CASE STUDY

CS (AR) 171

PROCESSING OF GROUNDWATER DATA

आपो हिष्ठा मयोभुवः

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667 (INDIA)

1994-95

PREFACE

For proper assessment and management of groundwater resources, different types of groundwater data is collected. To make some preliminary inferences about the groundwater environment, processing of groundwater data is necessary.

Hydrological maps are commonly used to represent large amount of information about the water regimes of the surface and near surface of the earth. They display the information in its spatial relationships and in relationship to the configuration of the land itself. Groundwater mapping is a method of recording the results of investigations of the subsurface part of the hydrosphere.

In this report groundwater data for the Jabalpur District of Madhya Pradesh as provided by State Groundwater Board is used.

This report entitled "Processing of Groundwater Data" is part of the work programme of the Hydrological Information Systems Division of the institute for 1994-95 and has been prepared by Shri Vijay Kumar, Scientist-B under the guidence of Shri A.K. Bhar, Scientist-E.

(S.M. Seth)
Director

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Groundwater is a major source of water supply for a large portion of the world population. For its evaluation, rational development and management, various types of groundwater data is collected and stored in various forms. To represent the data in more informative and useful form, processing of this data is necessary. Groundwater maps provide large amount of information about the occurence and movement of groundwater. The distributed groundwater models require the spatial and temporal variation of aquifer parameters. Groundwater data, which is usually measured at random points, require interpolation.

This report deals with the processing of groundwater data for the Jabalpur District of Madhya Pradesh. Groundwater maps have been prepared. Polynomial interpolation technique has been used in the report for interpolation of groubdwater levels.

1.0 INTRODUCTION

Groundwater is a major source of water supply for a large portion of the world population. The evaluation, rational development and management of groundwater resources, which is very essential to feed the growing population, requires a through knowledge of the subsurface environment and an understanding of the hydrological processes that governs the occurrence, movement and yield of groundwater. To do this various types of groundwater data is collected and stored in various forms.

The processing of this basic data is necessary to represent the data in more informative and useful form so that the data becomes meaningful to make some preliminary inferences and for further use. The one way to represent the data is maps. Maps are graphic expression of data, information and interpretation. Maps of elements of hydrological cycle can be very valuable. This type of data presentation can convey a vivid and rapid impression on the areal variability of a parameter. If carefully prepared, maps can provide a large amount of information in a small space. Hydrological maps are usually applied maps which can be used for many purposes. They contribute to the solving technical and scientific problems i.e. regarding the use of groundwater or mode of its occurrence and movement.

For the analysis of complex groundwater flow problems, different types of models are used. In distributed models, the spatial and temporal variation of aquifer parameters is required. One such type of input is groundwater levels. The values are required to be measured at nodal points of a prespecified grid.

But in practice, these observations are taken at random points which do not coincide with nodal points. So, there is need to interpolate the values at nodal points to be used in different models. The observed point data can be employed to generate continuous functions which approximate the true functional relation between the waterlevel and the spatial coordinates. These functional relations can be used for the interpolation of the data.

Different methods of interpolation of spatial variables are available and are used. Methods available are based on distance weighing function, trend surface analysis and geostatistical techniques. In distance weighing function method, it is assumed that the value of any variable at any point depends on some function of distance between this point and other points. All the available software of contouring uses this method. Geostatistical methods are stochastic methods and assumes that the hydrological variables are too complex to be studied by deterministic expressions. Trend surface analysis involves fitting a polynomial between the measured variable and the space coordinates. Least square polynomial approximation is one such method of trend surface analysis. In this report the least square technique is used to fit a polynomial for interpolation.

The area selected for this study is Jabalpur district in Madhya Pradesh. The groundwater depth measurement was started in the year 1974 from 52 observation wells. The measurement is done twice a year i.e. premonsoon and postmonsoon. The location of observation wells in Jabalpur district is shown in Fig. 1. From the year 1986 onwards observations of groundwater depth are taken at 102 points. Fig. 2 shows the location of 102 observation wells in Jabalpur district.

Due to the lack of pump test data, the processing of groundwater data in this report is incomplete in some respect.

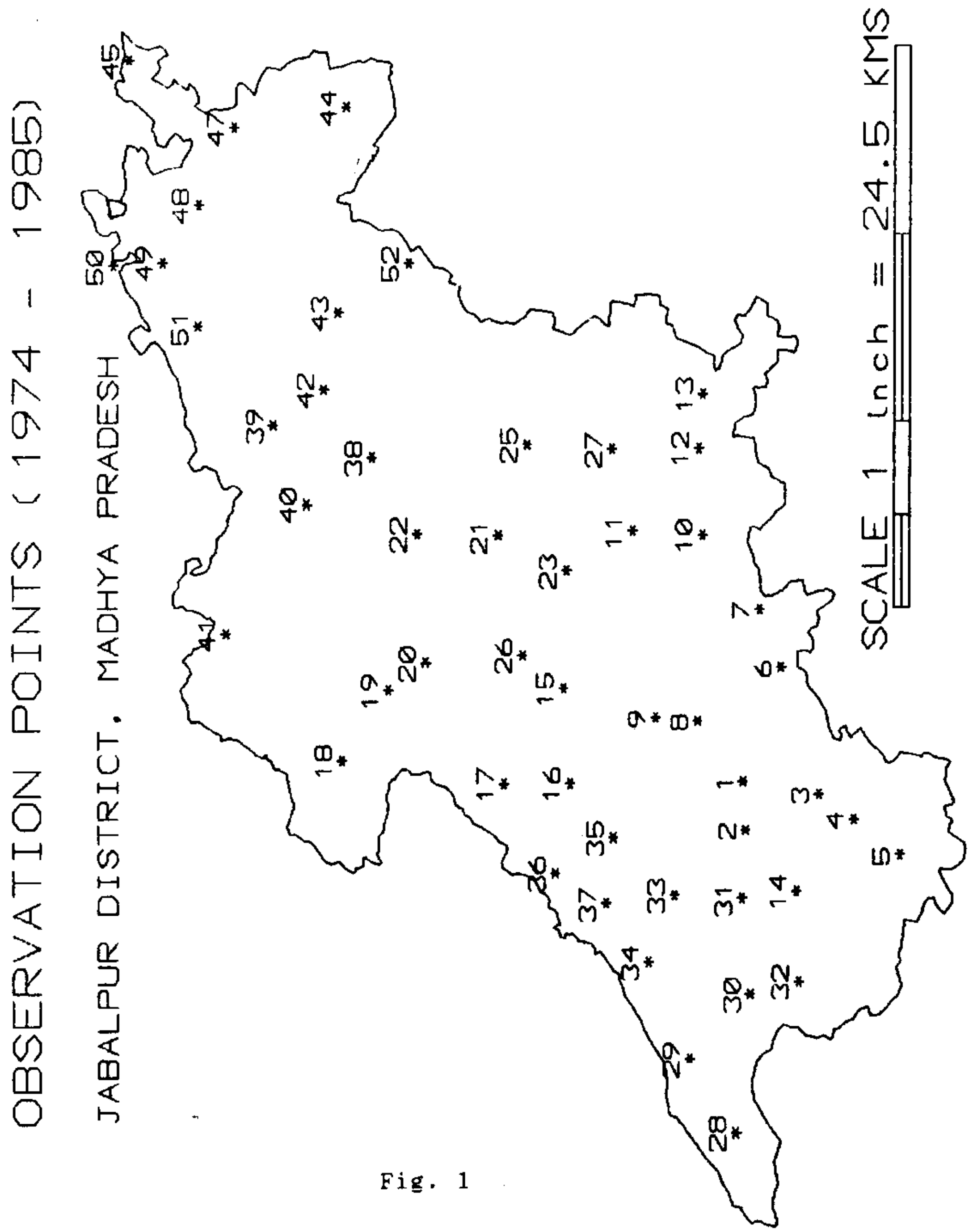

OBSERVATION POINTS (1974 - 1985)
JABALPUR DISTRICT, MADHYA PRADESH
SCALE 1 Inch = 24.5 KMS

Fig. 1

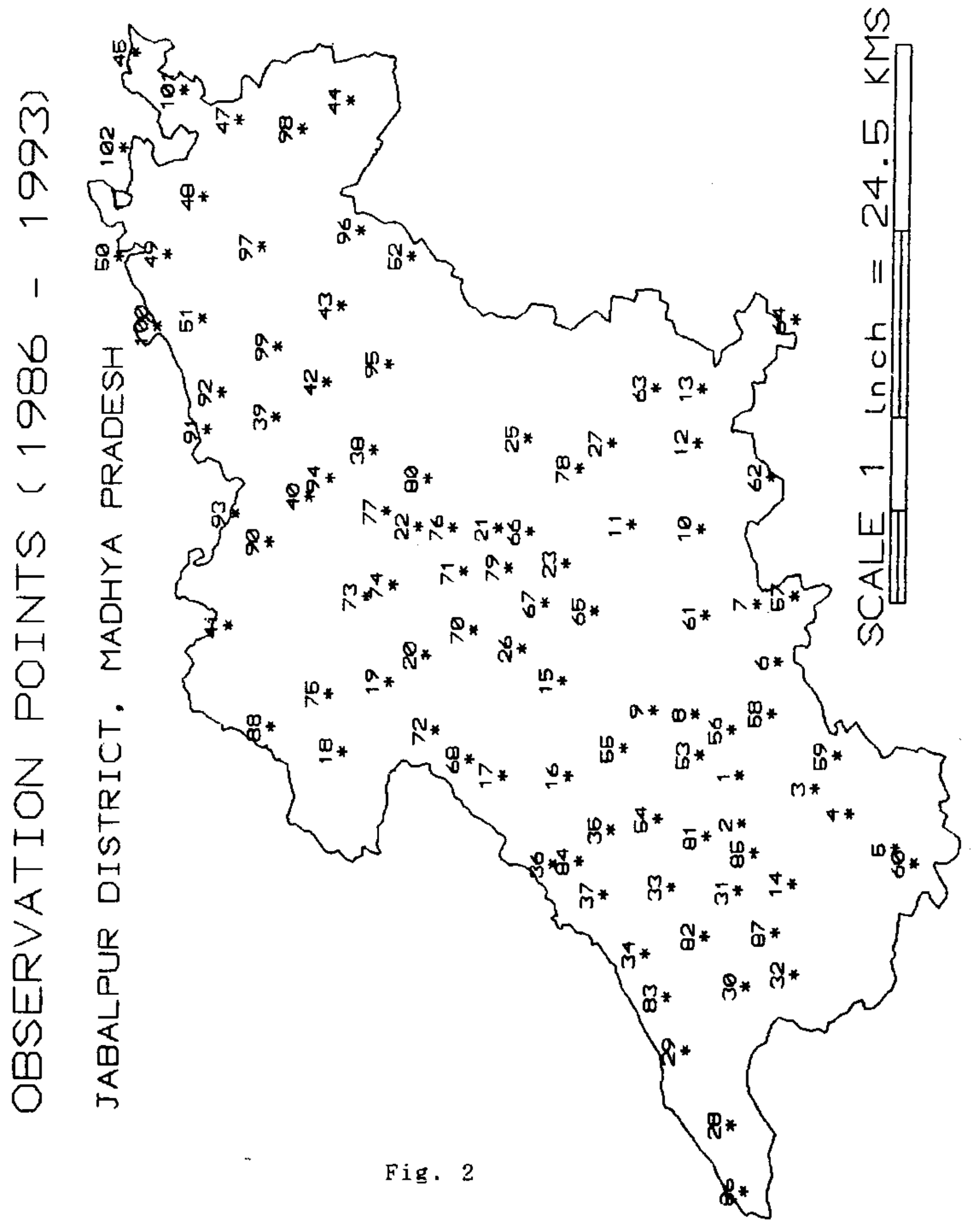

OBSERVATION POINTS (1986 - 1993)
JABALPUR DISTRICT, MADHYA PRADESH
SCALE 1 Inch = 24.5 KMS

Fig. 2

2.0 SUMMARY STATISTICS

The important features of the data can be captured by a few characteristics of data. It is known as summary statistics and includes measure of location, measures of spread and measures of shape.

The basic measure of location of data is some type of average value. Various measures like mode, median and arithmetic average exist. The arithmetic average, also referred as mean, is the commonly used characteristic. It is defined as the sum of all observations divided by the number of observation.

$$\bar{x} = \frac{1}{n} \sum x_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The measure of spread or dispersion about the mean is given by variance and the standard deviation. Variance is defined as the average squared deviation of all possible observations from the mean. It is given as

$$\sigma^2 = \frac{1}{n} \sum (x_i - \bar{x})^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Since it involves squared difference, the variance is sensitive to erratic high values. Standard deviation is often used instead of variance since its units are the same as the units of the variable being described. It is defined simply as the square root of variance.

A small value of standard deviation indicates that observations are clustered tightly around a central value. On the other hand, a large standard deviation indicates that values are scattered widely about the mean and the tendency for central clustering is weak.

The shape of the distribution is described by the coefficient of skewness and the coefficient of variation. Coefficient of skewness provides information on the symmetry while the coefficient of variation provides information on the length of the tail for certain type of distribution. Coefficient of skewness is the most commonly used statistic for summarising the symmetry of data. It is given as:

$$\text{Coeff. of skewness} = \frac{\frac{1}{n}\sum(x_i - \bar{x})^3}{\sigma^3} \quad \ldots\ldots(3)$$

It is defined as the average cubed difference between the data value and their mean divided by cube of standard deviation. Coefficient of skewness suffers even more than mean and variance from a sensitivity of erratic values. Quite often one does not use the magnitude of the coefficient of skewness but rather only its sign to describe the symmetry. A positively skewed data has some very high values and a negatively skewed data has some very small values. If the skewness is close to zero, the histogram of data is approximately symmetric.

Coefficient of variation is a statistics that is often used as an alternative to skewness to describe the shape of the distribution. it is used primarily for distributions whose values are all positive and whose skewness is also positive. It is defined as the ratio of standard deviation to the mean. A CV greater than one indicates the presence of some erratic high sample values. Table 1 and 2 shows the summary statistics of groundwater depth in premonsoon, postmonsoon season for the period 1974 -93 respectively. The summary statistics of groundwater fluctuation is given in Table 3.

Table 1. Summary Statistics of Groundwater Depth (Premonsoon Period)

YEAR	NO. OF POINTS	MEAN	VARI.	STD. DEVI.	COFF OF SKEWNESS	COFF OF VARI.
1974	52	8.11	10.66	3.27	.52	.40
1975	51	8.43	9.70	3.11	.50	.37
1976	50	8.11	9.12	3.02	.02	.37
1977	51	8.91	10.79	3.28	.01	.37
1978	52	7.90	10.08	3.17	.11	.40
1979	50	8.35	10.36	3.22	.11	.39
1980	40	9.59	10.52	3.24	.27	.34
1981	48	8.18	11.08	3.33	.56	.41
1982	52	8.51	10.57	3.25	.40	.38
1983	51	8.12	11.76	3.43	.34	.42
1984	51	8.15	12.08	3.48	.31	.43
1985	52	7.80	9.79	3.13	.37	.40
1986	61	7.93	12.16	3.49	1.26	.44
1987	100	8.02	12.76	3.57	.87	.45
1988	98	8.12	9.92	3.15	1.12	.39
1989	97	8.27	11.12	3.34	.99	.40
1990	101	8.22	10.40	3.23	.98	.39
1991	101	7.58	8.65	2.94	1.03	.39
1992	100	8.10	8.57	2.93	.59	.36
1993	99	7.93	8.88	2.98	.47	.38

Table 2. Summary Statistics of Groundwater Depth (Postmonsoon Period)

YEAR	NO. OF POINTS	MEAN	VARI.	STD. DEVI.	COFF OF SKEWNESS	COFF OF VARI.
1974	52	4.05	3.57	1.89	1.04	.47
1975	51	4.54	4.43	2.11	.45	.46
1976	50	5.00	4.79	2.19	.10	.44
1977	51	4.80	8.33	2.89	1.12	.60
1978	52	4.95	6.36	2.52	.16	.51
1979	50	7.16	10.35	3.22	.43	.45
1980	40	3.94	5.77	2.40	1.46	.61
1981	48	5.09	6.85	2.62	1.02	.51
1982	52	5.18	8.30	2.88	.86	.56
1983	51	4.13	6.89	2.62	1.04	.64
1984	51	4.27	6.98	2.64	.96	.62
1985	52	4.22	6.25	2.50	.74	.59
1986	61	4.90	6.72	2.59	.75	.53
1987	100	4.12	5.48	2.34	.89	.57
1988	98	4.80	5.76	2.40	.80	.50
1989	97	5.48	7.39	2.72	.85	.50
1990	101	3.95	5.02	2.24	1.19	.57
1991	101	4.61	6.01	2.45	1.04	.53
1992	100	4.17	6.11	2.47	1.01	.59
1993	99	4.19	6.61	2.57	.99	.61

Table 3. Summary Statistics of Groundwater Depth Fluctuation

YEAR	NO.OF POINTS	MEAN	VARI.	STD. DEVI.	COFF OF SKEWNESS	COFF OF VARI.
1974	52	4.07	7.06	2.66	1.58	.65
1975	51	3.90	3.16	1.78	.50	.46
1976	50	3.11	2.79	1.67	.54	.54
1977	51	4.11	6.84	2.62	.36	.64
1978	52	2.95	2.06	1.44	.19	.49
1979	50	1.19	2.16	1.47	.50	1.24
1980	40	5.65	7.01	2.65	1.03	.47
1981	48	3.09	3.89	1.97	.75	.64
1982	52	3.34	4.31	2.08	1.48	.62
1983	51	3.99	3.71	1.93	.94	.48
1984	51	3.87	3.81	1.95	.97	.50
1985	52	3.58	3.94	1.99	.77	.56
1986	61	3.03	4.20	2.05	1.07	.68
1987	100	3.91	7.84	2.80	1.44	.72
1988	98	3.32	4.83	2.20	2.07	.66
1989	97	2.79	4.43	2.10	1.44	.75
1990	101	4.27	4.36	2.09	.67	.49
1991	101	2.98	3.43	1.85	2.58	.62
1992	100	3.93	3.56	1.89	.65	.48
1993	99	3.74	4.65	2.16	.97	.58

3.0 GROUNDWATER MAPS

Groundwater maps provide a bank of information on gravitational water in the upper part of the lithosphere and also provides the basis for learning about and understanding the relationship between groundwater and its geological and hydrological environment. A great deal of information, both qualitative and quantitative, can be obtained from maps which show depth to groundwater and related data such as elevation of the water table. Such information is usually presented on maps showing lines of equal depth to water, contours of equal elevation of water table or lines of equal change in depth to water over a given period of time. Groundwater maps have been prepared for the Jabalpur District using SURFER software.

3.1 DEPTH TO WATER TABLE MAP

Depth to water table map, also known as isobath map, show the configuration of depth to water table from ground surface. Isobath lines are lines of equal depth to water table. These maps indicate at a glance the areas affected by high water table problems which is usually the criterion for determining the need for subsurface drainage. Prepared at regular intervals these maps indicate the seasonal variation of affected areas. In areas provided with subsurface drainage the isobath maps indicate the effectiveness of the drainage system in different parts of the area. Groundwater depth maps for the years 1974, 1980, 1985, 1990, 1993, for both premonsoon and postmonsoon season are given in Fig. 3 to Fig. 12.

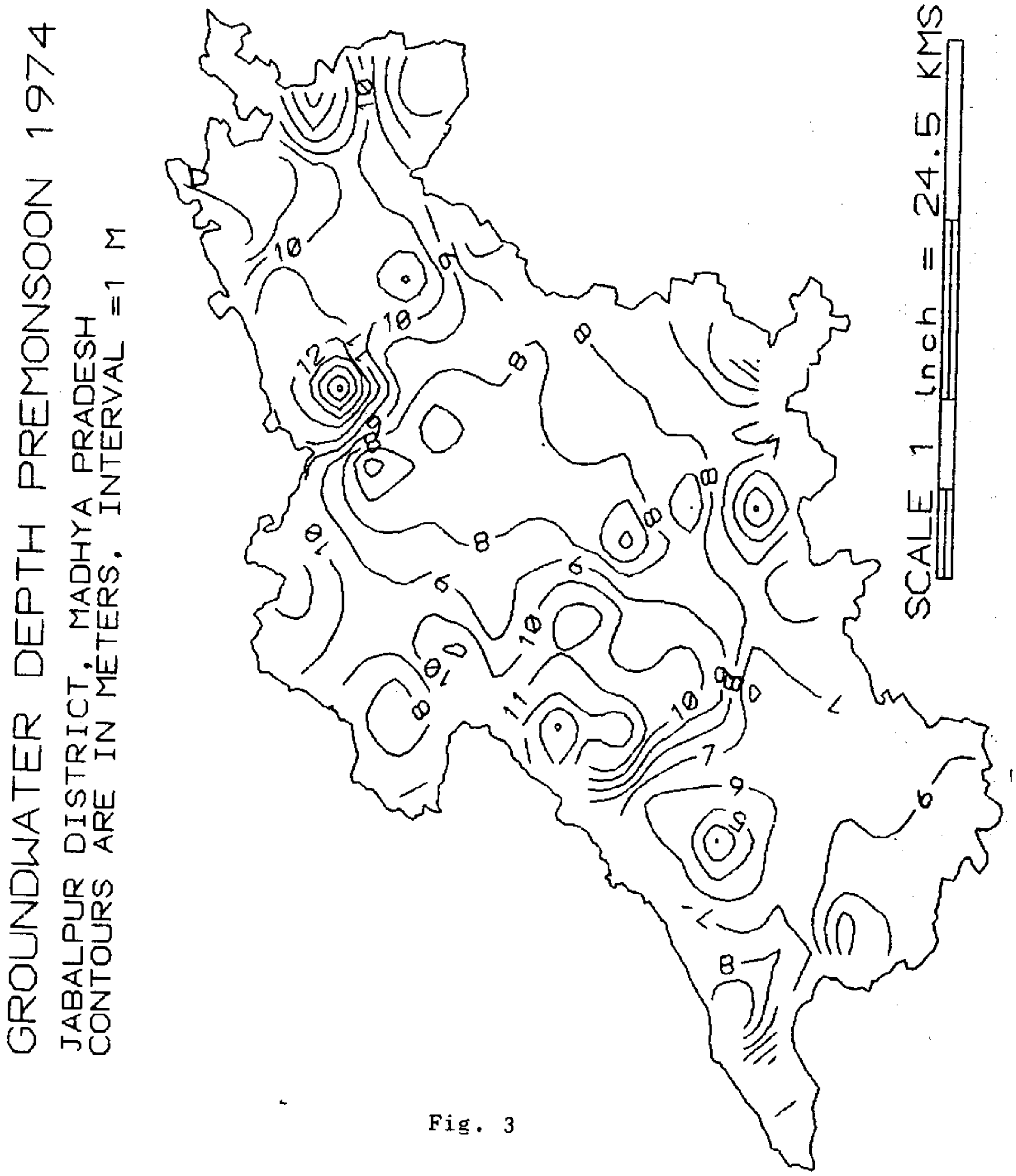

GROUNDWATER DEPTH PREMONSOON 1974
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 Inch = 24.5 KMS

Fig. 3

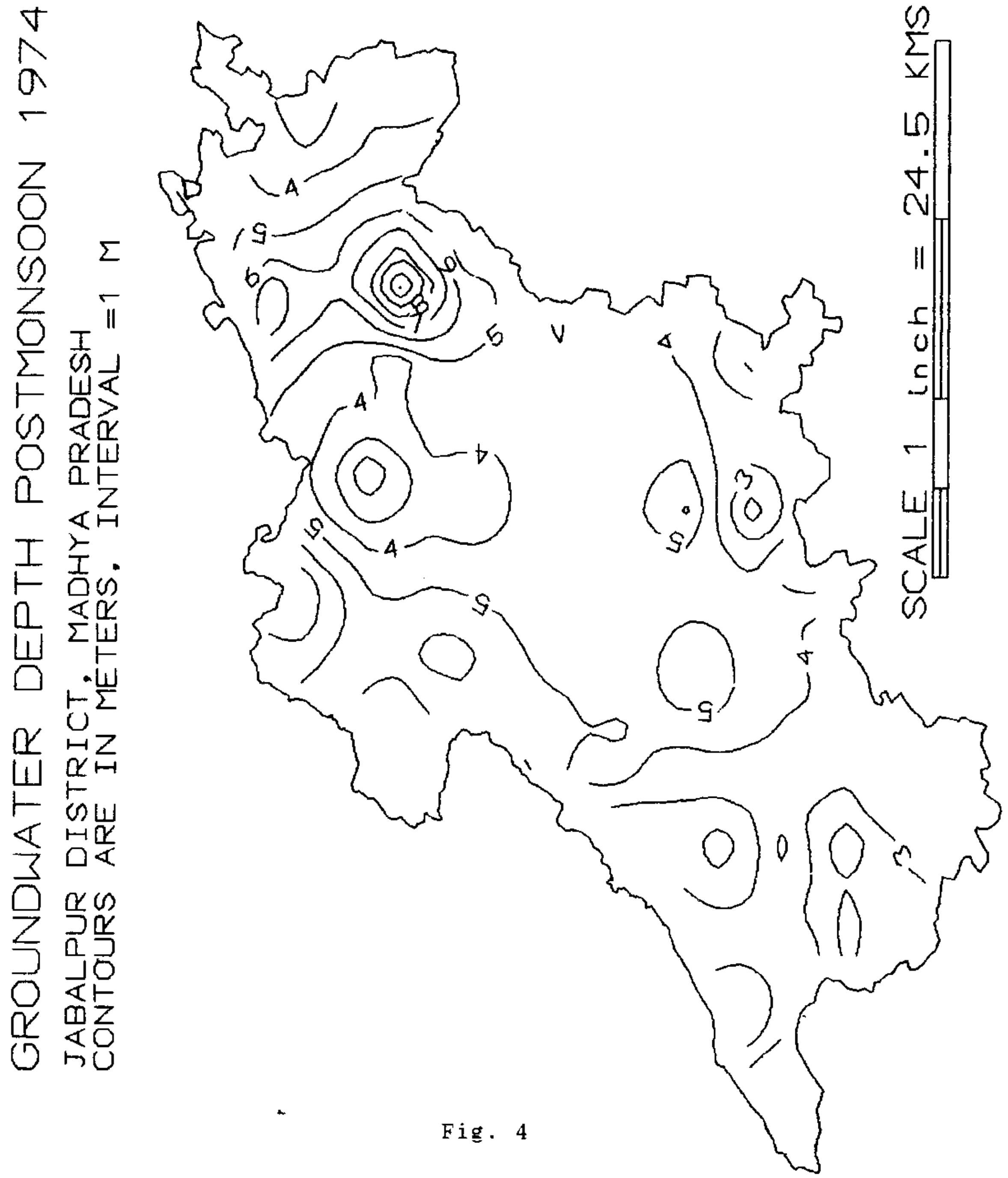

GROUNDWATER DEPTH POSTMONSOON 1974
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 4

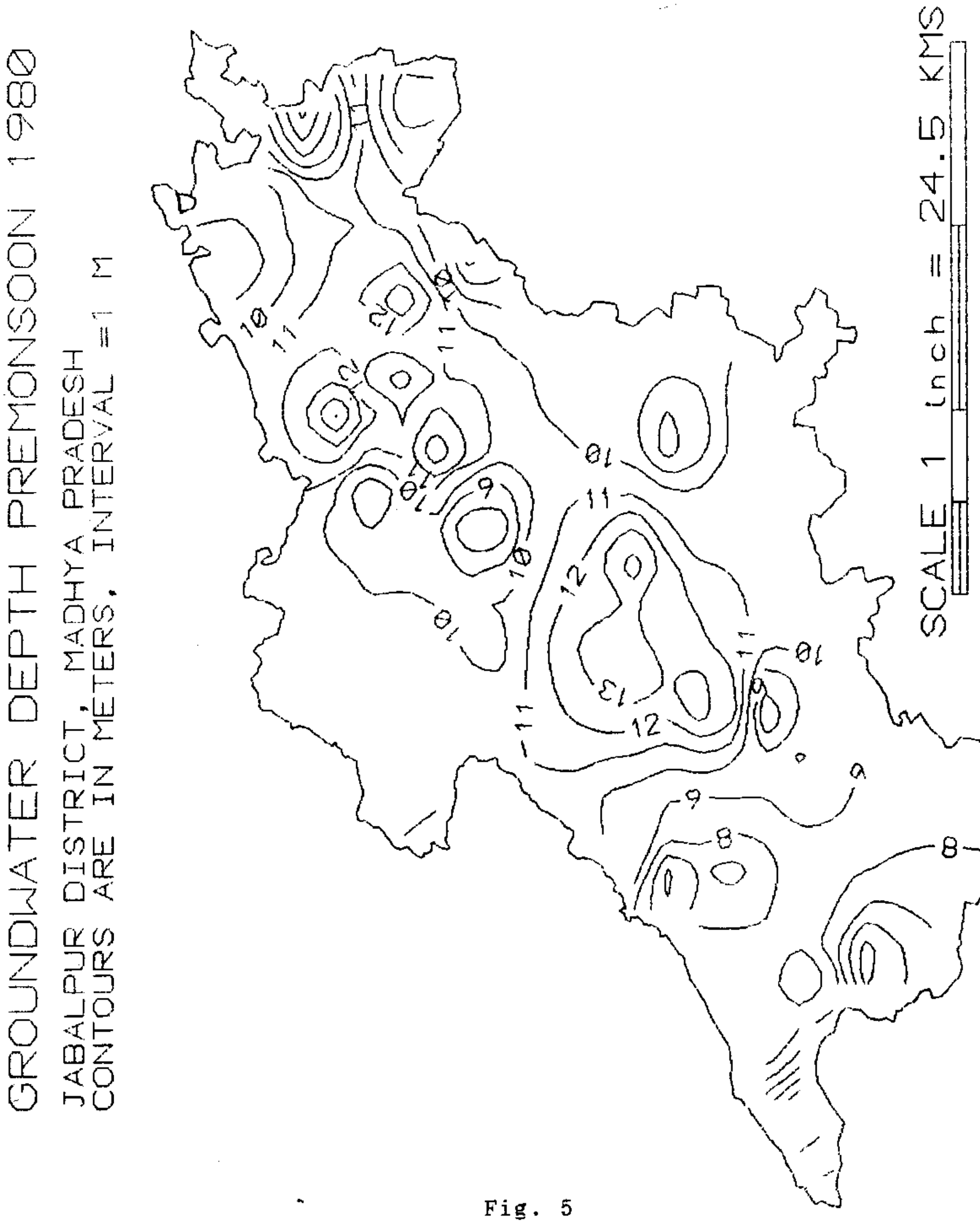

GROUNDWATER DEPTH PREMONSOON 1980
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 5

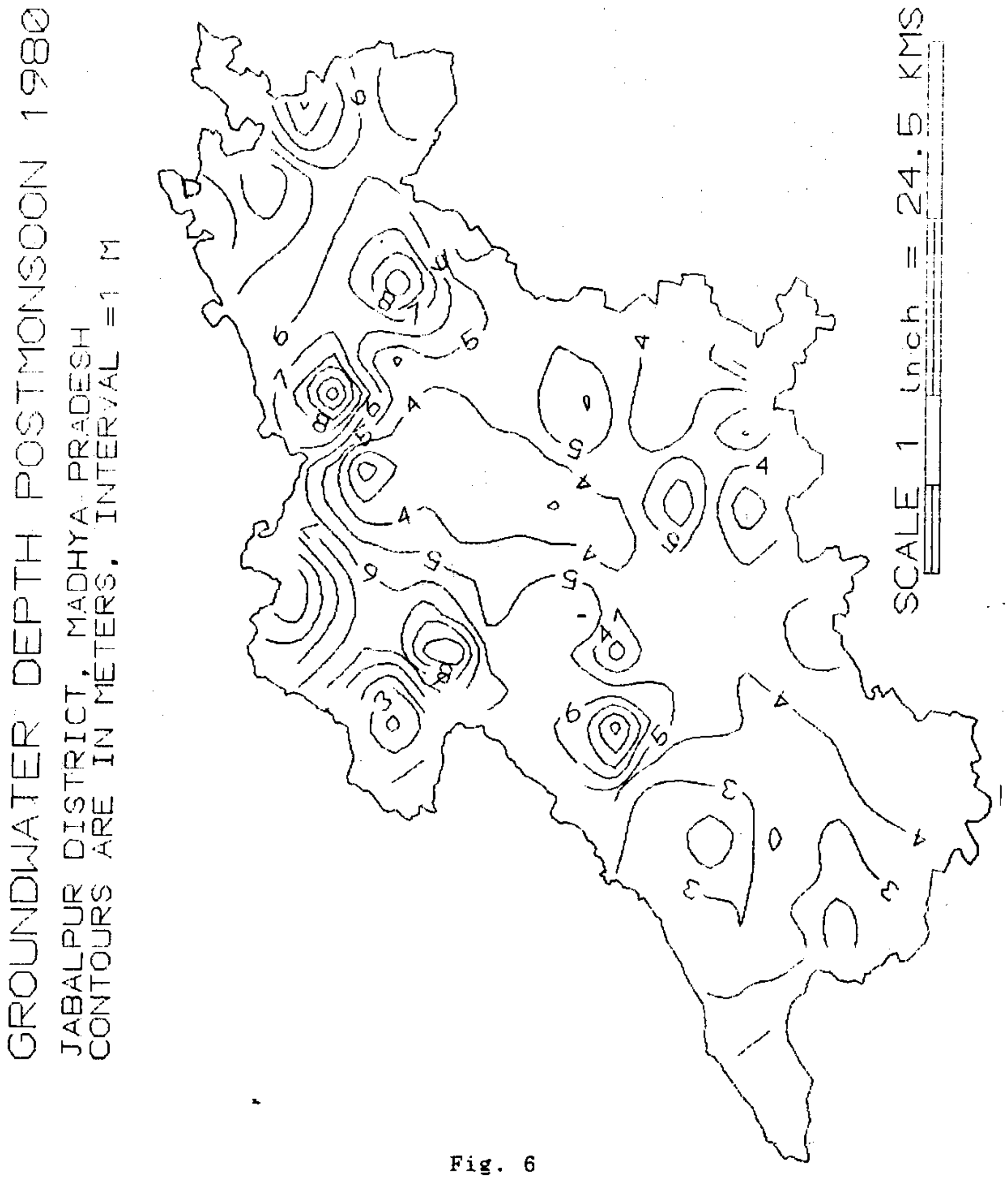

GROUNDWATER DEPTH POSTMONSOON 1980
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 6

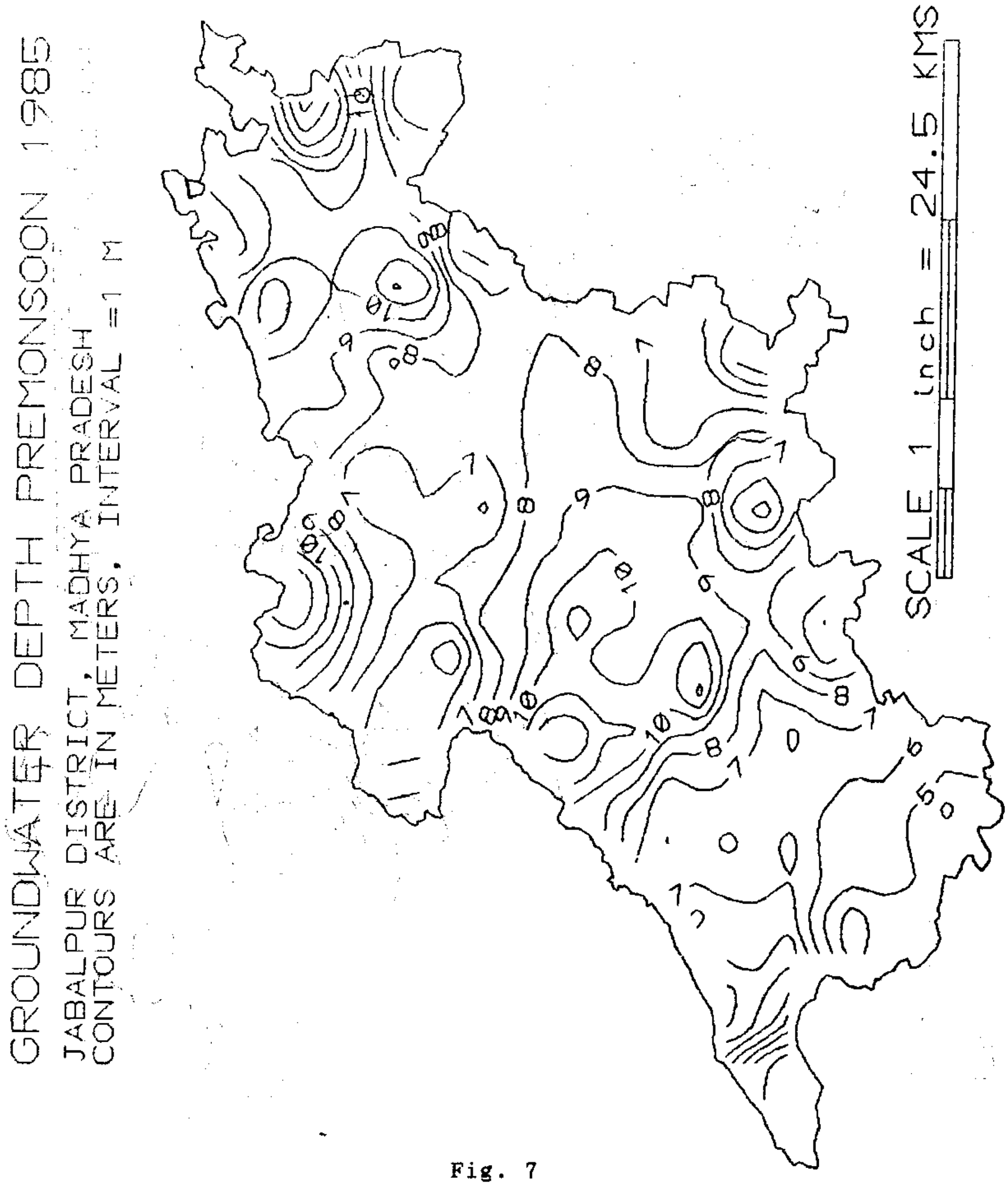

GROUNDWATER DEPTH PREMONSOON 1985
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 7

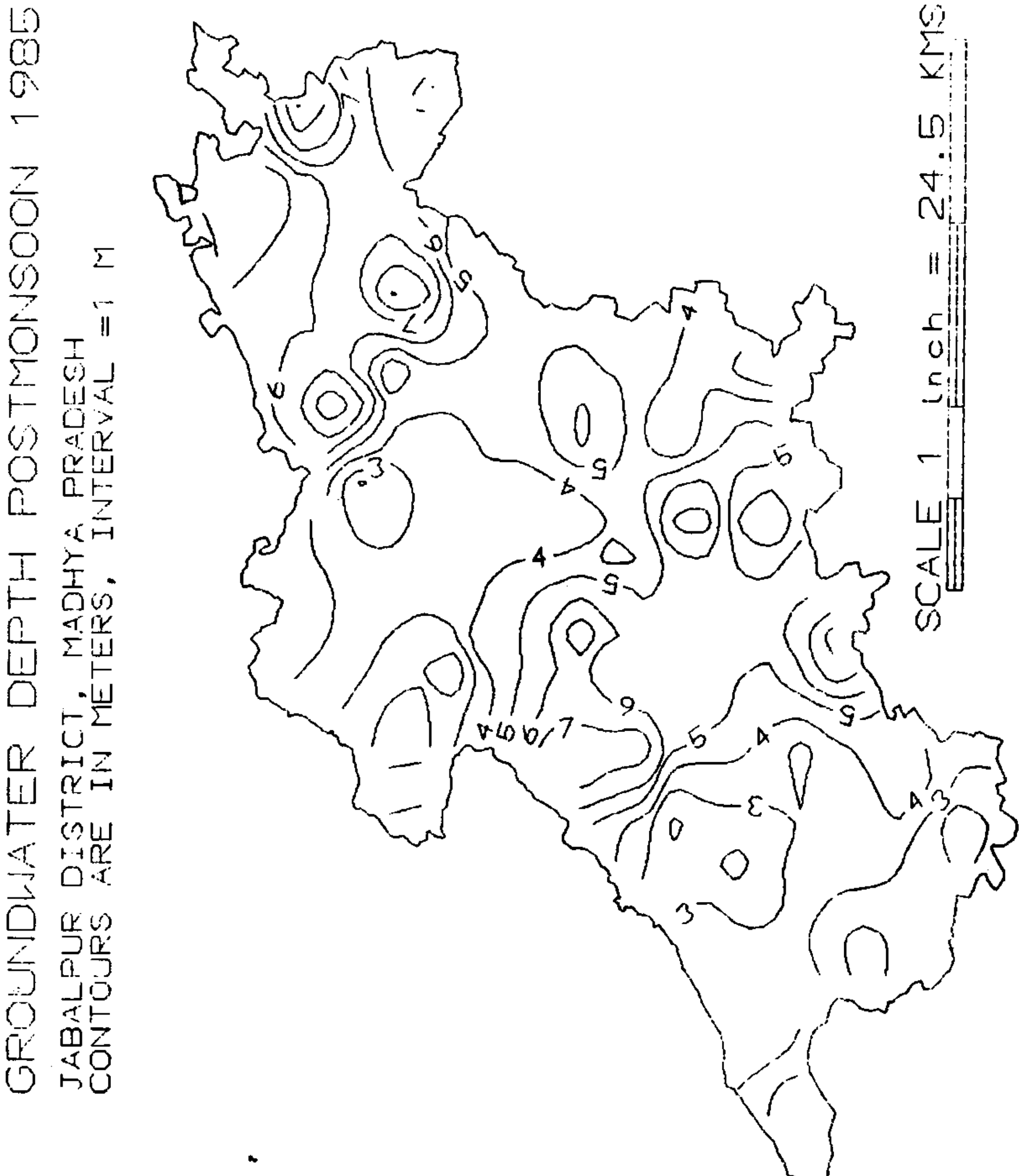

GROUNDWATER DEPTH POSTMONSOON 1985
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 Inch = 24.5 KMS

Fig. 8

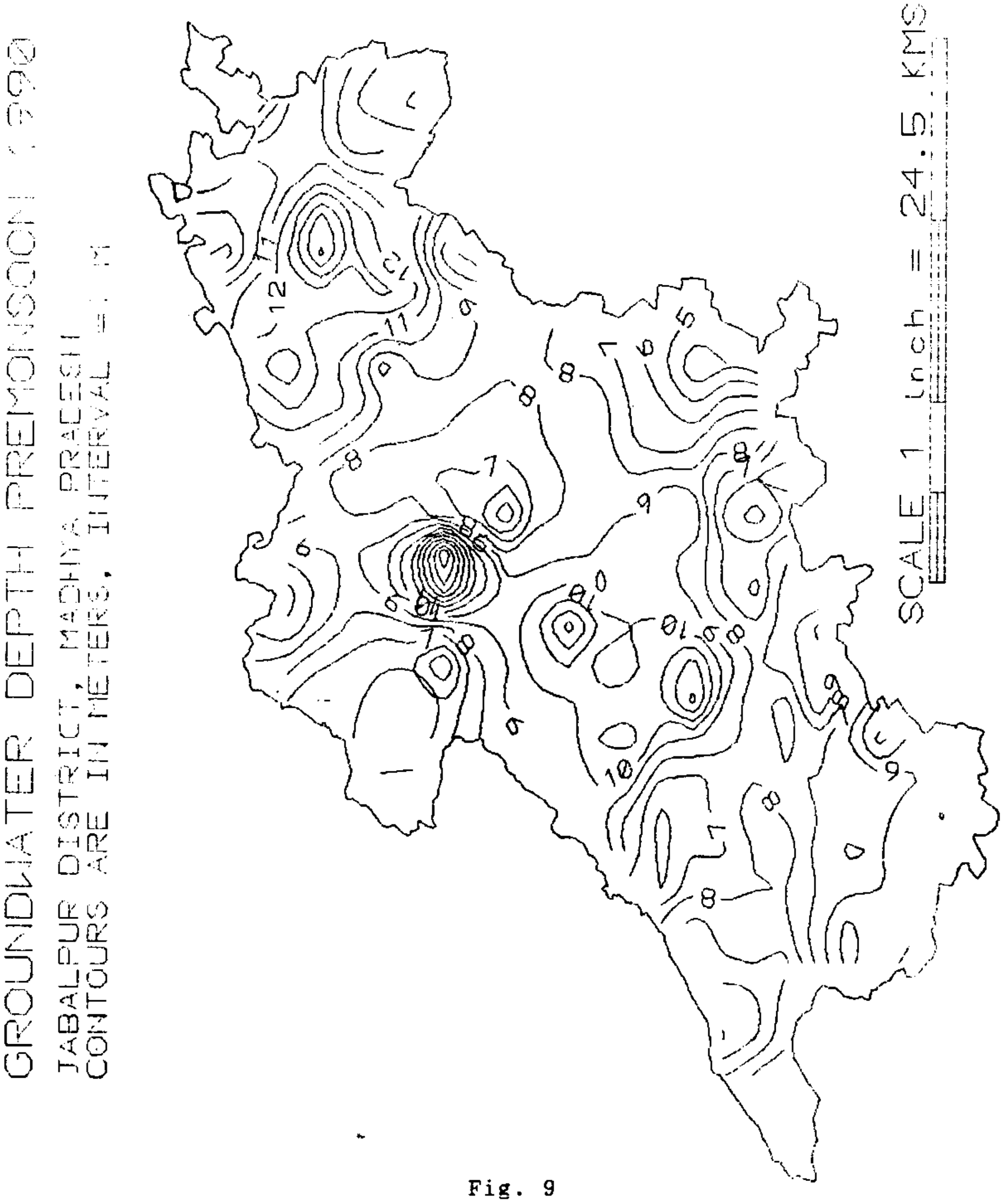

GROUNDWATER DEPTH PREMONSOON (1990
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL = 1 M
SCALE 1 inch = 24.5 KMS

Fig. 9

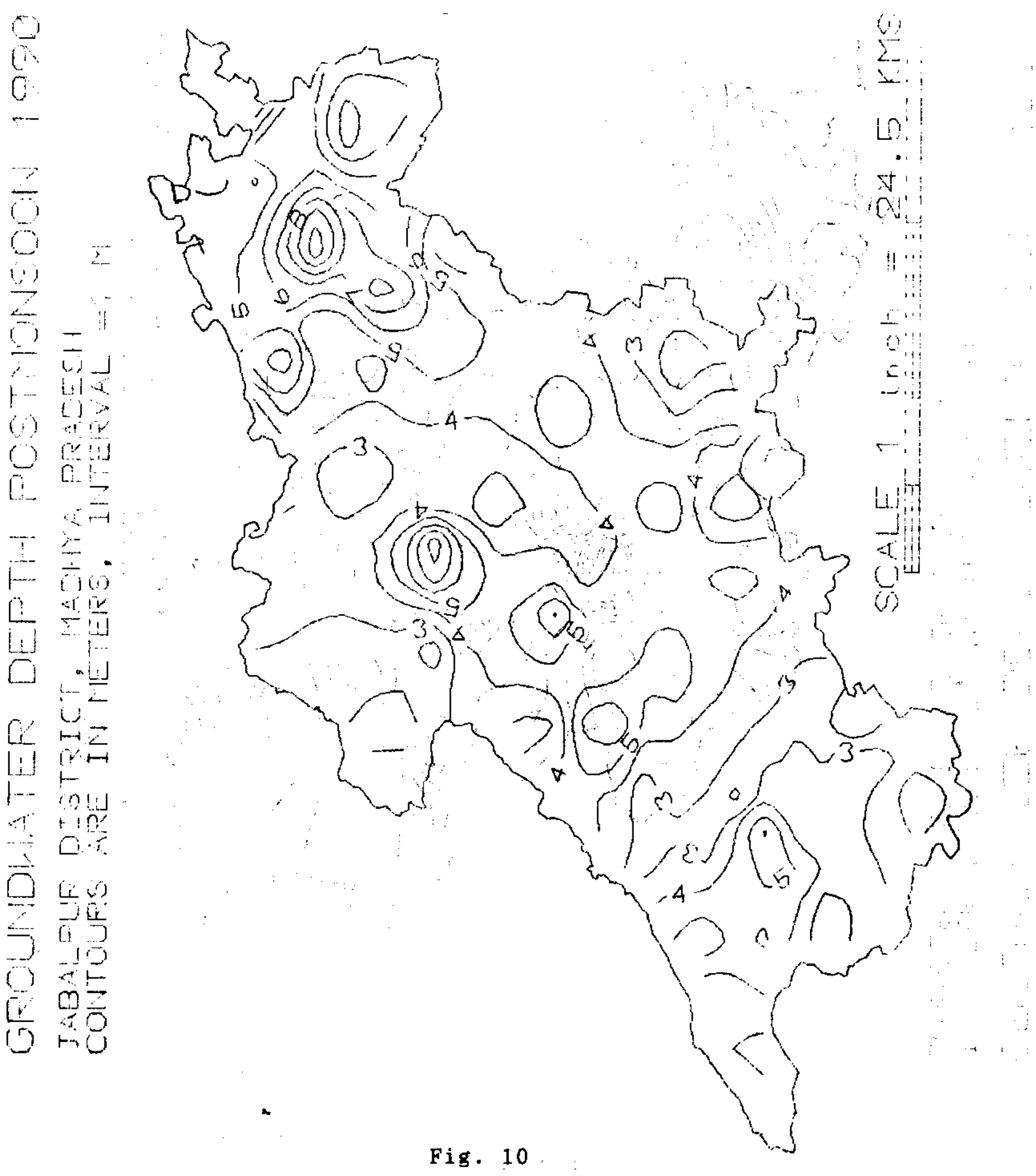

GROUNDWATER DEPTH POSTMONSOON 1990
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 10

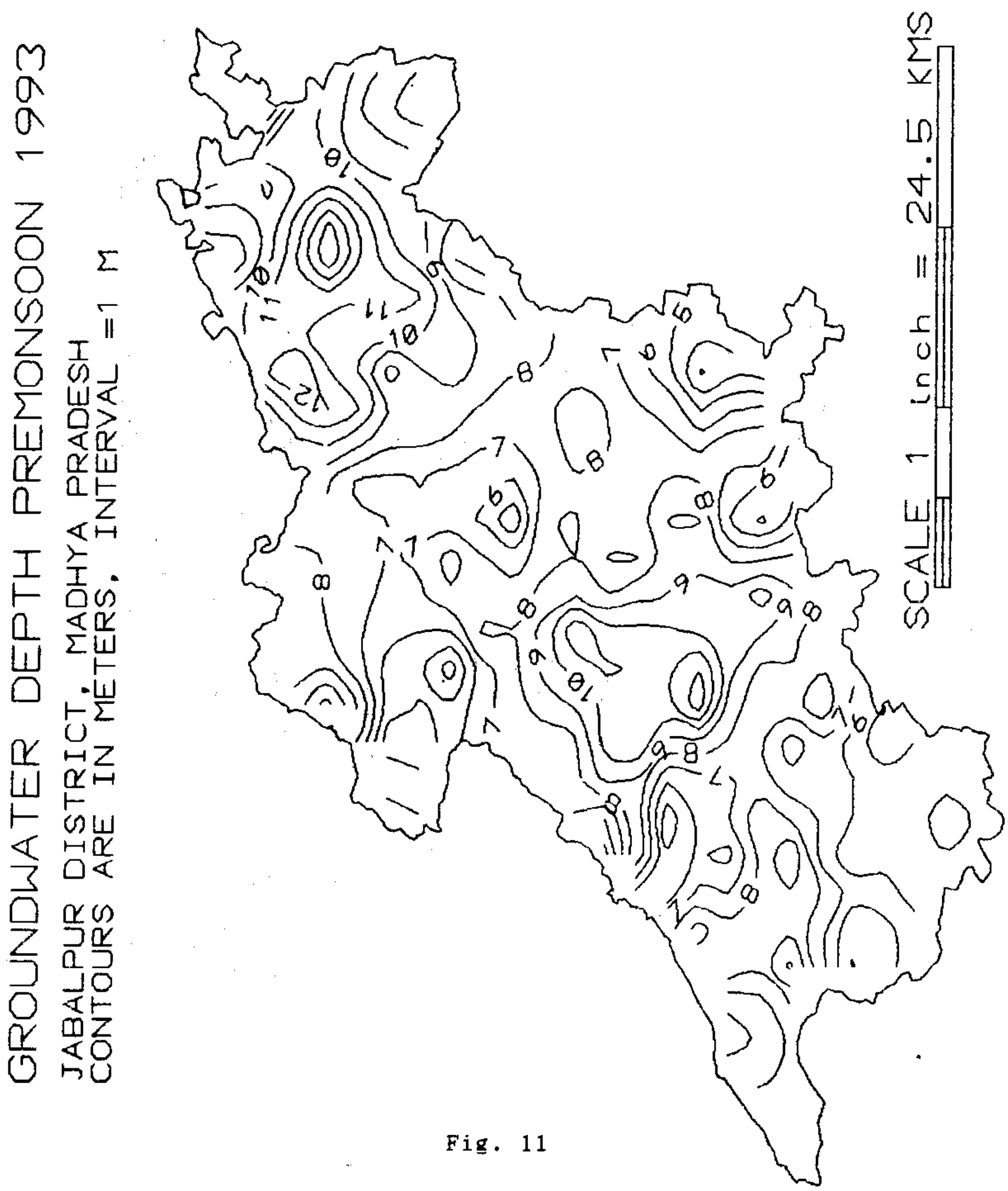

GROUNDWATER DEPTH PREMONSOON 1993
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 inch = 24.5 KMS

Fig. 11

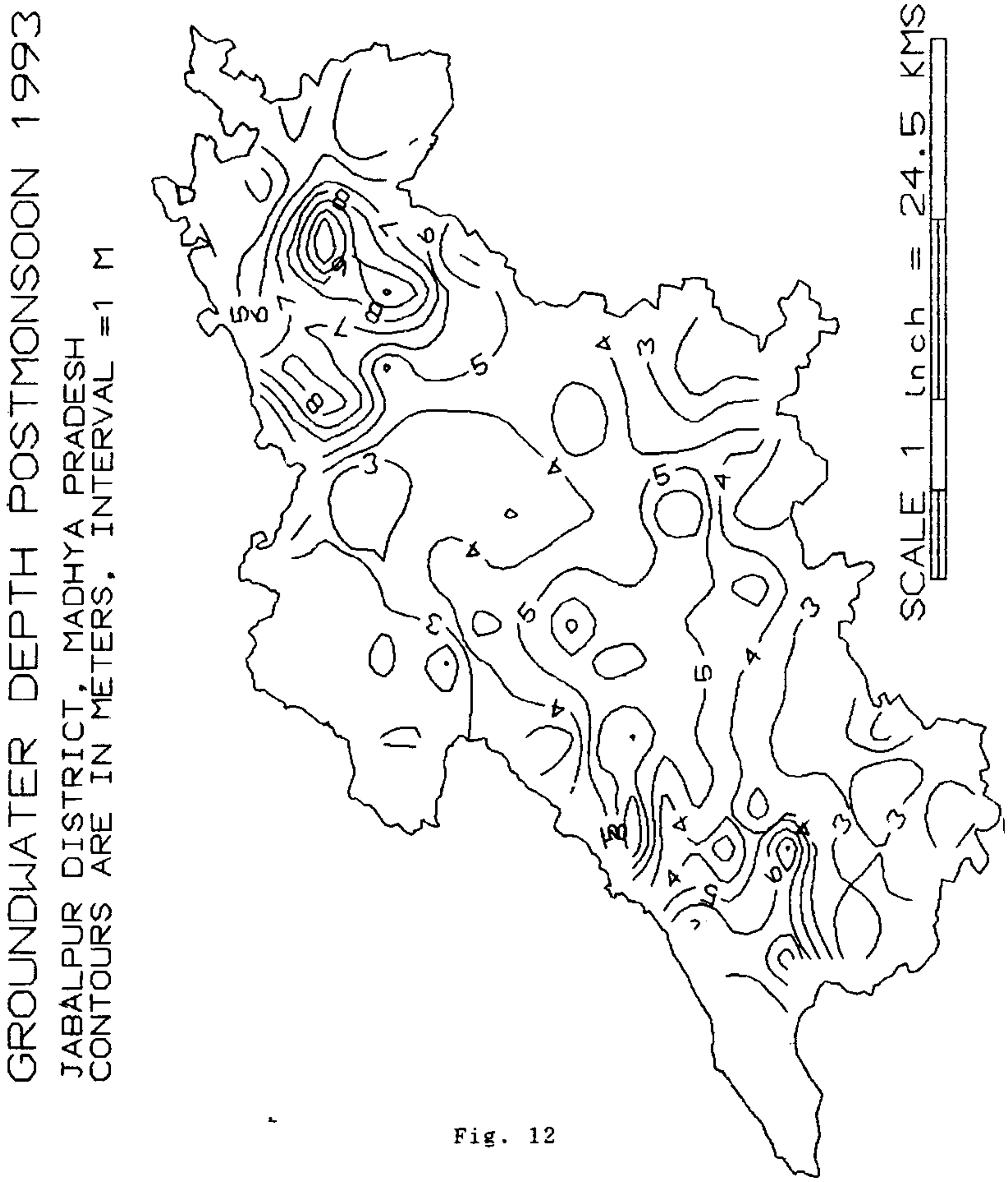

GROUNDWATER DEPTH POSTMONSOON 1993
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS, INTERVAL =1 M
SCALE 1 Inch = 24.5 KMS

Fig. 12

3.2 WATER TABLE CONTOUR MAP

Water table contour map shows the configuration of the water table surface, at a specified time, the same way as the contour map of an area shows the configuration of the land surface. A water table contour line is the locus of points on the water table surface for which hydraulic head is constant. The contour lines of water table map are infact equipotential lines. Hence, the direction of the groundwater flow which is perpendicular to the equipotential lines, can be directly obtained from these maps. These maps are also useful in determining the location and extent of high water table areas. It also provides direct visual information on the slope of the water table. Generally, there is horizontal movement of groundwater in the direction of the slope of the water table. In absence of subsurface artesian conditions and if the application of water to soil surface is uniform, a region of steep slope of the water table would be expected to occur where barriers to the horizontal movement of groundwater occur or where hydraulic conductivity of the strata below the water table is low. On the other hand, an area of small slope of water table may indicate the presence of aquifers that permit the ready transfer to groundwater in horizontal direction.

A water table contour map of a semi-confined aquifer is a graphic representation of the hydraulic gradient of water table. Small hydraulic gradients (flat water table slopes) reflect a high hydraulic conductivity of the water transmitting material. Hence, if in a certain direction the spacing of the contour lines is narrowing (hydraulic gradient becoming greater) the hydraulic conductivity of the material becomes lower. Fig. 13 to Fig. 22 gives the water table contour maps of the premonsoon and postmonsoon for the year 1974, 1980, 1985, 1990 and 1993.

3.3 GROUNDWATER FLUCTUATION MAP

Groundwater fluctuation map is constructed by plotting, for a given span of time, the change of water level in observation wells and drawing lines of equal change. The measurement of water level fluctuation in piezometers and observation wells are important fact in many groundwater studies. Groundwater level fluctuation directly reflects the storage change in groundwater. When recharge exceeds discharge, water level will rise and when discharge exceeds recharge, water level will fall. Generally, recharge and discharge occurs in different areas of the catchment simultaneously. Groundwater level fluctuations reflect the net change of storage resulting from the interaction of these two components. However, the relationship between storage and water level are complicated by the fact that the letter responds to factors other than storage changes. In case of unconfined aquifers, the water table fluctuations tend to follow a seasonal pattern. Seasonal fluctuations are normally of considerable interest to the hydrologist, in the sense they represent large scale contrasts in water availability for both natural and artificial uses. In case of confined aquifers,the fluctuations of piezometric surface are less likely to reflect changes in groundwater storage. In this study, groundwater fluctuation is calculated from the year 1974 to 1985 and from 1987 to 1993 for both premonsoon and postmonsoon period. The maps are given in Fig. 23 to Fig. 26. The groundwater fluctuation within a year, i.e. from premonsoon to postmonsoon is also calculated for the years 1974, 1980, 1985, 1990 and 1993. The maps are shown in Fig. 27 to Fig. 31.

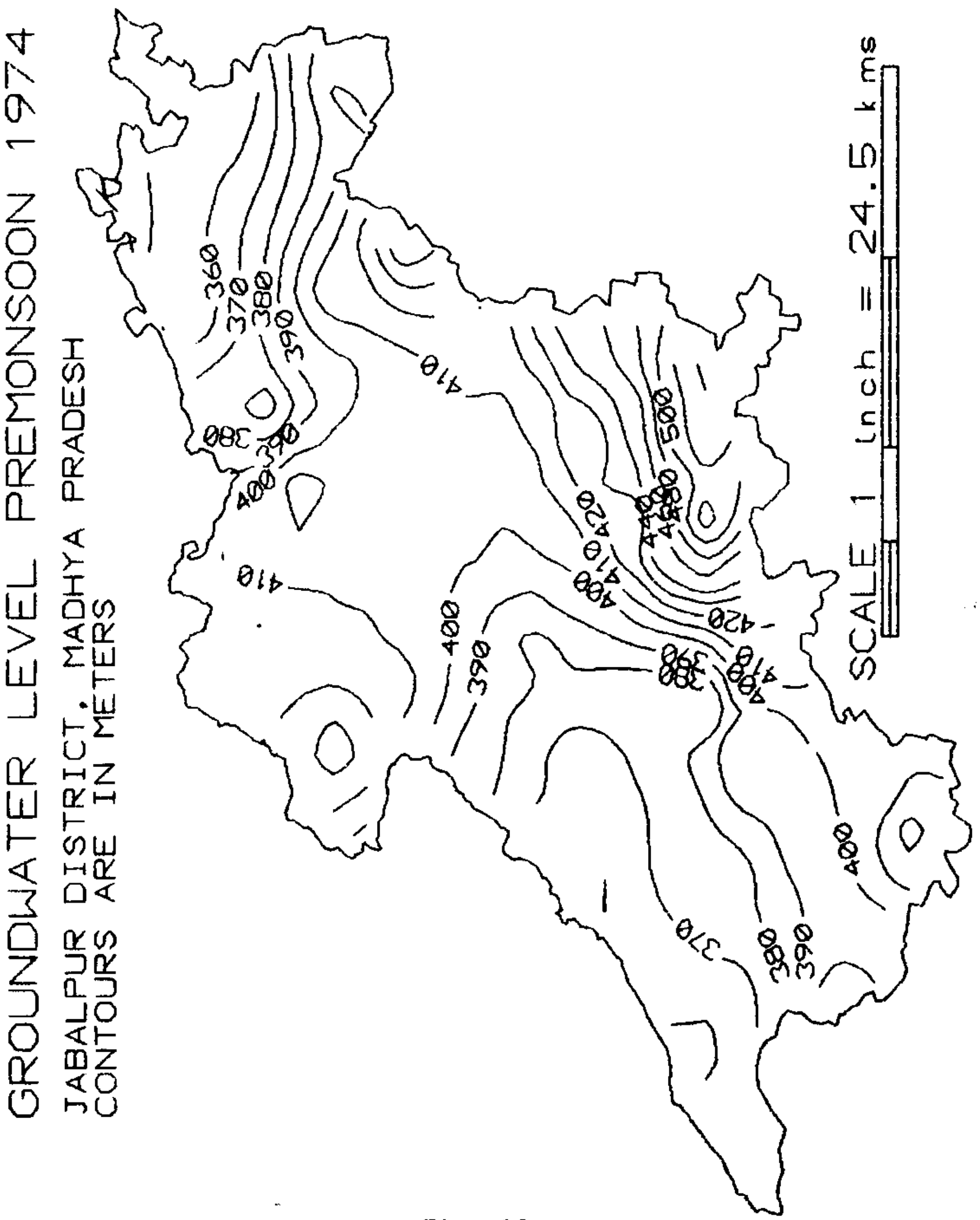

GROUNDWATER LEVEL PREMONSOON 1974
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 kms

Fig. 13

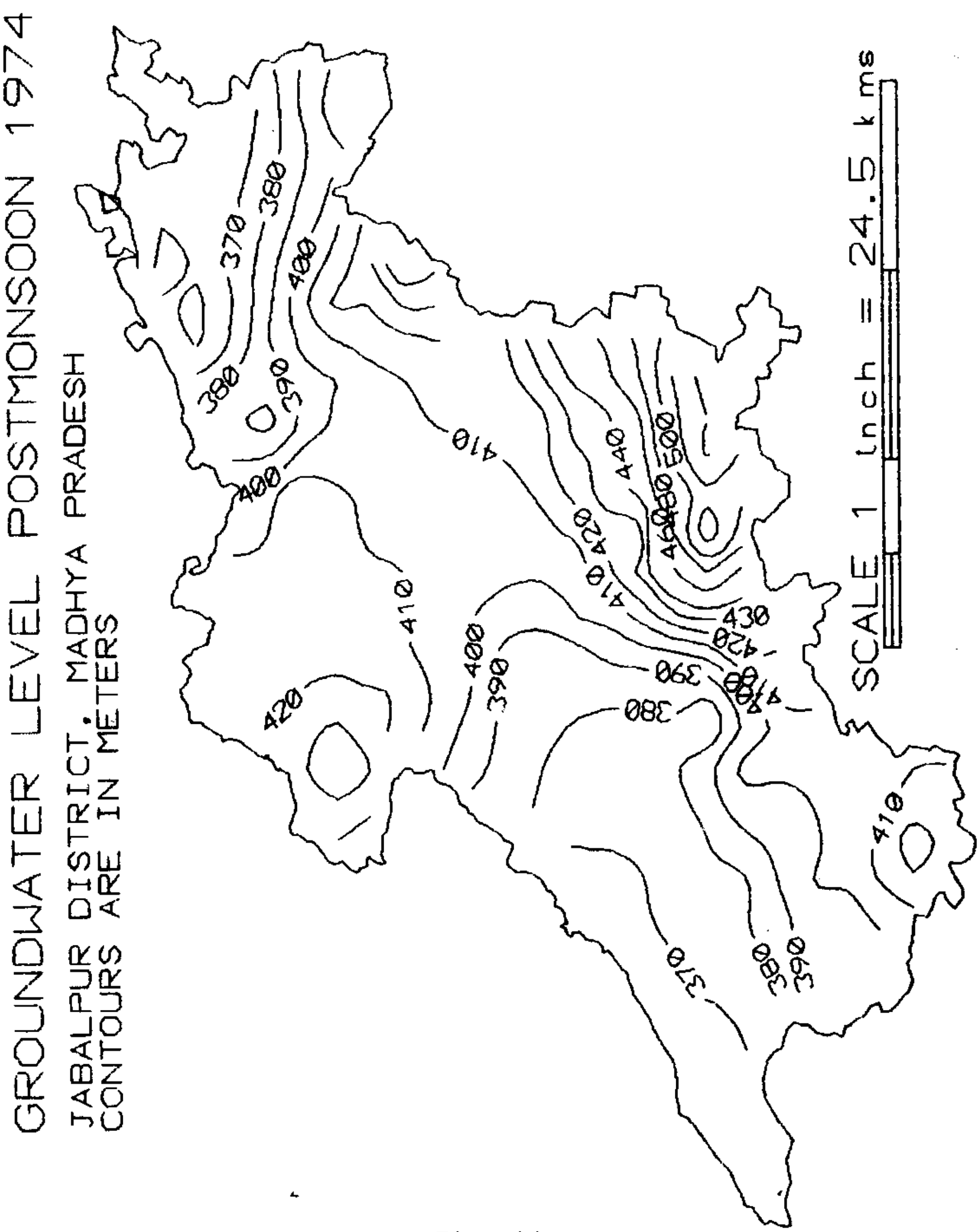

GROUNDWATER LEVEL POSTMONSOON 1974
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms
370
380
390
400
410
420
430
440
500

Fig. 14

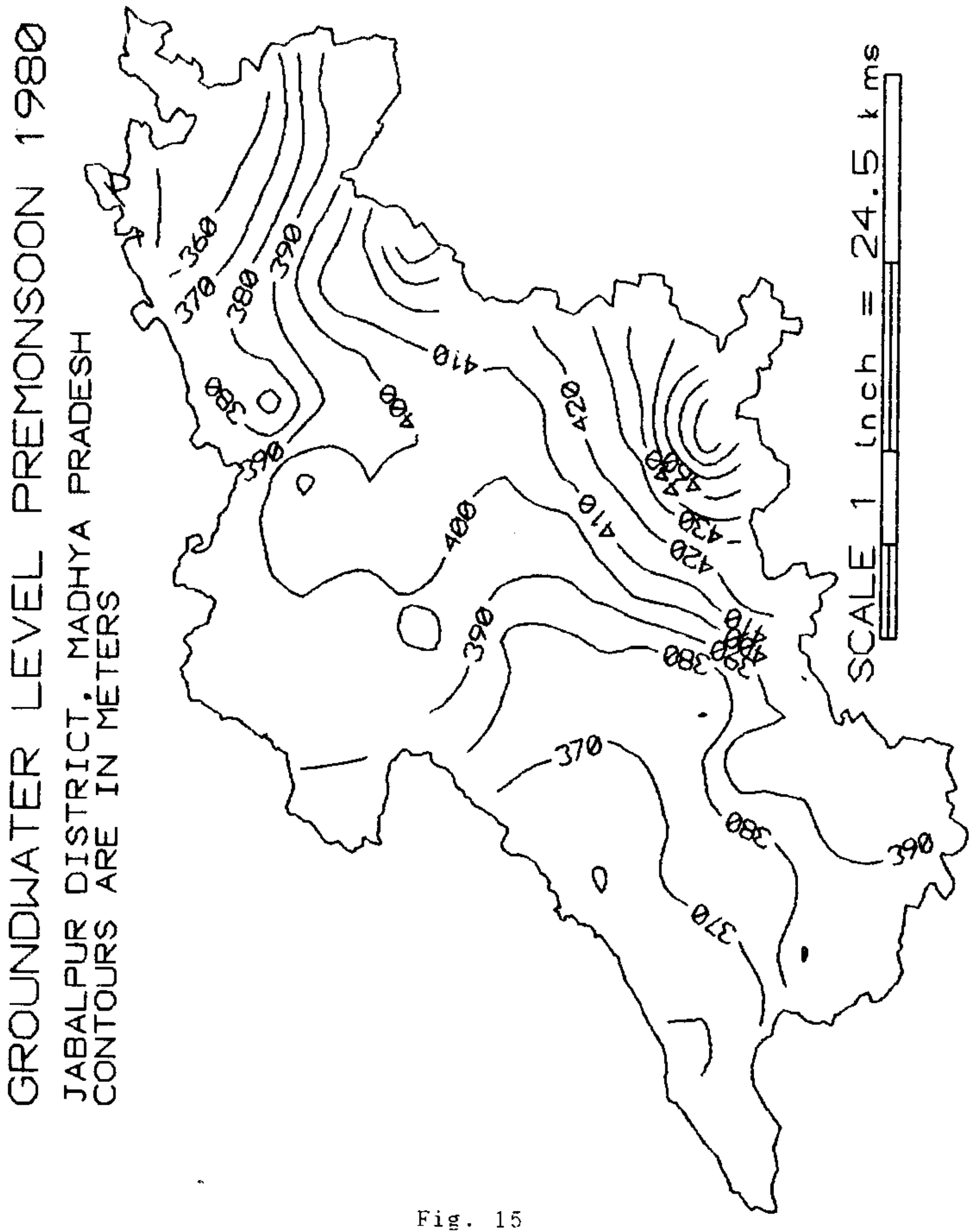

GROUNDWATER LEVEL PREMONSOON 1980
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms

Fig. 15

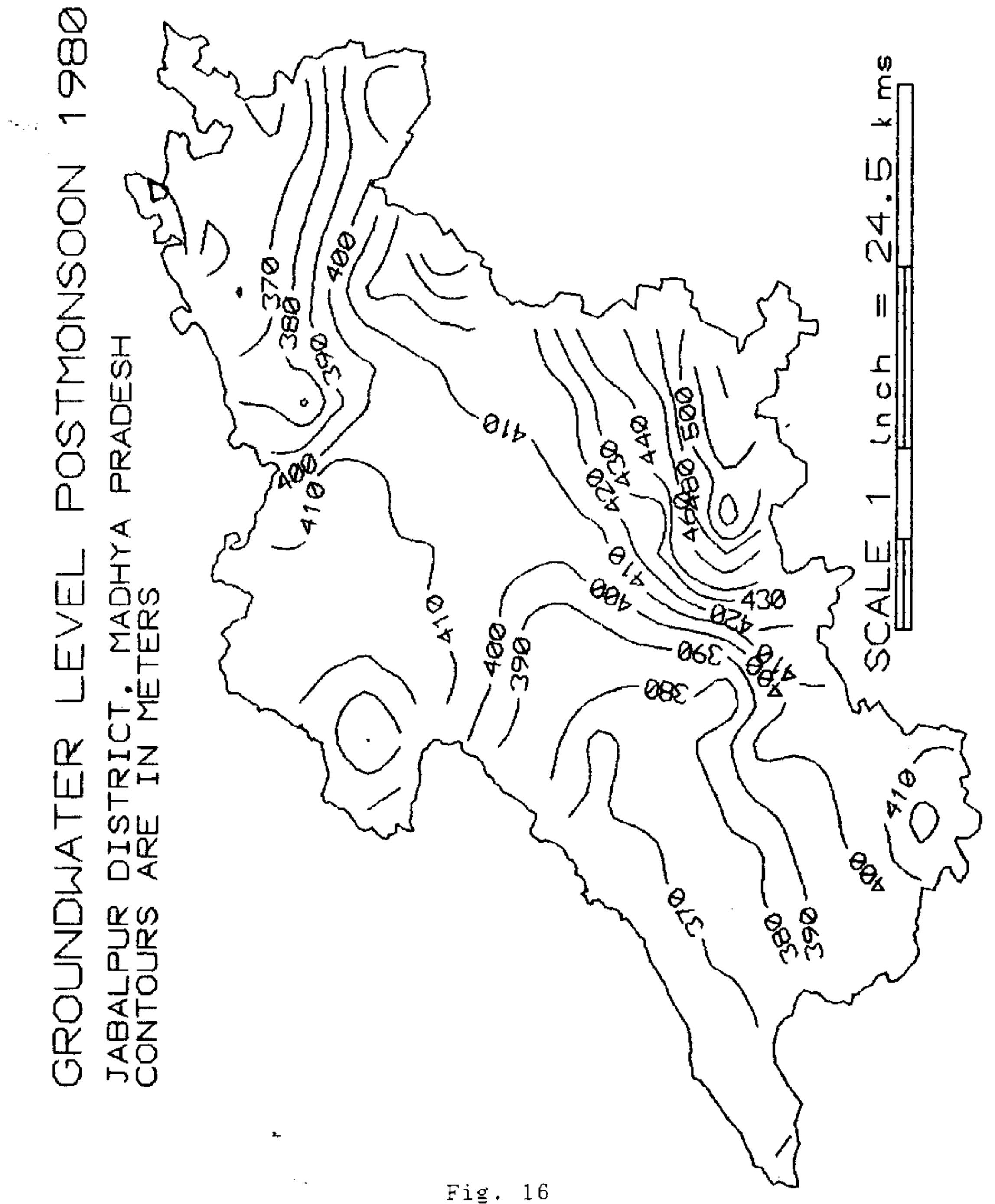

GROUNDWATER LEVEL POSTMONSOON 1980
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms

Fig. 16

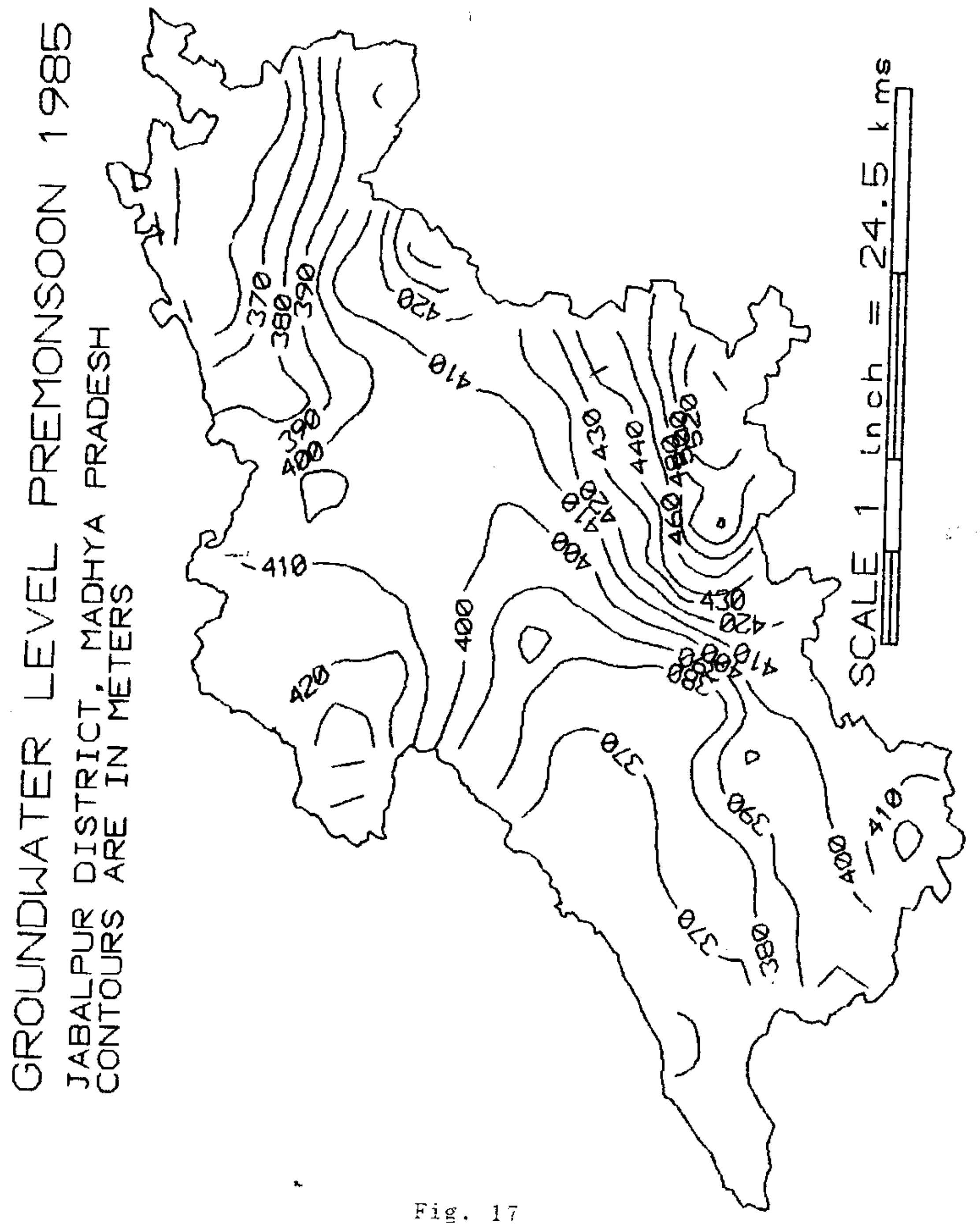

GROUNDWATER LEVEL PREMONSOON 1985
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms
370
380
390
400
410
420
430
440
460

Fig. 17

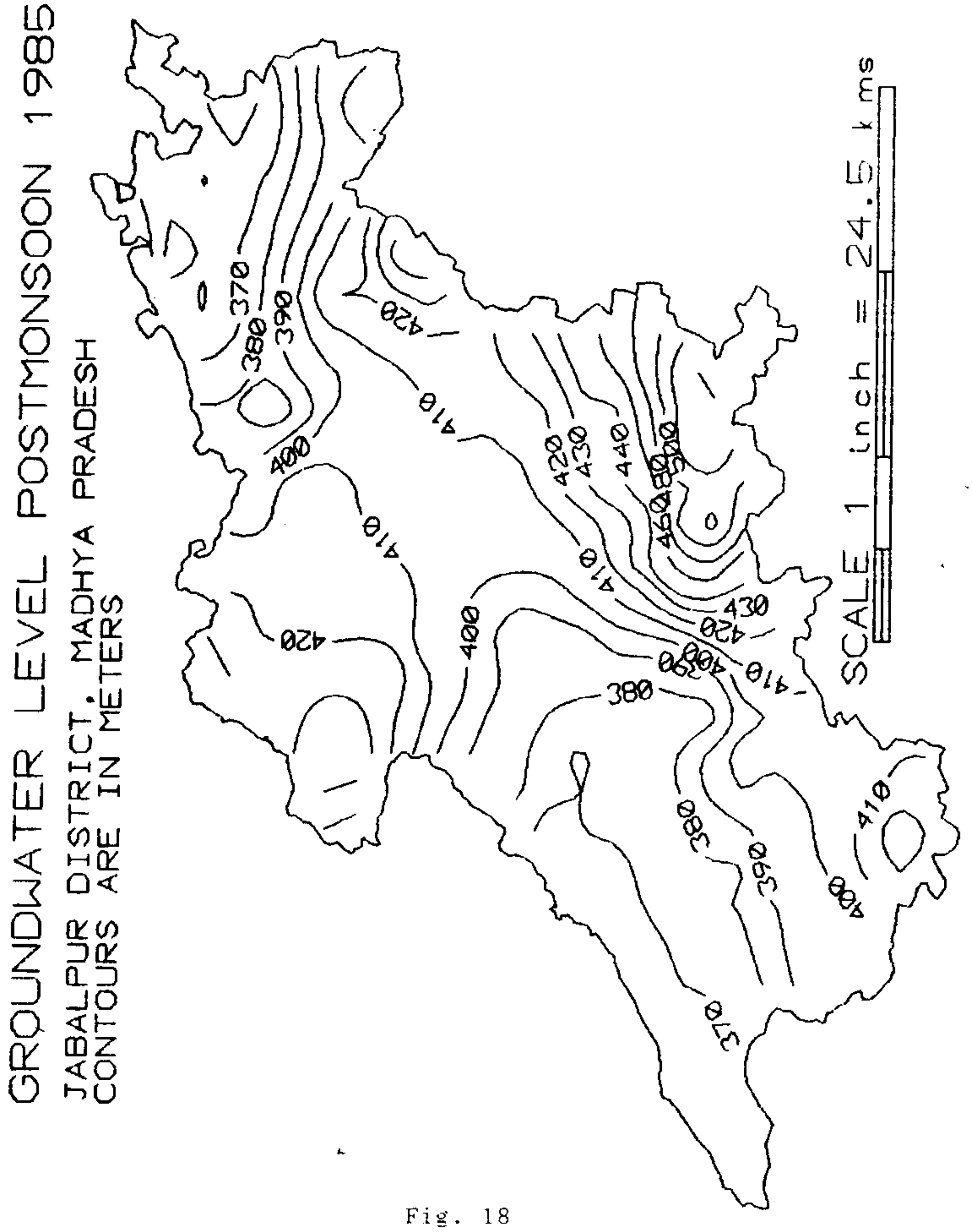

GROUNDWATER LEVEL POSTMONSOON 1985
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms

Fig. 18

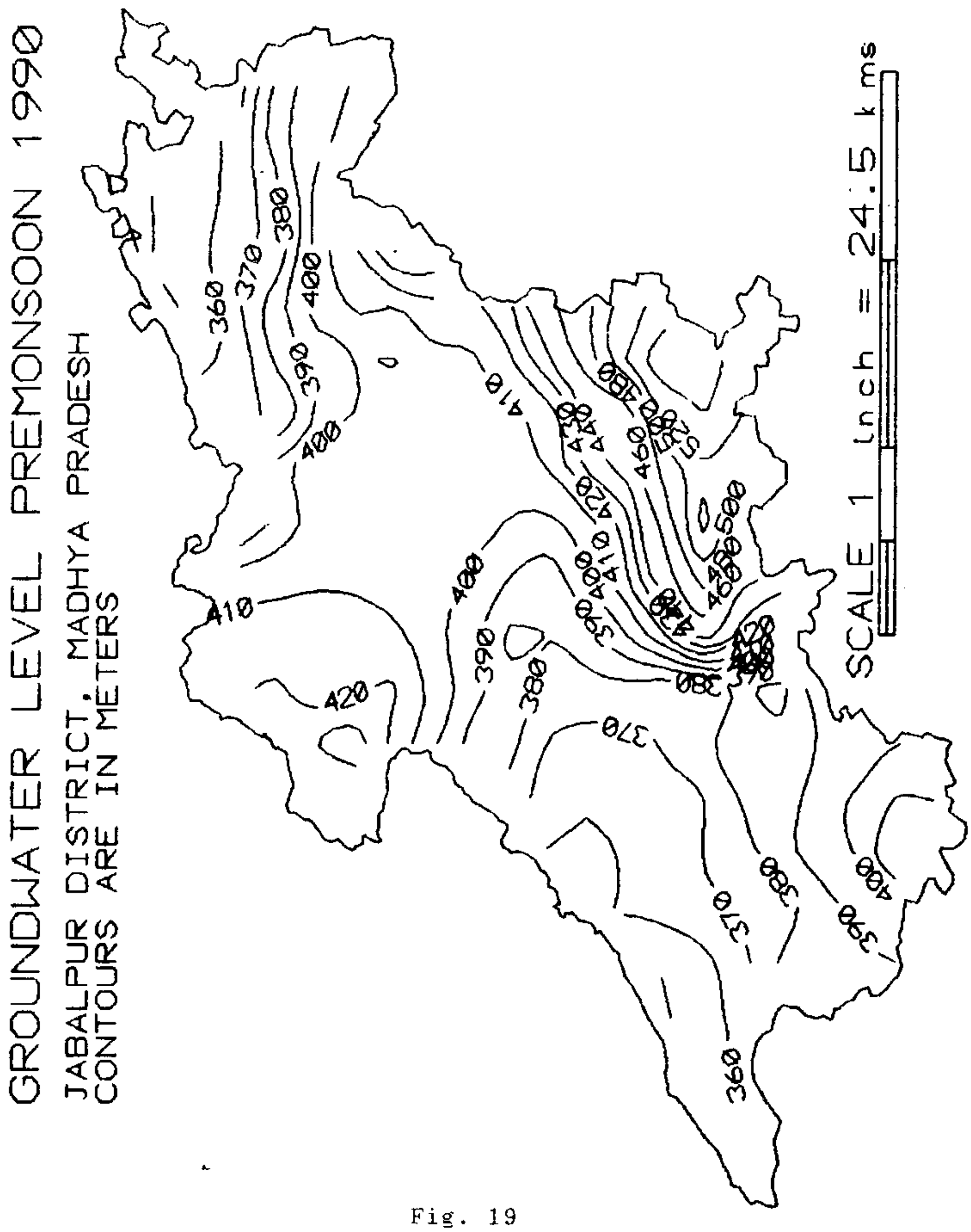

GROUNDWATER LEVEL PREMONSOON 1990
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 kms

Fig. 19

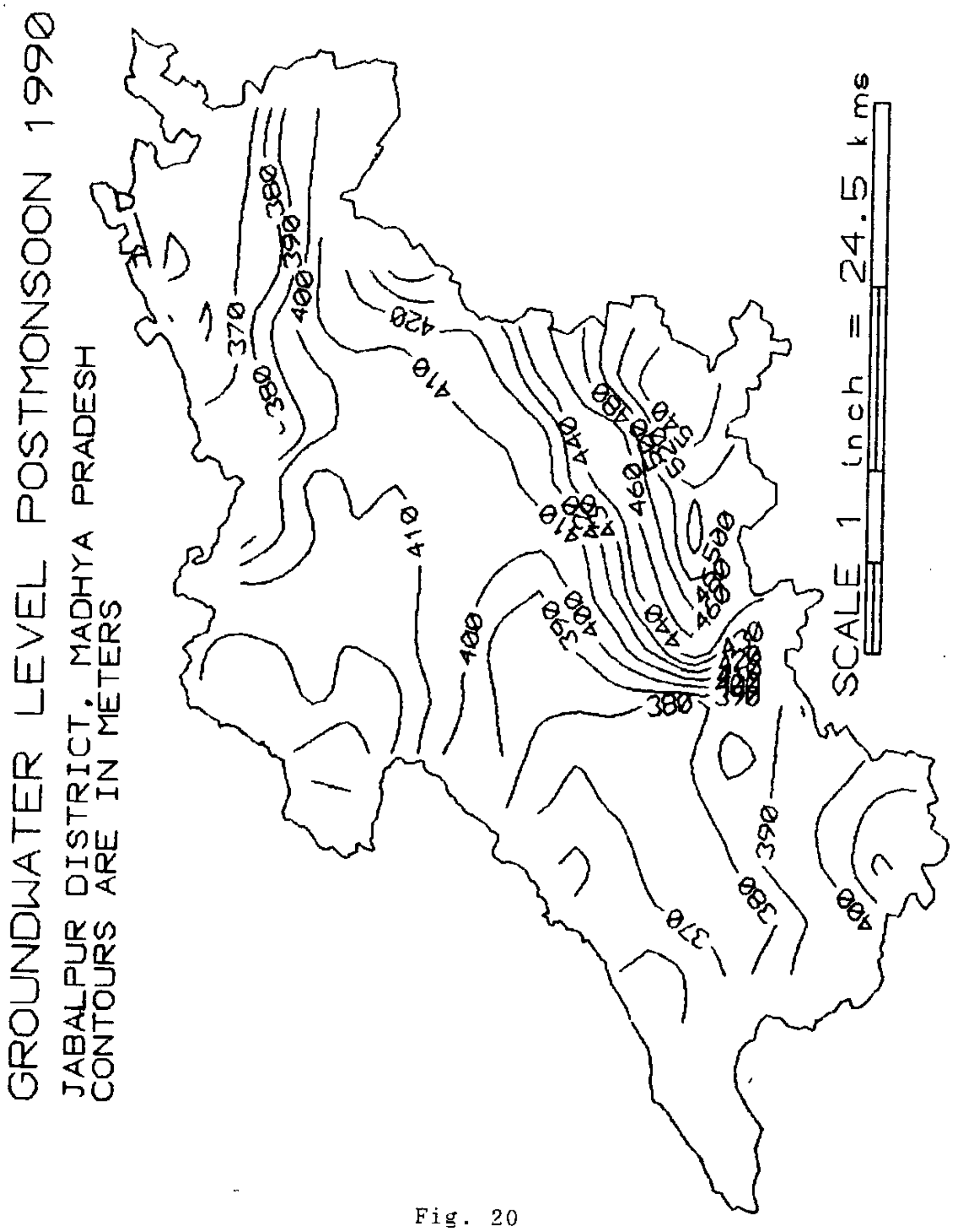

GROUNDWATER LEVEL POSTMONSOON 1990
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms

Fig. 20

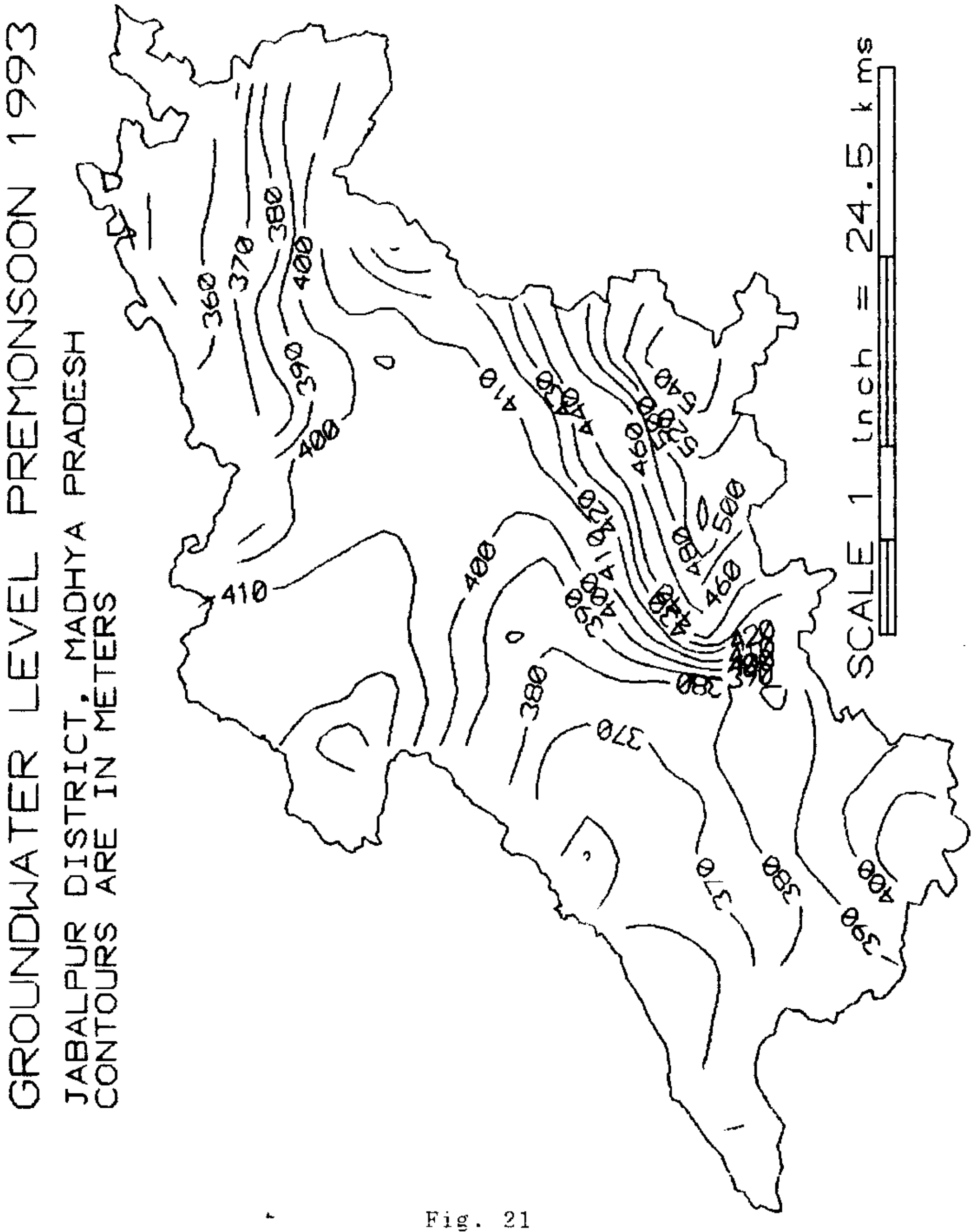

GROUNDWATER LEVEL PREMONSOON 1993
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 kms

Fig. 21

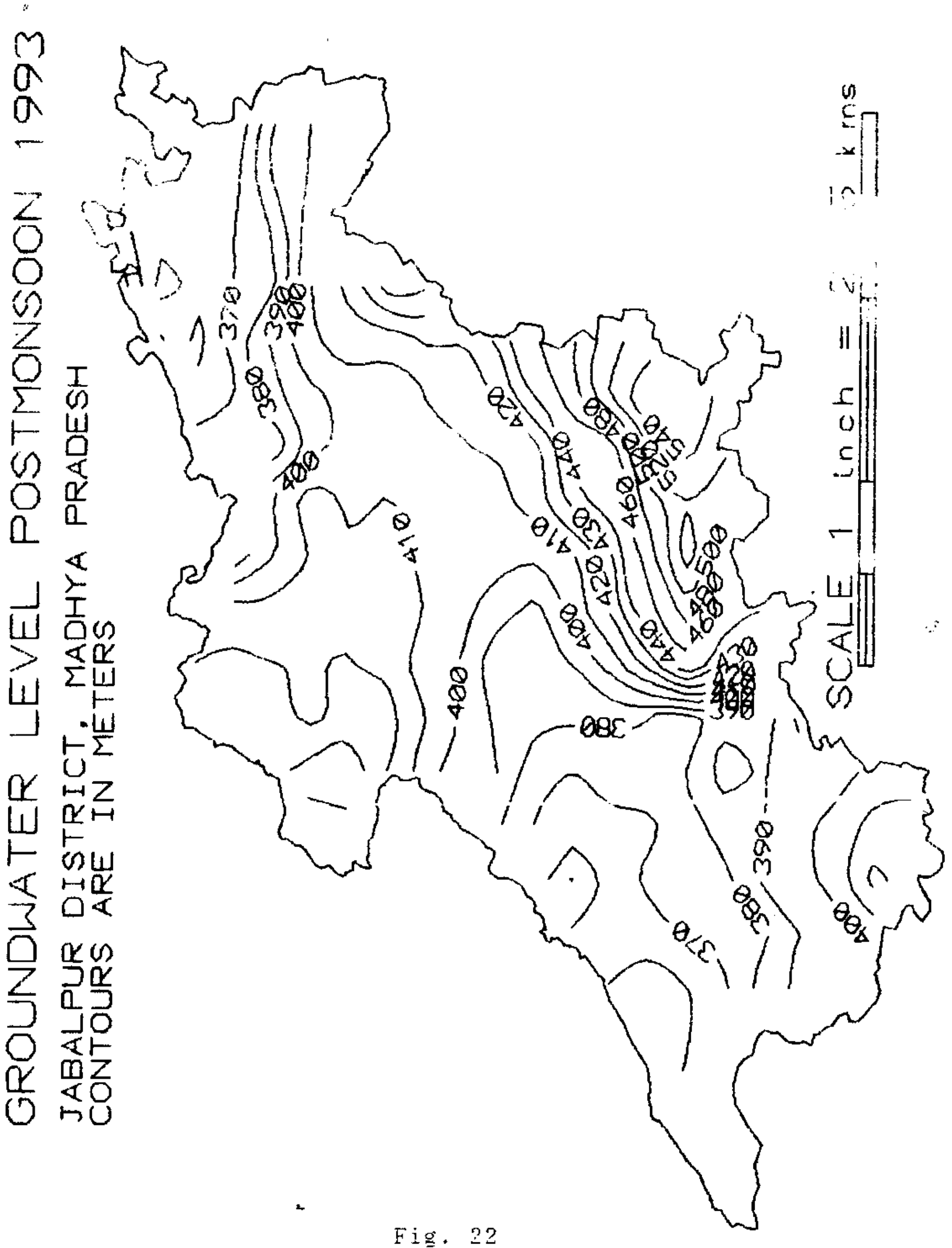

GROUNDWATER LEVEL POSTMONSOON 1993
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS

Fig. 22

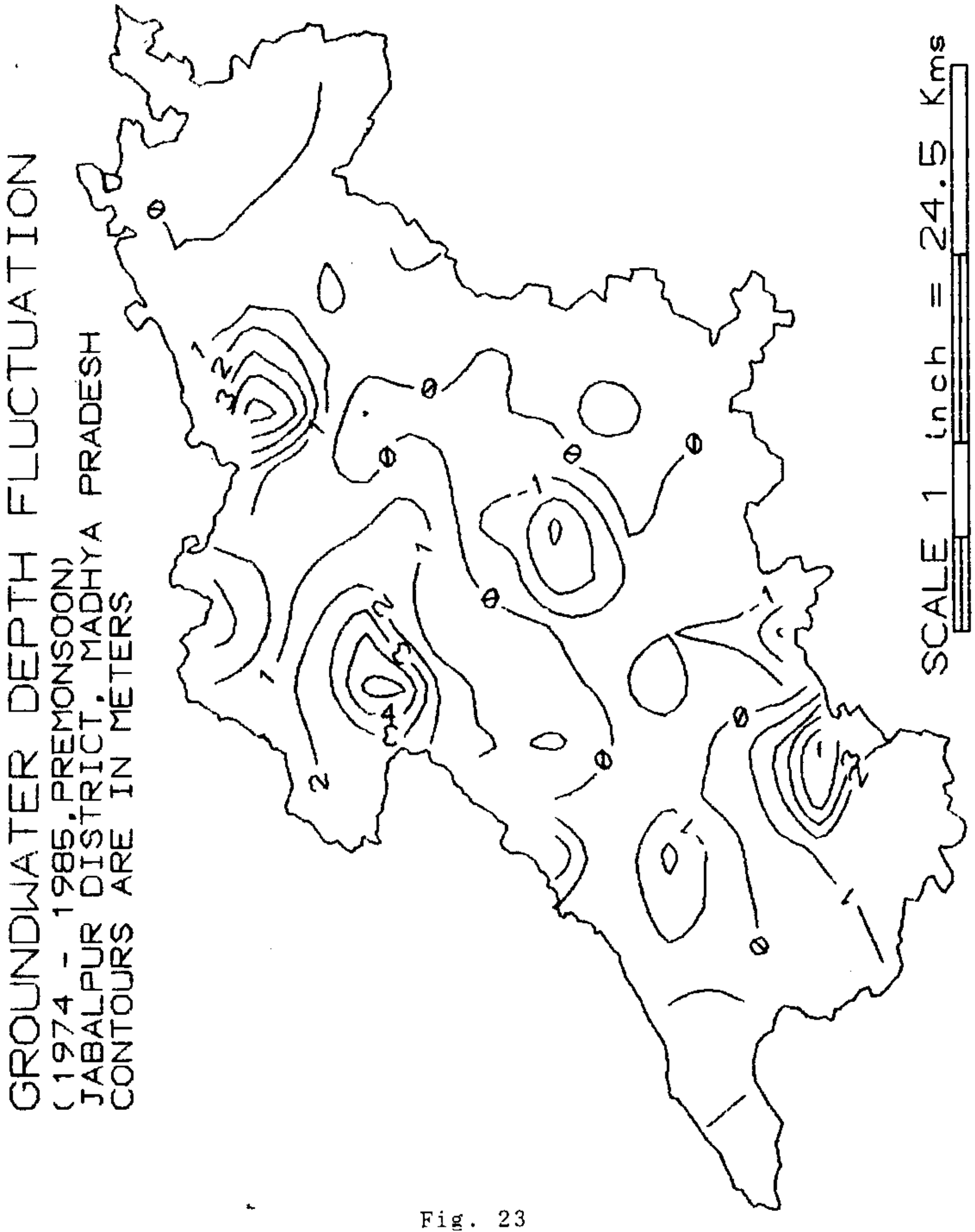

GROUNDWATER DEPTH FLUCTUATION
(1974 - 1985, PREMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 Kms

Fig. 23

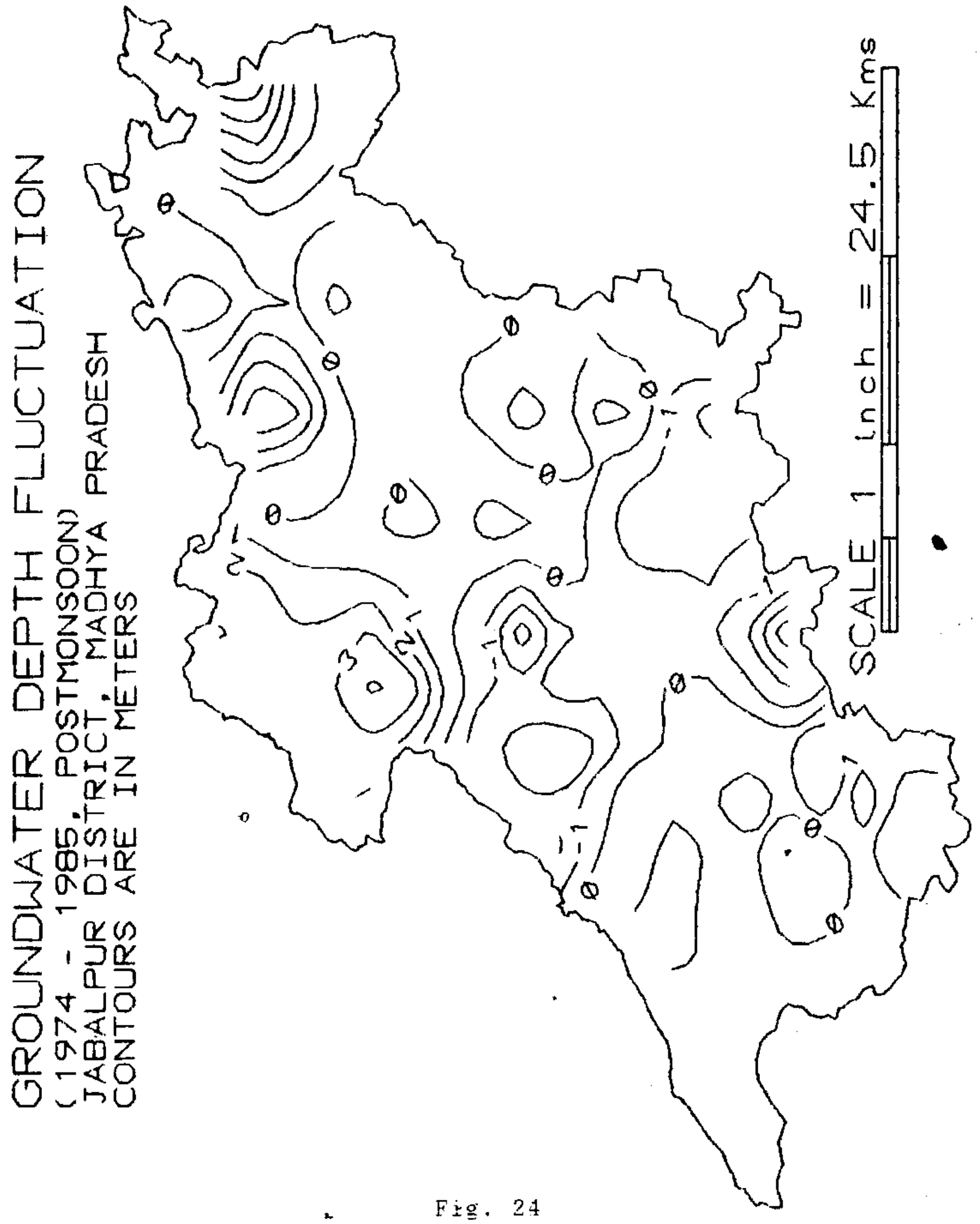

GROUNDWATER DEPTH FLUCTUATION
(1974 - 1985, POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 Kms

Fig. 24

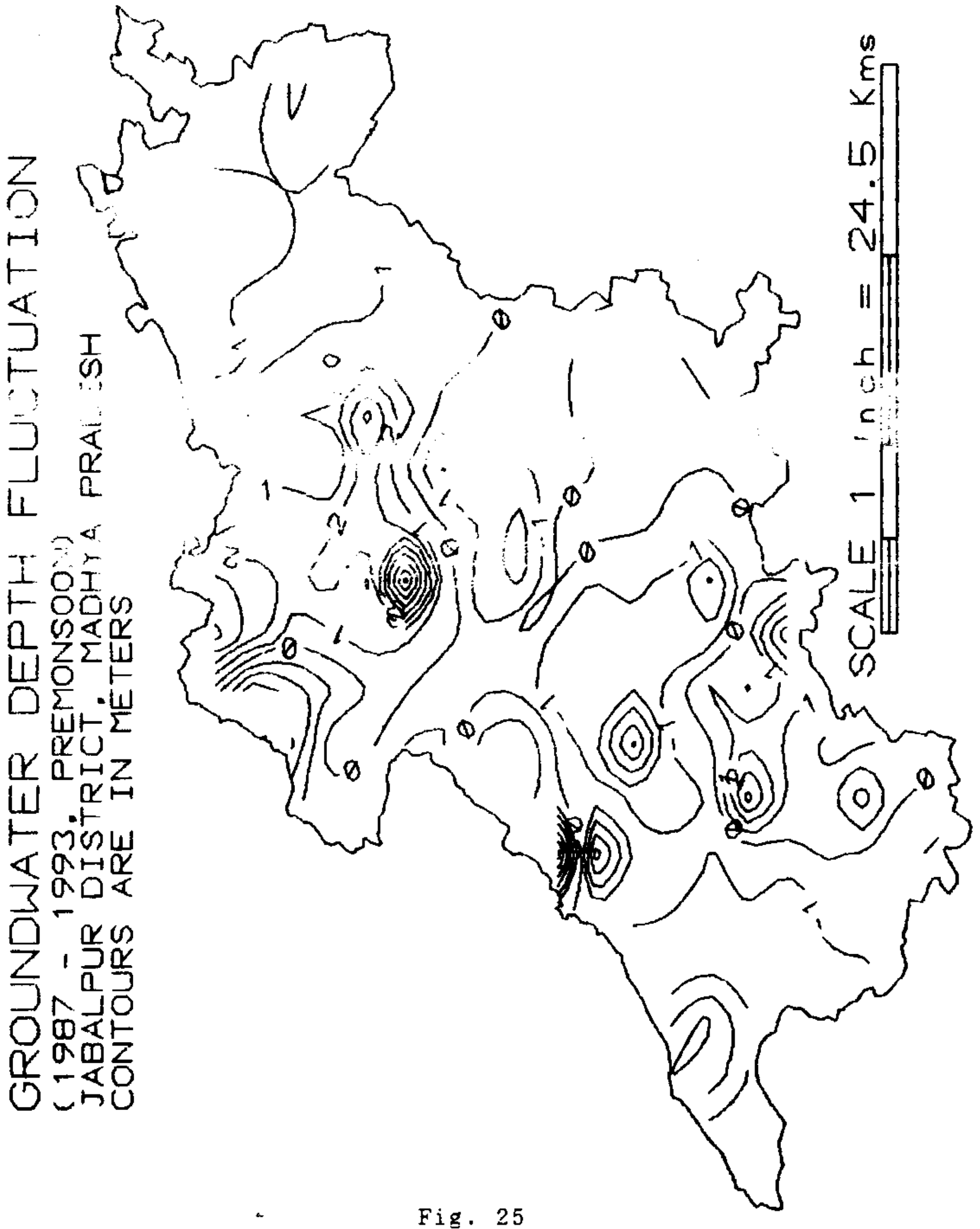

GROUNDWATER DEPTH FLUCTUATION
(1987 - 1993, PREMONSOON)
JABALPUR DISTRICT, MADHYA
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 Kms

Fig. 25

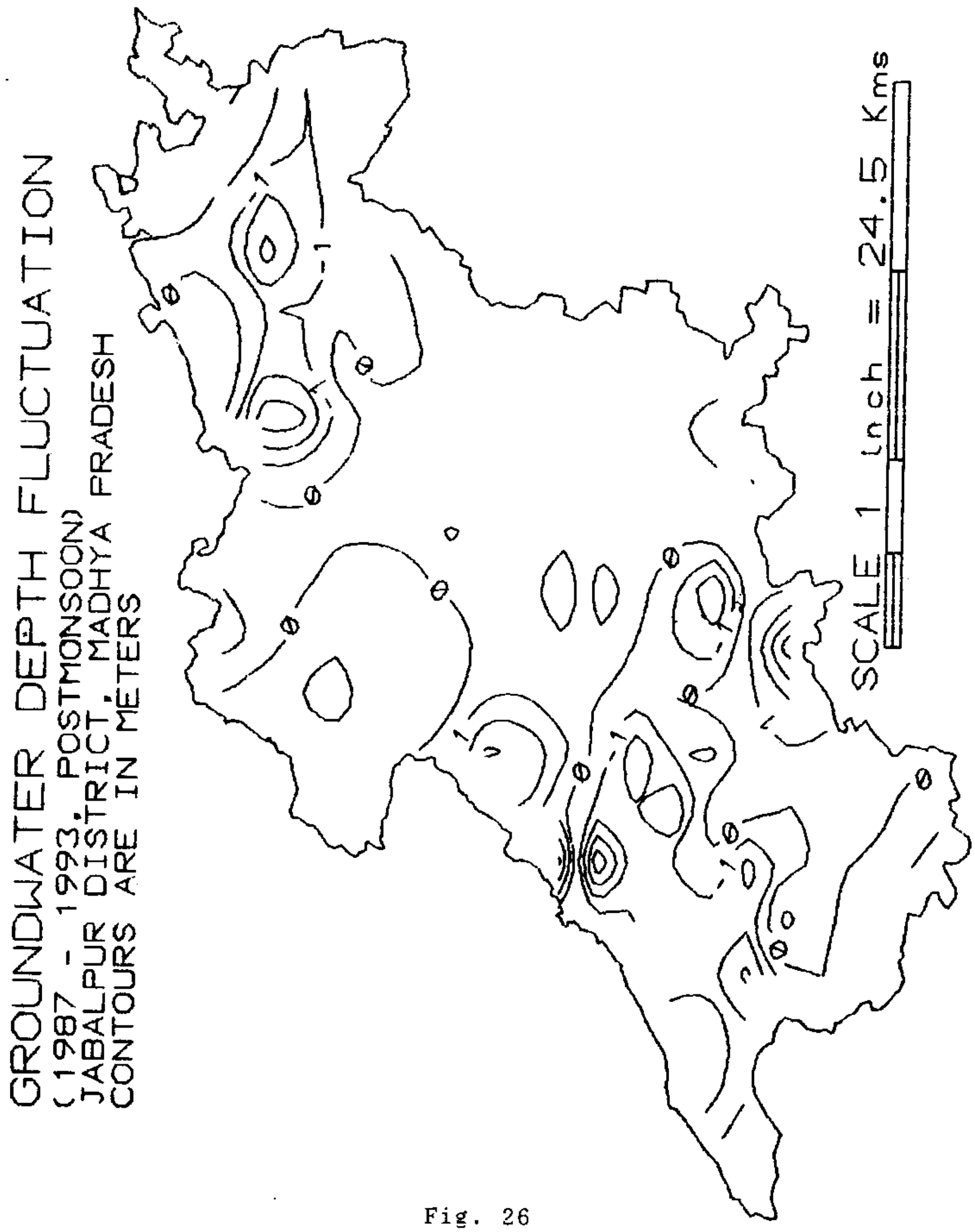

GROUNDWATER DEPTH FLUCTUATION
(1987 - 1993, POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 Kms

Fig. 26

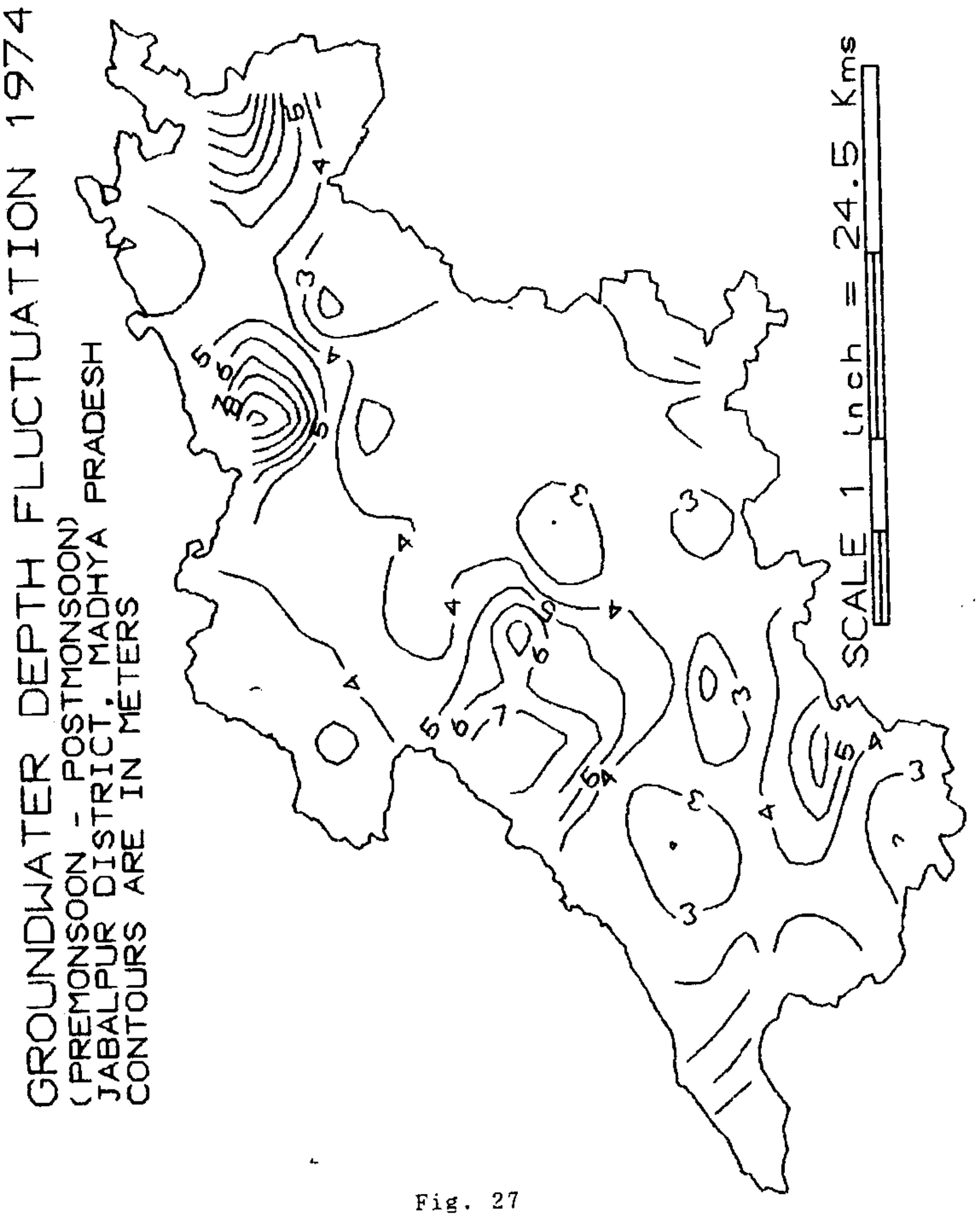

GROUNDWATER DEPTH FLUCTUATION 1974
(PREMONSOON - POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 Kms

Fig. 27

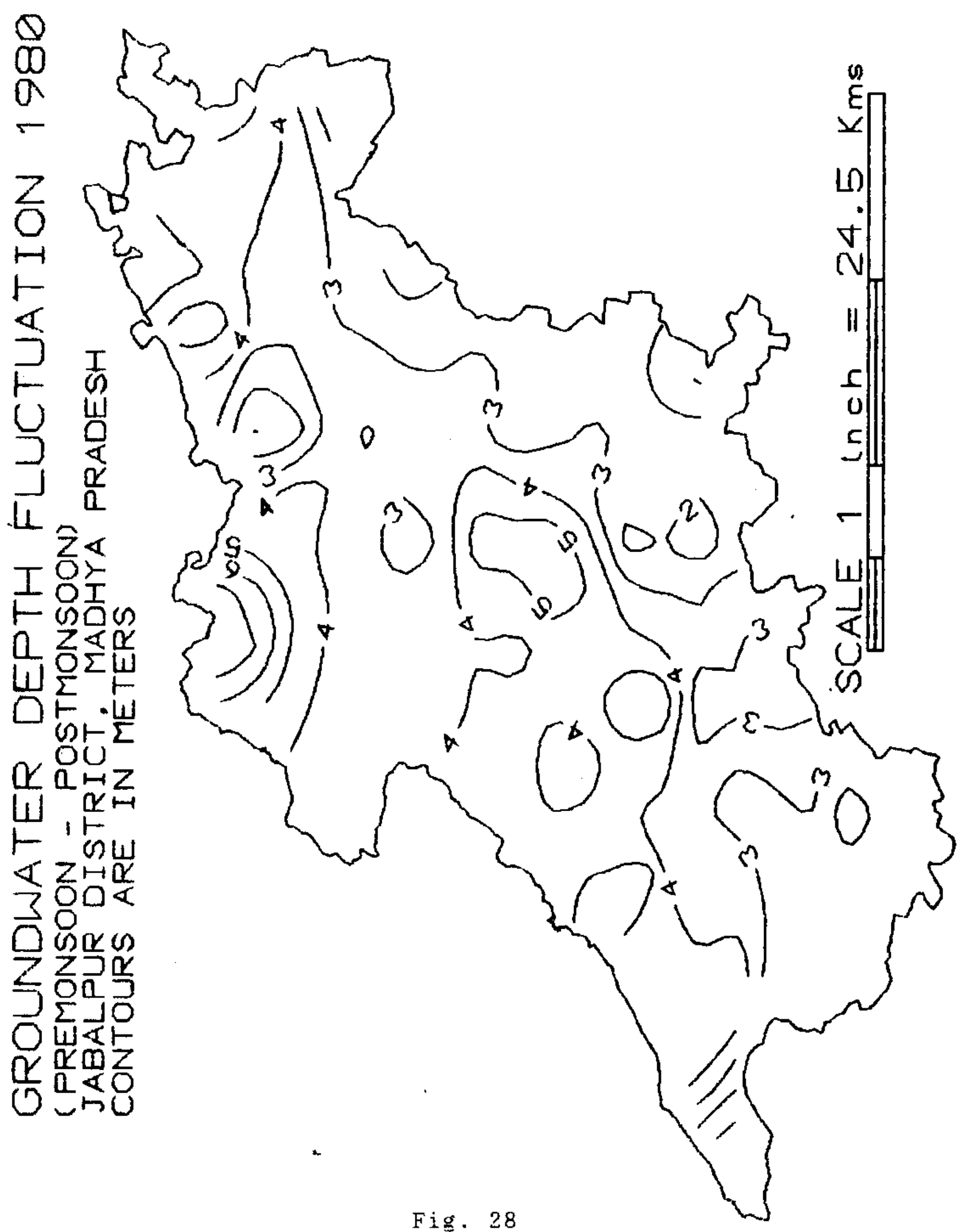

GROUNDWATER DEPTH FLUCTUATION 1980
(PREMONSOON - POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 Kms

Fig. 28

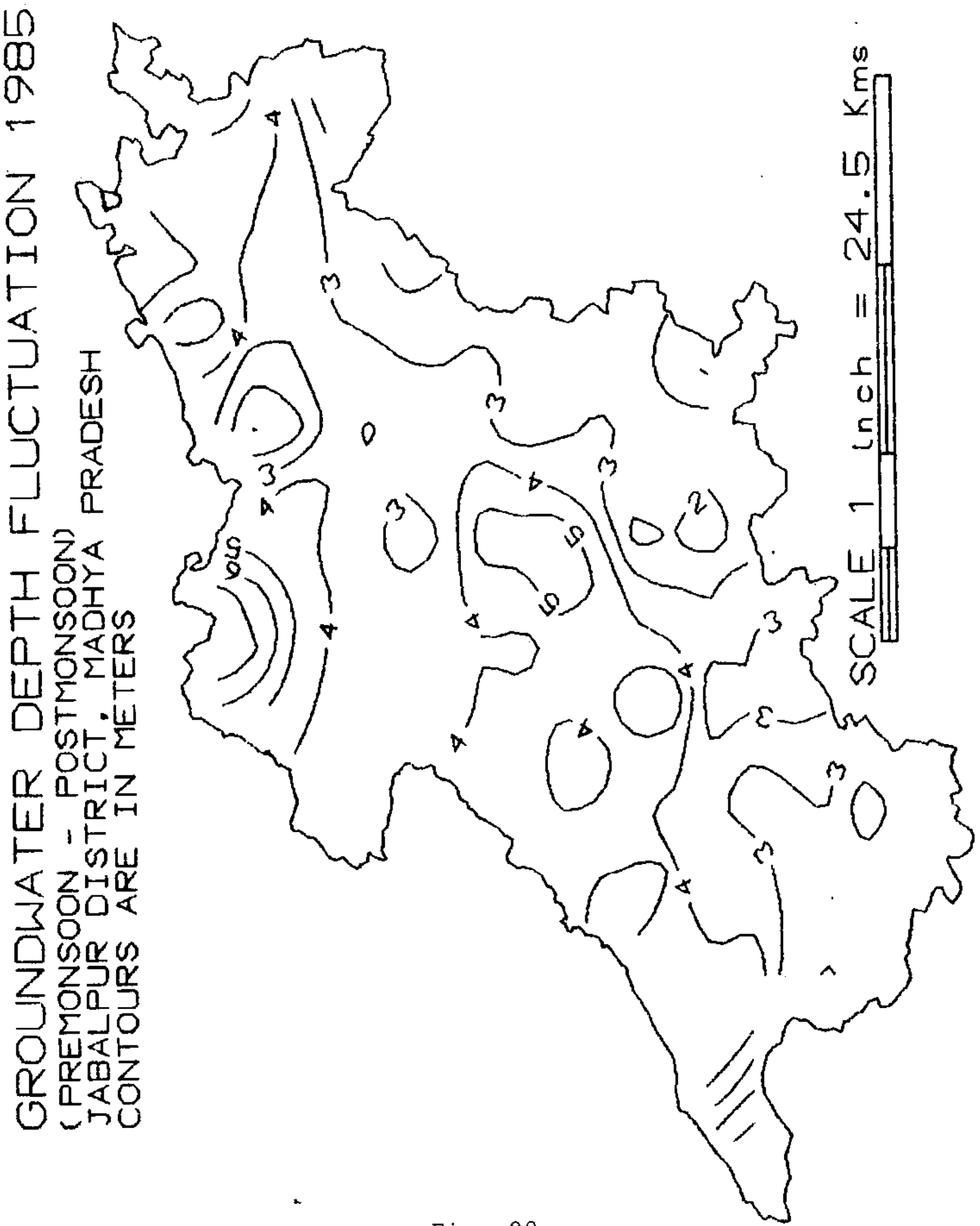

GROUNDWATER DEPTH FLUCTUATION 1985
(PREMONSOON - POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 Kms

Fig. 29

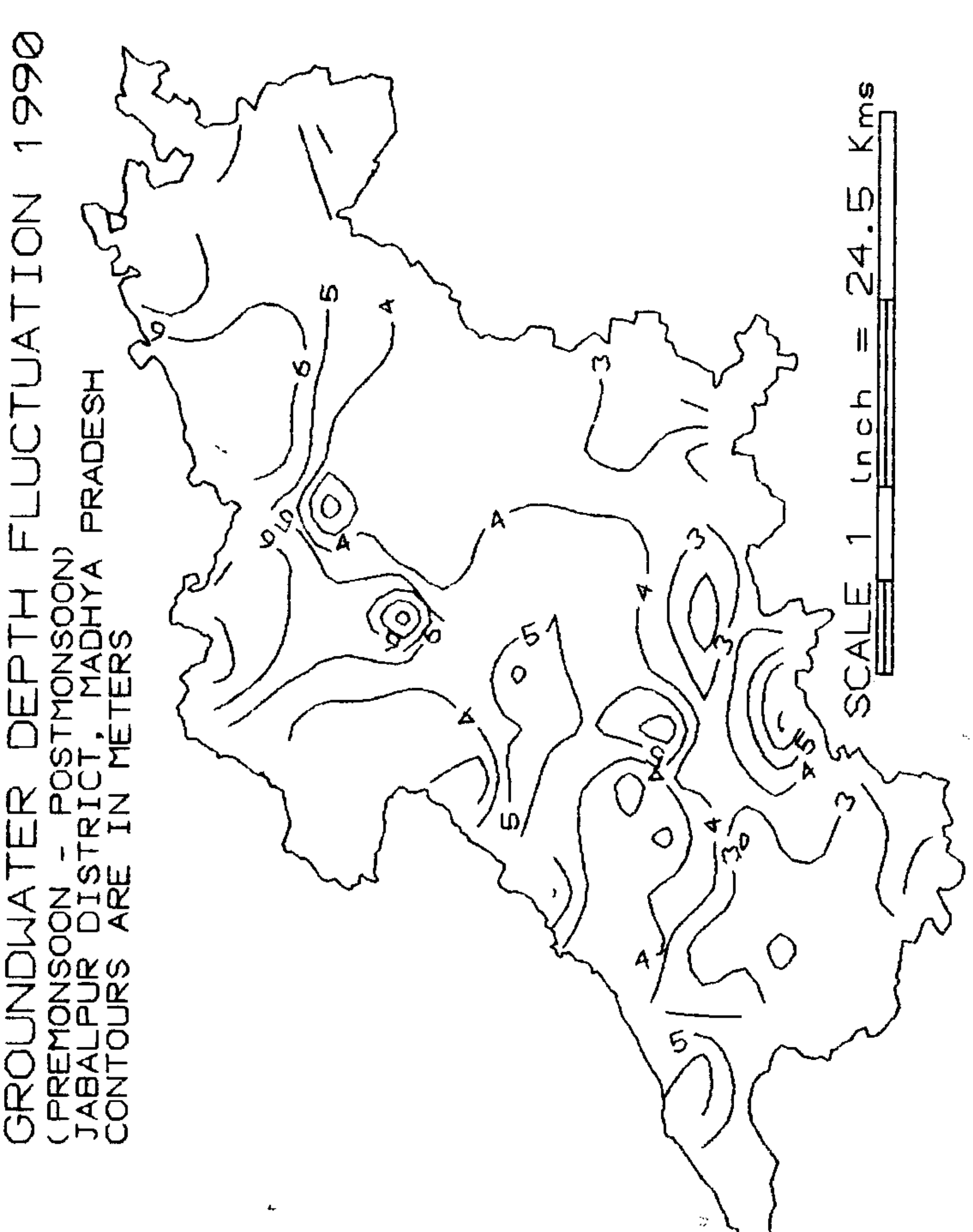

GROUNDWATER DEPTH FLUCTUATION 1990
(PREMONSOON - POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 inch = 24.5 Kms

Fig. 30

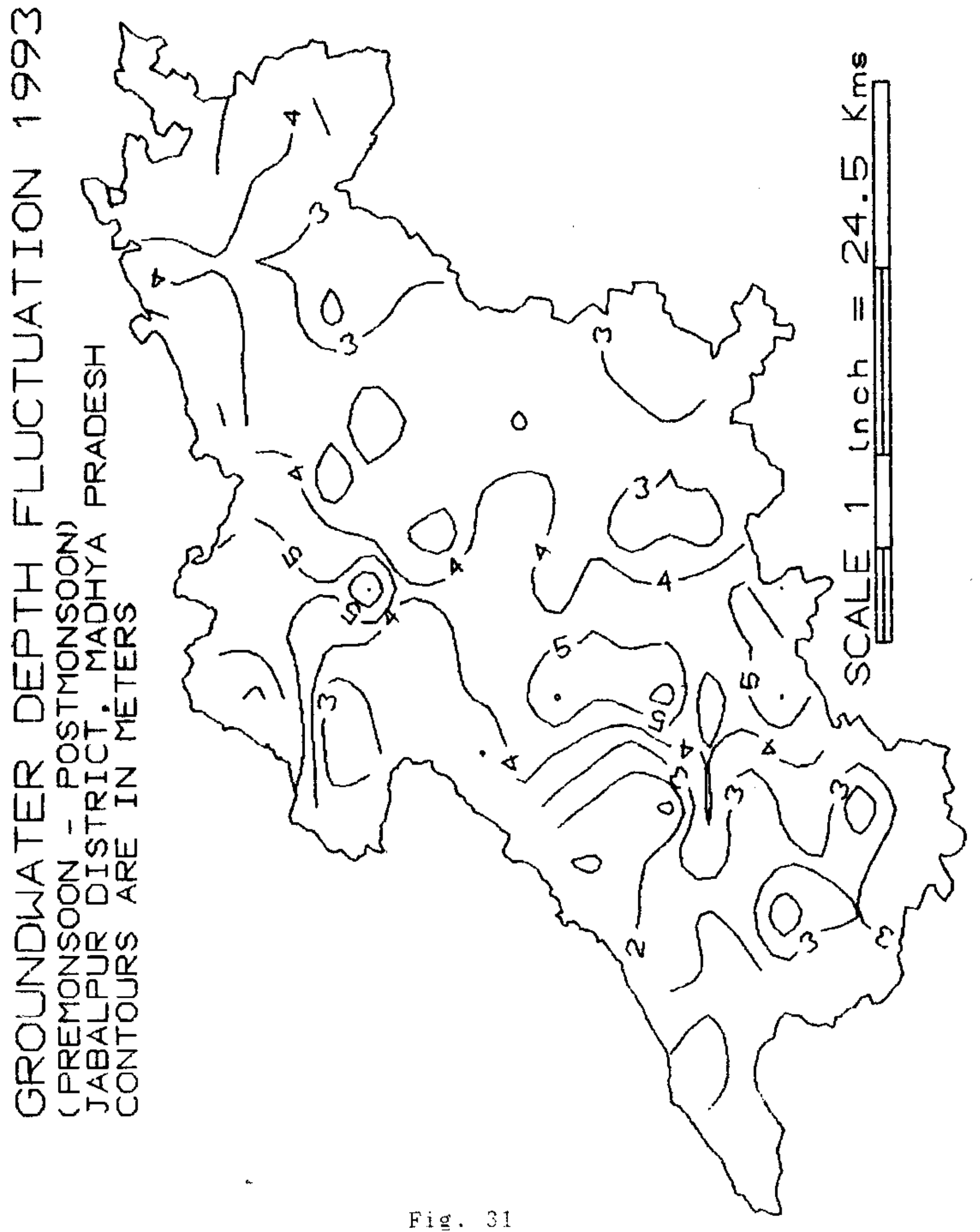
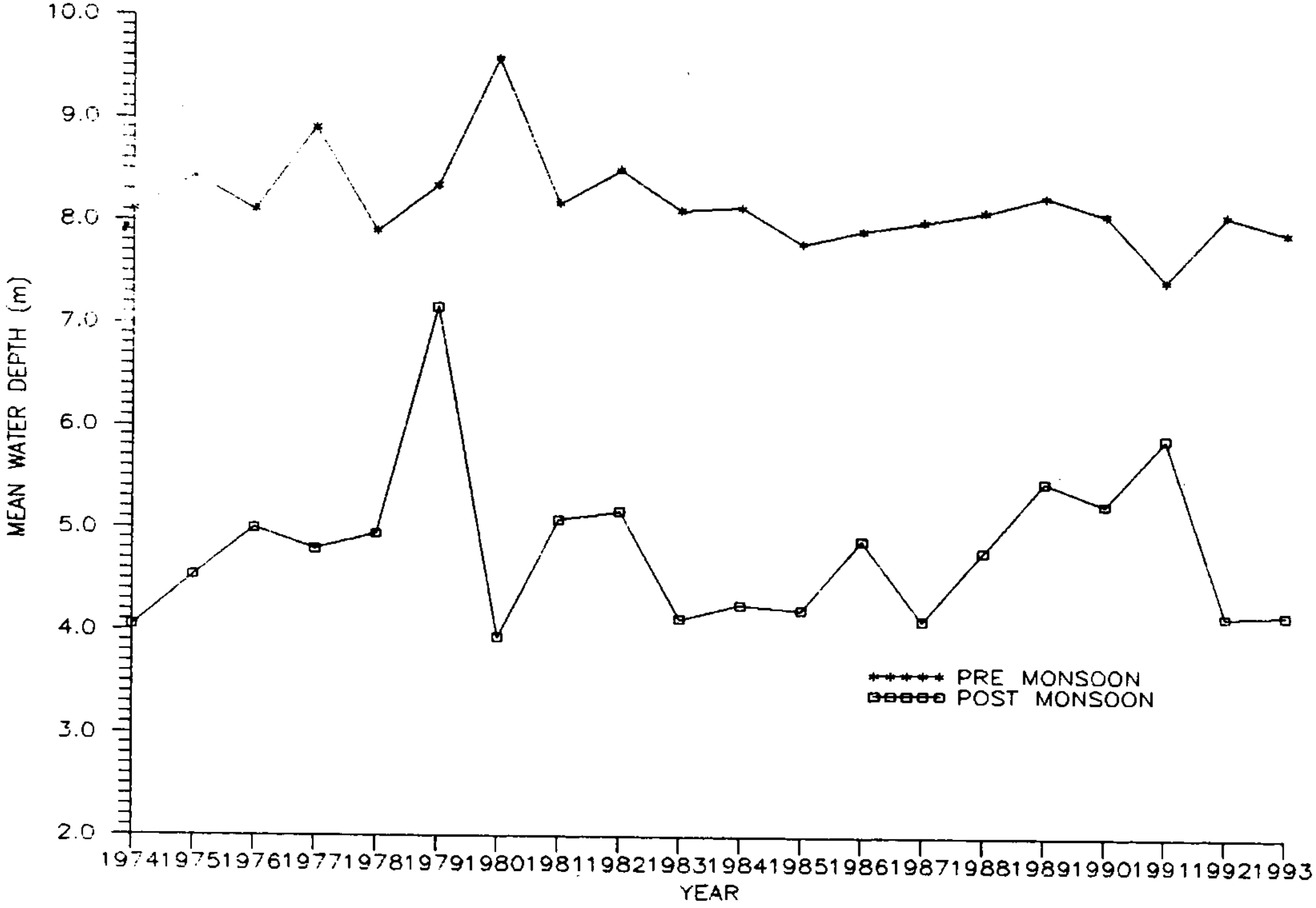

GROUNDWATER DEPTH FLUCTUATION 1993
(PREMONSOON - POSTMONSOON)
JABALPUR DISTRICT, MADHYA PRADESH
CONTOURS ARE IN METERS
SCALE 1 Inch = 24.5 Kms

Fig. 31

4.0 TIME SERIES OF GROUNDWATER DEPTH

A time series is a chronological sequence of observations of a specified variable. In some cases the observations are continuous over time, and in other cases the observations are made only at discrete time intervals. A groundwater depth time series reflects all natural hydrological processes as well as the influences of man upon the aquifer.

The plots showing the value of any variable with respect to time is known as time series plot of that variable. These type of graphs are important to see the behavior of variable with time. It is also used in the time series modeling. By looking at the graph the variation of any variable from one season to another and from one year to another can be easily interpreted. The plots plotted in this study includes time series plot of mean water depth for premonsoon and postmonsoon (Fig. 32), mean groundwater fluctuations (Fig. 33) and the time series plot of watertable, depth for a particular observation point (Fig. 34 to Fig. 38). Mean value of groundwater depth for a particular year is calculated simple as the arithmetic mean. By a cursory look at the mean groundwater depth plot, it can be said that the mean groundwater depth for premonsoon period is almost same over the years. On the other hand there are small variations in mean groundwater depth for postmonsoon season. The reason for these small variations may be due to the fluctuation of amount of rainfall over the years. The mean fluctuation plot shows the mean of the difference between water depth in premonsoon and postmonsoon over the years.



MEAN WATER DEPTH (m)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993
YEAR
PRE MONSOON
POST MONSOON

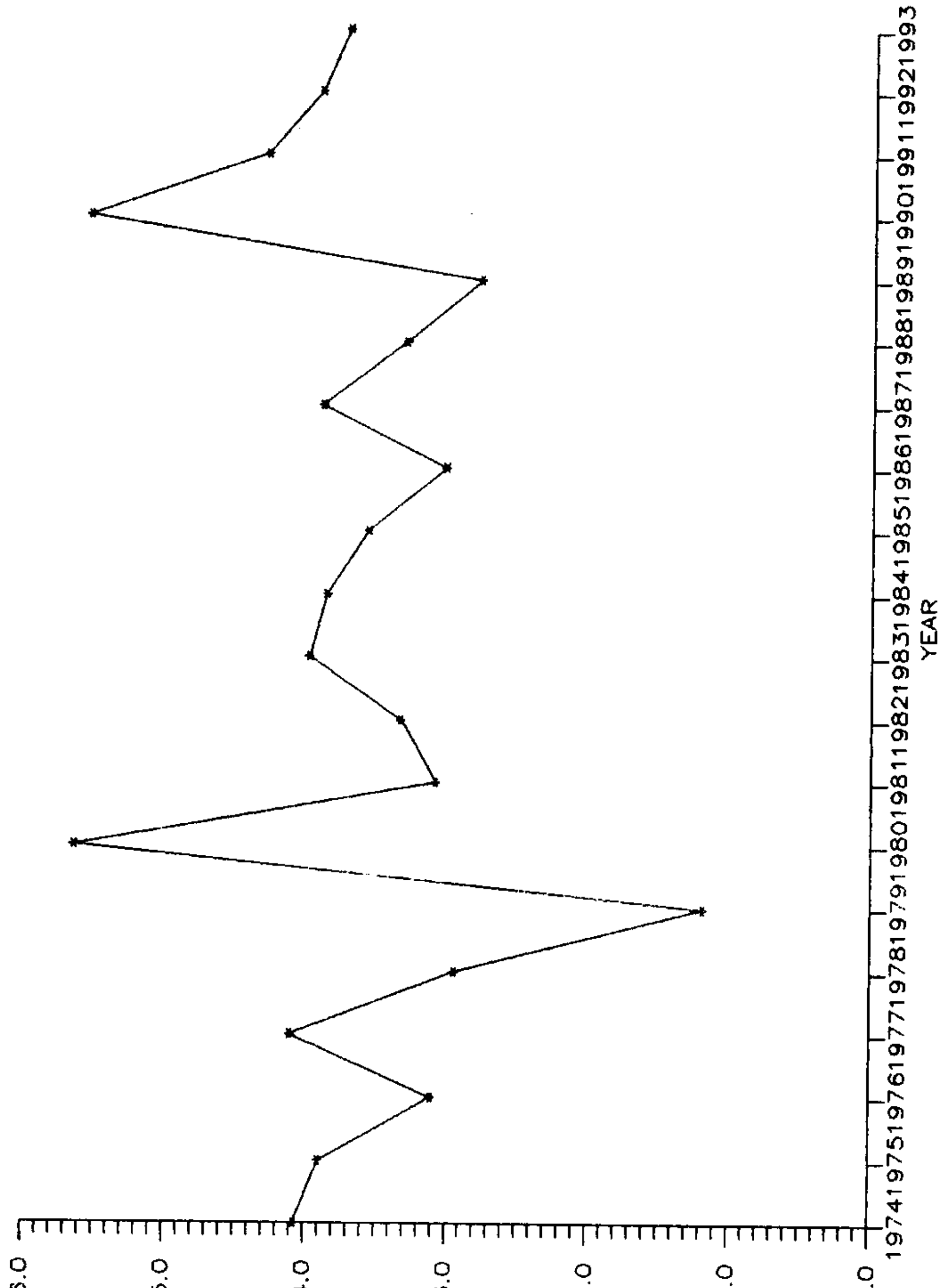

MEAN FLUCTUATION (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
YEAR
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993

Fig. 33

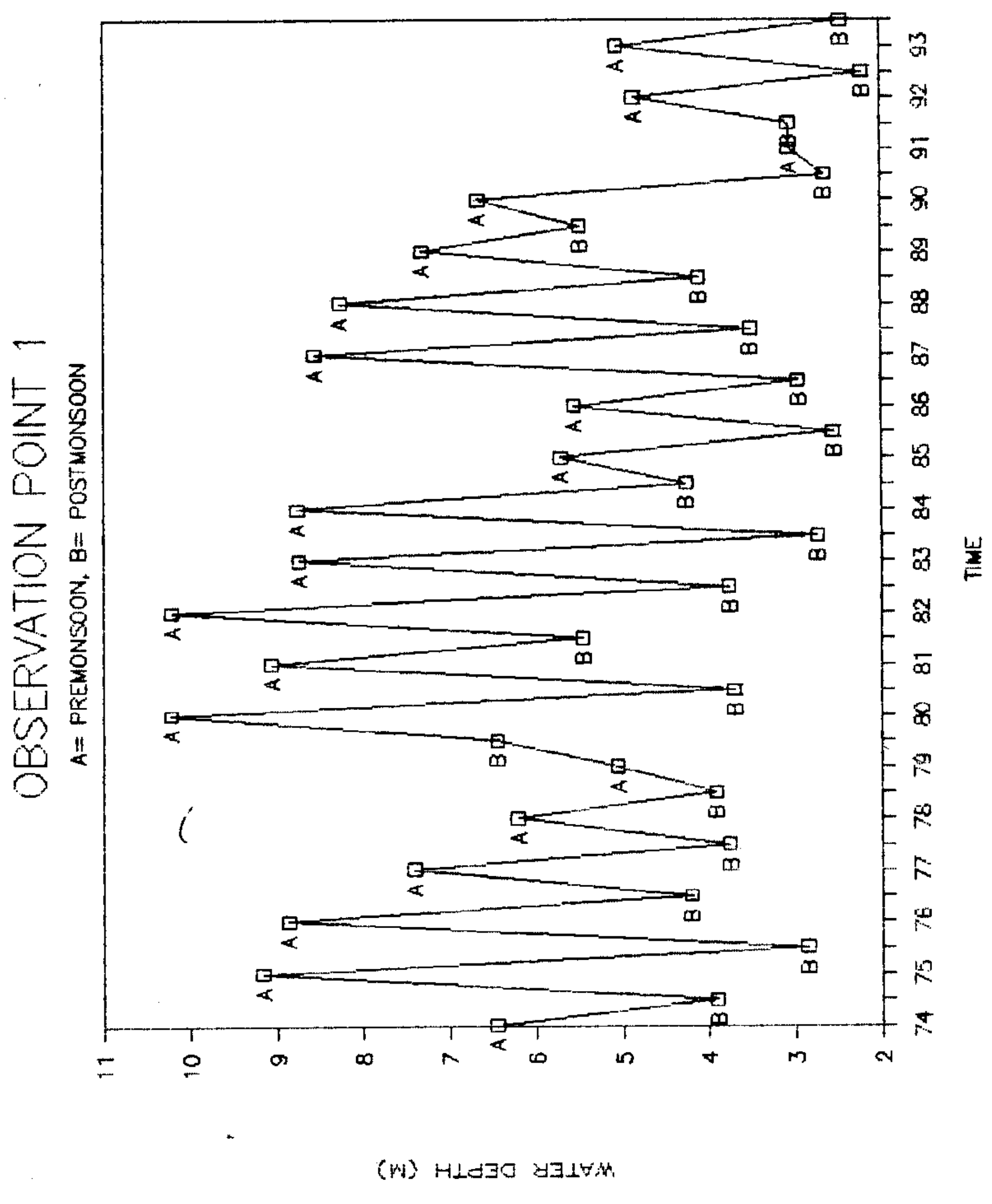

OBSERVATION POINT 1
A= PREMONSOON, B= POSTMONSOON
WATER DEPTH (M)
TIME
74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
2 3 4 5 6 7 8 9 10 11

Fig. 34

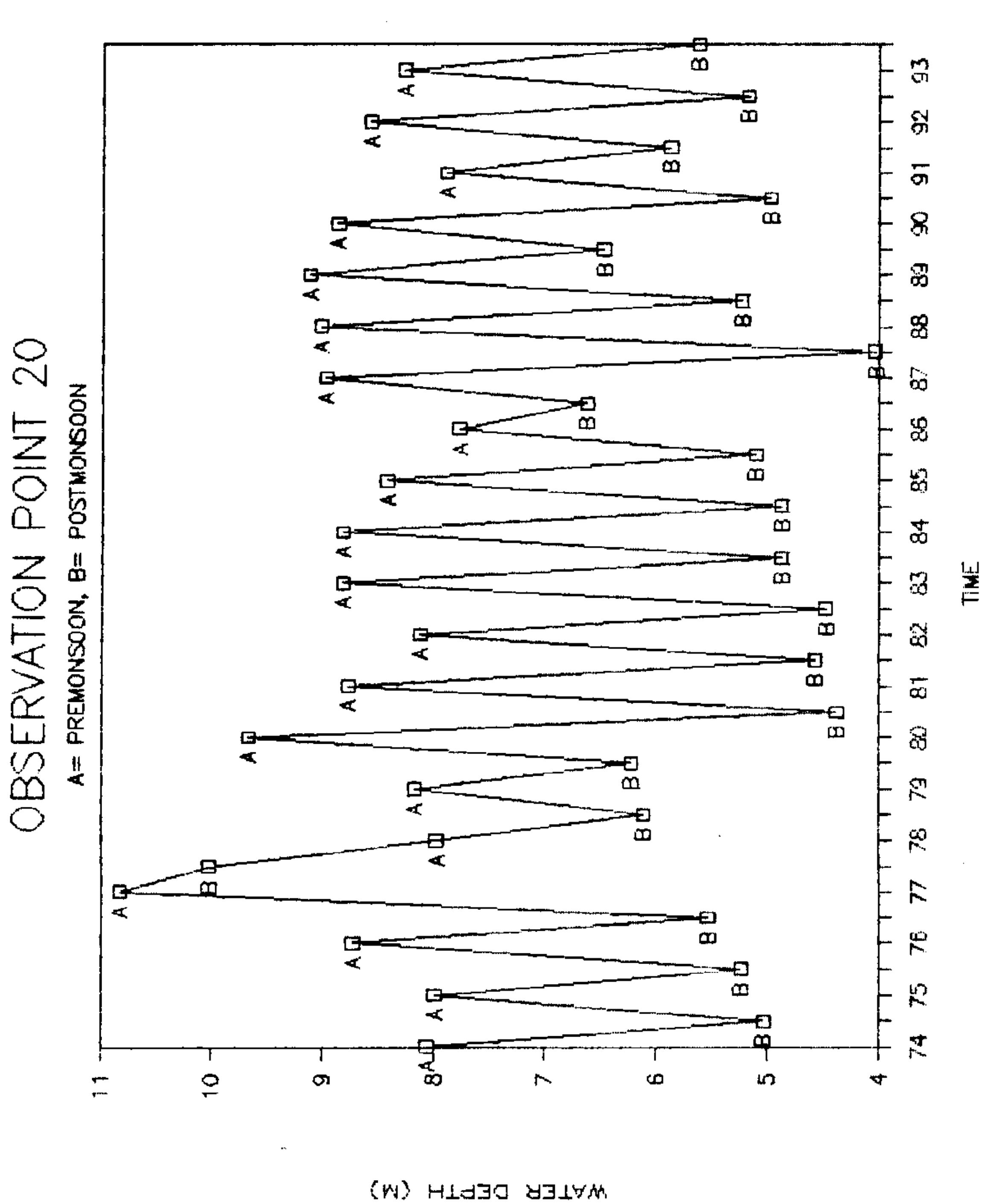

OBSERVATION POINT 20
A= PREMONSOON, B= POSTMONSOON
TIME
WATER DEPTH (M)

Fig. 35

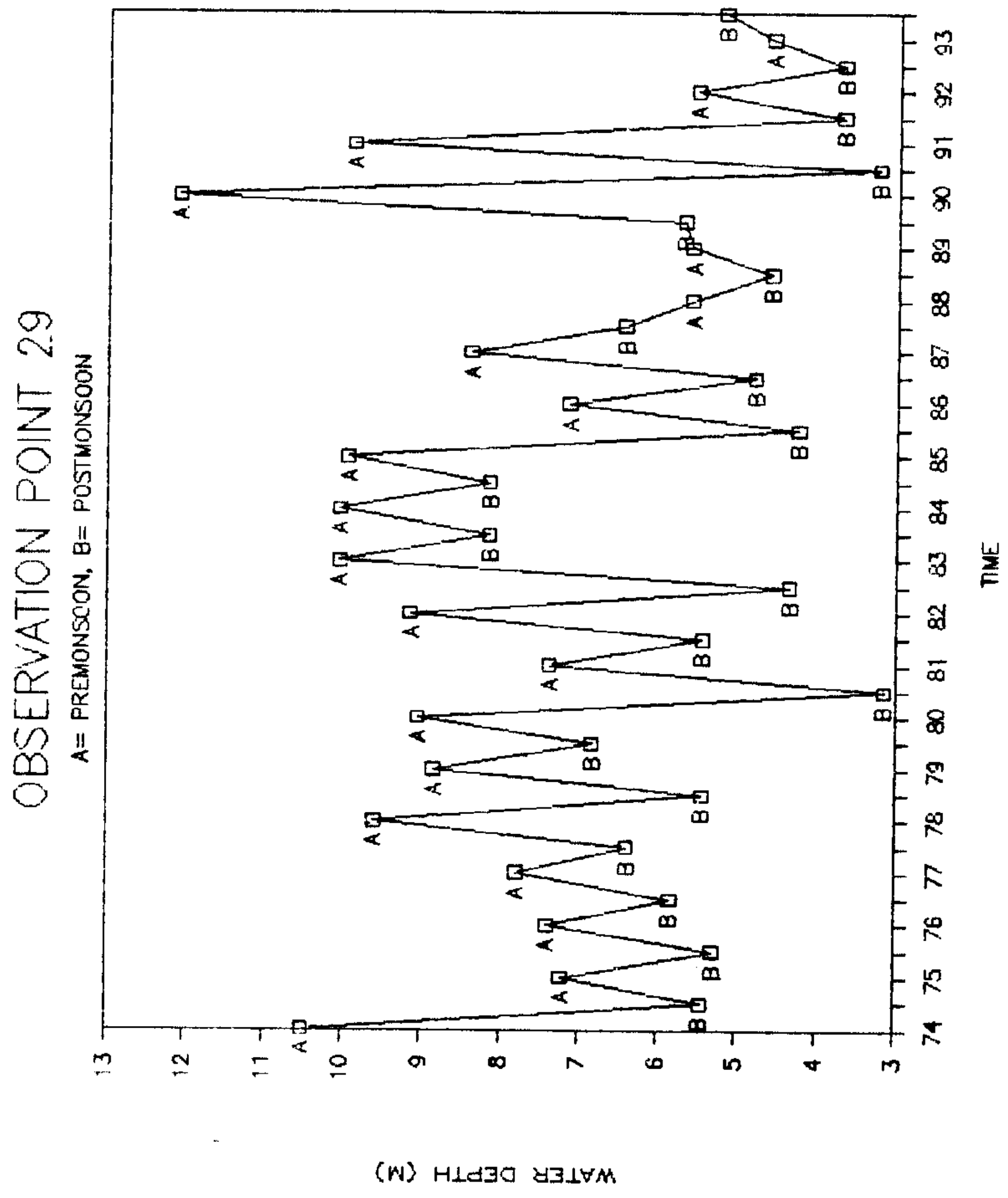
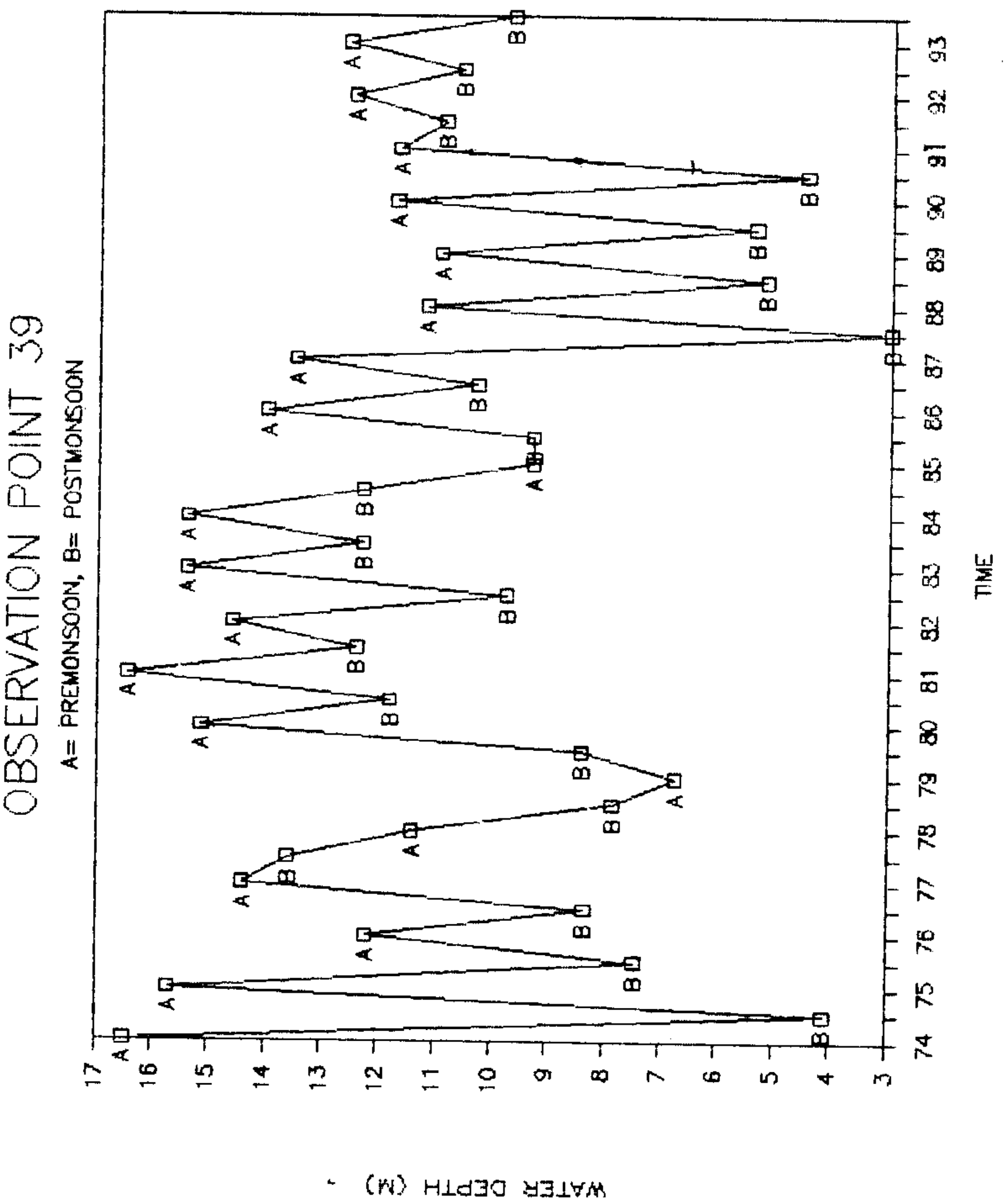

OBSERVATION POINT 29
A= PREMONSOON, B= POSTMONSOON
TIME
WATER DEPTH (M)

Fig. 36



OBSERVATION POINT 39
A= PREMONSOON, B= POSTMONSOON
WATER DEPTH (M)
TIME
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3
74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93

Fig. 37

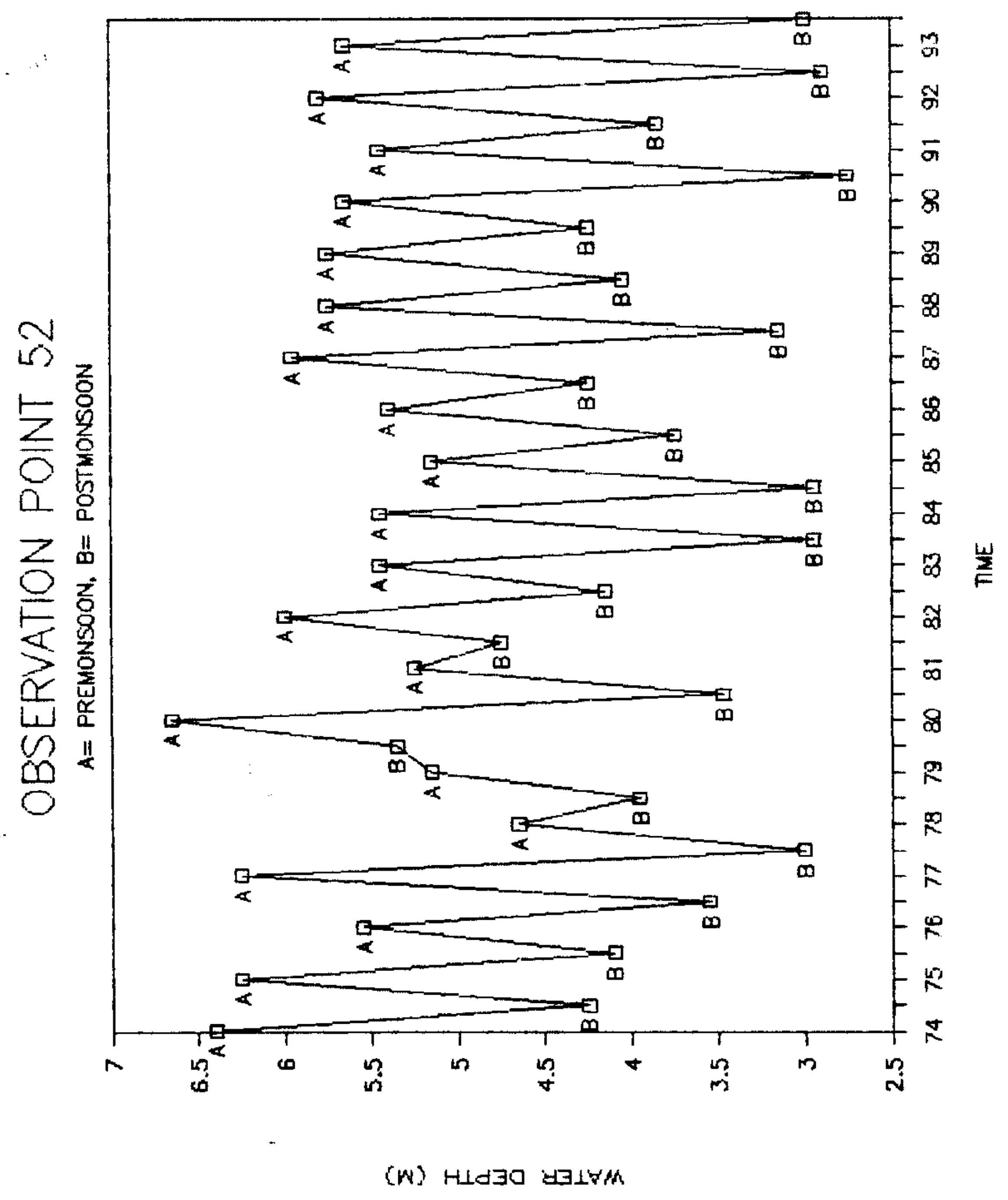

OBSERVATION POINT 52
A= PREMONSOON, B= POSTMONSOON
WATER DEPTH (M)
TIME
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93

Fig. 38

5.0 LEAST SQUARE POLYNOMIAL APPROXIMATION

The functional approximation of hydraulic head values, at any particular time, can be represented by

$$h_i = f(x_i, y_i) + e_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where h_i = observed value of water table

x_i, y_i = coordinate of the ith point

e_i = random error associated with observation and assumed to be statistically uncorrelated.

The value of h_i can be approximated by polynomial of the spatial coordinates x and y.

$$h^*_1 = b_0 + b_1 x_1 + b_2 y_1 + b_3 x^2_1 + b_4 y^2_1 + b_5 x_1 y_1 + \text{--------}$$

$$h^*_2 = b_0 + b_1 x_2 + b_2 y_2 + b_3 x^2_2 + b_4 y^2_2 + b_5 x_2 y_2 + \text{--------}$$

$$h^*_3 = b_0 + b_1 x_3 + b_2 y_3 + b_3 x^2_3 + b_4 y^2_3 + b_5 x_3 y_3 + \text{--------}$$

$$\vdots \qquad\qquad\qquad\qquad \vdots$$

$$h^*_n = b_0 + b_1 x_n + b_2 y_n + b_3 x^2_n + b_4 y^2_n + b_5 x_1 y_n + \text{--------} \quad \ldots(5)$$

The above equation can be written in the matrix form as below

$$[\ H\ ] = [\ A\ ]\ [\ B\ ] \qquad \ldots\ldots\ldots\ldots(6)$$

where [H] = column matrix of observed water table of order n*1

[B] = column matrix of coefficients to be calculated m*1

[A] = square matrix of order n*m

n = no. of observation points

m = no. of coefficients to be calculated

To find the value of coefficients b_0, b_1, b_2, b_3,......, the least square technique uses the criterion of minimization of square of error between the approximated and observed value i.e.

$$\text{Min. } e^2 = \sum (h_i^* - h_i)^2 \text{ ....(7)}$$

The minimisation of e^2 can be obtained by equating to zero the partial derivatives of the above equation with respect to the coefficients. The general solution of the equation (6), using the criterion of equation (4) is given by

$$[\ B\ ] = [\ A^T A\ ]^{-1}\ [\ A^T\ C\ ] \text{ ....(8)}$$

The degree of polynomial, which best fits the data, can be decided on the basis of criterion of minimum standard error given by

$$s = \sqrt{\frac{\sum (h_i^* - h_i)^2}{n - m}} \text{ ....(9)}$$

The significance of a regression can be tested by performing an analysis of variance. It gives the goodness of fit i.e. how well does the regression equation accounts for variations in the dependent variable. Numerically it is given by coefficient of determination (R^2).

$$R^2 = RSS/TSS \text{ ....(10)}$$

where

RSS = Regression (explained) sum of squared deviation

$$= \sum (h_i^* - \bar{h})^2$$

TSS = Total sum of squared deviation

$$= \sum (h_i - \bar{h})^2$$

R^2 indicates the explanatory power of the regression model. The possible values of the measure range from '+1' to '0'. When R^2 is near a value of +1, it shows a good fit of data.

The above explained technique was applied to groundwater level data for the premonsoon and postmonsoon data for the year 1993. It is found that for both periods a polynomial equation of degree 2 (i.e. no. of coefficients 6) fits the data best. The coefficients are given below

For Premonsoon 1993

b_0=271.36,	b_1=1.424,	b_2=1.345
b_3=0.017,	b_4=0.019,	b_5=-0.052

For Postmonsoon 1993

b_0=265.36,	b_1=1.59,	b_2=1.32
b_3=0.016,	b_4=0.019,	b_5=-0.051

R^2 value for premonsoon comes out to be 0.74 and for postmonsoon 0.73. These values indicate that the least square fit is good.

6.0 REFERENCES

1. Davis, J.C. (1973). Statistics and Data Analysis in Geology. John Wiley, New York.
2. Kashyap, D. (1981). Mathematical Modeling of Groundwater Systems. Ph. D. Thesis. University of Roorkee.
3. Mahajan, G.(1989).Evaluation and Development of Groundwater. Ashish Pub. House, New Delhi.
4. Murty, V.V.N. (1985). Land And Water Management, Kalyani Pub., New Delhi.
5. National Institute of Hydrology (1985). Processing of Precipitation data. TR-2.
6. National Institute of Hydrology (1987). Surface Fitting of Groundwater Table by Means of Least Square Approach. TR-25.
7. U.S. Department of the Interior (1985). Groundwater Manual. Scientific Pub. Jodhpur.
8. UNESCO (1972). Groundwater Studies, Paris.
9. UNESCO (1977). Hydrological Maps, Paris.

DIRECTOR	: Dr. S.M.SETH
DIV. HEAD	: Sh. A.K.BHAR
STUDY GROUP	: Sh. VIJAY KUMAR