16                                                      D 381
      RP(IA)=0.0                                                         D 390
      RN(IA)=0.0                                                         D 400
      RPT(IA)=0.0                                                        D 401
      RNT(IA)=0.0                                                        D 402
   30 IPT(IA)=0                                                          D 410
C     ---SET UP LIMBO ARRAY---                                           D 420
      DO 40 IN=1,500                                                     D 430
   40 LIMBO(IN)=0                                                        D 441
      IND=1                                                              D 450
C     ***************************************************************    D 490
C     ---INSERT PARTICLES---                                             D 500
C        ---TRACK PARTICLE LOCATIONS IN COORDINATES OF PRIMARY GRID---  SD 505
      DO 410 IX=1,NMX                                                   SD 512
      JX=IX+MX-1                                                        SD 515
      DO 410 IY=1,NMY                                                   SD 522
      JY=IY+MY-1                                                        SD 525
      IF (THCK(JX,JY).EQ.0.0) GO TO 410                                 SD 531
      KR=0                                                               D 540
      KR2=0                                                              D 541
      TEST2=0.0                                                          D 550
      METH=1                                                             D 560
      NPCELL(IX,IY)=0                                                    D 570
      NPOLD(IX,IY)=NPTPND                                                D 575
      C1=CONC(IX,IY)                                                     D 580
      IF (NPTPND.EQ.1) GO TO 150                                         D 585
      IF (C1.LE.1.0E-05) TEST2=1.0                                       D 590
      IF (IX.EQ.1.OR.IX.EQ.NMX.OR.IY.EQ.1.OR.IY.EQ.NMY) TEST2=1.0       SD 595
      IF (VPRM(JX,JY).GT.0.09) TEST2=1.0                                SD 601
      IF (REC(JX,JY).NE.0.0) TEST2=1.0                                  SD 611
      IF (THCK(JX+1,JY+1).EQ.0.0.OR.THCK(JX+1,JY-1).EQ.0.0.OR.THCK(JX-1,SD 621
     1JY+1).EQ.0.0.OR.THCK(JX-1,JY-1).EQ.0.0) TEST2=1.0                 SD 631
      IF ((THCK(JX,JY+1).EQ.0.0.OR.THCK(JX,JY-1).EQ.0.0.OR.THCK(JX+1,JY)SD 641
     1.EQ.0.0.OR.THCK(JX-1,JY).EQ.0.0).AND.NPTPND.GT.5) TEST2=1.0       SD 651
      CNODE=C1*(1.0-F1)                                                  D 660
      IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 70                         D 670
      SUMC=CONC(IX+1,IY)+CONC(IX-1,IY)+CONC(IX,IY+1)+CONC(IX,IY-1)       D 680
      IF (NCHK.EQ.4) GO TO 60                                            D 690
      SUMC=SUMC+CONC(IX+1,IY+1)+CONC(IX+1,IY-1)+CONC(IX-1,IY+1)+CONC(IX- D 700
     11,IY-1)                                                            D 710
   60 AVC=SUMC/NCHK                                                      D 720
      IF (AVC.GT.C1) METH=2                                              D 730
C                                                                        D 740
C        ---PUT 4 PARTICLES ON CELL DIAGONALS---                         D 750
   70 DO 140 IT=1,2                                                      D 760
      EVET=(-1.0)**IT                                                    D 770
      DO 140 IS=1,2                                                      D 780
      IF(IONED.EQ.1.AND.IT.EQ.1.AND.IS.EQ.2) GO TO 140                   D 782
      IF(IONED.EQ.1.AND.IT.EQ.2.AND.IS.EQ.1) GO TO 140                   D 783
      EVES=(-1.0)**IS                                                    D 790
      KR=KR+1                                                            D 793
      IF (NPTPND.EQ.16) GO TO 72                                         D 795
      PART(1,IND)=JX+F1*EVET                                            SD 801
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      PART(2,IND)=JY+F1*EVES                                            SD 811
      PART(2,IND)=-PART(2,IND)                                           D 820
      PART(3,IND)=C1                                                     D 830
      IPT(KR)=IND                                                        D 833
      PTID(IND)=KR                                                       D 834
      IF(IONED.EQ.1.AND.IS.EQ.2) PTID(IND)=4                             D 834A
      GO TO 76                                                           D 835
   72 IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 135                        D 841
   76 IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 139                        D 845
      IXD=IX+EVET                                                        D 850
      IYD=IY+EVES                                                        D 860
      IF (METH.EQ.2) GO TO 80                                            D 890
      PARTC=CNODE+CONC(IXD,IYD)*F1                                       D 901
      GO TO 90                                                           D 910
   80 PARTC=2.0*C1*CONC(IXD,IYD)/(C1+CONC(IXD,IYD))                      D 921
   90 IF (C1-CONC(IXD,IYD)) 100,110,120                                  D 930
  100 RPT(KR)=CONC(IXD,IYD)-PARTC                                        D 941
      RNT(KR)=C1-PARTC                                                   D 951
      GO TO 130                                                          D 960
  110 RPT(KR)=0.0                                                        D 971
      RNT(KR)=0.0                                                        D 981
      GO TO 130                                                          D 990
  120 RPT(KR)=C1-PARTC                                                   D1001
      RNT(KR)=CONC(IXD,IYD)-PARTC                                        D1011
  130 IF (NPTPND.EQ.16) GO TO 135                                        D1012
      PART(3,IND)=PARTC                                                  D1013
      RP(KR)=RPT(KR)                                                     D1014
      RN(KR)=RNT(KR)                                                     D1015
      GO TO 139                                                          D1016
  135 DO 138 ITT = 1,2                                                   D1017
      EVET2=(-1.0)**ITT                                                  D1018
      DO 138 ISS = 1,2                                                   D1019
      IF(IONED.EQ.1.AND.ITT.EQ.1.AND.ISS.EQ.2) GO TO 138                 D1019A
      IF(IONED.EQ.1.AND.ITT.EQ.2.AND.ISS.EQ.1) GO TO 138                 D1019B
      EVES2=(-1.0)**ISS                                                  D1021
      PART(1,IND)=(JX+F1*EVET)+F2*EVET2                                 SD1022A
      PART(2,IND)=(JY+F1*EVES)+F2*EVES2                                 SD1023A
      PART(2,IND)=-PART(2,IND)                                           D1024
      KR2=KR2+1                                                          D1025
      IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 136                        D1026
      PART(3,IND) = PARTC                                                D1027
      RP(KR2) = RPT(KR)                                                  D1028
      RN(KR2) = RNT(KR)                                                  D1029
      IPT(KR2) = IND                                                     D1031
      GO TO 137                                                          D1032
  136 PART(3,IND) = C1                                                   D1033
  137 PTID(IND)=KR2                                                      D1034
      IF(IONED.EQ.1) THEN                                                D1034A
       IF(IT.EQ.1.AND.ISS.EQ.2) PTID(IND)=4                              D1034B
       IF(IT.EQ.2) THEN                                                  D1034C
        IF(ISS.EQ.1) PTID(IND)=13                                        D1034D
        IF(ISS.EQ.2) PTID(IND)=16                                        D1034E
       END IF                                                            D1034F
      END IF                                                             D1034G
      IND=IND+1                                                          D1035
  138 CONTINUE                                                           D1036
      GO TO 140                                                          D1037
  139 IND=IND+1                                                          D1038
  140 CONTINUE                                                           D1039
      IF (NPTPND.EQ.16) GO TO 290                                        D1045
      IF ((NPTPND.EQ.5.AND.IONED.NE.1).OR.NPTPND.EQ.9) GO TO 150         D1051
      IF (NPTPND.EQ.8.AND.IONED.EQ.1) GO TO 150                          D1052
      GO TO 160                                                          D1060
C         ---PUT ONE PARTICLE AT CENTER OF CELL---                       D1070
  150 PART(1,IND)=JX                                                    SD1076
      PART(2,IND)=-JY                                                   SD1091
      PART(3,IND)=C1                                                     D1100
      PTID(IND)=5                                                        D1105
      IND=IND+1                                                          D1110
      IF (NPTPND.EQ.1) GO TO 410                                         D1115
C         ---PLACE NORTH, SOUTH, EAST, AND WEST PARTICLES---             D1120
  160 IF (NPTPND.LT.8) GO TO 290                                         D1130
      IF(IONED.EQ.1) GO TO 290                                           D1132
      CNODE=C1*(1.0-F2)                                                  D1140
      DO 280 IT=1,2                                                      D1150
      EVET=(-1.0)**IT                                                    D1160
      PART(1,IND)=JX+F2*EVET                                            SD1171
      PART(2,IND)=-JY                                                   SD1181
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      PART(3,IND)=C1                                                    D1190
      IF (EVET.LT.0) PTID(IND)=6                                        D1192
      IF (EVET.GT.0) PTID(IND)=8                                        D1194
      IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 220                       D1200
      IXD=IX+EVET                                                       D1210
      KR=KR+1                                                           D1220
      IPT(KR)=IND                                                       D1230
      IF (METH.EQ.2) GO TO 170                                          D1240
      PART(3,IND)=CNODE+CONC(IXD,IY)*F2                                 D1250
      GO TO 180                                                         D1260
  170 PART(3,IND)=2.0*C1*CONC(IXD,IY)/(C1+CONC(IXD,IY))                 D1270
  180 IF (C1-CONC(IXD,IY)) 190,200,210                                  D1280
  190 RP(KR)=CONC(IXD,IY)-PART(3,IND)                                   D1290
      RN(KR)=C1-PART(3,IND)                                             D1300
      GO TO 220                                                         D1310
  200 RP(KR)=0.0                                                        D1320
      RN(KR)=0.0                                                        D1330
      GO TO 220                                                         D1340
  210 RP(KR)=C1-PART(3,IND)                                             D1350
      RN(KR)=CONC(IXD,IY)-PART(3,IND)                                   D1360
  220 IND=IND+1                                                         D1370
      PART(1,IND)=JX                                                   SD1381
      PART(2,IND)=JY+F2*EVET                                           SD1391
      PART(2,IND)=-PART(2,IND)                                          D1400
      PART(3,IND)=C1                                                    D1410
      IF (EVET.LT.0) PTID(IND)=7                                        D1412
      IF (EVET.GT.0) PTID(IND)=9                                        D1414
      IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 280                       D1420
      IYD=IY+EVET                                                       D1430
      KR=KR+1                                                           D1440
      IPT(KR)=IND                                                       D1450
      IF (METH.EQ.2) GO TO 230                                          D1460
      PART(3,IND)=CNODE+CONC(IX,IYD)*F2                                 D1470
      GO TO 240                                                         D1480
  230 PART(3,IND)=2.0*C1*CONC(IX,IYD)/(C1+CONC(IX,IYD))                 D1490
  240 IF (C1-CONC(IX,IYD)) 250,260,270                                  D1500
  250 RP(KR)=CONC(IX,IYD)-PART(3,IND)                                   D1510
      RN(KR)=C1-PART(3,IND)                                             D1520
      GO TO 280                                                         D1530
  260 RP(KR)=0.0                                                        D1540
      RN(KR)=0.0                                                        D1550
      GO TO 280                                                         D1560
  270 RP(KR)=C1-PART(3,IND)                                             D1570
      RN(KR)=CONC(IX,IYD)-PART(3,IND)                                   D1580
  280 IND=IND+1                                                         D1590
C                                                                       D1600
  290 IF (TEST.LT.98.0.OR.TEST2.GT.0.0) GO TO 410                       D1610
      SUMPT=0.0                                                         D1620
C        ---COMPUTE CONC. GRADIENT WITHIN CELL---                       D1630
      DO 300 KPT=1,NCHK                                                 D1640
      IK=IPT(KPT)                                                       D1650
  300 SUMPT=PART(3,IK)+SUMPT                                            D1660
      CBAR=SUMPT/NCHK                                                   D1670
C        ---CHECK MASS BALANCE WITHIN CELL AND ADJUST PT. CONCS.---     D1680
      SUMPT=0.0                                                         D1690
      IF (CBAR-C1) 310,410,330                                          D1700
  310 CRCT=1.0-(CBAR/C1)                                                D1710
      IF (METH.EQ.1) CRCT=CBAR/C1                                       D1720
      DO 320 KPT=1,NCHK                                                 D1730
      IK=IPT(KPT)                                                       D1740
      PART(3,IK)=PART(3,IK)+RP(KPT)*CRCT                                D1750
  320 SUMPT=SUMPT+PART(3,IK)                                            D1760
      CBARN=SUMPT/NCHK                                                  D1770
      GO TO 350                                                         D1780
  330 CRCT=1.0-(C1/CBAR)                                                D1790
      IF (METH.EQ.1) CRCT=C1/CBAR                                       D1800
      DO 340 KPT=1,NCHK                                                 D1810
      IK=IPT(KPT)                                                       D1820
      PART(3,IK)=PART(3,IK)+RN(KPT)*CRCT                                D1830
  340 SUMPT=SUMPT+PART(3,IK)                                            D1840
      CBARN=SUMPT/NCHK                                                  D1850
  350 IF (CBARN.EQ.C1) GO TO 410                                        D1860
C        ---CORRECT FOR OVERCOMPENSATION---                             D1870
      CRCT=C1/CBARN                                                     D1880
      DO 380 KPT=1,NCHK                                                 D1890
      IK=IPT(KPT)                                                       D1900
      PART(3,IK)=PART(3,IK)*CRCT                                        D1910
C        ---CHECK CONSTRAINTS---                                        D1920
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      IF (PART(3,IK)-C1) 360,380,370                                    D1930
  360 CLIM=C1-RP(KPT)+RN(KPT)                                           D1940
      IF (PART(3,IK).LT.CLIM) GO TO 390                                 D1950
      GO TO 380                                                         D1960
  370 CLIM=C1+RP(KPT)-RN(KPT)                                           D1970
      IF (PART(3,IK).GT.CLIM) GO TO 390                                 D1980
  380 CONTINUE                                                          D1990
      GO TO 410                                                         D2000
  390 TEST2=1.0                                                         D2010
      DO 400 KPT=1,NCHK                                                 D2020
      IK=IPT(KPT)                                                       D2030
  400 PART(3,IK)=C1                                                     D2040
  410 CONTINUE                                                          D2050
      NP=IND-1                                                          D2061
      IF (INT.EQ.0) CALL CHMOT                                          D2070
C     **************************************************************    D2080
      RETURN                                                            D2090
C     **************************************************************    D2100
      END                                                               D2110-


$LARGE
      SUBROUTINE ITERAT                                                 C  10
      DOUBLE PRECISION DMIN1,DEXP,DLOG,DABS                             C  20
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE C  30
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,   C  40
     1                 HMIN,PYR,ANFCTR                                  C  42
      DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV                         C  45
      DOUBLE PRECISION B,G,W,A,C,E,F,DR,DC,TBAR,TMK,COEF,BLH,BRK,CHK,QL, C  50
     1                 BRH                                              C  51
      DOUBLE PRECISION TOTLQ,TOTLQI,TPIN,TPOUT,PQIN,PQOUT,DELQ          C  52
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,    C  61
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,   C  71
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK              C  82
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                SC 111
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),         SC 121
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),   SC 131
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SC 135
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR  C 141
      COMMON /BALM/ TOTLQ,TOTLQI,TPIN,TPOUT                             C 146
      COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                            C 160
      DIMENSION W(040), B(040), G(040)                                 SC 172
C     *************************************************************     C 180
      KOUNT=0                                                           C 190
      PQIN=0.D0                                                         C 192
      PQOUT=0.D0                                                        C 193
C       DO NOT REPEAT SOLUTION FOR STEADY-STATE                         C 195
      IREPET=0                                                          C 196
      IF (S.EQ.0.0.AND.(N.GT.1.OR.(INT.GT.1.AND.ICHK.EQ.0))) THEN       C 197A
        IREPET=1                                                        C 197B
        GO TO 120                                                       C 197C
      END IF                                                            C 197D
C     ---COMPUTE ROW AND COLUMN---                                      C 200
C        ---CALL NEW ITERATION PARAMETER---                             C 210
   10 REMN=MOD(KOUNT,NITP)                                              C 220
      IF (REMN.EQ.0) NTH=0                                              C 230
      NTH=NTH+1                                                         C 240
      PARAM=AOPT(NTH)                                                   C 250
C     *************************************************************     C 260
C     ---ROW COMPUTATIONS---                                            C 270
      TEST=0.D0                                                         C 280
      RHO=S/TIM(N)                                                      C 290
      BRK=-RHO                                                          C 300
      DO 50 IY=1,NY                                                     C 310
      DO 20 M=1,NX                                                      C 320
      W(M)=0.D0                                                         C 330
      B(M)=0.D0                                                         C 340
      G(M)=0.D0                                                         C 350
   20 CONTINUE                                                          C 360
      DO 30 IX=1,NX                                                     C 370
      IF (THCK(IX,IY).EQ.0.0) GO TO 30                                  C 380
      COEF=VPRM(IX,IY)                                                  C 390
      QL=-COEF*WT(IX,IY)                                                C 400
      A=TMRX(IX-1,IY,1)*DXINV                                           C 410
      C=TMRX(IX,IY,1)*DXINV                                             C 420
      E=TMRX(IX,IY-1,2)*DYINV                                           C 430
      F=TMRX(IX,IY,2)*DYINV                                             C 440
      TBAR=A+C+E+F                                                      C 450
```

```
      TMK=TBAR*PARAM
      BLH=-A-C-RHO-COEF-TMK
      BRH=E+F-TMK
      DR=BRH*HC(IX,IY)+BRK*HK(IX,IY)-E*HC(IX,IY-1)-F*HC(IX,IY+1)+QL+RECH
     1(IX,IY)+REC(IX,IY)*ARINV
      W(IX)=BLH-A*B(IX-1)
      B(IX)=C/W(IX)
      G(IX)=(DR-A*G(IX-1))/W(IX)
   30 CONTINUE
C
C          ---BACK SUBSTITUTION---
      DO 40 J=2,NX
      IJ=J-1
      IS=NX-IJ
   40 HR(IS,IY)=G(IS)-B(IS)*HR(IS+1,IY)
   50 CONTINUE
C     ***************************************************************
C     ---COLUMN COMPUTATIONS---
      DO 90 IX=1,NX
      DO 60 M=1,NY
      W(M)=0.D0
      B(M)=0.D0
   60 G(M)=0.D0
      DO 70 IY=1,NY
      IF (THCK(IX,IY).EQ.0.0) GO TO 70
      COEF=VPRM(IX,IY)
      QL=-COEF*WT(IX,IY)
      A=TMRX(IX,IY-1,2)*DYINV
      C=TMRX(IX,IY,2)*DYINV
      E=TMRX(IX-1,IY,1)*DXINV
      F=TMRX(IX,IY,1)*DXINV
      TBAR=A+C+E+F
      TMK=TBAR*PARAM
      BLH=-A-C-RHO-COEF-TMK
      BRH=E+F-TMK
      DC=BRH*HR(IX,IY)+BRK*HK(IX,IY)-E*HR(IX-1,IY)-F*HR(IX+1,IY)+QL+RECH
     1(IX,IY)+REC(IX,IY)*ARINV
      W(IY)=BLH-A*B(IY-1)
      B(IY)=C/W(IY)
      G(IY)=(DC-A*G(IY-1))/W(IY)
   70 CONTINUE
C
C          ---BACK SUBSTITUTION---
      DO 80 J=2,NY
      IJ=J-1
      IB=NY-IJ
      HC(IX,IB)=G(IB)-B(IB)*HC(IX,IB+1)
      IF (THCK(IX,IB).EQ.0.0) GO TO 80
      CHK=DABS(HC(IX,IB)-HR(IX,IB))
      IF (CHK.GT.TOL) TEST=1.D0
   80 CONTINUE
   90 CONTINUE
C     ***************************************************************
      KOUNT=KOUNT+1
      IF (TEST.EQ.0.0) GO TO 120
      IF (KOUNT.GE.ITMAX) GO TO 100
      GO TO 10
C     ***************************************************************
C     ---TERMINATE PROGRAM -- ITMAX EXCEEDED---
  100 WRITE (6,160)
      DO 110 IX=1,NX
      DO 110 IY=1,NY
  110 HK(IX,IY)=HC(IX,IY)
      CALL OUTPT
      STOP
C     ***************************************************************
C     ---SET NEW HEAD (HK)---
  120 DO 130 IY=1,NY
      DO 130 IX=1,NX
      IF (THCK(IX,IY).EQ.0.0) GO TO 130
C      UPDATE THICKNESS*POROSITY FOR TRANSIENT FLOW
      IF (IREPET.EQ.0) THEN
      THCK(IX,IY)=THCK(IX,IY)+S*(HC(IX,IY)-HK(IX,IY))
      IF (THCK(IX,IY).LE.0.0) THEN
       WRITE (6,170) IX,IY
       THCK(IX,IY)=0.0
      END IF
      HR(IX,IY)=HK(IX,IY)
```

```
      HK(IX,IY)=HC(IX,IY)                                               C1170
      END IF                                                            C1175
C                                                                       C1180
C     ---CUMULATE PUMPAGE AND RECHARGE FOR MASS BALANCE---              C1181
      IF (REC(IX,IY).GT.0.0) GO TO 32                                   C1182
      PQIN=PQIN+REC(IX,IY)                                              C1183
      GO TO 34                                                          C1184
   32 PQOUT=PQOUT+REC(IX,IY)                                            C1185
   34 IF (RECH(IX,IY).GT.0.0) GO TO 36                                  C1186
      PQIN=PQIN+RECH(IX,IY)*AREA                                        C1187
      GO TO 38                                                          C1188
   36 PQOUT=PQOUT+RECH(IX,IY)*AREA                                      C1189
C     ---COMPUTE LEAKAGE FOR MASS BALANCE---                            C1190
   38 IF (VPRM(IX,IY).EQ.0.0) GO TO 130                                 C1201
      DELQ=VPRM(IX,IY)*AREA*(WT(IX,IY)-HK(IX,IY))                       C1210
      IF (DELQ.GT.0.0) GO TO 125                                        C1215
      TOTLQ=TOTLQ+DELQ*TIM(N)                                           C1220
      GO TO 130                                                         C1222
  125 TOTLQI=TOTLQI+DELQ*TIM(N)                                         C1224
  130 CONTINUE                                                          C1230
      TPIN=PQIN*TIM(N)+TPIN                                             C1232
      TPOUT=PQOUT*TIM(N)+TPOUT                                          C1233
C                                                                       C1240
      WRITE (6,140) N                                                   C1250
      IF (IREPET.EQ.0) THEN                                             C1255
      WRITE (6,150) KOUNT                                               C1260
      ELSE                                                              C1264
       WRITE (6,151)                                                    C1265
      END IF                                                            C1266
C     ****************************************************************  C1270
      RETURN                                                            C1280
C     ****************************************************************  C1290
C                                                                       C1300
C                                                                       C1310
C                                                                       C1320
  140 FORMAT (1H0//3X,4HN = ,1I4)                                       C1330
  150 FORMAT (1H ,2X,23HNUMBER OF ITERATIONS = ,1I4)                    C1340
  151 FORMAT (1H ,2X,43HNUMBER OF ITERATIONS = 0  (HEADS UNCHANGED))    C1342
  160 FORMAT (1H0,5X,64H***   EXECUTION TERMINATED -- MAX. NO. ITERATION C1350
     1S EXCEEDED   ***/26X,21HFINAL OUTPUT FOLLOWS:)                    C1360
  170 FORMAT (/' **** ERROR **** EFFECTIVE AQUIFER VOLUME IS ZERO ',    C1364
     1        'IN CELL ',I4,' ,',I4//)                                  C1365
      END                                                               C1370-


$LARGE
C     ****************************************************************  A  10
C     *                                                              *  A  20
C     *     SOLUTE TRANSPORT AND DISPERSION IN A POROUS MEDIUM       *  A  30
C     *      NUMERICAL SOLUTION --- METHOD OF CHARACTERISTICS        *  A  40
C     *      PROGRAMMED BY J. D. BREDEHOEFT AND L. F. KONIKOW        *  A  50
C     *               REVISED APRIL 1979, MARCH 1980                 *  A  55
C     *               REVISED DECEMBER 1980                          *  A  56
C     *               REVISED AUGUST 1981, JUNE 1982                 *  A  57
C     *               REVISED OCTOBER 1983                           *  A  58
C     * REV. JUNE-AUG. 1984 BY W. SANFORD TO ALLOW 16 PTS. PER NODE  *  A  59
C     *  REV. MAY-AUG. 1985 BY L. KONIKOW AND M. PERSON TO INCLUDE:  *  A  59R
C     *       DECAY AND EQUILIBRIUM SORPTION-DESORPTION REACTIONS    *  A  60R
C     *                                                              * SA  61
C     * REV. JULY-DEC.1985 TO ALLOW SECONDARY SUBGRID FOR TRANSPORT  * SA  62
C     *               REVISED JULY 1986                              *  A  63
C     *               REVISED MARCH 1987 BY D.J. GOODE               *  A  64
C     *               REVISED MAY 1987 BY D.J. GOODE                 *  A  67
C     *               REVISED JANUARY 1988                           *  A  68A
C     *               REVISED NOVEMBER 1988                          *  A  68B
C     *    REV. MARCH 1989 BY D.J. GOODE FOR NONLINEAR EQUILIBRIUM   *  A  68C
C     *     SORPTION AND ION-EXCHANGE FOR MONO AND DIVALENT IONS     *  A  68D
C     *                                                              *  A  69R
C     ****************************************************************  A  70
C     ****************************************************************
C     *                                                              *
C     *     PROGRAM : MOCADI  V2.0  (AS MODIFIED BY TECSOFT INC.)    *
C     *               MODIFICATIONS ARE COMMENTED OUT                *
C     *                                                              *
C     ****************************************************************
C
      DOUBLE PRECISION DMIN1,DEXP,DLOG,DABS                             A  80
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE A  90
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      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,     A 100
     1                 HMIN,PYR,ANFCTR                                     A 102
      DOUBLE PRECISION TINIT,TIMX                                          A 104
      DOUBLE PRECISION TINT                                                A 111
      DOUBLE PRECISION TMSUM,TDEL                                          A 114
      DOUBLE PRECISION TOTLQ,TOTLQI,TPIN,TPOUT                             A 117
      DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV                            A 118
      INTEGER PTID                                                         A 119
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,       A 121
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,      A 131
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK                 A 142
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),       SA 147
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                        A 148
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                   SA 171
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),            SA 181
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),      SA 185
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SA 191
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR    A 201
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                            SA 205
      COMMON /HEDD/ TINIT,TIMX                                             A 207
      COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                               A 208
      COMMON /BALM/ TOTLQ,TOTLQI,TPIN,TPOUT                                A 209
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040),  SA 212
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS,    SA 215
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,      A 221
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                       A 231
      COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)           SA 233
      COMMON /CHMP/ PTID(06400)                                            A 237
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,      A 238A
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,       A 238B
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6   A 238C
      COMMON /CHMR2/ CRETRD(020,020),CRDCOF(020,020),CELDCY(020,020)       A 238D
      COMMON /DIFUS/ DISP(020,020,4)                                       A 239
C      COMMON /SAVEBF/ ANSC,ANSH,ANSV
C      CHARACTER*1 ANSC,ANSH,ANSV
C      DIMENSION HKS(40)
C
C     ****************************************************************     A 240
C      ---LOAD DATA---                                                     A 250
      INT=0                                                                A 260
      TMSUM=0.D0                                                           A 265
      CALL PARLOD                                                          A 270
      CALL GENPT                                                           A 280
C     ****************************************************************     A 290
C     ---START COMPUTATIONS---                                             A 300
C        ---COMPUTE ONE PUMPING PERIOD---                                  A 310
      DO 150 INT=1,NPMP                                                    A 320
      IF (INT.GT.1) TMSUM=TMSUM+PYR                                        A 325
      IF (INT.GT.1) CALL PARLOD                                            A 330
      REMN=1.0                                                             A 338
C        ---COMPUTE ONE TIME STEP---                                       A 340
      DO 130 N=1,NTIM                                                      A 350
      IPRNT=0                                                              A 360
C        ---LOAD NEW DELTA T---                                            A 370
      TINT=SUMT-TMSUM                                                      A 381
      TDEL=DMIN1(TIM(N),PYR-TINT)                                          A 390
      SUMT=SUMT+TDEL                                                       A 400
      TIM(N)=TDEL                                                          A 410
      IF (NPNT.GT.0) REMN=MOD(N,NPNT)                                      A 421
      IF (SUMT.GE.(PYR+TMSUM)) IPRNT=1                                     A 425
C     ****************************************************************     A 430
      CALL ITERAT                                                          A 440
      IF (REMN.EQ.0.0.OR.N.EQ.NTIM.OR.IPRNT.EQ.1) CALL OUTPT               A 452
      CALL VELO                                                            A 460
  101 CALL MOVE                                                            A 471
C
C  SAVE CONCENTRATION FOR THIS TIME STEP?
C
C      IF(NPNCHV.NE.0.AND.N.EQ.NTIM) THEN
C
C  WRITE DATA FLAGS
C
C      IF(ANSC.EQ.'Y'.OR.ANSH.EQ.'Y'.OR.ANSV.EQ.'Y') THEN
C        XDELS=XDEL
C        YDELS=YDEL
C        WRITE(7) NX,NY,XDELS,YDELS
C        WRITE(7) ANSC,ANSH,ANSV
C      ENDIF
```

```
C
C  WRITE TIME INFORMATION
C
C      IF(ANSC.EQ.'Y'.OR.ANSH.EQ.'Y'.OR.ANSV.EQ.'Y') THEN
C        WRITE(7) N,INT,SUMT
C      ENDIF
C
C  WRITE CONCENTRATIONS IF DESIRED
C
C      IF(ANSC.EQ.'Y') THEN
C         DO 127 IY=1,NY
C  127    WRITE(7) (CONC(IX,IY),IX=1,NX)
C      ENDIF
C
C  WRITE HEADS IF REQUESTED
C
C      IF(ANSH.EQ.'Y') THEN
C         DO 103 IY=1,NY
C
C  STORE HEADS IN SINGLE PRECISION
C
C            DO 102 IIII=1,NX
C  102       HKS(IIII)=HK(IIII,IY)
C  103    WRITE(7) (HKS(IIII),IIII=1,NX)
C      ENDIF
C
C  WRITE VELOCITIES IF REQUESTED
C
C      IF(ANSV.EQ.'Y') THEN
C         DO 100 IY=1,NY
C  100    WRITE(7) (VX(IX,IY),IX=1,NX)
C         DO 108 IY=1,NY
C  108    WRITE(7) (VY(IX,IY),IX=1,NX)
C      ENDIF
C      ENDIF
C     *****************************************************************     A 480
      IF (SUMT.GE.(PYR+TMSUM)) GO TO 140                                    A 621
  130 CONTINUE                                                              A 630
C     *****************************************************************     A 640
  140 CONTINUE                                                              A 660
  150 CONTINUE                                                              A 690
C     *****************************************************************     A 700
      ENDFILE(6)                                                            A 702
      IF (NPNCHV.EQ.0) GO TO 155                                            A 703
C      IF(ANSC.NE.'Y'.AND.ANSH.NE.'Y'.AND.ANSV.NE.'Y') GO TO 155
      ENDFILE(7)                                                            A 704
  155 CONTINUE                                                              A 705
C      CALL CLRPGE(0,7,0)
      STOP                                                                  A 710
C     *****************************************************************     A 720
      END                                                                   A 730-


$LARGE
C     ******************************************************************    A  10
C     *                                                                *    A  20
C     *     SOLUTE TRANSPORT AND DISPERSION IN A POROUS MEDIUM         *    A  30
C     *      NUMERICAL SOLUTION --- METHOD OF CHARACTERISTICS          *    A  40
C     *      PROGRAMMED BY J. D. BREDEHOEFT AND L. F. KONIKOW          *    A  50
C     *               REVISED APRIL 1979, MARCH 1980                   *    A  55
C     *               REVISED DECEMBER 1980                            *    A  56
C     *               REVISED AUGUST 1981, JUNE 1982                   *    A  57
C     *               REVISED OCTOBER 1983                             *    A  58
C     * REV. JUNE-AUG. 1984 BY W. SANFORD TO ALLOW 16 PTS. PER NODE    *    A  59
C     *  REV. MAY-AUG. 1985 BY L. KONIKOW AND M. PERSON TO INCLUDE:    *    A  59R
C     *       DECAY AND EQUILIBRIUM SORPTION-DESORPTION REACTIONS      *    A  60R
C     *                                                                *   SA  61
C     * REV. JULY-DEC.1985 TO ALLOW SECONDARY SUBGRID FOR TRANSPORT    *   SA  62
C     *               REVISED JULY 1986                                *    A  63
C     *               REVISED MARCH 1987 BY D.J. GOODE                 *    A  64
C     *               REVISED MAY 1987 BY D.J. GOODE                   *    A  67
C     *               REVISED JANUARY 1988                             *    A  68A
C     *               REVISED NOVEMBER 1988                            *    A  68B
C     *    REV. MARCH 1989 BY D.J. GOODE FOR NONLINEAR EQUILIBRIUM     *    A  68C
C     *     SORPTION AND ION-EXCHANGE FOR MONO AND DIVALENT IONS       *    A  68D
C     *                                                                *    A  69R
C     ******************************************************************    A  70
C     ******************************************************************
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C      *                                                              *
C      *      PROGRAM : MOCSIP  V2.0  (AS MODIFIED BY TECSOFT INC.)    *
C      *                MODIFICATIONS ARE COMMENTED OUT               *
C      *                                                              *
C      ****************************************************************
C
       DOUBLE PRECISION DMIN1,DEXP,DLOG,DABS                             A  80
       DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE A  90
       DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,   A 100
     1                  HMIN,PYR,ANFCTR                                  A 102
       DOUBLE PRECISION TINIT,TIMX                                       A 104
       DOUBLE PRECISION TINT                                             A 111
       DOUBLE PRECISION TMSUM,TDEL                                       A 114
       DOUBLE PRECISION TOTLQ,TOTLQI,TPIN,TPOUT                          A 117
       DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV                         A 118
       INTEGER PTID                                                      A 119
       COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,    A 121
     1               NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,   A 131
     2               NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK              A 142
       COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),    SA 147
     1               LIMBO(0500),IXOBS(05),IYOBS(05)                     A 148
       COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                SA 171
       COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),         SA 181
     1               HR(040,040),HC(040,040),HK(040,040),WT(040,040),   SA 185
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL,SA 191
     3               S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR A 201
       COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                         SA 205
       COMMON /HEDD/ TINIT,TIMX                                          A 207
       COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                            A 208
       COMMON /BALM/ TOTLQ,TOTLQI,TPIN,TPOUT                             A 209
       COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040),SA 212
     1               VY(040,040),CONINT(020,020),CNRECH(020,020),POROS, SA 215
     2               SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,   A 221
     3               FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                    A 231
       COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)        SA 233
       COMMON /CHMP/ PTID(06400)                                         A 237
       COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,   A 238A
     1               EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,    A 238B
     2         RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 A 238C
       COMMON /CHMR2/ CRETRD(020,020),CRDCOF(020,020),CELDCY(020,020)    A 238D
       COMMON /DIFUS/ DISP(020,020,4)                                    A 239
C      COMMON /SAVEBF/ ANSC,ANSH,ANSV
C      CHARACTER*1 ANSC,ANSH,ANSV
C      DIMENSION HKS(40)
C
C      **************************************************************    A 240
C       ---LOAD DATA---                                                  A 250
       INT=0                                                             A 260
       TMSUM=0.D0                                                        A 265
       CALL PARLOD                                                       A 270
       CALL GENPT                                                        A 280
C      **************************************************************    A 290
C      ---START COMPUTATIONS---                                          A 300
C         ---COMPUTE ONE PUMPING PERIOD---                               A 310
       DO 150 INT=1,NPMP                                                 A 320
       IF (INT.GT.1) TMSUM=TMSUM+PYR                                     A 325
       IF (INT.GT.1) CALL PARLOD                                         A 330
       REMN=1.0                                                          A 338
C         ---COMPUTE ONE TIME STEP---                                    A 340
       DO 130 N=1,NTIM                                                   A 350
       IPRNT=0                                                           A 360
C         ---LOAD NEW DELTA T---                                         A 370
       TINT=SUMT-TMSUM                                                   A 381
       TDEL=DMIN1(TIM(N),PYR-TINT)                                       A 390
       SUMT=SUMT+TDEL                                                    A 400
       TIM(N)=TDEL                                                       A 410
       IF (NPNT.GT.0) REMN=MOD(N,NPNT)                                   A 421
       IF (SUMT.GE.(PYR+TMSUM)) IPRNT=1                                  A 425
C      **************************************************************    A 430
       CALL ITERAT                                                       A 440
       IF (REMN.EQ.0.0.OR.N.EQ.NTIM.OR.IPRNT.EQ.1) CALL OUTPT            A 452
       CALL VELO                                                         A 460
   101 CALL MOVE                                                         A 471
C
C  SAVE CONCENTRATION FOR THIS TIME STEP?
C
C       IF(NPNCHV.NE.0.AND.N.EQ.NTIM) THEN
C
```

```
C  WRITE DATA FLAGS
C
C      IF(ANSC.EQ.'Y'.OR.ANSH.EQ.'Y'.OR.ANSV.EQ.'Y') THEN
C        XDELS=XDEL
C        YDELS=YDEL
C        WRITE(7) NX,NY,XDELS,YDELS
C        WRITE(7) ANSC,ANSH,ANSV
C      ENDIF
C
C  WRITE TIME INFORMATION
C
C      IF(ANSC.EQ.'Y'.OR.ANSH.EQ.'Y'.OR.ANSV.EQ.'Y') THEN
C        WRITE(7) N,INT,SUMT
C      ENDIF
C
C  WRITE CONCENTRATIONS IF DESIRED
C
C      IF(ANSC.EQ.'Y') THEN
C         DO 127 IY=1,NY
C  127    WRITE(7) (CONC(IX,IY),IX=1,NX)
C      ENDIF
C
C  WRITE HEADS IF REQUESTED
C
C      IF(ANSH.EQ.'Y') THEN
C         DO 103 IY=1,NY
C
C  STORE HEADS IN SINGLE PRECISION
C
C              DO 102 IIII=1,NX
C  102         HKS(IIII)=HK(IIII,IY)
C  103    WRITE(7) (HKS(IIII),IIII=1,NX)
C      ENDIF
C
C  WRITE VELOCITIES IF REQUESTED
C
C      IF(ANSV.EQ.'Y') THEN
C         DO 100 IY=1,NY
C  100    WRITE(7) (VX(IX,IY),IX=1,NX)
C         DO 108 IY=1,NY
C  108    WRITE(7) (VY(IX,IY),IX=1,NX)
C      ENDIF
C      ENDIF
C     ***************************************************************       A 480
      IF (SUMT.GE.(PYR+TMSUM)) GO TO 140                                    A 621
  130 CONTINUE                                                              A 630
C     ***************************************************************       A 640
  140 CONTINUE                                                              A 660
  150 CONTINUE                                                              A 690
C     ***************************************************************       A 700
      ENDFILE(6)                                                            A 702
      IF (NPNCHV.EQ.0) GO TO 155                                            A 703
C      IF(ANSC.NE.'Y'.AND.ANSH.NE.'Y'.AND.ANSV.NE.'Y') GO TO 155
      ENDFILE(7)                                                            A 704
  155 CONTINUE                                                              A 705
      STOP                                                                  A 710
C     ***************************************************************       A 720
      END   -                                                               A 730-


$LARGE
      SUBROUTINE MOVE                                                       F  10
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE     F  20
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,       F  30
     1                 HMIN,PYR,ANFCTR                                      F  31A
      DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV                             F  32
      DOUBLE PRECISION DCYFCT,DCYT,DCYT2                                    F  33
      INTEGER PTID                                                          F  36
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,        F  41
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,       F  51
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK                  F  62
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),        SF  67
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                         F  68
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                    SF  91
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),             SF 101
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),       SF 111
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL,   SF 115
```

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     3           S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR   F 121
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                        SF 125
      COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                           F 130
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040), SF 142
     1           VY(040,040),CONINT(020,020),CNRECH(020,020),POROS,   SF 151
     2           SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,     F 155
     3           FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                      F 161
      COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)       SF 169
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,  F 173R
     1           EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,      F 174A
     2       RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 F 174B
      COMMON /CHMR2/ CRETRD(020,020),CRDCOF(020,020),CELDCY(020,020)   F 175R
      COMMON /CHMP/ PTID(06400)                                        F 177
C     ***************************************************************  F 190
      WRITE (6,680) NMOV                                               F 200
      IF (THALF.GT.0.0.AND.THALF.LT.TIMV) WRITE (6,685)                F 205R
      SUMTCH=SUMT-TIM(N)                                               F 210
      IONED=0                                                          F 211A
      IF(NX.EQ.3.OR.NY.EQ.3) IONED=1                                   F 211B
      F1=0.30                                                          F 212
      F2=1.0/3.0                                                       F 214
      IF (NPTPND.EQ.4) F1=0.25                                         F 216
      IF (NPTPND.EQ.5.AND.IONED.EQ.1) F1=0.25                          F 217
      IF (NPTPND.EQ.9) F1=F2                                           F 218
      IF (NPTPND.EQ.8.AND.IONED.NE.1) F2=0.25                          F 222A
      IF (NPTPND.EQ.8.AND.IONED.EQ.1) F1=F2                            F 222B
      IF (NPTPND.EQ.16) F1=0.25                                        F 223
      IF (NPTPND.EQ.16) F2=0.125                                       F 224
      CONST1=TIMV*DXINV/RF                                             F 251R
      CONST2=TIMV*DYINV/RF                                             F 261R
      DCYFCT=TIMV*DECAY                                                F 265R
      DCYT=1.D0                                                        F 268A
      DCYT2=1.D0                                                       F 268B
      IF(DECAY.NE.0.0) THEN                                            F 268C
       DCYT=DEXP(-DCYFCT)                                              F 268D
       DCYT2=DEXP(-DCYFCT*0.5D0)                                       F 268E
      END IF                                                           F 268F
      DO 8 IY=1,NMY                                                    F 269A
      JY=IY+MY-1                                                      SF 269B
      DO 8 IX=1,NMX                                                    F 269C
      JX=IX+MX-1                                                      SF 269D
      CRETRD(IX,IY)=1.0                                                F 269E
      CRDCOF(IX,IY)=1.0                                                F 269F
      CELDCY(IX,IY)=1.0                                                F 269G
      IF (IREACT.LE.1.OR.THCK(JX,JY).EQ.0.0) GO TO 8                  SF 269H
      CALL RETRD2(CONC(IX,IY),CRETRD(IX,IY),CRDCOF(IX,IY))             F 269I
      IF (DECAY.NE.0.0)                                                F 269J
     1    CELDCY(IX,IY)=EXP(-DCYFCT*CRDCOF(IX,IY)/CRETRD(IX,IY))       F 269K
    8 CONTINUE                                                         F 269L
C     ---MOVE PARTICLES 'NMOV' TIMES---                                F 270
      DO 650 IMOV=1,NMOV                                               F 280
   10 NPTM=NP                                                          F 290
C        ---MOVE EACH PARTICLE---                                      F 300
      DO 590 IN=1,NP                                                   F 310
      IF (PART(1,IN).EQ.0.0) GO TO 590                                 F 320
      KFLAG=0                                                          F 330
      NLOC=0                                                          SF 335
C     ***************************************************************  F 340
C           ---COMPUTE OLD LOCATION---                                 F 350
   20 XOLD=PART(1,IN)                                                  F 400
      IX=XOLD+0.5                                                      F 410
      JX=IX-MX+1                                                      SF 415
      IFLAG=1                                                          F 420
      IF (PART(2,IN).GE.0.0) GO TO 30                                  F 430
      IFLAG=-1                                                         F 440
      PART(2,IN)=-PART(2,IN)                                           F 450
   30 YOLD=PART(2,IN)                                                  F 460
      IY=YOLD+0.5                                                      F 470
      JY=IY-MY+1                                                      SF 475
      IF (THCK(IX,IY).EQ.0.0) GO TO 590                                F 482
C     ***************************************************************  F 490
C           ---COMPUTE NEW LOCATION AND LOCATE CLOSEST NODE---         F 500
C           ---LOCATE NORTHWEST CORNER---                              F 510
      IVX=XOLD                                                         F 520
      IVY=YOLD                                                         F 530
      IXE=IVX+1                                                        F 540
      IYS=IVY+1                                                        F 550
C     ***************************************************************  F 560
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C        ---LOCATE QUADRANT, VEL. AT 4 CORNERS, CHECK FOR BOUNDARIES---  F 570
      CELDX=XOLD-IX                                                      F 580
      CELDY=YOLD-IY                                                      F 590
      ICD=9                                                              F 595
      IF (CELDX.EQ.0.0.AND.CELDY.EQ.0.0) GO TO 280                       F 600
      IF (CELDX.GE.0.0.OR.CELDY.GE.0.0) GO TO 70                         F 610
C              ---PT. IN NW QUADRANT---                                  F 620
      VXNW=VXBDY(IVX,IVY)                                                F 630
      VXNE=VX(IXE,IVY)                                                   F 640
      VXSW=VXBDY(IVX,IYS)                                                F 650
      VXSE=VX(IXE,IYS)                                                   F 660
      VYNW=VYBDY(IVX,IVY)                                                F 670
      VYNE=VYBDY(IXE,IVY)                                                F 680
      VYSW=VY(IVX,IYS)                                                   F 690
      VYSE=VY(IXE,IYS)                                                   F 700
      ICD=1                                                              F 705
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 50                                 F 710
      IF (REC(IXE,IVY).EQ.0.0.AND.VPRM(IXE,IVY).LT.0.09) GO TO 40        F 720
      IF (THCK(IXE+1,IVY).NE.0.0) VXNE=VXNW                              F 731
   40 IF (REC(IVX,IYS).EQ.0.0.AND.VPRM(IVX,IYS).LT.0.09) GO TO 50        F 740
      IF (THCK(IVX,IYS+1).NE.0.0) VYSW=VYNW                              F 751
   50 IF (REC(IXE,IYS).EQ.0.0.AND.VPRM(IXE,IYS).LT.0.09) GO TO 270       F 760
      IF (THCK(IVX,IYS).EQ.0.0) GO TO 60                                 F 770
      IF (THCK(IXE+1,IYS).GT.0.0) VXSE=VXSW                              F 782
   60 IF (THCK(IXE,IVY).EQ.0.0) GO TO 270                                F 790
      IF (THCK(IXE,IYS+1).GT.0.0) VYSE=VYNE                              F 802
      GO TO 270                                                          F 810
C                                                                        F 820
   70 IF (CELDX.LE.0.0.OR.CELDY.GE.0.0) GO TO 130                        F 830
C              ---PT. IN NE QUADRANT---                                  F 840
   80 VXNW=VX(IVX,IVY)                                                   F 850
      VXNE=VXBDY(IVX,IVY)                                                F 860
      VXSW=VX(IVX,IYS)                                                   F 870
      VXSE=VXBDY(IVX,IYS)                                                F 880
      VYNW=VYBDY(IVX,IVY)                                                F 890
      VYNE=VYBDY(IXE,IVY)                                                F 900
      VYSW=VY(IVX,IYS)                                                   F 910
      VYSE=VY(IXE,IYS)                                                   F 920
      ICD=2                                                              F 925
      IF (CELDX.EQ.0.0) GO TO 120                                        F 930
      IF (THCK(IXE,IVY).EQ.0.0) GO TO 100                                F 940
      IF (REC(IVX,IVY).EQ.0.0.AND.VPRM(IVX,IVY).LT.0.09) GO TO 90        F 950
      IF (THCK(IVX-1,IVY).NE.0.0) VXNW=VXNE                              F 961
   90 IF (REC(IXE,IYS).EQ.0.0.AND.VPRM(IXE,IYS).LT.0.09) GO TO 100       F 970
      IF (THCK(IXE,IYS+1).NE.0.0) VYSE=VYNE                              F 981
  100 IF (REC(IVX,IYS).EQ.0.0.AND.VPRM(IVX,IYS).LT.0.09) GO TO 270       F 990
      IF (THCK(IXE,IYS).EQ.0.0) GO TO 110                                F1000
      IF (THCK(IVX-1,IYS).GT.0.0) VXSW=VXSE                              F1012
  110 IF (THCK(IVX,IVY).EQ.0.0) GO TO 270                                F1020
      IF (THCK(IVX,IYS+1).GT.0.0) VYSW=VYNW                              F1032
      GO TO 270                                                          F1040
  120 IF (REC(IVX,IYS).EQ.0.0.AND.VPRM(IVX,IYS).LE.0.09) GO TO 270       F1050
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 270                                F1060
      IF (THCK(IVX,IYS+1).GT.0.0) VYSW=VYNW                              F1072
      GO TO 270                                                          F1080
C                                                                        F1090
  130 IF (CELDY.LE.0.0.OR.CELDX.GE.0.0) GO TO 190                        F1100
C              ---PT. IN SW QUADRANT---                                  F1110
  140 VXNW=VXBDY(IVX,IVY)                                                F1120
      VXNE=VX(IXE,IVY)                                                   F1130
      VXSW=VXBDY(IVX,IYS)                                                F1140
      VXSE=VX(IXE,IYS)                                                   F1150
      VYNW=VY(IVX,IVY)                                                   F1160
      VYNE=VY(IXE,IVY)                                                   F1170
      VYSW=VYBDY(IVX,IVY)                                                F1180
      VYSE=VYBDY(IXE,IVY)                                                F1190
      ICD=3                                                              F1195
      IF (CELDY.EQ.0.0) GO TO 180                                        F1200
      IF (THCK(IVX,IYS).EQ.0.0) GO TO 160                                F1210
      IF (REC(IVX,IVY).EQ.0.0.AND.VPRM(IVX,IVY).LT.0.09) GO TO 150       F1220
      IF (THCK(IVX,IVY-1).NE.0.0) VYNW=VYSW                              F1231
  150 IF (REC(IXE,IYS).EQ.0.0.AND.VPRM(IXE,IYS).LT.0.09) GO TO 160       F1240
      IF (THCK(IXE+1,IYS).NE.0.0) VXSE=VXSW                              F1251
  160 IF (REC(IXE,IVY).EQ.0.0.AND.VPRM(IXE,IVY).LT.0.09) GO TO 270       F1260
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 170                                F1270
      IF (THCK(IXE+1,IVY).GT.0.0) VXNE=VXNW                              F1282
  170 IF (THCK(IXE,IYS).EQ.0.0) GO TO 270                                F1290
      IF (THCK(IXE,IVY-1).GT.0.0) VYNE=VYSE                              F1302
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      GO TO 270                                                         F1310
  180 IF (REC(IXE,IVY).EQ.0.0.AND.VPRM(IXE,IVY).LE.0.09) GO TO 270      F1320
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 270                               F1330
      IF (THCK(IXE+1,IVY).GT.0.0) VXNE=VXNW                             F1342
      GO TO 270                                                         F1350
C                                                                       F1360
  190 IF (CELDY.LE.0.0.OR.CELDX.LE.0.0) GO TO 260                       F1370
C                ---PT. IN SE QUADRANT---                               F1380
  200 VXNW=VX(IVX,IVY)                                                  F1390
      VXNE=VXBDY(IVX,IVY)                                               F1400
      VXSW=VX(IVX,IYS)                                                  F1410
      VXSE=VXBDY(IVX,IYS)                                               F1420
      VYNW=VY(IVX,IVY)                                                  F1430
      VYNE=VY(IXE,IVY)                                                  F1440
      VYSW=VYBDY(IVX,IVY)                                               F1450
      VYSE=VYBDY(IXE,IVY)                                               F1460
      ICD=4                                                             F1465
      IF (CELDY.EQ.0.0) GO TO 240                                       F1470
      IF (CELDX.EQ.0.0) GO TO 250                                       F1480
      IF (THCK(IXE,IYS).EQ.0.0) GO TO 220                               F1490
      IF (REC(IXE,IVY).EQ.0.0.AND.VPRM(IXE,IVY).LT.0.09) GO TO 210      F1500
      IF (THCK(IXE,IVY-1).NE.0.0) VYNE=VYSE                             F1511
  210 IF (REC(IVX,IYS).EQ.0.0.AND.VPRM(IVX,IYS).LT.0.09) GO TO 220      F1520
      IF (THCK(IVX-1,IYS).NE.0.0) VXSW=VXSE                             F1531
  220 IF (REC(IVX,IVY).EQ.0.0.AND.VPRM(IVX,IVY).LT.0.09) GO TO 270      F1540
      IF (THCK(IXE,IVY).EQ.0.0) GO TO 230                               F1550
      IF (THCK(IVX-1,IVY).GT.0.0) VXNW=VXNE                             F1562
  230 IF (THCK(IVX,IYS).EQ.0.0) GO TO 270                               F1570
      IF (THCK(IVX,IVY-1).GT.0.0) VYNW=VYSW                             F1582
      GO TO 270                                                         F1590
  240 IF (REC(IVX,IVY).EQ.0.0.AND.VPRM(IVX,IVY).LE.0.09) GO TO 270      F1600
      IF (THCK(IXE,IVY).EQ.0.0) GO TO 270                               F1610
      IF (THCK(IVX-1,IVY).GT.0.0) VXNW=VXNE                             F1622
      GO TO 270                                                         F1630
  250 IF (REC(IVX,IVY).EQ.0.0.AND.VPRM(IVX,IVY).LE.0.09) GO TO 270      F1640
      IF (THCK(IVX,IYS).EQ.0.0) GO TO 270                               F1650
      IF (THCK(IVX,IVY-1).GT.0.0) VYNW=VYSW                             F1662
      GO TO 270                                                         F1670
C                                                                       F1680
  260 IF (CELDX.EQ.0.0.AND.CELDY.LT.0.0) GO TO 80                       F1690
      IF (CELDX.LT.0.0.AND.CELDY.EQ.0.0) GO TO 140                      F1700
      IF (CELDX.GT.0.0.AND.CELDY.EQ.0.0) GO TO 200                      F1710
      IF (CELDX.EQ.0.0.AND.CELDY.GT.0.0) GO TO 200                      F1720
      WRITE (6,690) IN,IX,IY                                            F1730
  270 CONTINUE                                                          F1740
C              --- CHECK FOR ADJACENT NO-FLOW BOUNDARIES---             F1741A
      GO TO (1270,1275,1280,1285,1290) ICD                              F1741B
      GO TO 1290                                                        F1741C
 1270 IF (THCK(IXE,IVY).EQ.0.0) GO TO 1272                              F1742A
      IF (THCK(IVX,IYS).EQ.0.0) GO TO 1273                              F1742B
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 1274                              F1742C
      GO TO 1290                                                        F1742D
 1272 VXNE=VXSE                                                         F1742E
      IF (THCK(IVX,IYS).GT.0.0) GO TO 1274                              F1742F
 1273 VYSW=VYSE                                                         F1742G
 1274 VXNW=VXSW                                                         F1742H
      VYNW=VYNE                                                         F1742I
      GO TO 1290                                                        F1742J
 1275 IF (THCK(IVX,IVY).EQ.0.0) GO TO 1277                              F1744A
      IF (THCK(IXE,IYS).EQ.0.0) GO TO 1278                              F1744B
      IF (THCK(IXE,IVY).EQ.0.0) GO TO 1279                              F1744C
      GO TO 1290                                                        F1744D
 1277 VXNW=VXSW                                                         F1744E
      IF (THCK(IXE,IYS).GT.0.0) GO TO 1279                              F1744F
 1278 VYSE=VYSW                                                         F1744G
 1279 VXNE=VXSE                                                         F1744H
      VYNE=VYNW                                                         F1744I
      GO TO 1290                                                        F1744J
 1280 IF (THCK(IXE,IYS).EQ.0.0) GO TO 1282                              F1746A
      IF (THCK(IVX,IVY).EQ.0.0) GO TO 1283                              F1746B
      IF (THCK(IVX,IYS).EQ.0.0) GO TO 1284                              F1746C
      GO TO 1290                                                        F1746D
 1282 VXSE=VXNE                                                         F1746E
      IF (THCK(IVX,IVY).GT.0.0) GO TO 1284                              F1746F
 1283 VYNW=VYNE                                                         F1746G
 1284 VXSW=VXNW                                                         F1746H
      VYSW=VYSE                                                         F1746I
      GO TO 1290                                                        F1746J
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 1285 IF (THCK(IVX,IYS).EQ.0.0) GO TO 1287                                F1748A
      IF (THCK(IXE,IVY).EQ.0.0) GO TO 1288                                F1748B
      IF (THCK(IXE,IYS).EQ.0.0) GO TO 1289                                F1748C
      GO TO 1290                                                          F1748D
 1287 VXSW=VXNW                                                           F1748E
      IF (THCK(IXE,IVY).GT.0.0) GO TO 1289                                F1748F
 1288 VYNE=VYNW                                                           F1748G
 1289 VYSE=VYSW                                                           F1748H
      VXSE=VXNE                                                           F1748I
 1290 CONTINUE                                                            F1749A
C     ****************************************************************    F1750
C        ---BILINEAR INTERPOLATION---                                     F1760
      CELXD=XOLD-IVX                                                      F1770
      CELDXH=AMOD(CELXD,0.5)                                              F1780
      CELDX=CELDXH*2.0                                                    F1790
      CELDY=YOLD-IVY                                                      F1800
C     ****************************************************************    F1810
C           ---X VELOCITY---                                              F1820
      VXN=VXNW*(1.0-CELDX)+VXNE*CELDX                                     F1830
      VXS=VXSW*(1.0-CELDX)+VXSE*CELDX                                     F1850
      XVEL=(VXN*(1.0-CELDY)+VXS*CELDY)/THCK(IX,IY)                        F1871
C           ---Y VELOCITY---                                              F1900
      CELDYH=AMOD(CELDY,0.5)                                              F1910
      CELYD=CELDYH*2.0                                                    F1921
      VYW=VYNW*(1.0-CELYD)+VYSW*CELYD                                     F1931
      VYE=VYNE*(1.0-CELYD)+VYSE*CELYD                                     F1951
      YVEL=(VYW*(1.0-CELXD)+VYE*CELXD)/THCK(IX,IY)                        F1971
C                                                                         F2000
      GO TO 290                                                           F2010
  280 XVEL=VX(IX,IY)/THCK(IX,IY)                                          F2021
      YVEL=VY(IX,IY)/THCK(IX,IY)                                          F2031
  290 DISTX=XVEL*CONST1                                                   F2040
      DISTY=YVEL*CONST2                                                   F2050
      IF (IREACT.GE.2) THEN                                               F2052R
       RF2INV=1.0/CRETRD(JX,JY)                                          SF2053R
       DISTX=DISTX*RF2INV                                                 F2054R
       DISTY=DISTY*RF2INV                                                 F2055R
      ENDIF                                                               F2056R
C     ****************************************************************    F2060
C         ---BOUNDARY CONDITIONS---                                       F2070
      TEMPX=XOLD+DISTX                                                    F2080
      TEMPY=YOLD+DISTY                                                    F2090
      INX=TEMPX+0.5                                                       F2100
      INY=TEMPY+0.5                                                       F2110
      IF (THCK(INX,INY).GT.0.0) GO TO 330                                 F2120
C     ****************************************************************    F2130
C             ---X BOUNDARY---                                            F2140
      IF (THCK(INX,IY).EQ.0.0) GO TO 300                                  F2150
      PART(1,IN)=TEMPX                                                    F2160
      GO TO 310                                                           F2170
  300 BEYON=TEMPX-IX                                                      F2180
      IF (BEYON.LT.0.0) BEYON=BEYON+0.5                                   F2190
      IF (BEYON.GT.0.0) BEYON=BEYON-0.5                                   F2200
      PART(1,IN)=TEMPX-2.0*BEYON                                          F2210
      INX=PART(1,IN)+0.5                                                  F2220
      TEMPX=PART(1,IN)                                                    F2230
C     ****************************************************************    F2240
C             ---Y BOUNDARY---                                            F2250
  310 IF (THCK(INX,INY).EQ.0.0) GO TO 320                                 F2260
      PART(2,IN)=TEMPY                                                    F2270
      GO TO 340                                                           F2280
C     ****************************************************************    F2290
  320 BEYON=TEMPY-IY                                                      F2300
      IF (BEYON.LT.0.0) BEYON=BEYON+0.5                                   F2310
      IF (BEYON.GT.0.0) BEYON=BEYON-0.5                                   F2320
      PART(2,IN)=TEMPY-2.0*BEYON                                          F2330
      INY=PART(2,IN)+0.5                                                  F2340
      TEMPY=PART(2,IN)                                                    F2350
      GO TO 340                                                           F2360
  330 PART(1,IN)=TEMPX                                                    F2370
      PART(2,IN)=TEMPY                                                    F2380
  340 CONTINUE                                                            F2390
      JNX=INX-MX+1                                                       SF2395
      JNY=INY-MY+1                                                       SF2396
      IF (MCHK.EQ.0) GO TO 342                                           SF2397
      IF (JNX.LT.1.OR.JNX.GT.NMX.OR.JNY.LT.1.OR.JNY.GT.NMY) NLOC=1       SF2398
C     ****************************************************************    F2400
      IF (NLOC.GT.0) GO TO 345                                           SF2405
```

```
  342 CONTINUE                                                          SF2407
C        ---SUM CONCENTRATIONS AND COUNT PARTICLES---                    F2410
C           ---DECAY PARTICLES---                                        F2414R
      IF (DECAY.NE.0.0) THEN                                             F2415A
       IF (IREACT.LE.1) THEN                                             F2415B
      PART(3,IN)=PART(3,IN)*DCYT                                         F2416R
       ELSE                                                              F2417R
        PART(3,IN)=PART(3,IN)*CELDCY(JX,JY)                             SF2418A
       END IF                                                            F2418B
      END IF                                                             F2419R
      SUMC(JNX,JNY)=SUMC(JNX,JNY)+PART(3,IN)                            SF2421
      NPCELL(JNX,JNY)=NPCELL(JNX,JNY)+1                                 SF2431
C     ****************************************************************   F2440
  345 CONTINUE                                                          SF2445
C        ---CHECK FOR CHANGE IN CELL LOCATION---                         F2450
      IF (IX.EQ.INX.AND.IY.EQ.INY) GO TO 580                             F2460
C           ---CHECK FOR CONST.-HEAD BDY. OR SOURCE AT OLD LOCATION---   F2470
      IBD=0                                                             SF2478
C     IF (REC(IX,IY).LT.-0.1) GO TO 350                                   FXXX
C     IF (REC(IX,IY).GT.0.1) GO TO 360                                   FXXX
      IF (REC(IX,IY).LT.0.0) GO TO 350                                   F2480
      IF (REC(IX,IY).GT.0.0) GO TO 360                                   F2490
      IF (VPRM(IX,IY).LT.0.09) GO TO 348                                SF2501
      IF (WT(IX,IY).GT.HK(IX,IY)) GO TO 350                              F2510
      IF (WT(IX,IY).LT.HK(IX,IY)) GO TO 360                              F2520
  348 IF (MCHK.EQ.0) GO TO 540                                          SF2522
      IF (JX.EQ.1.AND.VXBDY(IX-1,IY).GT.0.0.AND.JNX.GT.JX) IBD=1        SF2523
      IF (JX.EQ.NMX.AND.VXBDY(IX,IY).LT.0.0.AND.JNX.LT.JX) IBD=1        SF2524
      IF (JY.EQ.1.AND.VYBDY(IX,IY-1).GT.0.0.AND.JNY.GT.JY) IBD=1        SF2525
      IF (JY.EQ.NMY.AND.VYBDY(IX,IY).LT.0.0.AND.JNY.LT.JY) IBD=1        SF2526
      IF (IBD.EQ.1) GO TO 350                                           SF2527
      GO TO 540                                                          F2530
C     ****************************************************************   F2540
C           ---CREATE NEW PARTICLES AT BOUNDARIES---                     F2550
  350 IF (IFLAG.GT.0) GO TO 550                                          F2560
      KFLAG=1                                                            F2570
  360 CONTINUE                                                           F2581
C     ****************************************************************   F2630
C           ---GENERATE NEW TEMPORARY PARTICLE---                        F2641
      IF (NPTM.EQ.NPMAX) GO TO 600                                       F2650
      NPTM=NPTM+1                                                        F2660
      IP=NPTM                                                            F2670
C                                                                        F2700
  390 IF (KFLAG.EQ.0) GO TO 398                                          F2705
      IF (IBD.EQ.1) GO TO 525                                           SF2708
      ITEM=PTID(IN)                                                      F2845
      GO TO 399                                                          F2855
  398 IF (IREACT.LE.1) THEN                                              F2864R
       SUMC(JX,JY)=SUMC(JX,JY)+CONC(JX,JY)*DCYT2                        SF2865R
      ELSE                                                               F2866R
       SUMC(JX,JY)=SUMC(JX,JY)+CONC(JX,JY)*SQRT(CELDCY(JX,JY))          SF2867R
      END IF                                                             F2869R
      NPCELL(JX,JY)=NPCELL(JX,JY)+1                                     SF2876
      IF (NPOLD(JX,JY).GT.0) NPOLD(JX,JY)=NPOLD(JX,JY)-1                SF2886
      IF (IFLAG.GT.0) GO TO 441                                          F2895
      IF (KFLAG.EQ.0) GO TO 441                                          F2899
  399 IF (NPTPND.EQ.16) GO TO 400                                        F2901
      GO TO (401,411,421,431,441,451,461,471,481),ITEM                   F2906
      GO TO 441                                                          F2915
  400 GO TO (482,483,484,485,486,487,488,489,490,491,492,493,494,495,    F2921
     1         496,497),ITEM                                             F2922
      GO TO 441                                                          F2924
  401 PART(1,IP)=IX-F1                                                   F2925
      PART(2,IP)=IY-F1                                                   F2935
      PTID(IP)=1                                                         F2945
      GO TO 530                                                          F2955
  411 PART(1,IP)=IX-F1                                                   F2965
      PART(2,IP)=IY+F1                                                   F2975
      PTID(IP)=2                                                         F2985
      GO TO 530                                                          F2995
  421 PART(1,IP)=IX+F1                                                   F3005
      PART(2,IP)=IY-F1                                                   F3015
      PTID(IP)=3                                                         F3025
      GO TO 530                                                          F3035
  431 PART(1,IP)=IX+F1                                                   F3045
      PART(2,IP)=IY+F1                                                   F3055
      PTID(IP)=4                                                         F3065
      GO TO 530                                                          F3075
```

```
  441 PART(1,IP)=IX                                                    F3085
      PART(2,IP)=IY                                                    F3095
      PTID(IP)=5                                                       F3105
      GO TO 530                                                        F3115
  451 PART(1,IP)=IX-F2                                                 F3125
      PART(2,IP)=IY                                                    F3135
      PTID(IP)=6                                                       F3145
      GO TO 530                                                        F3155
  461 PART(1,IP)=IX                                                    F3165
      PART(2,IP)=IY-F2                                                 F3175
      PTID(IP)=7                                                       F3185
      GO TO 530                                                        F3195
  471 PART(1,IP)=IX+F2                                                 F3205
      PART(2,IP)=IY                                                    F3215
      PTID(IP)=8                                                       F3225
      GO TO 530                                                        F3235
  481 PART(1,IP)=IX                                                    F3245
      PART(2,IP)=IY+F2                                                 F3255
      PTID(IP)=9                                                       F3265
      GO TO 530                                                        F3266
  482 PART(1,IP)=IX-F1-F2                                              F3267
      PART(2,IP)=IY-F1-F2                                              F3268
      PTID(IP)=1                                                       F3269
      GO TO 530                                                        F3271
  483 PART(1,IP)=IX-F1-F2                                              F3272
      PART(2,IP)=IY-F1+F2                                              F3273
      PTID(IP)=2                                                       F3274
      GO TO 530                                                        F3275
  484 PART(1,IP)=IX-F1+F2                                              F3276
      PART(2,IP)=IY-F1-F2                                              F3277
      PTID(IP)=3                                                       F3278
      GO TO 530                                                        F3279
  485 PART(1,IP)=IX-F1+F2                                              F3281
      PART(2,IP)=IY-F1+F2                                              F3282
      PTID(IP)=4                                                       F3283
      GO TO 530                                                        F3284
  486 PART(1,IP)=IX-F1-F2                                              F3285
      PART(2,IP)=IY+F1-F2                                              F3286
      PTID(IP)=5                                                       F3287
      GO TO 530                                                        F3288
  487 PART(1,IP)=IX-F1-F2                                              F3289
      PART(2,IP)=IY+F1+F2                                              F3291
      PTID(IP)=6                                                       F3292
      GO TO 530                                                        F3293
  488 PART(1,IP)=IX-F1+F2                                              F3294
      PART(2,IP)=IY+F1-F2                                              F3295
      PTID(IP)=7                                                       F3296
      GO TO 530                                                        F3297
  489 PART(1,IP)=IX-F1+F2                                              F3298
      PART(2,IP)=IY+F1+F2                                              F3299
      PTID(IP)=8                                                       F3301
      GO TO 530                                                        F3302
  490 PART(1,IP)=IX+F1-F2                                              F3303
      PART(2,IP)=IY-F1-F2                                              F3304
      PTID(IP)=9                                                       F3305
      GO TO 530                                                        F3306
  491 PART(1,IP)=IX+F1-F2                                              F3307
      PART(2,IP)=IY-F1+F2                                              F3308
      PTID(IP)=10                                                      F3309
      GO TO 530                                                        F3311
  492 PART(1,IP)=IX+F1+F2                                              F3312
      PART(2,IP)=IY-F1-F2                                              F3313
      PTID(IP)=11                                                      F3314
      GO TO 530                                                        F3315
  493 PART(1,IP)=IX+F1+F2                                              F3316
      PART(2,IP)=IY-F1+F2                                              F3317
      PTID(IP)=12                                                      F3318
      GO TO 530                                                        F3319
  494 PART(1,IP)=IX+F1-F2                                              F3321
      PART(2,IP)=IY+F1-F2                                              F3322
      PTID(IP)=13                                                      F3323
      GO TO 530                                                        F3324
  495 PART(1,IP)=IX+F1-F2                                              F3325
      PART(2,IP)=IY+F1+F2                                              F3326
      PTID(IP)=14                                                      F3327
      GO TO 530                                                        F3328
  496 PART(1,IP)=IX+F1+F2                                              F3329
      PART(2,IP)=IY+F1-F2                                              F3331
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      PTID(IP)=15                                                        F3332
      GO TO 530                                                          F3333
  497 PART(1,IP)=IX+F1+F2                                                F3334
      PART(2,IP)=IY+F1+F2                                                F3335
      PTID(IP)=16                                                        F3336
      GO TO 530                                                          F3337
  525 DLX=INX-IX                                                        SF3425
      PART(1,IP)=TEMPX-DLX                                              SF3435
      DLY=INY-IY                                                        SF3455
      PART(2,IP)=TEMPY-DLY                                              SF3465
      PART(2,IP)=-PART(2,IP)                                            SF3475
      IF (IREACT.LE.1) THEN                                              F3478A
       PART(3,IP)=CONC(JX,JY)*DCYT                                      SF3478B
      ELSE                                                               F3478C
       PART(3,IP)=CONC(JX,JY)*CELDCY(JX,JY)                             SF3478D
      END IF                                                             F3478E
      SUMC(JX,JY)=SUMC(JX,JY)+PART(3,IP)                                SF3479
      NPCELL(JX,JY)=NPCELL(JX,JY)+1                                     SF3481
      GO TO 540                                                         SF3483
C                                                                        F3510
  530 PART(2,IP)=-PART(2,IP)                                             F3520
      PART(3,IP)=CONC(JX,JY)                                            SF3531
C     ***************************************************************    F3550
C            ---CHECK FOR DISCHARGE BOUNDARY AT NEW LOCATION---          F3560
  540 IFLAG=1                                                            F3571
  550 IF (NLOC.GT.0) GO TO 565                                          SF3575
      IF (VPRM(INX,INY).GT.0.09.AND.WT(INX,INY).LT.HK(INX,INY)) GO TO 56 SF3581
     10                                                                  F3590
C     IF (REC(INX,INY).GT.0.1) GO TO 560                                 FXXX
      IF (REC(INX,INY).GT.0.0) GO TO 560                                 F3600
      GO TO 590                                                          F3610
C     ***************************************************************    F3620
C            ---PUT PT. IN LIMBO IF PT. DENSITY NOT INCREASED---         F3625
  560 IF (NPOLD(JNX,JNY).LE.0) GO TO 590                                SF3636
  565 CONTINUE                                                          SF3638
      PART(1,IN)=0.0                                                     F3645
      PART(2,IN)=0.0                                                     F3650
      PART(3,IN)=0.0                                                     F3660
      IF (NLOC.GT.0) GO TO 567                                          SF3661
      SUMC(JNX,JNY)=SUMC(JNX,JNY)-CONC(JNX,JNY)                         SF3663
      NPCELL(JNX,JNY)=NPCELL(JNX,JNY)-1                                 SF3665
      NPOLD(JNX,JNY)=NPOLD(JNX,JNY)-1                                   SF3667
  567 CONTINUE                                                          SF3668
      DO 570 ID=1,500                                                    F3670
      IF (LIMBO(ID).GT.0) GO TO 570                                      F3680
      LIMBO(ID)=IN                                                       F3690
      GO TO 590                                                          F3700
  570 CONTINUE                                                           F3710
C                                                                        F3720
  580 IF (IFLAG.LT.0) PART(2,IN)=-TEMPY                                  F3730
  590 CONTINUE                                                           F3750
C     ---END OF LOOP---                                                  F3760
C     ***************************************************************    F3762
C                                                                        F3763
C          ---INSERT TEMPORARY PARTICLES INTO LIMBO LOCATIONS---         F3764
      IF(NPTM.EQ.NP) GO TO 620                                           F3765
      IN=NPTM                                                            F3766
      DO 595 IL=1,500                                                    F3767
      IP=LIMBO(IL)                                                       F3768
      IF(IP.EQ.0) GO TO 595                                              F3769
      PART(1,IP)=PART(1,IN)                                              F3771
      PART(1,IN)=0.0                                                     F3772
      PART(2,IP)=PART(2,IN)                                              F3773
      PART(2,IN)=0.0                                                     F3774
      PART(3,IP)=PART(3,IN)                                              F3775
      PART(3,IN)=0.0                                                     F3776
      PTID(IP)=PTID(IN)                                                  F3777
      PTID(IN)=0                                                         F3778
      LIMBO(IL)=0                                                        F3779
      IN=IN-1                                                            F3781
      IF(IN.LE.NP) GO TO 596                                             F3782
  595 CONTINUE                                                           F3783
  596 NPTM=IN                                                            F3784
      GO TO 620                                                          F3785
C        ---RESTART MOVE IF PT. LIMIT EXCEEDED---                        F3790
  600 WRITE (6,700) IMOV,IN                                              F3800
      TEST=100.D0                                                        F3810
      CALL GENPT                                                         F3820
```

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      DO 610 IX=1,NMX                                                   SF3831
      DO 610 IY=1,NMY                                                   SF3841
      SUMC(IX,IY)=0.0                                                    F3850
  610 NPCELL(IX,IY)=0                                                    F3860
      TEST=0.D0                                                          F3870
      GO TO 10                                                           F3880
C     ***************************************************************    F3890
  620 SUMTCH=SUMTCH+TIMV                                                 F3900
C        ---ADJUST NUMBER OF PARTICLES---                                F3910
      NP=NPTM                                                            F3920
      WRITE (6,670) NP,IMOV                                              F3930
C     ***************************************************************    F3940
      CALL CNCON                                                         F3950
C     ***************************************************************    F3960
C        ---STORE OBS. WELL DATA---                                      F3971
      IF (NUMOBS.LE.0) GO TO 650                                         F3983
      IF (S.GT.0.0) THEN                                                 F3985
       IF (IMOV.NE.NMOV) GO TO 650                                       F3987
       J=MOD(N,50)                                                       F3993
      ELSE                                                               F3997
      J=MOD(IMOV,50)                                                     F4000
      END IF                                                             F4005
      IF (J.EQ.0) J=50                                                   F4010
      TMOBS(J)=SUMTCH                                                    F4020
      DO 630 I=1,NUMOBS                                                  F4030
      TMWL(I,J)=HK(IXOBS(I),IYOBS(I))                                    F4040
      IX=IXOBS(I)-MX+1                                                  SF4042
      IF (IXOBS(I).LT.MX.OR.IXOBS(I).GT.MMX) GO TO 630                  SF4043
      IY=IYOBS(I)-MY+1                                                  SF4044
      IF (IYOBS(I).LT.MY.OR.IYOBS(I).GT.MMY) GO TO 630                  SF4045
      TMCN(I,J)=CONC(IX,IY)                                             SF4051
  630 CONTINUE                                                          SF4053
C        ---PRINT CHEMICAL OUTPUT---                                     F4060
  650 CALL CHMOT                                                         F4084
C     ***************************************************************    F4090
  660 RETURN                                                             F4100
C     ***************************************************************    F4110
C                                                                        F4120
C                                                                        F4130
C                                                                        F4140
  670 FORMAT (1H0,2X,2HNP,7X,2H= ,8X,I4,10X,11HIMOV      = ,8X,I4)       F4150
  680 FORMAT (1H0,10X,61HNO. OF PARTICLE MOVES REQUIRED TO COMPLETE THIS F4160
     1 TIME STEP  = ,I4//)                                               F4170
  685 FORMAT (1H0,5X,51H*** CAUTION ***  DECAY HALF-LIFE IS LESS THAN TI F4174R
     1MV;/23X,24HACCURACY MAY BE AFFECTED/23X,34H(REDUCE TIMV BY DECREAS F4175R
     2ING CELDIS))                                                       F4176R
  690 FORMAT (1H0,5X,53H*** WARNING ***      QUADRANT NOT LOCATED FOR PT. F4180
     1 NO. ,I5,11H , IN CELL ,2I4)                                       F4190
  700 FORMAT (1H0,5X,17H ***   NOTE   ***,10X,23HNPTM.EQ.NPMAX --- IMOV= F4200
     1,I4,5X,8HPT. NO.=,I4,5X,10HCALL GENPT/)                            F4210
      END                                                                F4220-


$LARGE
      SUBROUTINE OUTPT                                                   H  10
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE  H  20
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,    H  30
     1                 HMIN,PYR,ANFCTR                                   H  31A
      DOUBLE PRECISION TOTLQ,TOTLQI,TPIN,TPOUT,PQIN,PQOUT,DELQ,QOUT,QIN, H  32
     1                 QNET,DDRW                                         H  32A
      DOUBLE PRECISION QSTR,TPUM,PUMP,TOTLQN,SRCS,SINKS,ERRMB,DENOM,     H  33
     1                 PCTERR                                            H  34
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,NUMO H  40
     1BS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,NPNTMV,NPNTVL,NPNTD,N H  50
     2PNCHV,NPDELC,ICHK                                                  H  61
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                 SH  91
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),          SH 101
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),    SH 111
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL, SH 115
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR  H 121
      COMMON /BALM/ TOTLQ,TOTLQI,TPIN,TPOUT                              H 126
      DIMENSION IH(040)                                                 SH 142
C     ***************************************************************    H 150
      TIMD=SUMT/86400.                                                   H 160
      TIMY=SUMT/(86400.0*365.25)                                         H 170
C     ---PRINT HEAD VALUES---                                            H 180
      WRITE (6,120)                                                      H 190
      WRITE (6,130) N                                                    H 200
```

```
      WRITE (6,140) SUMT
      WRITE (6,150) TIMD
      WRITE (6,160) TIMY
      WRITE (6,170)
      DO 10 IY=1,NY
   10 WRITE (6,180) (HK(IX,IY),IX=1,NX)
      IF (N.EQ.0) GO TO 110
C     **************************************************************
C     ---PRINT HEAD MAP---
      WRITE (6,120)
      WRITE (6,130) N
      WRITE (6,140) SUMT
      WRITE (6,150) TIMD
      WRITE (6,160) TIMY
      WRITE (6,170)
      DO 30 IY=1,NY
      DO 20 IX=1,NX
   20 IH(IX)=NINT(HK(IX,IY))
   30 WRITE (6,190) (IH(ID),ID=1,NX)
C     **************************************************************
C     ---COMPUTE WATER BALANCE AND DRAWDOWN---
      QSTR=0.D0
      PUMP=0.D0
      PQIN=0.D0
      PQOUT=0.D0
      TPUM=0.D0
      QIN=0.D0
      QOUT=0.D0
      QNET=0.D0
      DELQ=0.D0
      PCTERR=0.D0
      WRITE (6,290)
C
      DO 80 IY=1,NY
      DO 70 IX=1,NX
      IH(IX)=0
      IF (THCK(IX,IY).EQ.0.0) GO TO 70
      IF (REC(IX,IY).GT.0.0) GO TO 32
      PQIN=PQIN+REC(IX,IY)
      GO TO 34
   32 PQOUT=PQOUT+REC(IX,IY)
   34 IF (RECH(IX,IY).GT.0.0) GO TO 36
      PQIN=PQIN+RECH(IX,IY)*AREA
      GO TO 38
   36 PQOUT=PQOUT+RECH(IX,IY)*AREA
   38 IF (VPRM(IX,IY).EQ.0.0) GO TO 60
      DELQ=VPRM(IX,IY)*AREA*(WT(IX,IY)-HK(IX,IY))
      IF (DELQ.GT.0.0) GO TO 40
      QOUT=QOUT+DELQ
      GO TO 50
   40 QIN=QIN+DELQ
   50 QNET=QNET+DELQ
   60 DDRW=HI(IX,IY)-HK(IX,IY)
      IH(IX)=NINT(DDRW)
      QSTR=QSTR+DDRW*AREA*S
   70 CONTINUE
C         ---PRINT DRAWDOWN MAP---
      WRITE (6,300) (IH(IX),IX=1,NX)
   80 CONTINUE
      TPUM=PQIN+PQOUT
      PUMP=TPIN+TPOUT
      TOTLQN=TOTLQ+TOTLQI
      SRCS=QSTR-TPIN+TOTLQI
      SINKS=TPOUT-TOTLQ
      ERRMB=SRCS-SINKS
      DENOM=(SRCS+SINKS)*0.5D0
      IF (DENOM.EQ.0.0) GO TO 100
      PCTERR=ERRMB*100.D0/DENOM
C         ---PRINT MASS BALANCE DATA FOR FLOW MODEL---
  100 WRITE (6,240)
      WRITE (6,211) TPIN
      WRITE (6,212) TPOUT
      WRITE (6,250) PUMP
      WRITE (6,230) QSTR
      WRITE (6,202) TOTLQI
      WRITE (6,203) TOTLQ
      WRITE (6,260) TOTLQN
      WRITE (6,270) ERRMB
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      WRITE (6,280) PCTERR                                              H 883
      WRITE (6,201)                                                     H 886
      WRITE (6,202) QIN                                                 H 889
      WRITE (6,203) QOUT                                                H 892
      WRITE (6,204) QNET                                                H 895
      WRITE (6,211) PQIN                                                H 898
      WRITE (6,212) PQOUT                                               H 901
      WRITE (6,210) TPUM                                                H 910
C     ************************************************************      H 940
  110 RETURN                                                            H 950
C     ************************************************************      H 960
C                                                                       H 970
C                                                                       H 980
C                                                                       H 990
  120 FORMAT (1H1,23HHEAD DISTRIBUTION - ROW)                           H1000
  130 FORMAT (1X,23HNUMBER OF TIME STEPS = ,1I5)                        H1010
  140 FORMAT (8X,16HTIME(SECONDS) = ,1G12.5)                            H1020
  150 FORMAT (8X,16HTIME(DAYS)    = ,1E12.5)                            H1030
  160 FORMAT (8X,16HTIME(YEARS)   = ,1E12.5)                            H1040
  170 FORMAT (1H )                                                      H1050
  180 FORMAT (1H0,10F12.7)                                              H1055
  190 FORMAT (1H0,30I4)                                                SH1071
  201 FORMAT (1H0,2X,33HRATE MASS BALANCE -- (IN C.F.S.) //)            H1073
  202 FORMAT (4X,29HLEAKAGE INTO AQUIFER        = ,E12.5)               H1076
  203 FORMAT (4X,29HLEAKAGE OUT OF AQUIFER      = ,E12.5)               H1083
  204 FORMAT (4X,29HNET LEAKAGE    (QNET)       = ,E12.5)               H1086
  210 FORMAT (4X,29HNET WITHDRAWAL    (TPUM)    = ,E12.5)               H1093
  211 FORMAT (4X,29HRECHARGE AND INJECTION      = ,E12.5)               H1096
  212 FORMAT (4X,29HPUMPAGE AND E-T WITHDRAWAL = ,E12.5)                H1103
  230 FORMAT (4X,29HWATER RELEASE FROM STORAGE = ,1E12.5)               H1120
  240 FORMAT (1H0,2X,38HCUMULATIVE MASS BALANCE -- (IN FT**3) //)       H1125
  250 FORMAT (4X,29HCUMULATIVE  NET  PUMPAGE    = ,1E12.5)              H1140
  260 FORMAT (4X,29HCUMULATIVE  NET  LEAKAGE    = ,1E12.5)              H1150
  270 FORMAT (1H0,7X,25HMASS BALANCE RESIDUAL  = ,G12.5)                H1160
  280 FORMAT (1H ,7X,25HERROR  (AS PERCENT)     = ,G12.5/)              H1170
  290 FORMAT (1H1,8HDRAWDOWN)                                           H1180
  300 FORMAT (3H   ,25I5)                                              SH1191
      END                                                               H1200-


$LARGE
      SUBROUTINE PARLOD                                                 B  10
      DOUBLE PRECISION DMIN1,DEXP,DLOG,DABS                             B  20
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE B  30
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,   B  40
     1                 HMIN,PYR,ANFCTR                                  B  42
      DOUBLE PRECISION FCTR,TIMX,TINIT,PIES,YNS,XNS,RAT,HMX,HMY         B  50
      DOUBLE PRECISION ANTIM                                            B  54
      DOUBLE PRECISION DXINV,DYINV,ARINV,PORINV                         B  57
      DOUBLE PRECISION ALPHA1,ANITP                                     B  61
      DOUBLE PRECISION TOTLQ,TOTLQI,TPIN,TPOUT                          B  62
      INTEGER OVERRD                                                    B  65
      CHARACTER*26 REACTN(9)                                            B  67R
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,    B  71
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,   B  81
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK              B  92
      COMMON /PRMC/ NODEID(040,040),NPCELL(020,020),NPOLD(020,020),    SB  97
     1              LIMBO(0500),IXOBS(05),IYOBS(05)                     B  98
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                SB 121
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),         SB 131
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),   SB 141
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL,SB 145
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR B 151
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                         SB 155
      COMMON /HEDD/ TINIT,TIMX                                          B 157
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040),SB 162
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS, SB 171
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,   B 175
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                    B 181
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,   B 181R
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,    B 183R
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 B 184R
      COMMON /BALM/ TOTLQ,TOTLQI,TPIN,TPOUT                             B 186
      COMMON /XINV/ DXINV,DYINV,ARINV,PORINV                            B 200
      COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)        SB 212
      DATA REACTN/                        'NONE                      ', B 213R
     1 'LINEAR SORPTION           ','FREUNDLICH SORPTION       ',       B 214R
     2 'LANGMUIR SORPTION         ','MONOVALENT ION EXCHANGE   ',       B 215R
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     3 'DIVALENT ION EXCHANGE     ','MONO-DIVALENT ION EXCHANGE',      B 216R
     4 'DI-MONOVALENT ION EXCHANGE','DECAY ONLY                 '/     B 217R
C     ****************************************************************  B 220
      IF (INT.GT.1) GO TO 10                                            B 230
      WRITE (6,750)                                                     B 240
      READ (5,720) TITLE                                                B 250
      WRITE (6,730) TITLE                                               B 260
C     ****************************************************************  B 270
C     ---INITIALIZE TEST AND CONTROL VARIABLES---                       B 280
      STORMI=0.0                                                        B 290
      SORBI=0                                                           B 295R
      RHOB=0.0                                                          B 296R
      DK=0.0                                                            B 297R
      CINMAX=0.0                                                        B 298R
      TEST=0.D0                                                         B 300
      EKF=0.0                                                           B 301R
      EKL=0.0                                                           B 302R
      EK=0.0                                                            B 303R
      XNF=1.0                                                           B 304R
      CEC=0.0                                                           B 305R
      CTOT=0.0                                                          B 306R
      RF2MIN=1.0                                                        B 307R
      RF2MAX=1.0                                                        B 308R
      TOTLQ=0.D0                                                        B 310
      TOTLQI=0.D0                                                       B 315
      TPIN=0.D0                                                         B 317
      TPOUT=0.D0                                                        B 318
      SUMT=0.D0                                                         B 320
      SUMTCH=0.0                                                        B 330
      INT=0                                                             B 340
      IPRNT=0                                                           B 350
      MX=1                                                             SB 353
      MY=1                                                             SB 354
      MCHK=0                                                           SB 355
      NCA2=0                                                           SB 356
      NCA=0                                                             B 360
      N=0                                                               B 370
      IMOV=0                                                            B 380
      NMOV=0                                                            B 390
      ICHK=0                                                            B 395
      DMASS1=0.0                                                        B 396R
      RF=1.0                                                            B 397R
      DECAY=0.0                                                         B 398R
      THALF=0.0                                                         B 399R
C     ****************************************************************  B 400
C     ---LOAD CONTROL PARAMETERS---                                     B 410
      READ (5,740) NTIM,NPMP,NX,NY,NPMAX,NPNT,NITP,NUMOBS,ITMAX,NREC,NPT B 420
     1PND,NCODES,NPNTMV,NPNTVL,NPNTD,NPDELC,NPNCHV,IREACT               B 431A
      NMX=NX                                                           SB 432
      NMY=NY                                                           SB 433
      MMX=NX-1                                                         SB 434
      MMY=NY-1                                                         SB 435
C        ---READ UPPER LEFT AND LOWER RIGHT NODAL COORDS. OF           SB 436
C           TRANSPORT SUBGRID, IN FREE FORMAT, IF NX.LT.0---           SB 437
      IF (NX.GT.0) GO TO 5                                             SB 438A
      NX=-NX                                                           SB 438B
      MCHK=1                                                           SB 438C
      READ (5,*) MX,MY,MMX,MMY                                         SB 438D
      NMX=MMX-MX+1                                                     SB 439A
      NMY=MMY-MY+1                                                     SB 439B
    5 CONTINUE                                                         SB 439H
      READ (5,800) PINT,TOL,POROS,BETA,S,TIMX,TINIT,XDEL,YDEL,DLTRAT,CEL B 440
     1DIS,ANFCTR                                                        B 450
C        ---READ REACTION TERMS IN FREE FORMAT---                       B 454R
      IF (IREACT.EQ.1) READ (5,*) DK,RHOB,THALF                         B 456R
      IF (IREACT.LT.-1.OR.IREACT.GT.7) IREACT=0                         B 457R
      IF (IREACT.EQ.-1) READ (5,*) THALF                                B 458R
      IF (IREACT.EQ.2) READ (5,*) RHOB,EKF,XNF,THALF                    B 459R
      IF (IREACT.EQ.3) READ (5,*) RHOB,EKL,CEC,THALF                    B 461R
      IF (IREACT.GE.4) READ (5,*) RHOB,EK,CEC,CTOT,THALF                B 462R
      XNFM1=XNF-1.                                                      B 463R
      FCTRF=RHOB*EKF*XNF/POROS                                          B 464R
      EKLCEC=EKL*CEC                                                    B 465R
      FCTRL=RHOB*EKLCEC/POROS                                           B 466R
      EKCEC=EK*CEC                                                      B 467R
      IF (CTOT.GT.0.0) FCTRE=RHOB*EKCEC/(POROS*CTOT)                    B 468A
      C3=RHOB/POROS                                                     B 468B
      C4=EKCEC                                                          B 468C
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      C5=C4*CEC                                                          B 468D
      C6=CTOT*CTOT                                                       B 468E
C      CZERO IS THE MINIMUM CONC. LEVEL FOR NONLINEAR RETARDATION        B 468F
      CZERO=0.9E-15                                                      B 468G
      CALL RETRD2(1.E-15,RF2MAX,RDCOEF)                                  B 468H
      CZERO=1.E-15                                                       B 469R
      NNX=NX-1                                                           B 470
      NNY=NY-1                                                           B 480
      NP=NPMAX                                                           B 490
      DXINV=1.D0/XDEL                                                    B 500
      DYINV=1.D0/YDEL                                                    B 510
      ARINV=DXINV*DYINV                                                  B 520
      PORINV=1.D0/POROS                                                  B 530
      RF=1.0+(DK*RHOB/POROS)                                             B 532R
      IF (THALF.GT.0.0) DECAY=ALOG(2.0)/THALF                            B 534R
C     ---PRINT CONTROL PARAMETERS---                                     B 540
      WRITE (6,755)                                                     SB 545
      WRITE (6,760)                                                      B 550
      WRITE (6,770) NX,NY,XDEL,YDEL                                      B 560
      IF (MCHK.GT.0) WRITE (6,775) NMX,NMY,MX,MY,MMX,MMY                SB 565
      WRITE (6,780) NTIM,NPMP,PINT,TIMX,TINIT                            B 570
      WRITE (6,790) S,POROS,BETA,DLTRAT,ANFCTR                           B 580
      WRITE (6,870) NITP,TOL,ITMAX,CELDIS,NPMAX,NPTPND                   B 590
      IF (NPTPND.NE.4.AND.NPTPND.NE.5.AND.NPTPND.NE.8.AND.NPTPND.NE.9.   B 601
     1.AND.NPTPND.NE.16.AND.NPTPND.NE.1) WRITE(6,880)                    B 612
      IF (NPTPND.EQ.1) WRITE (6,882)                                     B 614
      IF((NX.EQ.3.OR.NY.EQ.3).AND.NPTPND.NE.1) WRITE(6,883)              B 614A
      IF (NITP.LE.0) WRITE (6,885)                                       B 615
      WRITE (6,888)                                                     SB 617
      WRITE (6,890) NPNT,NPNTMV,NPNTVL,NPNTD,NUMOBS,NREC,NCODES,NPNCHV,N B 620
     1PDELC,IREACT                                                       B 631R
      IF (IREACT.EQ.-1) THEN                                             B 632A
       WRITE (6,891) REACTN(9)                                           B 632B
       IREACT=0                                                          B 632C
      ELSE                                                               B 632D
       WRITE (6,891) REACTN(IREACT+1)                                    B 632E
      END IF                                                             B 632F
      IF (IREACT.GE.1) THEN                                              B 633R
       WRITE (6,892) RHOB                                                B 634R
       IF (IREACT.EQ.1) THEN                                             B 636R
        WRITE (6,893) DK,RF                                              B 637R
       ELSE                                                              B 638R
        IF (IREACT.EQ.2) WRITE (6,894) EKF,XNF                           B 639R
        IF (IREACT.EQ.3) WRITE (6,895) EKL,CEC                           B 641R
        IF (IREACT.GE.4) WRITE (6,896) EK,CEC,CTOT                       B 642R
        IF (BETA.EQ.0.0) WRITE (6,897)                                   B 643R
       END IF                                                            B 644R
      END IF                                                             B 645R
      IF (DECAY.NE.0.0) WRITE (6,898) THALF,DECAY                        B 646R
      GO TO 20                                                           B 650
C     ***********************************************************        B 660
C     ---READ DATA TO REVISE TIME STEPS AND STRESSES FOR SUBSEQUENT      B 670
C        PUMPING PERIODS---                                              B 680
   10 READ (5,1060) ICHK                                                 B 690
      IF (ICHK.LE.0) WRITE (6,1110) INT                                  B 695
      IF (ICHK.LE.0) GO TO 20                                            B 701
C     ---REINITIALIZE REC AND CNRECH IN REC CELLS---                     B 702
C        AND RESET MINIMUM RETARDATION                                   B 703A
      IF (NREC.GT.0.OR.(IREACT.GE.2.AND.IREACT.LE.7)) THEN               B 703B
       CINMAX=0.0                                                        B 703C
       DO 12 IY=2,NNY                                                    B 704A
       DO 12 IX=2,NNX                                                    B 704B
       JX=IX-MX+1                                                       SB 704C
       JY=IY-MY+1                                                       SB 704D
       IF (REC(IX,IY).NE.0.0) THEN                                       B 704E
        REC(IX,IY)=0.D0                                                  B 705B
        IF (JX.GT.0.AND.JX.LE.NMX.AND.JY.GT.0.AND.JY.LE.NMY)            SB 707A
     1      CNRECH(JX,JY)=0.0                                           SB 707B
       END IF                                                            B 707C
       IF (JX.GT.0.AND.JX.LE.NMX.AND.JY.GT.0.AND.JY.LE.NMY) THEN        SB 707D
        IF (CONC(JX,JY).GT.CINMAX) CINMAX=CONC(JX,JY)                   SB 707E
        IF ((VPRM(IX,IY).NE.0.0.OR.RECH(JX,JY).LT.0.0)                  SB 707F
     1          .AND.CNRECH(JX,JY).GT.CINMAX)  CINMAX=CNRECH(JX,JY)     SB 707G
       END IF                                                            B 707H
   12  CONTINUE                                                          B 708
       CALL RETRD2(CINMAX,RF2MIN,RDCOEF)                                 B 708A
       IF (IREACT.EQ.2.AND.XNFM1.GT.0.0) RF2MIN=RF2MAX                   B 708B
      END IF                                                             B 709
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      READ (5,1070) NTIM,NPNT,NITP,ITMAX,NREC,NPNTMV,NPNTVL,NPNTD,NPDELC  B 710
     1,NPNCHV,PINT,TIMX,TINIT                                              B 720
      WRITE (6,1080) INT                                                  B 730
      WRITE (6,1090) NTIM,NPNT,NITP,ITMAX,NREC,NPNTMV,NPNTVL,NPNTD,NPDEL  B 740
     1C,NPNCHV,PINT,TIMX,TINIT                                            B 750
C     **************************************************************      B 760
C     ---LIST TIME INCREMENTS---                                          B 770
   20 DO 30 J=1,100                                                       B 780
      TIM(J)=0.D0                                                         B 790
   30 CONTINUE                                                            B 800
      PYR=PINT*86400.D0*365.25D0                                          B 805
      TIM(1)=TINIT                                                        B 810
      IF (NPNTMV.EQ.0) NPNTMV=999                                         B 815
      IF (S.GT.0.0) THEN                                                  B 821
      DO 40 K=2,NTIM                                                      B 830
   40 TIM(K)=TIMX*TIM(K-1)                                                B 840
      WRITE (6,470)                                                       B 850
      WRITE (6,490) (TIM(K),K=1,NTIM)                                     B 861
      IF (TINIT.GT.PYR) WRITE (6,475)                                     B 865
      ELSE                                                                B 871
   50 ANTIM=NTIM                                                          B 882
      DO 55 K=1,NTIM                                                      B 884
   55 TIM(K)=PYR/ANTIM                                                    B 886
       WRITE (6,480)                                                      B 891
       WRITE (6,490) (TIM(K),K=1,NTIM)                                    B 892
      END IF                                                              B 893
C     **************************************************************      B 900
C     ---INITIALIZE MATRICES---                                           B 910
   60 IF (INT.GT.1) GO TO 100                                             B 920
      DO 70 IY=1,NY                                                       B 930
      DO 70 IX=1,NX                                                       B 940
      VPRM(IX,IY)=0.D0                                                    B 950
      THCK(IX,IY)=0.0                                                     B 970
      RECH(IX,IY)=0.D0                                                    B 980
      REC(IX,IY)=0.D0                                                     B1000
      NODEID(IX,IY)=0                                                     B1010
      TMRX(IX,IY,1)=0.D0                                                  B1020
      TMRX(IX,IY,2)=0.D0                                                  B1030
      HI(IX,IY)=0.D0                                                      B1040
      HR(IX,IY)=0.D0                                                      B1050
      HC(IX,IY)=0.D0                                                      B1060
      HK(IX,IY)=0.D0                                                      B1070
      WT(IX,IY)=0.D0                                                      B1080
      VX(IX,IY)=0.0                                                       B1090
      VY(IX,IY)=0.0                                                       B1100
      VXBDY(IX,IY)=0.0                                                    B1110
      VYBDY(IX,IY)=0.0                                                    B1120
   70 CONTINUE                                                            B1160
      DO 75 IY=1,NMY                                                     SB1161
      DO 75 IX=1,NMX                                                     SB1162
      CNRECH(IX,IY)=0.0                                                  SB1163
      CONC(IX,IY)=0.0                                                    SB1164
      CONINT(IX,IY)=0.0                                                  SB1165
      SUMC(IX,IY)=0.0                                                    SB1166
      NPCELL(IX,IY)=0                                                    SB1167
   75 CONTINUE                                                           SB1168
C     ****************************************************************    B1170
C     ---READ OBSERVATION WELL LOCATIONS---                               B1180
      IF (NUMOBS.LE.0) GO TO 100                                          B1190
      WRITE (6,755)                                                       B1195
      WRITE (6,900)                                                       B1200
      DO 80 J=1,NUMOBS                                                    B1210
      READ (5,700) IX,IY                                                  B1220
      WRITE (6,810) J,IX,IY                                               B1230
      IXOBS(J)=IX                                                         B1240
   80 IYOBS(J)=IY                                                         B1250
      DO 90 I=1,NUMOBS                                                    B1260
      DO 90 J=1,50                                                        B1270
      TMWL(I,J)=0.0                                                       B1280
   90 TMCN(I,J)=0.0                                                       B1290
C     ****************************************************************    B1300
C     ---READ PUMPAGE DATA -- (X-Y COORDINATES AND RATE IN CFS)---        B1310
C        ---SIGNS : WITHDRAWAL = POS.;  INJECTION = NEG.---               B1320
C        ---IF INJ. WELL, ALSO READ CONCENTRATION OF INJECTED WATER---    B1330
  100 IF (NREC.LE.0) GO TO 120                                            B1340
      IF (INT.GT.1.AND.ICHK.LE.0) THEN                                    B1346A
       IF (IREACT.GE.2.AND.IREACT.LE.7) WRITE (6,899) RF2MIN              B1346B
       RETURN                                                             B1346C
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      END IF                                                            B1346D
      WRITE (6,755)                                                     B1347
      WRITE (6,910)                                                     B1350
      DO 110 I=1,NREC                                                   B1360
      READ (5,710) IX,IY,FCTR,CNREC                                     B1370
      JX=IX-MX+1                                                        SB1372
      JY=IY-MY+1                                                        SB1373
      IF (JX.LT.1.OR.JY.LT.1.OR.JX.GT.NMX.OR.JY.GT.NMY) GO TO 105      SB1374
      IF (FCTR.LT.0.0) CNRECH(JX,JY)=CNREC                              SB1382
      IF (FCTR.LT.0.0.AND.CNREC.GT.CINMAX) CINMAX=CNREC                 B1384R
  105 REC(IX,IY)=FCTR                                                   SB1392
  110 WRITE (6,820) IX,IY,REC(IX,IY),CNREC                              SB1402
      CALL RETRD2(CINMAX,RF2MIN,RDCOEF)                                 B1404R
      IF (IREACT.EQ.2.AND.XNFM1.GT.0.0) RF2MIN=RF2MAX                   B1405R
C     ***************************************************************** B1410
  120 IF (INT.GT.1) THEN                                                B1421R
        IF (IREACT.GE.2.AND.IREACT.LE.7) WRITE (6,899) RF2MIN           B1422R
        RETURN                                                          B1423R
      END IF                                                            B1424R
      AREA=XDEL*YDEL                                                    B1430
      WRITE (6,755)                                                     B1435
      WRITE (6,690) AREA                                                B1440
      WRITE (6,600)                                                     B1450
      WRITE (6,610) XDEL                                                B1460
      WRITE (6,610) YDEL                                                B1470
C     ***************************************************************** B1480
C     ---READ TRANSMISSIVITY IN FT**2/SEC INTO VPRM ARRAY---            B1490
C        ---FCTR = TRANSMISSIVITY MULTIPLIER  --->  FT**2/SEC---        B1500
      WRITE (6,530)                                                     B1510
      WRITE (6,755)                                                     B1515
      READ (5,550) INPUT,FCTR                                           B1520
      DO 160 IY=1,NY                                                    B1530
      IF (INPUT.EQ.1) READ (5,560) (VPRM(IX,IY),IX=1,NX)                B1540
      DO 150 IX=1,NX                                                    B1550
      IF (INPUT.NE.1) GO TO 130                                         B1560
      VPRM(IX,IY)=VPRM(IX,IY)*FCTR                                      B1570
      GO TO 140                                                         B1580
  130 VPRM(IX,IY)=FCTR                                                  B1590
  140 IF (IX.EQ.1.OR.IX.EQ.NX) VPRM(IX,IY)=0.D0                         B1600
      IF (IY.EQ.1.OR.IY.EQ.NY) VPRM(IX,IY)=0.D0                         B1610
  150 CONTINUE                                                          B1620
  160 WRITE (6,840) (VPRM(IX,IY),IX=1,NX)                               B1631
C     ***************************************************************** B1640
C     ---SET UP COEFFICIENT MATRIX --- BLOCK-CENTERED GRID---           B1650
C     ---AVERAGE TRANSMISSIVITY --- HARMONIC MEAN---                    B1660
      IF (ANFCTR.NE.0.0) GO TO 170                                      B1670
      WRITE (6,1050)                                                    B1680
      ANFCTR=1.D0                                                       B1690
  170 PIES=3.1415927D0*3.1415927D0/2.D0                                 B1700
      YNS=NY*NY                                                         B1710
      XNS=NX*NX                                                         B1720
      HMIN=2.D0                                                         B1730
      DO 180 IY=2,NNY                                                   B1740
      DO 180 IX=2,NNX                                                   B1750
      IF (VPRM(IX,IY).EQ.0.0) GO TO 180                                 B1760
      TMRX(IX,IY,1)=2.D0*VPRM(IX,IY)*VPRM(IX+1,IY)/                     B1771
     1                ((VPRM(IX,IY)+VPRM(IX+1,IY))*XDEL)                B1781
      TMRX(IX,IY,2)=2.D0*VPRM(IX,IY)*VPRM(IX,IY+1)/                     B1791
     1                ((VPRM(IX,IY)+VPRM(IX,IY+1))*YDEL)                B1801
C        ---ADJUST COEFFICIENT FOR ANISOTROPY---                        B1810
      TMRX(IX,IY,2)=TMRX(IX,IY,2)*ANFCTR                                B1820
C        ---COMPUTE MINIMUM ITERATION PARAMETER (HMIN)---               B1830
      IF (TMRX(IX,IY,1).EQ.0.0) GO TO 180                               B1840
      IF (TMRX(IX,IY,2).EQ.0.0) GO TO 180                               B1850
      RAT=TMRX(IX,IY,1)*YDEL/(TMRX(IX,IY,2)*XDEL)                       B1860
      HMX=PIES/(XNS*(1.D0+RAT))                                         B1870
      HMY=PIES/(YNS*(1.D0+(1.D0/RAT)))                                  B1880
      IF (HMX.LT.HMIN) HMIN=HMX                                         B1890
      IF (HMY.LT.HMIN) HMIN=HMY                                         B1900
  180 CONTINUE                                                          B1910
      IF (NX.GT.3.AND.NY.GT.3) GO TO 185                                B1912
      HMX=PIES/XNS                                                      B1913
      HMY=PIES/YNS                                                      B1914
      HMIN=DMIN1(HMIN,HMX,HMY)                                          B1915
  185 CONTINUE                                                          B1916
C     ***************************************************************** B1920
C     ---READ AQUIFER THICKNESS---                                      B1930
      WRITE (6,510)                                                     B1940
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      WRITE (6,755)                                                     B1945
      READ (5,550) INPUT,FCTR                                           B1950
      DO 210 IY=1,NY                                                    B1960
      IF (INPUT.EQ.1) READ (5,540) (THCK(IX,IY),IX=1,NX)                B1970
      DO 200 IX=1,NX                                                    B1980
      IF (INPUT.NE.1) GO TO 190                                         B1990
      THCK(IX,IY)=THCK(IX,IY)*FCTR                                      B2000
      GO TO 200                                                         B2010
  190 IF (VPRM(IX,IY).NE.0.0) THCK(IX,IY)=FCTR                          B2020
  200 CONTINUE                                                          B2030
      WRITE (6,500) (THCK(IX,IY),IX=1,NX)                               B2041
C     ---STORE THICKNESS*POROSITY IN THCK ARRAY---                      B2043
      DO 205 IX=1,NX                                                    B2044
  205 THCK(IX,IY)=THCK(IX,IY)*POROS                                     B2045
  210 CONTINUE                                                          B2046
C     ************************************************************      B2050
C     ---READ DIFFUSE RECHARGE AND DISCHARGE---                         B2060
      WRITE (6,830)                                                     B2070
      WRITE (6,755)                                                     B2075
      READ (5,550) INPUT,FCTR                                           B2080
      DO 240 IY=1,NY                                                    B2090
      IF (INPUT.EQ.1) READ (5,560) (RECH(IX,IY),IX=1,NX)                B2100
      DO 230 IX=1,NX                                                    B2110
      IF (INPUT.NE.1) GO TO 220                                         B2120
      RECH(IX,IY)=RECH(IX,IY)*FCTR                                      B2130
      GO TO 230                                                         B2140
  220 IF (THCK(IX,IY).NE.0.0) RECH(IX,IY)=FCTR                          B2150
  230 CONTINUE                                                          B2160
  240 WRITE (6,840) (RECH(IX,IY),IX=1,NX)                               B2170
C     ************************************************************      B2180
C     ---COMPUTE PERMEABILITY FROM TRANSMISSIVITY---                    B2190
C     ---COUNT NO. OF CELLS IN AQUIFER---                               B2200
C     ---SET NZCRIT = 2% OF THE NO. OF CELLS IN THE AQUIFER---          B2210
      DO 250 IX=1,NX                                                    B2220
      DO 250 IY=1,NY                                                    B2230
      IF (THCK(IX,IY).EQ.0.0) GO TO 250                                 B2240
      VPRM(IX,IY)=(VPRM(IX,IY)*POROS)/THCK(IX,IY)                       B2251
      NCA=NCA+1                                                         B2260
      IF (MCHK.EQ.0) GO TO 250                                         SB2262
      IF (IX.LT.MX.OR.IX.GT.MMX) GO TO 250                             SB2263
      IF (IY.LT.MY.OR.IY.GT.MMY) GO TO 250                             SB2264
      NCA2=NCA2+1                                                      SB2265
  250 CONTINUE                                                          B2271
C                                                                       B2280
      AAQ=NCA*AREA                                                      B2290
      NZCRIT=(NCA+25)/50                                                B2300
      IF (MCHK.GT.0) NZCRIT=(NCA2+25)/50                               SB2301
      IF (NZCRIT.EQ.0) NZCRIT=1                                        SB2305
      WRITE (6,620)                                                     B2310
      WRITE (6,755)                                                     B2315
      DO 260 IY=1,NY                                                    B2320
      WRITE (6,840) (VPRM(IX,IY),IX=1,NX)                               B2322
      DO 260 IX=1,NX                                                    B2324
  260 VPRM(IX,IY)=0.D0                                                  B2326
      IF (MCHK.EQ.0) GO TO 265                                         SB2332
      AAQ2=NCA2*AREA                                                   SB2333
      WRITE (6,633)                                                    SB2334
      WRITE (6,635) NCA,AAQ                                            SB2335
      WRITE (6,634)                                                    SB2336
      WRITE (6,630) NCA2,AAQ2,NZCRIT                                   SB2337
      GO TO 267                                                        SB2338
  265 CONTINUE                                                         SB2339
      WRITE (6,630) NCA,AAQ,NZCRIT                                      B2340
  267 CONTINUE                                                         SB2345
C     ************************************************************      B2350
C     ---READ NODE IDENTIFICATION CARDS---                              B2360
C        ---SET VERT. PERM., SOURCE CONC., AND DIFFUSE RECHARGE---      B2370
C           ---SPECIFY CODES TO FIT YOUR NEEDS---                       B2380
      WRITE (6,570)                                                     B2390
      READ (5,550) INPUT,FCTR                                           B2400
      DO 280 IY=1,NY                                                    B2410
      IF (INPUT.EQ.1) READ (5,640) (NODEID(IX,IY),IX=1,NX)              B2420
      DO 270 IX=1,NX                                                    B2430
  270 IF (INPUT.NE.1.AND.THCK(IX,IY).NE.0.0) NODEID(IX,IY)=FCTR         B2440
  280 WRITE (6,580) (NODEID(IX,IY),IX=1,NX)                             B2450
      WRITE (6,920) NCODES                                              B2460
      IF (NCODES.LE.0) GO TO 310                                        B2470
      WRITE (6,930)                                                     B2480
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      DO 300 IJ=1,NCODES                                                B2490
      READ (5,850) ICODE,FCTR1,FCTR2,FCTR3,OVERRD                       B2500
      DO 290 IX=1,NX                                                    B2510
      DO 290 IY=1,NY                                                    B2520
      IF (NODEID(IX,IY).NE.ICODE) GO TO 290                             B2530
      VPRM(IX,IY)=FCTR1                                                 B2540
      JX=IX-MX+1                                                       SB2544
      JY=IY-MY+1                                                       SB2545
      IF (JX.LT.1.OR.JY.LT.1.OR.JX.GT.NMX.OR.JY.GT.NMY) GO TO 285      SB2546
      CNRECH(JX,JY)=FCTR2                                              SB2551
      IF (FCTR2.GT.CINMAX) CINMAX=FCTR2                                 B2553R
  285 CONTINUE                                                         SB2555
      IF (OVERRD.NE.0) RECH(IX,IY)=FCTR3                                B2560
  290 CONTINUE                                                          B2570
      WRITE (6,860) ICODE,FCTR1,FCTR2                                   B2580
  300 IF (OVERRD.NE.0) WRITE (6,1100) FCTR3                             B2590
  310 WRITE (6,590)                                                     B2600
      WRITE (6,755)                                                     B2615
      DO 320 IY=1,NY                                                    B2610
  320 WRITE (6,840) (VPRM(IX,IY),IX=1,NX)                               B2621
C     ***************************************************************   B2630
C     ---READ WATER-TABLE ELEVATION---                                  B2640
      WRITE (6,670)                                                     B2650
      WRITE (6,755)                                                     B2655
      READ (5,550) INPUT,FCTR                                           B2660
      DO 350 IY=1,NY                                                    B2670
      IF (INPUT.EQ.1) READ (5,660) (WT(IX,IY),IX=1,NX)                  B2680
      DO 340 IX=1,NX                                                    B2690
      IF (INPUT.NE.1) GO TO 330                                         B2700
      WT(IX,IY)=WT(IX,IY)*FCTR                                          B2710
      GO TO 340                                                         B2720
  330 IF (THCK(IX,IY).NE.0.0) WT(IX,IY)=FCTR                            B2730
  340 CONTINUE                                                          B2740
  350 WRITE (6,680) (WT(IX,IY),IX=1,NX)                                 B2750
C     ***************************************************************   B2760
C     ---SET INITIAL HEADS---                                           B2770
      DO 360 IX=1,NX                                                    B2780
      DO 360 IY=1,NY                                                    B2790
      HI(IX,IY)=WT(IX,IY)                                               B2800
      HC(IX,IY)=HI(IX,IY)                                               B2810
      HR(IX,IY)=HI(IX,IY)                                               B2820
  360 HK(IX,IY)=HI(IX,IY)                                               B2830
C                                                                       B2840
      CALL OUTPT                                                        B2850
C     ***************************************************************   B2860
C     ---COMPUTE ITERATION PARAMETERS---                                B2870
      DO 370 ID=1,20                                                    B2880
      AOPT(ID)=0.D0                                                     B2890
  370 CONTINUE                                                          B2900
      ANITP=NITP-1.D0                                                   B2910
      ALPHA1=DEXP(DLOG(1.D0/HMIN)/ANITP)                                B2920
      AOPT(1)=HMIN                                                      B2930
      DO 380 IP=2,NITP                                                  B2940
  380 AOPT(IP)=AOPT(IP-1)*ALPHA1                                        B2950
C                                                                       B2960
      WRITE (6,450)                                                     B2970
      WRITE (6,460) (AOPT(IP),IP=1,NITP)                                B2981
C     ***************************************************************   B2990
C     ---READ INITIAL CONCENTRATIONS AND COMPUTE INITIAL MASS STORED--- B3000
C        ---IF USING SMALLER SUBGRID FOR TRANSPORT, READ INITIAL       SB3005
C           CONCENTRATION ARRAY FOR SUBGRID NODES ONLY---              SB3006
      READ (5,550) INPUT,FCTR                                           B3010
      CFCTR2=DK*RHOB/POROS                                              B3016R
      DO 420 IY=1,NMY                                                  SB3021
      JY=IY+MY-1                                                       SB3025
      IF (INPUT.EQ.1) READ (5,660) (CONC(IX,IY),IX=1,NMX)              SB3031
      DO 410 IX=1,NMX                                                  SB3041
      JX=IX+MX-1                                                       SB3045
      IF (INPUT.NE.1) GO TO 390                                         B3050
      CONC(IX,IY)=CONC(IX,IY)*FCTR                                      B3060
      GO TO 400                                                         B3070
  390 IF (THCK(JX,JY).NE.0.0) CONC(IX,IY)=FCTR                         SB3081
  400 CONINT(IX,IY)=CONC(IX,IY)                                         B3090
      CFCTR=CONINT(IX,IY)*THCK(JX,JY)*AREA                             SB3093R
      SORBI=SORBI+CFCTR*CFCTR2                                          B3094R
      IF (IREACT.GE.2)                                                  B3095A
     1    SORBI=SORBI+RHOB/POROS*AREA*THCK(JX,JY)*SORB2(CONINT(IX,IY)) SB3095B
      IF (CONINT(IX,IY).GT.CINMAX) CINMAX=CONINT(IX,IY)                 B3095C
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  410 STORMI=STORMI+CFCTR                                                B3097R
  420 CONTINUE                                                           B3110
      CALL RETRD2(CINMAX,RF2MIN,RDCOEF)                                  B3112R
      IF (IREACT.EQ.2.AND.XNFM1.GT.0.0) RF2MIN=RF2MAX                    B3113R
      IF (IREACT.GE.2.AND.IREACT.LE.7) WRITE (6,899) RF2MIN              B3114R
C     *************************************************************     B3120
C     ---CHECK DATA SETS FOR INTERNAL CONSISTENCY---                     B3130
      DO 440 IX=1,NX                                                     B3140
      DO 440 IY=1,NY                                                     B3150
      IF (THCK(IX,IY).GT.0.0) THEN                                       B3161
       IF (IX.EQ.1.OR.IY.EQ.1.OR.IX.EQ.NX.OR.IY.EQ.NY)                   B3162
     1     WRITE (6,935) IX,IY                                           B3163
       GO TO 430                                                         B3164
      END IF                                                             B3165
      IF (TMRX(IX,IY,1).GT.0.0) WRITE (6,940) IX,IY                      B3170
      IF (TMRX(IX,IY,2).GT.0.0) WRITE (6,950) IX,IY                      B3180
      IF (IX.NE.1) THEN                                                  B3182
       IF (TMRX(IX-1,IY,1).GT.0.0) WRITE (6,940) IX,IY                   B3183
      END IF                                                             B3184
      IF (IY.NE.1) THEN                                                  B3185
       IF (TMRX(IX,IY-1,2).GT.0.0) WRITE (6,950) IX,IY                   B3186
      END IF                                                             B3187
      IF (NODEID(IX,IY).GT.0) WRITE (6,960) IX,IY                        B3190
      IF (WT(IX,IY).NE.0.0) WRITE (6,970) IX,IY                          B3200
      IF (RECH(IX,IY).NE.0.0) WRITE (6,980) IX,IY                        B3210
      IF (REC(IX,IY).NE.0.0) WRITE (6,990) IX,IY                         B3220
  430 IF (TMRX(IX,IY,1).GT.0.0.OR.TMRX(IX,IY,2).GT.0.0) GO TO 440        B3231
      IF (IX.NE.1) THEN                                                  B3232
       IF (TMRX(IX-1,IY,1).GT.0.0) GO TO 440                             B3233
      END IF                                                             B3234
      IF (IY.NE.1) THEN                                                  B3235
       IF (TMRX(IX,IY-1,2).GT.0.0) GO TO 440                             B3236
      END IF                                                             B3237
      IF (NODEID(IX,IY).GT.0.0) WRITE (6,1000) IX,IY                     B3240
      IF (WT(IX,IY).NE.0.0) WRITE (6,1010) IX,IY                         B3250
      IF (RECH(IX,IY).NE.0.0) WRITE (6,1020) IX,IY                       B3260
      IF (REC(IX,IY).NE.0.0) WRITE (6,1030) IX,IY                        B3270
      IF (THCK(IX,IY).GT.0.0) WRITE (6,1040) IX,IY                       B3280
  440 CONTINUE                                                           B3290
C     *************************************************************     B3300
      RETURN                                                             B3310
C     *************************************************************     B3320
C                                                                        B3330
C                                                                        B3340
C                                                                        B3350
  450 FORMAT (1H1,20HITERATION PARAMETERS)                               B3360
  460 FORMAT (3H    ,1G20.6)                                             B3370
  470 FORMAT (1H1,27HTIME INTERVALS (IN SECONDS))                        B3380
  475 FORMAT (1H0,5X,65H*** WARNING ***   INITIAL TIME STEP IS LONGER TH B3384
     1AN PUMPING PERIOD/25X,34H***ADJUST EITHER TINIT OR PINT.***/)      B3385
  480 FORMAT (1H1,15X,17HSTEADY-STATE FLOW//5X,55HTIME INTERVALS (IN SEC B3391
     1) FOR SOLUTE-TRANSPORT SIMULATION)                                 B3401
  490 FORMAT (3H    ,10G12.5)                                            B3410
  500 FORMAT (3H    ,25F5.1)                                            SB3421
  510 FORMAT (1H1,22HAQUIFER THICKNESS (FT))                             B3430
  530 FORMAT (1H1,30HTRANSMISSIVITY MAP (FT*FT/SEC))                     B3450
  540 FORMAT (20G3.0)                                                    B3460
  550 FORMAT (I1,G10.0)                                                  B3470
  560 FORMAT (20G4.1)                                                    B3480
  570 FORMAT (1H1,23HNODE IDENTIFICATION MAP//)                          B3490
  580 FORMAT (1H ,40I3)                                                 SB3501
  590 FORMAT (1H1,45HVERTICAL PERMEABILITY/THICKNESS (FT/(FT*SEC)))      B3510
  600 FORMAT (1H0,10X,12HX-Y SPACING:)                                   B3520
  610 FORMAT (1H ,12X,10G12.5)                                           B3530
  620 FORMAT (1H1,24HPERMEABILTY MAP (FT/SEC))                           B3540
  630 FORMAT (1H0,05X,05X,44HNO. OF FINITE-DIFFERENCE CELLS IN AQUIFER = SB3551
     1 ,I4//10X,28HAREA OF AQUIFER IN MODEL  = ,G12.5,10H   SQ. FT.////1 B3560
     20X,47HNZCRIT   (MAX. NO. OF CELLS THAT CAN BE VOID OF/20X,56HPARTI B3570
     3CLES;  IF EXCEEDED, PARTICLES ARE REGENERATED)   = ,I4/)           B3580
  633 FORMAT (1H0,////2X,26HFLOW MODEL (PRIMARY GRID):/)                SB3582
  634 FORMAT (1H0,///2X,18HTRANSPORT SUBGRID:/)                         SB3583
  635 FORMAT (1H0,05X,05X,44HNO. OF FINITE-DIFFERENCE CELLS IN AQUIFER = SB3584
     1 ,I4//10X,28HAREA OF AQUIFER IN MODEL  = ,G12.5,10H   SQ. FT./)   SB3585
  640 FORMAT (20I1)                                                      B3590
  660 FORMAT (20G4.0)                                                    B3610
  670 FORMAT (1H1,11HWATER TABLE)                                        B3620
  680 FORMAT (1H ,20F5.0)                                                B3630
  690 FORMAT (1H0,10X,19HAREA OF ONE CELL = ,G12.4)                      B3640
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  700 FORMAT (2I2)                                                         B3650
  710 FORMAT (2I2,2G8.2)                                                   B3660
  720 FORMAT (10A8)                                                        B3670
  730 FORMAT (1H0,10A8)                                                    B3680
  740 FORMAT (18I4)                                                        B3691R
  750 FORMAT (1H1,77HU.S.G.S. METHOD-OF-CHARACTERISTICS MODEL FOR SOLUTE   B3700
     1 TRANSPORT IN GROUND WATER)                                          B3710
  755 FORMAT (1H )                                                        SB3715
  760 FORMAT (1H0,21X,21HI N P U T     D A T A)                            B3720
  770 FORMAT (1H0,23X,16HGRID DESCRIPTORS//13X,30HNX     (NUMBER OF COLUM  B3730
     1NS)  =  ,I4/13X,28HNY     (NUMBER OF ROWS)      =,I6/13X,29HXDEL  (X  B3740
     2-DISTANCE IN FEET) = ,F7.1/13X,29HYDEL  (Y-DISTANCE IN FEET) = ,F7   B3750
     3.1)                                                                  B3760
  775 FORMAT (1H0,18X,31HSECONDARY SUBGRID FOR TRANSPORT//16X,30HNMX    ( SB3763
     1NUMBER OF COLUMNS)  =  ,I4/16X,30HNMY   (NUMBER OF ROWS)      =  ,I SB3764
     24//16X,38HCROSS-REF. TO PRIMARY GRID       IX  IY/46X,8H --- ---/18 SB3765
     3X,28HFIRST NODE (UPPER LEFT) AT: ,2I4/18X,28HLAST NODE (LOWER RIGH SB3766
     4T) AT: ,2I4)                                                        SB3767
  780 FORMAT (1H0,23X,16HTIME  PARAMETERS//13X,40HNTIM   (MAX. NO. OF TI   B3770
     1ME STEPS)         = ,I6/13X,40HNPMP   (NO. OF PUMPING PERIODS)       B3780
     2 = ,I6/13X,39HPINT   (PUMPING PERIOD IN YEARS)      =,F11.3/13X,39   B3791
     3HTIMX   (TIME INCREMENT MULTIPLIER)    =,F10.2/13X,39HTINIT  (INIT   B3800
     4IAL TIME STEP IN SEC.)    =,F8.0)                                    B3810
  790 FORMAT (1H0,14X,34HHYDROLOGIC AND CHEMICAL PARAMETERS//13X,1HS,7X,   B3820
     129H(STORAGE COEFFICIENT)         =,5X,F9.6/13X,28HPOROS    (EFFECTIVE  B3830
     2 POROSITY),8X,3H=  ,F9.3/13X,39HBETA    (LONGITUDINAL DISPERSIVITY SB3841
     3) =  ,F7.1/13X,31HDLTRAT  (RATIO OF TRANSVERSE TO/21X,30HLONGITUDI SB3851
     4NAL DISPERSIVITY)  = ,F9.2/13X,39HANFCTR  (RATIO OF T-YY TO T-XX)    B3860
     5     =  ,F12.6)                                                      B3870
  800 FORMAT (12G5.0)                                                      B3880
  810 FORMAT (1H ,16X,I2,5X,I2,4X,I2)                                      B3890
  820 FORMAT (1H ,7X,2I4,3X,F9.4,3X,F8.2)                                  B3895
  830 FORMAT (1H1,39HDIFFUSE RECHARGE AND DISCHARGE (FT/SEC))              B3910
  840 FORMAT (1H ,1P10E10.2)                                               B3920
  850 FORMAT (I2,3G10.2,I2)                                                B3930
  860 FORMAT (1H0,7X,I2,7X,E10.3,5X,F9.2)                                  B3940
  870 FORMAT (1H0,21X,20HEXECUTION PARAMETERS//13X,39HNITP    (NO. OF ITE  B3950
     1RATION PARAMETERS) = ,I4/13X,39HTOL     (CONVERGENCE CRITERIA - ADI  B3960
     2P) = ,E9.2/13X,39HITMAX  (MAX.NO.OF ITERATIONS - ADIP) = ,I4/13X,3   B3971
     34HCELDIS (MAX.CELL DISTANCE PER MOVE/24X,28HOF PARTICLES - M.O.C.)   B3980
     4     = ,F8.3/13X,30HNPMAX  (MAX. NO. OF PARTICLES),7X,2H= ,I4/12X,3  B3990
     52H NPTPND (NO. PARTICLES PER NODE),6X,3H=  ,I4)                      B4000
  880 FORMAT (1H0,5X,47H*** WARNING *** NPTPND MUST =  1,4,5,8,9, OR 16)   B4011A
  882 FORMAT (1H0,5X,58H*** CAUTION *** USE OF NPTPND=1 MAY CAUSE LOSS O   B4012A
     1F ACCURACY)                                                          B4012B
  883 FORMAT (1H0,5X,56H*** ONE-DIMENSIONAL *** WILL USE ONLY 1 ROW OF P   B4013A
     1ARTICLES/13X,35HUSE 2 PARTICLES FOR NPTPND = 4 OR 5/13X,35HUSE 3 P   B4013B
     2ARTICLES FOR NPTPND = 8 OR 9/13X,31HUSE 4 PARTICLES FOR NPTPND = 1   B4013C
     36)                                                                   B4013D
  885 FORMAT (1H0,5X,38H*** WARNING ***  NITP MUST BE POSITIVE)            B4015
  888 FORMAT (1H1)                                                        SB4017
  890 FORMAT (1H0,23X,15HPROGRAM OPTIONS//13X,30HNPNT    (TIME STEP INTER  B4020
     1VAL FOR/21X,18HCOMPLETE PRINTOUT),7X,3H=  ,I4/13X,31HNPNTMV (MOVE    B4030
     2INTERVAL FOR CHEM./21X,28HCONCENTRATION PRINTOUT)  =  ,I4/13X,30HN   B4041
     3PNTVL (TIME STEP INTERVAL FOR/21X,'VELOCITY PRINTOUT; 0=NEVER;'/     B4045
     4 21X,'-1=FIRST TIME STEP;'/21X,'-2=LAST TIME STEP)',7X,3H=  ,I4/     B4051
     5 13X,'NPNTD  (PRINT OPTION-DISP.COEF.'/21X,                          B4055
     6 '0=NO; 1=FIRST TIME STEP;'/21X,'2=ALL TIME STEPS)',8X,3H=  ,I4/     B4061
     7 13X,'NUMOBS (NO. OF OBSERVATION WELLS'/                             B4065
     8 21X,'FOR HYDROGRAPH PRINTOUT) =  ',I4/                              B4071
     9 13X,'NREC   (NO. OF PUMPING WELLS)     = ',I5/                      B4075
     $ 13X,'NCODES (FOR NODE IDENT.)',9X,2H= ,I5/                          B4081
     1 13X,'NPNCHV (TIME STEP INTERVAL FOR'/21X,'VELOCITY PRINTOUT ON'/    B4091
     2 21X,'FILE UNIT 7; 0=NEVER;'/21X,'-1=FIRST TIME STEP;'/              B4101
     3 21X,'-2=LAST TIME STEP)',7X,2H= ,I5/                                B4111
     4 13X,'NPDELC (PRINT OPT.-CONC. CHANGE) =  ',I4/                      B4118R
     5 13X,'IREACT (REACTION SPECIFIER)       = ',I5)                      B4126R
  891 FORMAT (//13X,'REACTION - ',A26/)                                    B4127R
  892 FORMAT (13X,'RHOB    (BULK DENSITY)                 = ',1PE12.5)     B4128A
  893 FORMAT (13X,'DK      (DISTRIBUTION COEFFICIENT)     = ',1PE12.5/     B4128B
     1        13X,'RF      (RETARDATION FACTOR)           = ',1PE12.5)     B4128C
  894 FORMAT (13X,'EKF     (FREUNDLICH SORPTION CONSTANT)= ',1PE12.5/      B4128D
     1        13X,'XNF     (FREUNDLICH SORPTION SLOPE)    = ',1PE12.5)     B4128E
  895 FORMAT (13X,'EKL     (LANGMUIR SORPTION CONSTANT)   = ',1PE12.5/     B4128F
     1        13X,'CEC     (CATION EXCHANGE CAPACITY)     = ',1PE12.5)     B4128G
  896 FORMAT (13X,'EK      (ION EXCHANGE CONSTANT)        = ',1PE12.5/     B4128H
     1        13X,'CEC     (CATION EXCHANGE CAPACITY)     = ',1PE12.5/     B4128I
     2        13X,'CTOT    (TOTAL SOLUTE CONCENTRATION)   = ',1PE12.5)     B4128J
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  897 FORMAT (/' *** WARNING ***  BETA.EQ.0.0 AND SORPTION-EXCHANGE IS',
     1                                         ' NONLINEAR')
  898 FORMAT (/13X,'THALF   (HALF LIFE OF DECAY,IN SEC)     = ',1PE12.5/
     1           13X,'DECAY   (DECAY CONSTANT=LN 2/THALF)     = ',1PE12.5)
  899 FORMAT (1H0,' MINIMUM NONLINEAR RETARDATION FACTOR FOR THIS',
     1              ' PUMPING PERIOD'//10X,' RF2MIN = ',1PE12.4)
  900 FORMAT (1H0,10X,29HLOCATION OF OBSERVATION WELLS//17X,3HNO.,5X,1HX
     1,5X,1HY/)
  910 FORMAT (1H0,10X,28HLOCATION  OF  PUMPING  WELLS//11X,28HX    Y    RA
     1TE(IN CFS)   CONC./)
  920 FORMAT (1H0,5X,37HNO. OF NODE IDENT. CODES SPECIFIED = ,I2)
  930 FORMAT (1H0,10X,41HTHE FOLLOWING ASSIGNMENTS HAVE BEEN MADE:/5X,51
     1HCODE NO.      LEAKANCE      SOURCE CONC.      RECHARGE)
  935 FORMAT (1H ,5X,54H*** WARNING ***    THCK.NE.0.0 ON BOUNDARY AT NOD
     1E IX =,I4,6H, IY =,I4)
  940 FORMAT (1H ,5X,61H*** WARNING ***    THCK.EQ.0.0 AND TMRX(X).GT.0.0
     1 AT NODE IX =,I4,6H, IY =,I4)
  950 FORMAT (1H ,5X,61H*** WARNING ***    THCK.EQ.0.0 AND TMRX(Y).GT.0.0
     1 AT NODE IX =,I4,6H, IY =,I4)
  960 FORMAT (1H ,5X,61H*** WARNING ***     THCK.EQ.0.0 AND NODEID.GT.0.0
     1 AT NODE IX =,I4,6H, IY =,I4)
  970 FORMAT (1H ,5X,56H*** WARNING ***    THCK.EQ.0.0 AND WT.NE.0.0 AT N
     1ODE IX =,I4,6H, IY =,I4)
  980 FORMAT (1H ,5X,58H*** WARNING ***    THCK.EQ.0.0 AND RECH.NE.0.0 AT
     1 NODE IX =,I4,6H, IY =,I4)
  990 FORMAT (1H ,5X,58H*** WARNING ***     THCK.EQ.0.0 AND REC.NE.0.0 AT
     1 NODE IX =,I4,6H, IY =,I4)
 1000 FORMAT (1H ,5X,61H*** WARNING ***     TMRX.EQ.0.0 AND NODEID.GT.0.0
     1 AT NODE IX =,I4,6H, IY =,I4)
 1010 FORMAT (1H ,5X,56H*** WARNING ***    TMRX.EQ.0.0 AND WT.NE.0.0 AT N
     1ODE IX =,I4,6H, IY =,I4)
 1020 FORMAT (1H ,5X,58H*** WARNING ***    TMRX.EQ.0.0 AND RECH.NE.0.0 AT
     1 NODE IX =,I4,6H, IY =,I4)
 1030 FORMAT (1H ,5X,58H*** WARNING ***     TMRX.EQ.0.0 AND REC.NE.0.0 AT
     1 NODE IX =,I4,6H, IY =,I4)
 1040 FORMAT (1H ,5X,58H*** WARNING ***    TMRX.EQ.0.0 AND THCK.GT.0.0 AT
     1 NODE IX =,I4,6H, IY =,I4)
 1050 FORMAT (1H0,5X,45H*** WARNING ***    ANFCTR WAS SPECIFIED AS 0.0/23
     1X,34HDEFAULT ACTION: RESET ANFCTR = 1.0)
 1060 FORMAT (I1)
 1070 FORMAT (10I4,3G5.0)
 1080 FORMAT (1H1,5X,25HSTART PUMPING PERIOD NO. ,I2//2X,75HTHE FOLLOWIN
     1G TIME STEP, PUMPAGE, AND PRINT PARAMETERS HAVE BEEN REDEFINED:/)
 1090 FORMAT (1H0,14X,9HNTIM    = ,I4/15X,9HNPNT    = ,I4/15X,9HNITP    = ,
     1I4/15X,9HITMAX   = ,I4/15X,9HNREC    = ,I4/15X,9HNPNTMV = ,I4/15X,9H
     2NPNTVL = ,I4/15X,9HNPNTD   = ,I4/15X,9HNPDELC = ,I4/15X,9HNPNCHV =
     3,I4/15X,9HPINT    = ,F10.3/15X,9HTIMX    = ,F10.3/15X,9HTINIT   = ,F1
     40.3/)
 1100 FORMAT (1H ,46X,E10.3)
 1110 FORMAT (1H1,5X,25HSTART PUMPING PERIOD NO. ,I2//2X,23HNO PARAMETER
     1S REDEFINED/)
      END
```

```
$LARGE
      SUBROUTINE RETRD2(CONC,RF2,RDCOEF)
C
C     ******************************************************************
      DOUBLE PRECISION AA,BB,CC,QUADX
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,
     2         RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6
C     ******************************************************************
C     ---COMPUTE NONLINEAR RETARDATION FACTOR (RF2) AND CORRECTION TERM
C          FOR DECAY OF SORBED SOLUTE (RDCOEF)---
C
      RF2=1.0
      RDCOEF=1.0
      IF (IREACT.LE.1) RETURN
      C=CONC
      IF (C.LE.CZERO) THEN
       RF2=RF2MAX
       RDCOEF=RF2MAX
       RETURN
      END IF
C
C     ---FREUNDLICH ISOTHERM---
```

```
      IF (IREACT.EQ.2) THEN
       TERM=FCTRF*C**XNFM1
       RF2=1.+TERM
       RDCOEF=1.+TERM/XNF
C
C     ---LANGMUIR ISOTHERM---
      ELSE IF (IREACT.EQ.3) THEN
       DINV=1./(1.+EKL*C)
       TERM=FCTRL*DINV
       RF2=1.+TERM*DINV
       RDCOEF=1.+TERM
C
C     ---MONOVALENT ION EXCHANGE---
      ELSE IF (IREACT.EQ.4) THEN
       RF2=1.+FCTRE/((C/CTOT*(EK-1.)+1.)**2)
       RDCOEF=1.+FCTRE*CTOT/((CTOT-C)+EK*C)
C
C     ---DIVALENT ION EXCHANGE---
      ELSE IF (IREACT.EQ.5) THEN
       CTOT2=CTOT*0.5
       RF2=1.+FCTRE/((C/CTOT2*(EK-1.)+1.)**2)
       RDCOEF=1.+FCTRE*CTOT2/((CTOT2-C)+EK*C)
C
C     ---MONOVALENT-DIVALENT ION EXCHANGE---
      ELSE IF (IREACT.EQ.6) THEN
       C2=C*C
       AA=CTOT-C
       BB=C2*EK
       CC=-EKCEC*C2
       CBAR=QUADX(AA,BB,CC,1.D0)
       RDCOEF=1.+C3*CBAR/C
       DCBAR=(CBAR*CBAR-CBAR*2.*C*EK+2.*C*EKCEC)/
     1       ((CTOT-C)*2.*CBAR+C2*EK)
       RF2=1.+C3*DCBAR
C
C     ---DIVALENT-MONOVALENT ION EXCHANGE---
      ELSE
       C2=C*C
       AA=4.D0*EK*C
       BB=-4.D0*C4*C-C6+4.D0*C*CTOT-C2*4.D0
       CC=C5*C
       CBAR=QUADX(AA,BB,CC,-1.D0)
       RDCOEF=1.+C3*CBAR/C
       A=(-4.*CBAR*CBAR*EK-CBAR*(-4.*C4+4.*CTOT-8.*C)-C5)
       B=(4.*EK*C*(2.*CBAR-CEC)-C6+4.*C*CTOT-4.*C2)
       IF (B.EQ.0.0) THEN
        RF2=1.+C3*1.E-10
       ELSE
        RF2=1.+C3*A/B
       END IF
      END IF
      RETURN
      END
C     ***  SORB2  ******************************************************
C
      FUNCTION SORB2(CONC)
C
C     ******************************************************************
      DOUBLE PRECISION AA,BB,CC,QUADX
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6
C     ******************************************************************
C     ---SORB2 IS SORBED CONCENTRATION CORRESPONDING TO CONC IN SOLUTION
C
      SORB2=0.0
      IF (IREACT.LE.1) RETURN
      C=CONC
      IF (C.LE.CZERO) RETURN
C
C     ---FREUNDLICH ISOTHERM---
      IF (IREACT.EQ.2) THEN
       SORB2=EKF*C**XNF
C
C     ---LANGMUIR ISOTHERM---
      ELSE IF (IREACT.EQ.3) THEN
       SORB2=EKLCEC*C/(1.+EKL*C)
C
```

```
C     ---MONOVALENT ION EXCHANGE---                                     K1030
      ELSE IF (IREACT.EQ.4) THEN                                        K1040
       SORB2=EKCEC*C/(C*(EK-1.)+CTOT)                                   K1050
C                                                                       K1060
C     ---DIVALENT ION EXCHANGE---                                       K1070
      ELSE IF (IREACT.EQ.5) THEN                                        K1080
       SORB2=EKCEC*C/(2.*C*(EK-1.)+CTOT)                                K1090
C                                                                       K1100
C     ---MONOVALENT-DIVALENT ION EXCHANGE---                            K1110
      ELSE IF (IREACT.EQ.6) THEN                                        K1120
       AA=CTOT-C                                                        K1130
       C2=C*C                                                           K1140
       BB=C2*EK                                                         K1150
       CC=-EKCEC*C2                                                     K1160
       SORB2=QUADX(AA,BB,CC,1.D0)                                       K1170
C                                                                       K1180
C     ---DIVALENT-MONOVALENT ION EXCHANGE---                            K1190
      ELSE                                                              K1200
       AA=4.D0*EK*C                                                     K1210
       C2=C*C                                                           K1220
       BB=-4.D0*C4*C-C6+4.D0*C*CTOT-C2*4.D0                             K1230
       CC=C5*C                                                          K1240
       SORB2=QUADX(AA,BB,CC,-1.D0)                                      K1250
      END IF                                                            K1260
      RETURN                                                            K1270
      END                                                               K1280
C     ***  QUADX  ***************************************************** K1290
C                                                                       K1300
      DOUBLE PRECISION FUNCTION QUADX(A,B,C,D)                          K1310
C                                                                       K1320
C     ***************************************************************** K1330
      DOUBLE PRECISION A,B,C,D,T                                        K1340
C     ---SOLVE QUADRATIC EQUATION---                                    K1350
      T=B*B-4.D0*A*C                                                    K1360
      IF (T.LT.0.0) THEN                                                K1370
       QUADX=-B/(2.D0*A)                                                K1380
      ELSE                                                              K1390
       QUADX=(-B+D*DSQRT(T))/(2.D0*A)                                   K1400
      END IF                                                            K1410
      RETURN                                                            K1420
      END                                                               K1430


$LARGE
      SUBROUTINE VELO                                                   E  10
      DOUBLE PRECISION DMIN1,DEXP,DLOG,DABS                             E  20
      DOUBLE PRECISION TMRX,VPRM,HI,HR,HC,HK,WT,REC,RECH,TIM,AOPT,TITLE E  30
      DOUBLE PRECISION XDEL,YDEL,S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,   E  40
     1                 HMIN,PYR,ANFCTR                                  E  42
      DOUBLE PRECISION RATE,SLEAK,DIV                                   E  50
      COMMON /PRMJ/ NTIM,NPMP,NPNT,NITP,N,NX,NY,NP,NREC,INT,NNX,NNY,    E  61
     1              NUMOBS,NMOV,IMOV,NPMAX,ITMAX,NZCRIT,IPRNT,NPTPND,   E  71
     2              NPNTMV,NPNTVL,NPNTD,NPNCHV,NPDELC,ICHK              E  82
      COMMON /HEDA/ THCK(040,040),TMWL(05,50),TMOBS(50)                SE 111
      COMMON /HEDB/ TMRX(040,040,2),VPRM(040,040),HI(040,040),         SE 121
     1              HR(040,040),HC(040,040),HK(040,040),WT(040,040),   SE 131
     2 REC(040,040),RECH(040,040),TIM(100),AOPT(20),TITLE(10),XDEL,YDEL,SE 135
     3              S,AREA,SUMT,RHO,PARAM,TEST,TOL,PINT,HMIN,PYR,ANFCTR E 141
      COMMON /HEDC/ MX,MY,MMX,MMY,NMX,NMY,MCHK                         SE 145
      COMMON /CHMA/ PART(3,06400),CONC(020,020),TMCN(05,50),VX(040,040),SE 162
     1              VY(040,040),CONINT(020,020),CNRECH(020,020),POROS, SE 171
     2              SUMTCH,BETA,TIMV,STORM,STORMI,CMSIN,CMSOUT,FLMIN,   E 175
     3              FLMOT,SUMIO,CELDIS,DLTRAT,CSTORM                    E 181
      COMMON /CHMC/ SUMC(020,020),VXBDY(040,040),VYBDY(040,040)        SE 192
      COMMON /DIFUS/ DISP(020,020,4)                                    E 201
      COMMON /CHMR/ RF,DK,RHOB,THALF,DECAY,ADSORB,SORBI,DMASS1,CSTM2,   E 206R
     1              EKF,XNF,XNFM1,FCTRF,EKL,CEC,EKLCEC,FCTRL,CINMAX,    E 207R
     2        RF2MIN,RF2MAX,CZERO,IREACT,EK,EKCEC,FCTRE,CTOT,C3,C4,C5,C6 E 208R
C     ***************************************************************   E 210
C      DO NOT RECOMPUTE VELOCITY OR DISP.COEFS FOR STEADY-STATE FLOW    E 212
      ISOLV=1                                                           E 213
      IF (S.EQ.0.0.AND.ICHK.EQ.0.AND.(N.GT.1.OR.INT.GT.1)) THEN         E 214
       ISOLV=0                                                          E 215
       GO TO 28                                                         E 216
      END IF                                                            E 217
C     ---COMPUTE VELOCITIES AND STORE---                                E 220
      VMAX=1.0E-10                                                      E 230
      VMAY=1.0E-10                                                      E 240
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      VMXBD=1.0E-10                                                      E 250
      VMYBD=1.0E-10                                                      E 260
      TMV=TIM(N)*1.0E5                                                   E 275
      LIM=0                                                              E 280
      MAXX=0                                                             E 284
      MAXY=0                                                             E 285
      MAXVXI=0                                                           E 286
      MAXVXJ=0                                                           E 287
      MAXVYI=0                                                           E 288
      MAXVYJ=0                                                           E 289
C                                                                        E 290
      DO 20 IX=1,NX                                                      E 300
      DO 20 IY=1,NY                                                      E 310
      IF (IX.GT.NMX.OR.IY.GT.NMY) GO TO 12                              SE 315
      DO 10 IZ=1,4                                                       E 320
   10 DISP(IX,IY,IZ)=0.0                                                 E 330
C                                                                        E 340
   12 JCK=0                                                             SE 343
      IF (IX.LT.(MX-1).OR.IY.LT.(MY-1).OR.IX.GT.(MMX+1).OR.IY.GT.(MMY+1) SE 344
     1) JCK=1                                                           SE 345
      IF (THCK(IX,IY).EQ.0.0) GO TO 20                                   E 350
      RATE=REC(IX,IY)/AREA                                               E 360
      SLEAK=(HK(IX,IY)-WT(IX,IY))*VPRM(IX,IY)                            E 370
      DIV=0.D0                                                           E 381
      IF (RATE.LT.0.0) DIV=RATE                                          E 382
      IF (SLEAK.LT.0.0) DIV=DIV+SLEAK                                    E 383
      IF (RECH(IX,IY).LT.0.0) DIV=DIV+RECH(IX,IY)                        E 384
C                                                                        E 390
C        ---VELOCITIES AT CELL BOUNDARIES---                             E 580
C           TERM SAVED IS VELOCITY*THICKNESS*POROSITY                    E 582
      VXBDY(IX,IY)=TMRX(IX,IY,1)*(HK(IX,IY)-HK(IX+1,IY))                 E 585
      VYBDY(IX,IY)=TMRX(IX,IY,2)*(HK(IX,IY)-HK(IX,IY+1))                 E 595
C        ---VELOCITIES AT NODES---                                       E 605
C           TEMPORARILY SAVE SEEPAGE VELOCITY FOR PRINTING               E 607
      VX(IX,IY)=(0.5*(VXBDY(IX,IY)+VXBDY(IX-1,IY)))/THCK(IX,IY)          E 615
      VY(IX,IY)=(0.5*(VYBDY(IX,IY)+VYBDY(IX,IY-1)))/THCK(IX,IY)          E 625
      IF (JCK.EQ.0) THEN                                                SE 645
       IF (THCK(IX+1,IY).NE.0.0.AND.THCK(IX+1,IY).LT.THCK(IX,IY)) THEN   E 646
        ABVX=ABS(VXBDY(IX,IY))/THCK(IX+1,IY)                             E 647
       ELSE                                                              E 648
        ABVX=ABS(VXBDY(IX,IY))/THCK(IX,IY)                               E 649
       END IF                                                            E 651
       IF (THCK(IX,IY+1).NE.0.0.AND.THCK(IX,IY+1).LT.THCK(IX,IY)) THEN   E 652
        ABVY=ABS(VYBDY(IX,IY))/THCK(IX,IY+1)                             E 653
       ELSE                                                              E 654
        ABVY=ABS(VYBDY(IX,IY))/THCK(IX,IY)                               E 655
       END IF                                                            E 656
       IF (ABVX.GT.VMXBD) THEN                                           E 672
         VMXBD=ABVX                                                      E 673
         MAXVXI=IX                                                       E 674
         MAXVXJ=IY                                                       E 675
       END IF                                                            E 676
       IF (ABVY.GT.VMYBD) THEN                                           E 682
         VMYBD=ABVY                                                      E 683
         MAXVYI=IX                                                       E 684
         MAXVYJ=IY                                                       E 685
       END IF                                                            E 686
      END IF                                                            SE 687
C                                                                        E 690
      IF (DIV.GE.0.0) GO TO 20                                           E 700
      IF (JCK.GT.0) GO TO 20                                            SE 705
      TDIV=THCK(IX,IY)/DABS(DIV)                                         E 712
      IF (TDIV.GE.TMV) GO TO 20                                          E 722
      TMV=TDIV                                                           E 724
      MAXX=IX                                                            E 725
      MAXY=IY                                                            E 726
   20 CONTINUE                                                           E 728
      TMV=TMV*RF*RF2MIN                                                 E 729R
C       IF OUTPUT OF VELOCITIES ON CELL BOUNDARIES IS DESIRED,          E 731A
C        SEE LINES E 732, E 795A, E 839, E 909, E 986A, E1027A, AND E2399 E 731B
C      ACTIVATE NEXT 6 LINES TO COMPUTE BOUNDARY VELOCITIES FOR PRINTING E 732
C     DO 25 IY=2,NNY                                                     E 733
C     DO 25 IX=2,NNX                                                     E 734
C     IF (THCK(IX,IY).EQ.0.0) GO TO 25                                   E 735
C     VXBDY(IX,IY)=VXBDY(IX,IY)/(THCK(IX,IY)+THCK(IX+1,IY))*2.           E 736
C     VYBDY(IX,IY)=VYBDY(IX,IY)/(THCK(IX,IY)+THCK(IX,IY+1))*2.           E 737
C  25 CONTINUE                                                           E 738
C     ***************************************************************    E 740
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C     ---PRINT VELOCITIES---                                            E 750
   28 IF (NPNTVL.EQ.0) GO TO 80                                         E 761
      IF (NPNTVL.EQ.-2.AND.(N.EQ.NTIM.OR.IPRNT.EQ.1)) GO TO 30          E 771
      IF (NPNTVL.EQ.-1.AND.N.EQ.1) GO TO 30                             E 781
      IF (MOD(N,NPNTVL).EQ.0) GO TO 30                                  E 785
      GO TO 80                                                          E 790
   30 IF (ISOLV.EQ.0) THEN                                              E 792
       DO 32 IY=2,NNY                                                   E 793A
       DO 32 IX=2,NNX                                                   E 793B
       IF (THCK(IX,IY).EQ.0.0) GO TO 32                                 E 793C
       VX(IX,IY)=VX(IX,IY)/THCK(IX,IY)                                  E 794A
       VY(IX,IY)=VY(IX,IY)/THCK(IX,IY)                                  E 794B
C       ACTIVATE NEXT 2 LINES IF BOUNDARY VELOCITIES PRINTED            E 795A
C      VXBDY(IX,IY)=2.0*VXBDY(IX,IY)/(THCK(IX,IY)+THCK(IX+1,IY))        E 795B
C      VYBDY(IX,IY)=2.0*VYBDY(IX,IY)/(THCK(IX,IY)+THCK(IX,IY+1))        E 795C
   32  CONTINUE                                                         E 796
       ISOLV=-1                                                         E 797
      END IF                                                            E 798
      WRITE (6,320)                                                     E 801
      WRITE (6,330)                                                     E 810
      DO 40 IY=1,NY                                                     E 820
   40 WRITE (6,350) (VX(IX,IY),IX=1,NX)                                 E 830
C      ACTIVATE NEXT 3 LINES TO PRINT BOUNDARY VELOCITIES               E 839
C     WRITE (6,340)                                                     E 840
C     DO 50 IY=1,NY                                                     E 850
C  50 WRITE (6,350) (VXBDY(IX,IY),IX=1,NX)                              E 860
      WRITE (6,360)                                                     E 870
      WRITE (6,330)                                                     E 880
      DO 60 IY=1,NY                                                     E 890
   60 WRITE (6,350) (VY(IX,IY),IX=1,NX)                                 E 900
C      ACTIVATE NEXT 3 LINES TO PRINT BOUNDARY VELOCITIES               E 909
C     WRITE (6,340)                                                     E 910
C     DO 70 IY=1,NY                                                     E 920
C  70 WRITE (6,350) (VYBDY(IX,IY),IX=1,NX)                              E 930
C     ---WRITE VELOCITIES TO FILE UNIT 7---                             E 941
   80 IF (NPNCHV.EQ.0) GO TO 110                                        E 950
CTS   IF (NPNCHV.EQ.-2.AND.(N.EQ.NTIM.OR.IPRNT.EQ.1)) GO TO 90          E 961
CTS   IF (NPNCHV.EQ.-1.AND.N.EQ.1) GO TO 90                             E 971
CTS   IF (MOD(N,NPNCHV).EQ.0) GO TO 90                                  E 975
      IF(NPNCHV.EQ.-1.AND.(N.EQ.NTIM)) GO TO 90
      GO TO 110                                                         E 980
   90 IF (ISOLV.EQ.0) THEN                                              E 982
       DO 92 IY=2,NNY                                                   E 983A
       DO 92 IX=2,NNX                                                   E 983B
       IF (THCK(IX,IY).EQ.0.0) GO TO 92                                 E 984
       VX(IX,IY)=VX(IX,IY)/THCK(IX,IY)                                  E 985A
       VY(IX,IY)=VY(IX,IY)/THCK(IX,IY)                                  E 985B
C       ACTIVATE NEXT 2 LINES IF BOUNDARY VELOCITIES PRINTED            E 986A
C      VXBDY(IX,IY)=2.0*VXBDY(IX,IY)/(THCK(IX,IY)+THCK(IX+1,IY))        E 986B
C      VYBDY(IX,IY)=2.0*VYBDY(IX,IY)/(THCK(IX,IY)+THCK(IX,IY+1))        E 986C
   92  CONTINUE                                                         E 987
       ISOLV=-1                                                         E 988
      END IF                                                            E 989
CTS   WRITE (7,510) NX,NY,XDEL,YDEL,VMAX,VMAY                           E 991
CTS   DO 100 IY=1,NY                                                    E1000
CTS   WRITE (7,520) (VX(IX,IY),IX=1,NX)                                 E1010
CTS 100 WRITE (7,520) (VY(IX,IY),IX=1,NX)                               E1020
C      SAVE VELOCITY*THICKNESS*POROSITY                                 E1021
  110 IF (ISOLV.EQ.0) GO TO 240                                         E1022A
      DO 112 IY=2,NNY                                                   E1022B
      DO 112 IX=2,NNX                                                   E1023
      IF (THCK(IX,IY).EQ.0.0) GO TO 112                                 E1024
      VX(IX,IY)=VX(IX,IY)*THCK(IX,IY)                                   E1025
      VY(IX,IY)=VY(IX,IY)*THCK(IX,IY)                                   E1026
C      ACTIVATE NEXT 2 LINES IF BOUNDARY VELOCITIES PRINTED             E1027A
C     VXBDY(IX,IY)=VXBDY(IX,IY)*0.5*(THCK(IX,IY)+THCK(IX+1,IY))         E1027B
C     VYBDY(IX,IY)=VYBDY(IX,IY)*0.5*(THCK(IX,IY)+THCK(IX,IY+1))         E1027C
  112 CONTINUE                                                          E1028
      IF (ISOLV.NE.1) GO TO 240                                         E1029
C     ******************************************************************E1030
C     ---COMPUTE NEXT TIME STEP---                                      E1040
      WRITE (6,390)                                                     E1051
      WRITE (6,410) VMXBD,VMYBD                                         E1070
      IF (IREACT.LE.0) GO TO 115                                        E1072R
      VMXBD=VMXBD/(RF*RF2MIN)                                           E1077R
      VMYBD=VMYBD/(RF*RF2MIN)                                           E1078R
      WRITE (6,394) VMXBD,VMYBD                                         E1079R
  115 TDELXB=CELDIS*XDEL/VMXBD                                          E1082R
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      TDELYB=CELDIS*YDEL/VMYBD                                          E1110
      ITCD=0                                                            E1111
      IF (TDELYB.LT.TDELXB) ITCD=1                                      E1112
      TIMV=AMIN1(TDELXB,TDELYB)                                         E1121
      IF (AMAX1(VMXBD,VMYBD).LE.1.0E-10) WRITE(6,570)                   E1126
      WRITE (6,310) TMV,TIMV                                            E1130
      IF (TMV.LT.TIMV) GO TO 120                                        E1140
      LIM=-1                                                            E1150
      GO TO 130                                                         E1160
  120 TIMV=TMV                                                          E1170
      LIM=1                                                             E1180
  130 NTIMV=TIM(N)/TIMV                                                 E1190
      NMOV=NTIMV+1                                                      E1200
      WRITE (6,420) TIMV,NTIMV,NMOV                                     E1210
      TIMV=TIM(N)/NMOV                                                  E1220
      WRITE (6,370) TIM(N)                                              E1230
      WRITE (6,380) TIMV                                                E1240
C                                                                       E1250
      IF (BETA.EQ.0.0) GO TO 200                                        E1260
C     ******************************************************************E1270
C     ---COMPUTE DISPERSION COEFFICIENTS---                             E1280
      ALPHA=BETA                                                        E1290
      ALNG=ALPHA                                                        E1300
      TRAN=DLTRAT*ALPHA                                                 E1310
      XX2=XDEL*XDEL                                                     E1320
      YY2=YDEL*YDEL                                                     E1330
      XY2=4.0*XDEL*YDEL                                                 E1340
      DO 150 IX=2,MMX                                                  SE1351
      DO 150 IY=2,MMY                                                  SE1361
      IF (THCK(IX,IY).EQ.0.0) GO TO 150                                 E1370
      JX=IX-MX+1                                                       SE1375
      JY=IY-MY+1                                                       SE1376
      IF (JX.LT.1.OR.JY.LT.1) GO TO 150                                SE1377
      VXE=VXBDY(IX,IY)                                                  E1380
      VYS=VYBDY(IX,IY)                                                  E1390
      IF (THCK(IX+1,IY).EQ.0.0) GO TO 140                               E1400
      IF ((IX+1).GT.MMX) GO TO 140                                     SE1405
C        ---FORWARD COEFFICIENTS: X-DIRECTION---                        E1410
      VYE=(VYBDY(IX,IY-1)+VYBDY(IX+1,IY-1)+VYS+VYBDY(IX+1,IY))/4.0      E1420
      VXE2=VXE*VXE                                                      E1430
      VYE2=VYE*VYE                                                      E1440
      VMGE=SQRT(VXE2+VYE2)                                              E1450
      IF (VMGE.LT.1.0E-20) GO TO 140                                    E1460
      DALN=ALNG*VMGE                                                    E1470
      DTRN=TRAN*VMGE                                                    E1480
      VMGE2=VMGE*VMGE                                                   E1490
C           ---XX COEFFICIENT---                                        E1500
      DISP(JX,JY,1)=(DALN*VXE2+DTRN*VYE2)/(VMGE2*XX2)                  SE1511
C           ---XY COEFFICIENT---                                        E1520
      IF ((IY-1).LT.MY.OR.(IY+1).GT.MMY) GO TO 140                     SE1525
      DISP(JX,JY,3)=(DALN-DTRN)*VXE*VYE/(VMGE2*XY2)                    SE1531
C        ---FORWARD COEFFICIENTS: Y-DIRECTION---                        E1540
  140 IF (THCK(IX,IY+1).EQ.0.0) GO TO 150                               E1550
      IF ((IY+1).GT.MMY) GO TO 150                                     SE1555
      VXS=(VXBDY(IX-1,IY)+VXE+VXBDY(IX-1,IY+1)+VXBDY(IX,IY+1))/4.0      E1560
      VYS2=VYS*VYS                                                      E1570
      VXS2=VXS*VXS                                                      E1580
      VMGS=SQRT(VXS2+VYS2)                                              E1590
      IF (VMGS.LT.1.0E-20) GO TO 150                                    E1600
      DALN=ALNG*VMGS                                                    E1610
      DTRN=TRAN*VMGS                                                    E1620
      VMGS2=VMGS*VMGS                                                   E1630
C           ---YY COEFFICIENT---                                        E1640
      DISP(JX,JY,2)=(DALN*VYS2+DTRN*VXS2)/(VMGS2*YY2)                  SE1651
C           ---YX COEFFICIENT---                                        E1660
      IF ((IX-1).LT.MX.OR.(IX+1).GT.MMX) GO TO 150                     SE1665
      DISP(JX,JY,4)=(DALN-DTRN)*VXS*VYS/(VMGS2*XY2)                    SE1671
  150 CONTINUE                                                          E1680
C     ******************************************************************E1690
C     ---ADJUST CROSS-PRODUCT TERMS FOR ZERO THICKNESS---               E1700
      DO 160 IX=2,MMX                                                  SE1711
      DO 160 IY=2,MMY                                                  SE1721
      JX=IX-MX+1                                                       SE1725
      JY=IY-MY+1                                                       SE1726
      IF (JX.LT.1.OR.JY.LT.1) GO TO 160                                SE1727
      IF (THCK(IX,IY+1).EQ.0.0.OR.THCK(IX+1,IY+1).EQ.0.0.OR.THCK(IX,IY-1E1730
     1).EQ.0.0.OR.THCK(IX+1,IY-1).EQ.0.0) DISP(JX,JY,3)=0.0            SE1741
      IF (THCK(IX+1,IY).EQ.0.0.OR.THCK(IX+1,IY+1).EQ.0.0.OR.THCK(IX-1,IYE1750
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     1).EQ.0.0.OR.THCK(IX-1,IY+1).EQ.0.0) DISP(JX,JY,4)=0.0             SE1761
  160 CONTINUE                                                           E1770
C     ***************************************************************   E1780
C     ---CHECK FOR STABILITY OF EXPLICIT METHOD---                       E1790
      TIMDIS=0.0                                                         E1800
      DO 170 IX=1,NMX                                                   SE1811
      DO 170 IY=1,NMY                                                   SE1821
      JX=IX+MX-1                                                        SE1822
      JY=IY+MY-1                                                        SE1823
      IF (THCK(JX,JY).LE.0.0) GO TO 170                                 SE1824
      IF (IX.EQ.1) THEN                                                  E1825
       DISPX=DISP(IX,IY,1)                                               E1826
      ELSE                                                               E1827
       DISPX=AMAX1(DISP(IX,IY,1),DISP(IX-1,IY,1))                        E1828
      END IF                                                             E1832
      IF (IY.EQ.1) THEN                                                  E1833
       DISPY=DISP(IX,IY,2)                                               E1834
      ELSE                                                               E1835
       DISPY=AMAX1(DISP(IX,IY,2),DISP(IX,IY-1,2))                        E1836
      END IF                                                             E1837
      TDCO=(DISPX+DISPY)/THCK(JX,JY)                                    SE1838
      IF (TDCO.GT.TIMDIS) TIMDIS=TDCO                                    E1839
  170 CONTINUE                                                           E1841
      TIMDC=0.5*RF*RF2MIN/TIMDIS                                         E1852R
      WRITE (6,440) TIMDC                                                E1860
      NTIMD=TIM(N)/TIMDC                                                 E1870
      NDISP=NTIMD+1                                                      E1880
      IF (NDISP.LE.NMOV) GO TO 180                                       E1890
      NMOV=NDISP                                                         E1900
      TIMV=TIM(N)/NMOV                                                   E1910
      LIM=0                                                              E1920
  180 WRITE (6,430) TIMV,NTIMD,NMOV                                      E1930
C     ***************************************************************   E2040
  200 IF (NMOV.EQ.1) GO TO 235                                           E2052
      IF (LIM) 210,220,230                                               E2054
  210 WRITE (6,530)                                                      E2060
      IF (ITCD.GT.0) THEN                                                E2062
         MJ=MAXVYJ+1                                                     E2063
         WRITE (6,534) MAXVYI,MAXVYJ,MAXVYI,MJ                           E2064
       ELSE                                                              E2065
         MI=MAXVXI+1                                                     E2066
         WRITE (6,535) MAXVXI,MAXVXJ,MI,MAXVXJ                           E2067
      END IF                                                             E2068
      GO TO 240                                                          E2070
  220 WRITE (6,540)                                                      E2080
      GO TO 240                                                          E2090
  230 WRITE (6,550)                                                      E2100
      WRITE (6,560) MAXX,MAXY                                            E2102
      GO TO 240                                                          E2104
  235 WRITE (6,580)                                                      E2106
C     ***************************************************************   E2110
C     ---PRINT DISPERSION EQUATION COEFFICIENTS---                       E2120
  240 IF (NPNTD.EQ.0) GO TO 300                                          E2130
      IF (NPNTD.EQ.2) GO TO 250                                          E2140
      IF (NPNTD.EQ.1.AND.N.EQ.1) GO TO 250                               E2150
      GO TO 300                                                          E2160
  250 WRITE (6,450)                                                      E2170
      WRITE (6,460)                                                      E2180
      DO 260 IY=1,NMY                                                   SE2191
  260 WRITE (6,500) (DISP(IX,IY,1),IX=1,NMX)                            SE2201
      WRITE (6,470)                                                      E2210
      DO 270 IY=1,NMY                                                   SE2221
  270 WRITE (6,500) (DISP(IX,IY,2),IX=1,NMX)                            SE2231
      WRITE (6,480)                                                      E2240
      DO 280 IY=1,NMY                                                   SE2251
  280 WRITE (6,500) (DISP(IX,IY,3),IX=1,NMX)                            SE2261
      WRITE (6,490)                                                      E2270
      DO 290 IY=1,NMY                                                   SE2281
  290 WRITE (6,500) (DISP(IX,IY,4),IX=1,NMX)                            SE2291
C     ***************************************************************   E2300
  300 RETURN                                                             E2310
C     ***************************************************************   E2320
C                                                                        E2330
C                                                                        E2340
C                                                                        E2350
  310 FORMAT (1H0,19H TMV (MAX. INJ.) = ,G12.5/20H  TIMV (CELDIS)    = ,G E2361R
     112.5)                                                              E2370
  320 FORMAT (1H1,12HX VELOCITIES)                                       E2380
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  330 FORMAT (1H ,25X,8HAT NODES/)                                       E2390
C      ACTIVATE NEXT LINE IF BOUNDARY VELOCITIES PRINTED                 E2399
C 340 FORMAT (1H0,25X,41HON BOUNDARIES (USING INTERFACE THICKNESS)/)     E2401
  350 FORMAT (1H ,1P10E12.3)                                             E2411
  360 FORMAT (1H1,12HY VELOCITIES)                                       E2420
  370 FORMAT (3H   ,11HTIM (N)  = ,1G12.5)                               E2430
  380 FORMAT (3H   ,11HTIMEVELO = ,1G12.5)                               E2440
  390 FORMAT (1H1,10X,29HSTABILITY CRITERIA --- M.O.C.//)                E2450
  394 FORMAT (1H0,5X,46HMAXIMUM EFFECTIVE SOLUTE VELOCITIES:  X-VEL = ,  E2453R
     1  1PE9.2,5X,8HY-VEL = ,1PE9.2)                                     E2454R
  410 FORMAT (1H0,5X,35HMAXIMUM FLUID VELOCITIES:  X-VEL = ,1PE9.2,5X,   E2471
     1  8HY-VEL = ,1PE9.2)                                               E2472
  420 FORMAT (1H0,8H TIMV = ,1PE9.2,5X,8HNTIMV = ,I5,5X,7HNMOV = ,I5/)   E2480
  430 FORMAT (1H0,8H TIMV = ,1PE9.2,5X,8HNTIMD = ,I5,5X,7HNMOV = ,I5)    E2490
  440 FORMAT (3H   ,11HTIMEDISP = ,1E12.5)                               E2500
  450 FORMAT (1H1,32HDISPERSION EQUATION COEFFICIENTS,10X,33H=(D-IJ)*(B) E2511
     1*(POROS)/(GRID FACTOR))                                            E2521
  460 FORMAT (1H0,35X,14HXX COEFFICIENT/)                                E2531
  470 FORMAT (1H0,35X,14HYY COEFFICIENT/)                                E2541
  480 FORMAT (1H0,35X,14HXY COEFFICIENT/)                                E2551
  490 FORMAT (1H0,35X,14HYX COEFFICIENT/)                                E2561
  500 FORMAT (1H ,1P10E11.2)                                             E2571
  510 FORMAT (2I4,2F10.1,2F10.7)                                         E2580
  520 FORMAT (8F10.7)                                                    E2590
  530 FORMAT (1H0,10X,42HTHE LIMITING STABILITY CRITERION IS CELDIS)     E2600
  534 FORMAT (1H ,4X,52HMAX. Y-VEL. IS CONSTRAINT AND OCCURS BETWEEN NOD E2602
     1ES (,I2,1H,,I2,7H) AND (,I2,1H,,I2,1H))                            E2603
  535 FORMAT (1H ,4X,52HMAX. X-VEL. IS CONSTRAINT AND OCCURS BETWEEN NOD E2604
     1ES (,I2,1H,,I2,7H) AND (,I2,1H,,I2,1H))                            E2605
  540 FORMAT (1H0,10X,40HTHE LIMITING STABILITY CRITERION IS BETA)       E2610
  550 FORMAT (1H0,10X,58HTHE LIMITING STABILITY CRITERION IS MAXIMUM INJ E2620
     1ECTION RATE)                                                       E2630
  560 FORMAT (1H ,15X,35HMAX. INJECTION OCCURS AT CELL IX = ,I3,7H  IY = E2635
     1 ,I3)                                                              E2636
  570 FORMAT (1H0,5X,47H*** WARNING ***  DECREASE CRITERIA IN E 230-260) E2637
  580 FORMAT (1H0,10X,63H*TIME INCREMENT FOR SOLUTE TRANSPORT EQUALS TIM E2638
     1E STEP FOR FLOW*)                                                  E2639
      END                                                                E2640-
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EXAMPLE DATA FILE (LPS6.DAT) FOR MOC MODEL

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VERTICAL TWO-DIMENSIONAL SOLUTE TRANSPORT MODEL, LAS PINAS (40X24), CASE6
   1   1 -40  246400   1   7   4 200   0   9   5 100  -2   2   1  -2   0
           2           3          21          22
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276.  0.112.  0.  0.  0.  0. 63.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
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 5  1.00       .215E+05  .694E-06 1
1  3.28
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   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.  10.   0.
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   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.  10.   0.
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   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
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