PINSTECH/RIAD-130

AN ISOTOPIC APPROACH TO STUDY THE RECHARGE MECHANISM IN HARIPUR PLAIN-CONTRIBUTION TO THE AREA FROM TARBELA AND KHANPUR LAKES

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ABSTRACT

Environmental isotopic investigations were carried out in Haripur plain to determine the recharge mechanism in the area. The Haripur plain is bounded by river Doar (that falls in Tarbela lake) in the north, mountain ranges in the east and west, while the river Haro flows on the south eastern boundary upon which Khanpur dam has been built. Efforts were made to identify the different sources which recharge the aquifer in the area. Isotopic data reveal that the major source of recharge is the rainfall on adjoining hills. There is no contribution of Tarbela and Khanpur lakes. The residence time varies from a few years to more than fifty years depending upon the geology of the area.

C O N T E N T S

AN ISOTOPIC APPROACH TO STUDY THE RECHARGE MECHANISM IN HARIPUR PLAIN- CONTRIBUTION TO THE AREA FROM TARBELA AND KHANPUR LAKES

1. INTRODUCTION

The Haripur plain is bounded by the river Doar in the north, mountain ranges in the east and west, while the river Haro flows a little away from its southern boundary. In the north west Tarbela Lake is situated and on the south eastern boundary Khanpur dam has been built. It is believed that main source of recharge in the plain is precipitation along the boundary of alluvium by infilteration of run-off from the mountains. However, surface run-off through drains, rainfall , small storage dams and irrigation channels may also contribute to the groundwater body. Monitoring of open wells by Water and Power Development Authority (WAPDA) shows an upward trend in the water table near Tarbela lake when it attains highest level [Sheikh et al., 1982].

For the groundwater development and estimation of safe yield, it is important to identify the various sources of recharge and their relative contribution to the groundwater body in the Haripur plain. The isotopes of Oxygen(^{18}O) and Hydrogen(^{2}H & ^{3}H) being the parts of the water molecule are very good geochemical tracers of water because their concentrations are not subject to changes by interaction with aquifer materials [IAEA, 1968, 1983]. It was therefore, planned to apply the isotopic techniques to identify the different sources and their relative contribution to the recharge of the aquifer in the Haripur plain. In addition, the knowledge of residence time and flow velocities will help the groundwater exploitation to safe yield.

2. DESCRIPTION OF THE AREA

Haripur plain is part of Abbottabad District and is located about 160 kilometers north-east of Peshawar. This plain is situated between latitude 33^{0}-50' and 34^{0}-6' north and longitude 72^{0}-46' and 73^{0}-12' east (figure 1). It is bounded by the river Doar in the north, mountain ranges in the east and west while the river Haro flows a little away from its southern boundary.

The surface of the plain is gently undulating except along eastern and western boundaries where badland topography exists. The plain is dissected by numerous gullies. Surface altitude ranges from 915 meter above mean sea level (m.s.1) in the north eastern part to 442 meter above m.s.1 in the south western part of the alluvium.

Total catchment area of Haripur plain is 622 sq.km. of which 422 sq.km. is alluvial fill.

Haripur is the principal town of the area. Havellian, Sarai Saleh, Panian and Kot Najibullah are other places of importance. Agriculture is mostly dependent upon rainfall and to some extent on surface water from the river Doar near Sarai Saleh. However, groundwater is also being utilized as some tubewells have been installed by Irrigation Department and private people. The supply of surface water through irrigation canals, seasonally during flood season and regularly from Khanpur Dam, is available [Sheikh et al., 1982].

3. GEOLOGY

Haripur plain is extensively covered with alluvial fill. The western, eastern and south eastern parts of the plain are covered by thick clay deposits which have been eroded and gullied extensively by numerous nalas. Over most of the area, the clay cover varies in thickness from 30 to 60 m. This clay cover is underlain by sand, gravels and boulders of considerable thickness with some layers of clay in between them. The layers of sand, gravels and boulders between Hattar and Dingi in southern part of the area, are highly permeable. In the north and north eastern part of the plain, between Havellian and Sarai Saleh, the clay cover is comparatively less thick and overlies the boulders and gravels of considerable thickness. These boulders and gravels are highly permeable and form a good aquifer.

Depth of the water table is a function of topography and varies widely in the plain. It ranges from 18 meters in the north, north eastern and western parts to 76 meters in central and southern parts.

4. CLIMATE

The climate of this area is semi-arid with hot summers and mild winters. Mean maximum temperature in the hottest month (June) is 44 °C while the minimum temperature in the coldest month (January) is 3 °C. The mean annual precipitation in Haripur is 910 mm while that at the adjoining hills is about 2000 mm.

5. SAMPLE COLLECTION AND ANALYSIS

About 55 water sampling stations including tubewells, open wells, lakes, rivers and drains were established (listed in table no. 1). The location map of the sampling points is given in figure 1. Nine sets of samples were collected during October 1987 to June 1990. Temperature, pH and electrolytic conductivity measurements were made in situ. Laboratory analyses of samples for $\delta^{18}O$, $\delta^{2}H$, tritium and radicals like Na, Mg, Ca, CO_3, HCO_3, SO_4, Cl, etc. were carried out. Rain samples of the area were also collected and analysed. Tarbela lake was sampled more frequently to find its mean isotopic index.

6. RESULTS

6.1. Physico-Chemical Data

The data obtained from the field measurements and laboratory analyses of water samples is as follows:

Electrolytic conductivity of deep waters (tubewells) ranges from 300 to 800 uS/cm and that of shallow waters (open wells) from 400 to 1300 uS/cm. pH of both shallow and deep waters varies from 6.7 to 8.0, whereas that of surface waters from 7.7 to 8.7. Chloride content of these wells ranges between 5 to 85 mg/l but for most of them lie in the range of 5-15 mg/l. Temperature ranges of shallow and deep waters are 16-23 °C and 16-26 °C respectively.

6.2. Isotopic Data

$\delta^{18}O$ and $\delta^{2}H$ values of water samples collected during October 1987 to June 1990 (on quarterly basis) were measured on mass spectrometer. Figures 2-11 show the plots of $\delta^{18}O$ versus $\delta^{2}H$ values for mean and individual samplings of ground and surface waters. $\delta^{18}O$ and $\delta^{2}H$ values of Tarbela Lake averaged over the period of about three years (weekly/monthly samplings) are around -12.0‰ and -80.10‰ respectively. The variation for $\delta^{18}O$ is in the range of -13.3‰ to -10.4‰ as shown in figure 12.

7. DISCUSSION

The various possible input sources, contributing to the aquifer in Haripur plain are:

- Rainfall in mountainous catchment area,
- Local rain fall,
- Storage dams such as Tarbela , Khanpur and Chhattar lakes and
- Irrigation water.

7.1. Contribution to Recharge from Rainfall at Mountains

The saturated zone in the Haripur plain is overlain by 30 to 60 m thick clay layer. However, clay cover in the north and north-eastern part of the plain is comparatively less thick and is underlain by a permeable zone of sand, gravels and boulders of considerable thickness. Therefore, the run-off from the mountains can only infiltrate along this boundary of the alluvium. To find the isotopic index of rainfall on mountains, the river Doar (draining mountain rain) was sampled near Havellian and has mean $\delta^{18}O$ and $\delta^{2}H$ as -5.29 ± 0.25‰ and -28.08 ± 3.6‰ respectively. The true and more representative isotopic index of mountainous rainfall would be that of well no. 20, 21 and 22 (fig.1). Their mean $\delta^{18}O$ and $\delta^{2}H$ values are -5.38 ± 0.16‰ and -29.95 ± 2.2‰. Looking at the histograms of the frequency distribution of $\delta^{18}O$ of all the water samples (fig.13). It can be seen that the distribution has maximum frequency close to isotopic index (-5.38‰) of rainfall at mountains. This indicates that major recharge is from rainfall at mountains.

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7.2. Recharge to Aquifer from Local Rains

Local rains are to be isotopically heavier than the rains at mountains due to low altitude. The mean annual precipitation in Haripur plain is about 915 mm while that at the adjoining hills is 2000 mm. Its isotopic index is to be based on sampling over a long period. Taking the isotopic index $\delta^{18}O$ as -5.0‰ of adjacent Mardan Valley [Sajjad et al., 1987] also representative for Haripur plain, its contribution to the aquifer is possible but only through gullies [Sajjad et al., 1985]. However, this is superimposed by the variations of rainfall on adjacent hills which is a major source of recharge.

7.3. Contribution from Lakes

All the three lakes are characterized with quite different isotopic indices:

a) Tarbela Lake

Tarbela Dam, completed in 1976 has been built on the river Indus. Emerging from the land of glaciers on the northern slopes of Kailash ranges, some 5182 meters above m.s.l., the river Indus has its source near the lake Mansrowar in Himalyan catchment area.

The 80 Kilometer long reservoir of Tarbela lake has a gross capacity of 17.109×10^9 m^3 at the maximum lake elevation of 472 m, a residual capacity of 2.802×10^9 m^3 at the assumed level of maximum drawdown elevation of 396 m and a net capacity of 14.307×10^9 m^3. The total catchment area above Tarbela is spread over 168,000 km^2 which largely drains snow-melt in addition to some monsoon rains. Two main upstream tributaries join the river Indus; Shyok river at an elevation of 2438 meters above m.s.l near Skardu and Siran river just north of Tarbela. The Tarbela reservoir stores water during the summer months of June-August and attains its maximum level (472 m).

Tarbela lake (being in the north and north-west of Haripur plain) is mostly fed by snow-melt and rains at high mountains, and as such is very much depleted in ^{18}O and ^2H contents. The variations of ^{18}O content in Tarbela lake (fig.12) are closely related with amount of storage water (lake level). The lake water is isotopically most depleted in September - October when the lake level is maximum (472 m) and enriched in April-May when lake level is the lowest.

Tarbela lake was also sampled at point 49 near Haripur city. Here, variation of $\delta^{18}O$ is from -12.5 to -7.5‰. This variation is linked with the level of the reservoir. Its isotopic index, $\delta^{18}O$ = -12.5‰ is the same as that of dam channel when its level is high and -8.90‰ in February and -7.50‰ in April-May when lake is at its lowest level. This variation depends on the contributions from the river Doar and that of the groundwater being drained into the Tarbela lake. When the lake is at its highest level, the ratio of contributions to the lake from the river Indus to that of the river Doar is high and consequently its isotopic index is most depleted. The isotopic value of the lake water starts increasing as the above ratio decreases with the decrease of lake level.

The elevations of Haripur plain and that of the lake are such that the recharge from Tarbela lake can most probably take place when it is at its maximum level. During that period, it would be isotopically depleted and $\delta^{18}O$ would be close to -13‰.

Considering two component mixing of water, the percentage(%) contribution of each component to the aquifer can be determined from the relations [IAEA, 1983]:

% contribution from Tarbela lake is: $f_l = ((\delta - \delta_m)/(\delta_l - \delta_m)) \times 100$

% contribution from rains at high mountains is:

$$f_m = ((\delta_1 - \delta)/(\delta_l - {}_m)) \times 100$$

where; δ_l = delta value of Tarbela Lake
δ_m = delta value of rainfall on mountains
δ = delta value of mixture of two components

Even 10% contribution from the Tarbela lake ($\delta^{18}O$ = -13‰) to Haripur plain would shift its isotopic contents ($\delta^{18}O$ = -5.38‰) to -6.14‰. However, no such values are seen in the wells close to the lake boundary.

The possible causes of rise in water table observed by WAPDA in open wells near Tarbela lake, when it attains its highest level, are as follows:

i) The rise in water level of open wells could be due to infilteration from Tarbela lake. However, isotopic study does not support this proposition.

ii) The increase in watertable near Tarbela lake could be attributed to the hindrance to the drainage of aquifer towards low lying Tarbela lake because of high elevation of lake water. Consequently, water table of the plain starts rising as the recharging source of nearby wells is at higher hydrostatic head.

iii) The general rise in water table during the rainy season as observed at a few locations, may also be contributing to the upward trend of water table in open wells adjacent to Tarbela lake.

b) Chhatter Lake

A small lake at sampling point No. 28 (fig. 1) is fed by local rains and run-off from adjoining mountains. Due to high evaporation, the lake water is isotopically enriched with typical values of $\delta^{18}O$ and $\delta^{2}H$ as -1.58‰ and -12.79‰ in October, 1987. The deuterium excess of about zero per mil also indicates heavy evaporation.

The nearest available sampling well No. 27, in the direction of downward flow from the lake, does not indicate even slightest contribution from the lake. The very thick layer of clay does not allow the lake water to infiltrate into the aquifer.

c) **Khanpur Lake**

Surface altitude of Haripur plain ranges from 915 m above m.s.l. in the north eastern part to 442 m above m.s.l. in the south western part. Khanpur dam is located on the river Haro (south south-east of Haripur city) at an elevation of 600 m above m.s.l. The mean $\delta^{18}O$ and D values are -4.78 ± 0.52‰ and -25 ± 4.5‰ respectively. Infilteration from the lake seemed to be confined only to extreme southern parts of Haripur plain.

7.4. Irrigation Practices

The normal delta of irrigation (height of irrigation water in the field) is about 75 mm. This water keeps standing in the irrigation fields for hours as the percolation is very slow in loamy soils and penetrates to a maximum of one meter depth and most of it remains stored in the upper layers of soils whence it starts evaporating upward. During this process the field water encounters as much as 5‰ enrichment of $\delta^{18}O$ in about 40 hours [Sajjad et al., 1985].

However, such enriched waters have not been seen in the Haripur plain indicating that a contribution from irrigation practices through heavily textured soils, if any, is negligible.

8. RESIDENCE TIME DISTRIBUTION

Residence time distribution in the area can be estimated from the relation of tritium levels in precipitation, surface and subsurface waters. The tritium level in precipitation in the region was [IAEA, 1983] about 100 TU in 1969 while that in the nearby Mardan Valley was about 35 TU in 1986. The mean tritium content of the river Doar is 36 TU and that of three wells (20, 21, 22) along the bank of the river Doar is 37 ± 1 TU.

The groundwater has a range of mean tritium contents from 0 to 53 TU (as depicted in figure 1). Sampling stations with 0-2 TU seem to be recharged somewhere in 1950s or even before i.e. the pre-nuclear bomb test period. The recent recharge, if any, is insignificant. Further, this indicates a relatively long residence time; may be more than 40 years. The samples containing 3-8 TU in present studies, are indicative of mixing of old waters with fresh water.

The areas with 9-29 TU have either been recharged well after 1964 or the recharge is taking place relatively slowly. This could be due to mixing of fresh and tritium free groundwater.

The areas located along the river Doar and the surface run-off channels/drains usually have tritium values in the range 30-40 TU. Here, the water circulation is relatively quick and recharge area is located close by. This is supported by changes of $\delta^{18}O$ contents alongwith watertable fluctuations at most of the locations.

The testing of nuclear devices almost doubled the level of carbon-14 in the atmosphere carbon dioxide in 1963. The carbon-14 content of groundwater in the area under study is generally of the order of 100 pmc indicating the recharge to be of modern or recent origin.

9. GROUNDWATER CHEMISTRY ASPECTS

9.1 Physico-Chemical Characteristics

The important physico-chemical parameters like temperature, pH and EC of all the water samples collected were measured in the field. The measured values are given in table 1.

Temperature of shallow and deep waters ranges from 19 to 25 C and 19 to 29 C respectively.

Salinity levels in various shallow wells vary from 390 to 1150 mS/cm. The deep groundwater has EC values lower than 1000 mS/cm (375 to 742 mS/cm). The deep water has low salt contents than the shallow one. However, differences in mineralization of groundwater in two zones are very little. Groundwater in both the zones has fairly good chemical quality to be used for drinking and irrigation purposes.

Both the shallow and deep wells have pH in the range of 7 to 7.7 except for only one deep well (HR-2) where observed pH is 6.3. Hence, the groundwater has neutral to slightly alkaline character in terms of pH which is consistent with the low bicarbonate contents in these waters.

9.2 Major Ion Chemistry

All the water samples collected from different sampling stations were analyzed for their major ionic concentrations. The average values for different ions given in table 2 have been used for interpretation.

The shallow water at about 50 % locations has sodium as the dominant cation while at the remaining locations calcium or magnesium or both (equally abundant) are dominant. Whereas in case of anions shllow water has always bicarbonate as the dominant anion. It ranges from 143 to 540 ppm in different water samples. The chloride content varies from as low as 6 to 65 ppm. Sulphate is also less abundant.

In case of deep wells, calcium and magnesium appear to be the dominant cations in most of the samples. Their values lie in the range of 12 to 51 ppm and 7 to 31 ppm respectively. Waters with sodium as the dominat cation are very rare in the deep zone as compared to the shallow one. The dominant cations are balanced by the bicarbonate anion which is the most abundant anion in all the samples. Its concentration varies from 157 to 311 ppm in various deep water samples. Chloride content of these samples is very low which is a good thing for irrigatin use as chloride is toxic to most of the crops.

No carbonates could be detected in both the shallow and deep groundwater samples which is in good agreement with the measured pH values. So the alkalinity is entirely due to bicarbonate content.

10. CONCLUSIONS

Isotopic data of Haripur areas leads to the following conclusions:-

a) The major source of recharge in the Haripur plain is the rainfall on adjoining hills. Contribution from irrigation practices if any, seems to be insignificant.

b) Local rainfall only contributes through gullies while most of it is wasted as surface run-off.

c) Isotopic data do not support the proposition of any contribution from Tarbela lake to the rise in water table.

d) The residence time varies from a few years to more than fifty years depending on the geology of the area.

ACKNOWLEDGMENTS

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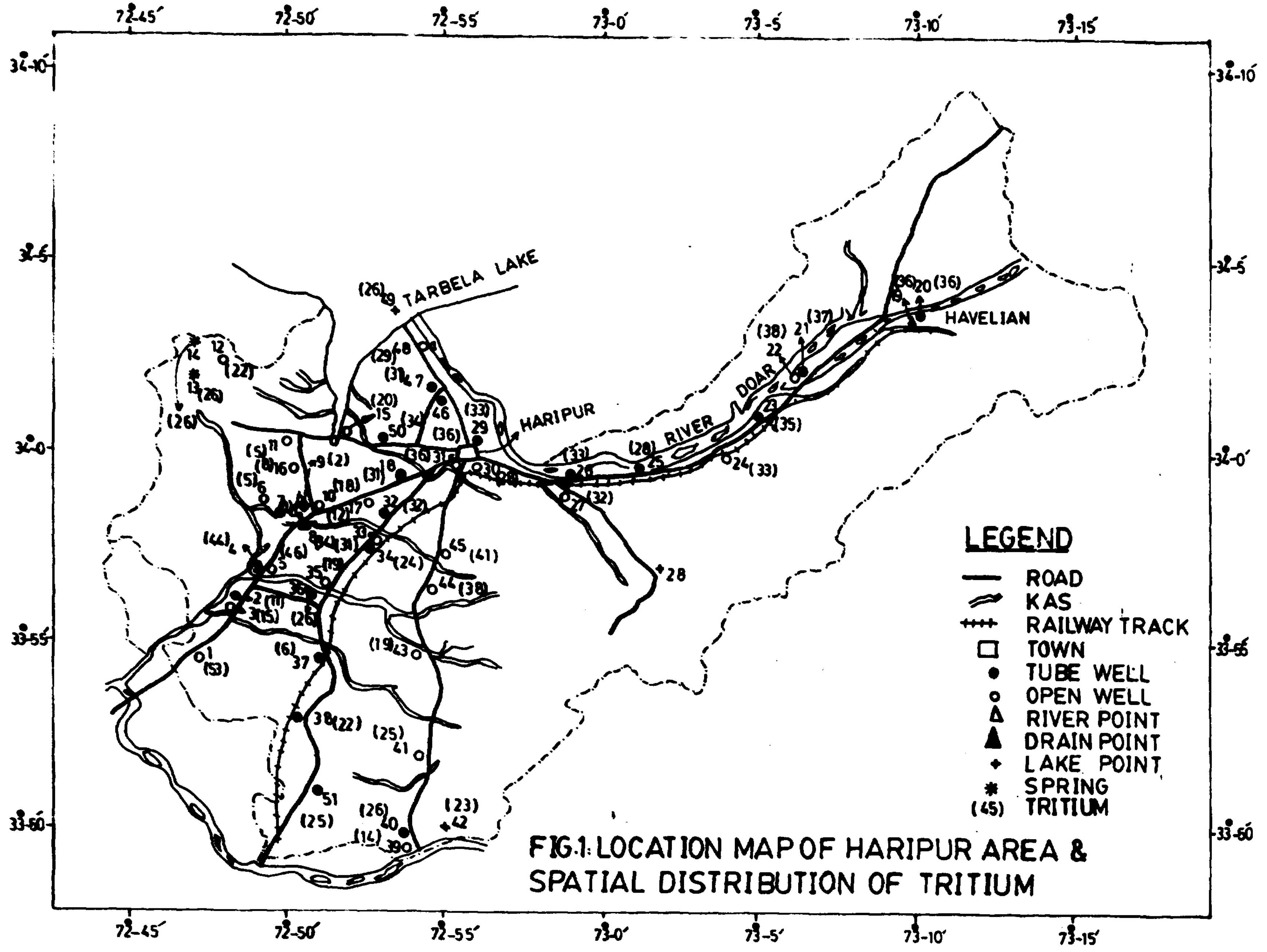

FIG.1: LOCATION MAP OF HARIPUR AREA & SPATIAL DISTRIBUTION OF TRITIUM

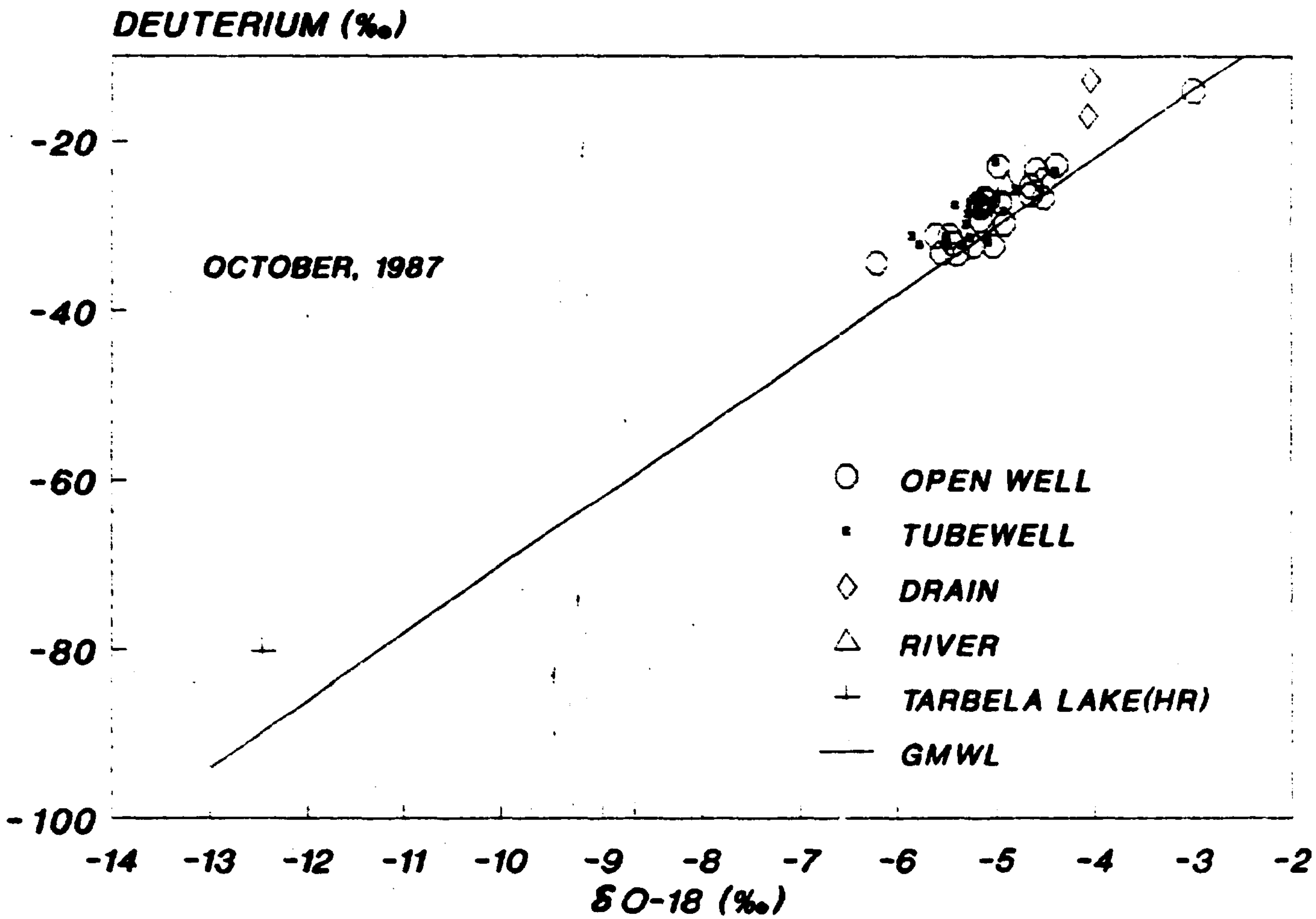

FIG. 2: δO-18 VS DEUTERIUM OF WATER SAMPLES

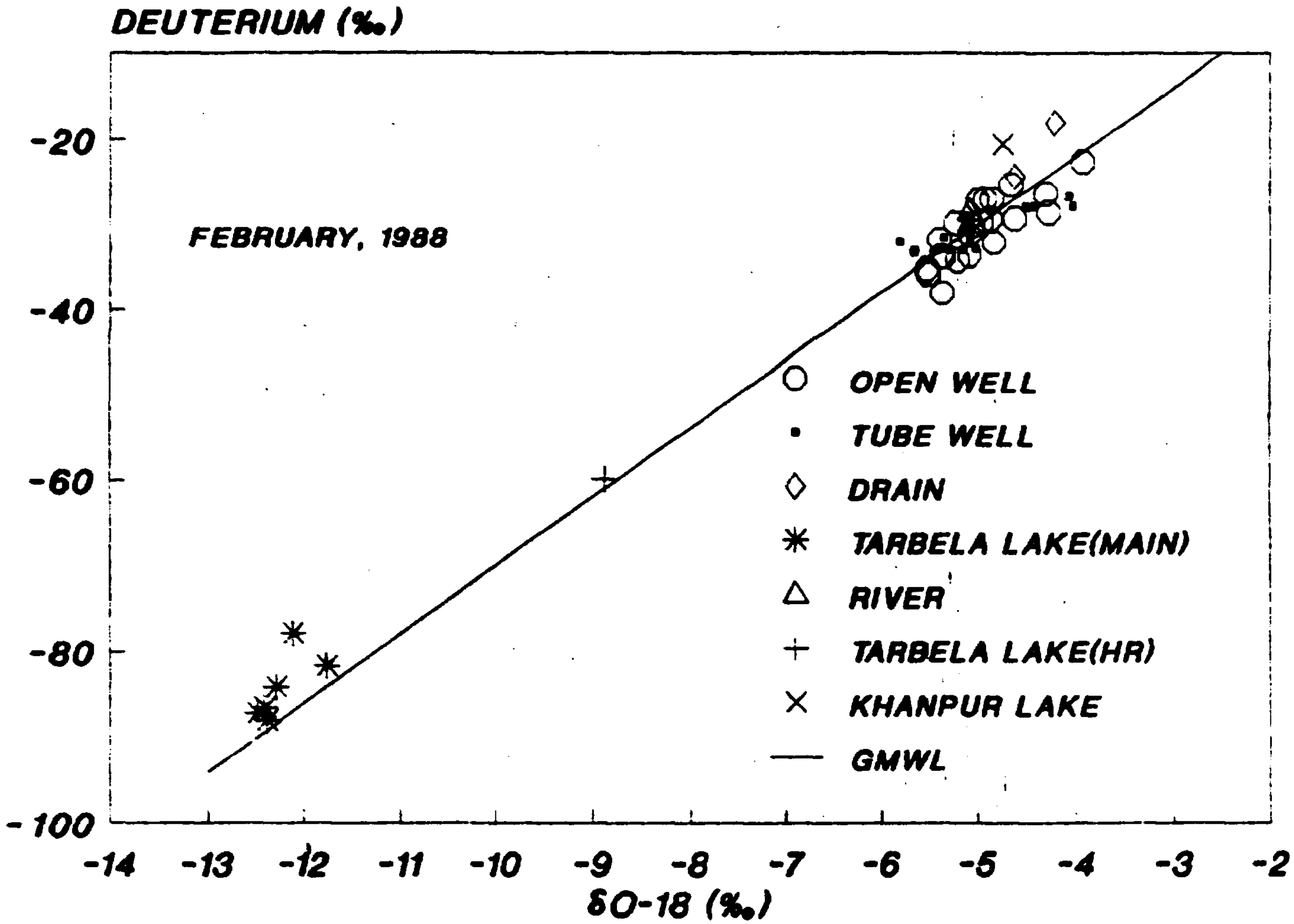

FIG. 3: δO-18 VS DEUTERIUM OF WATER SAMPLES

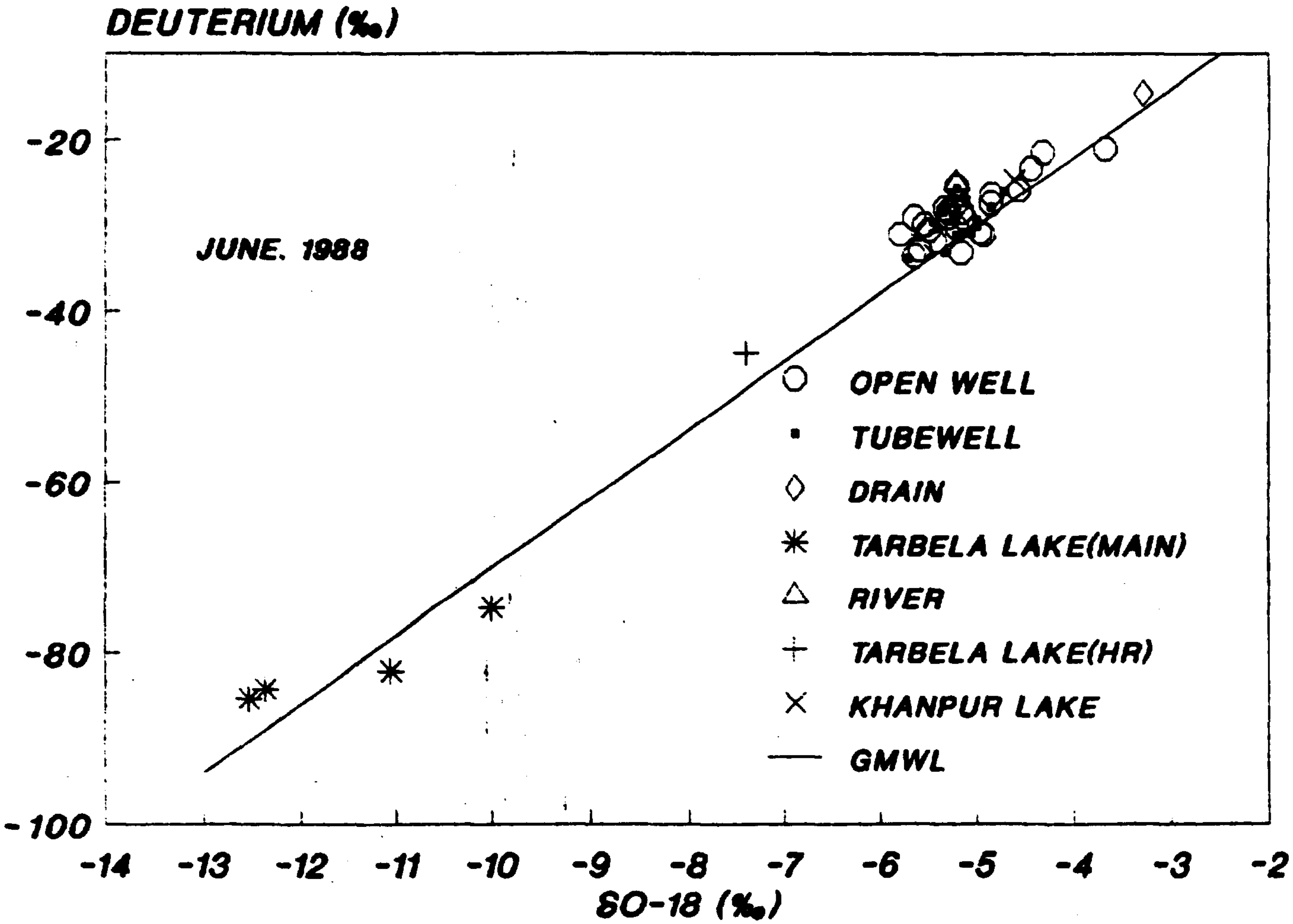

FIG. 4: δO-18 VS DEUTERIUM OF WATER SAMPLES

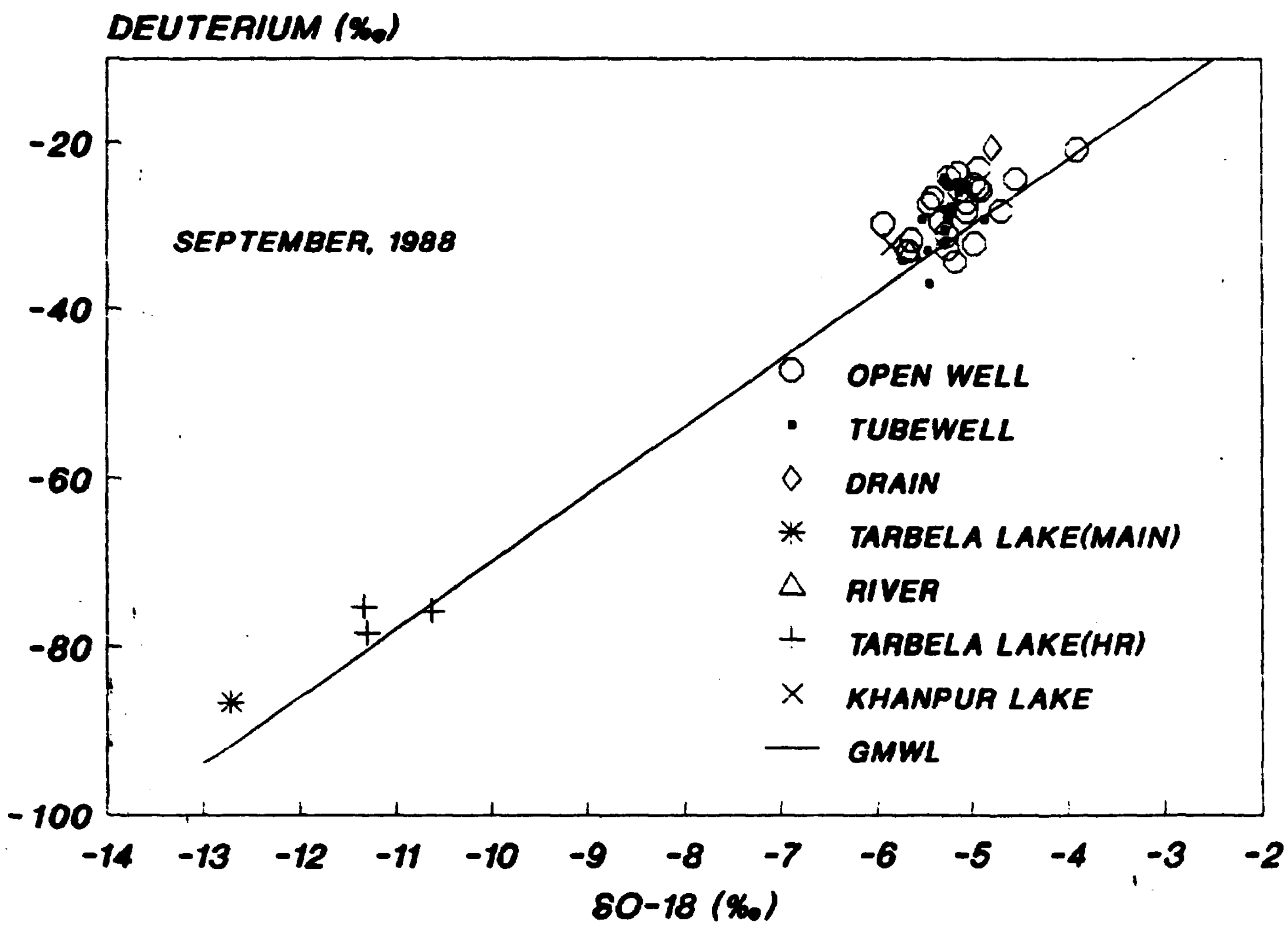

FIG. 5: δO-18 VS DEUTERIUM OF WATER SAMPLES

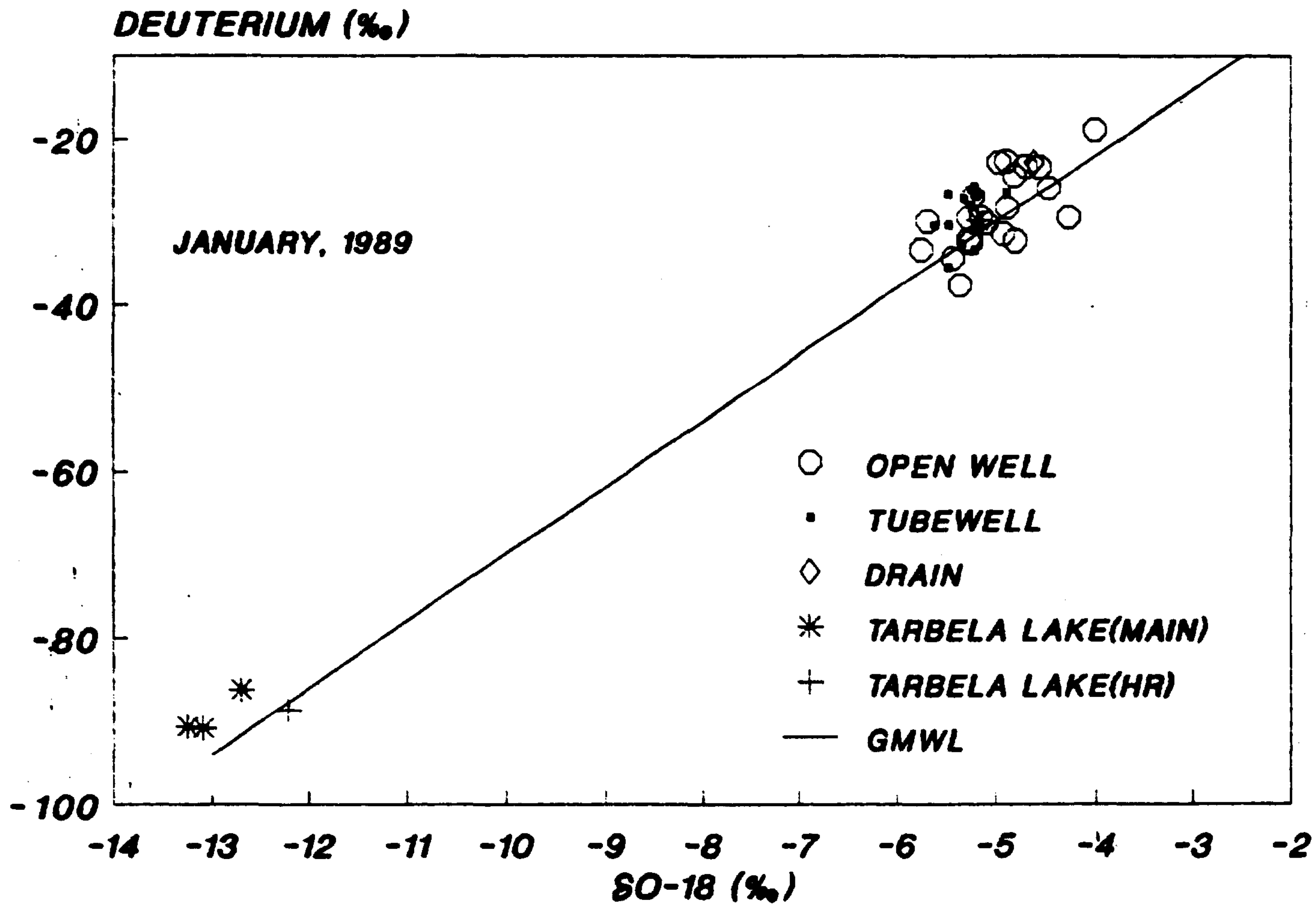

FIG. 6: δO-18 VS DEUTERIUM OF WATER SAMPLES

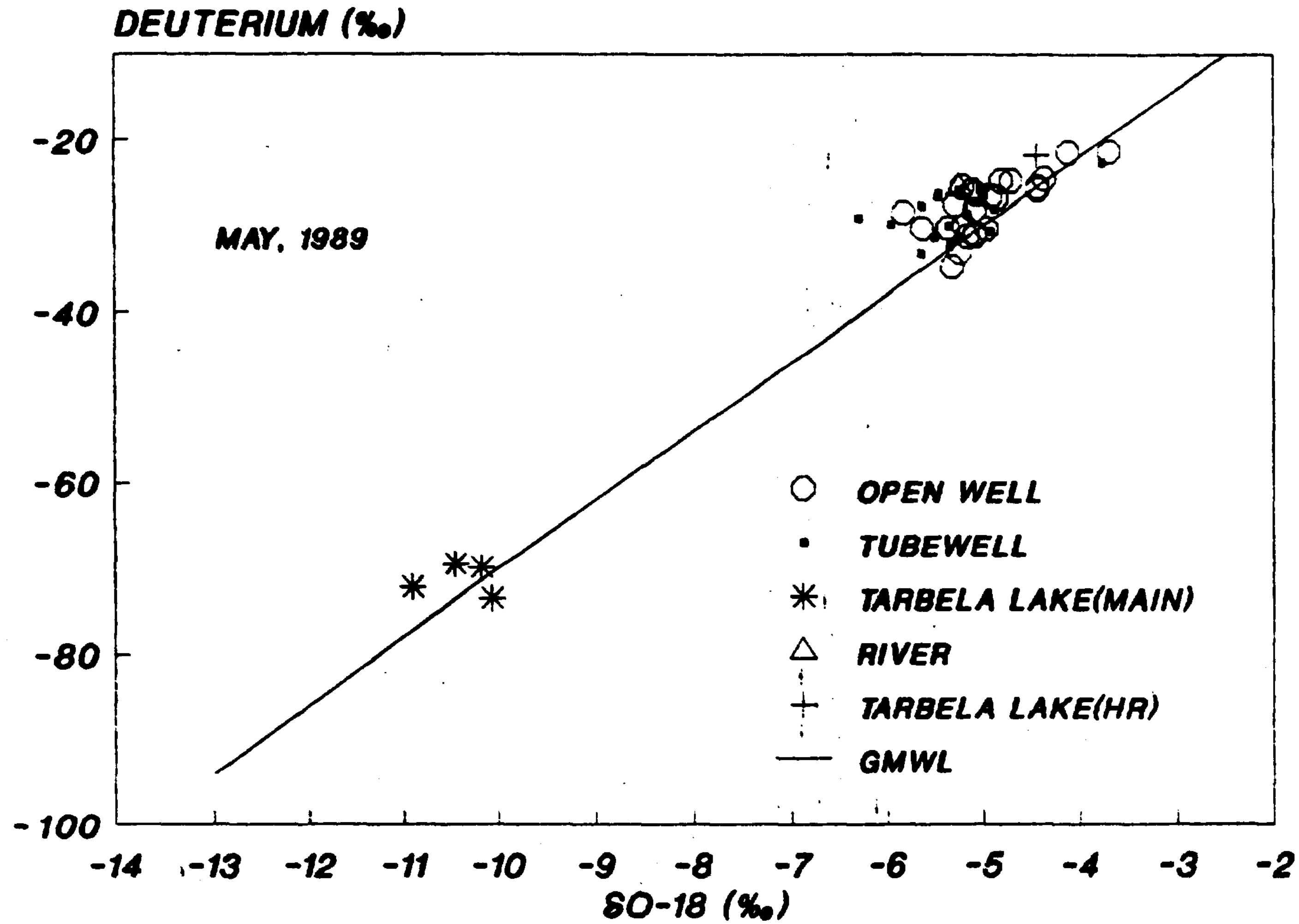

FIG. 7: δO-18 VS DEUTERIUM OF WATER SAMPLES

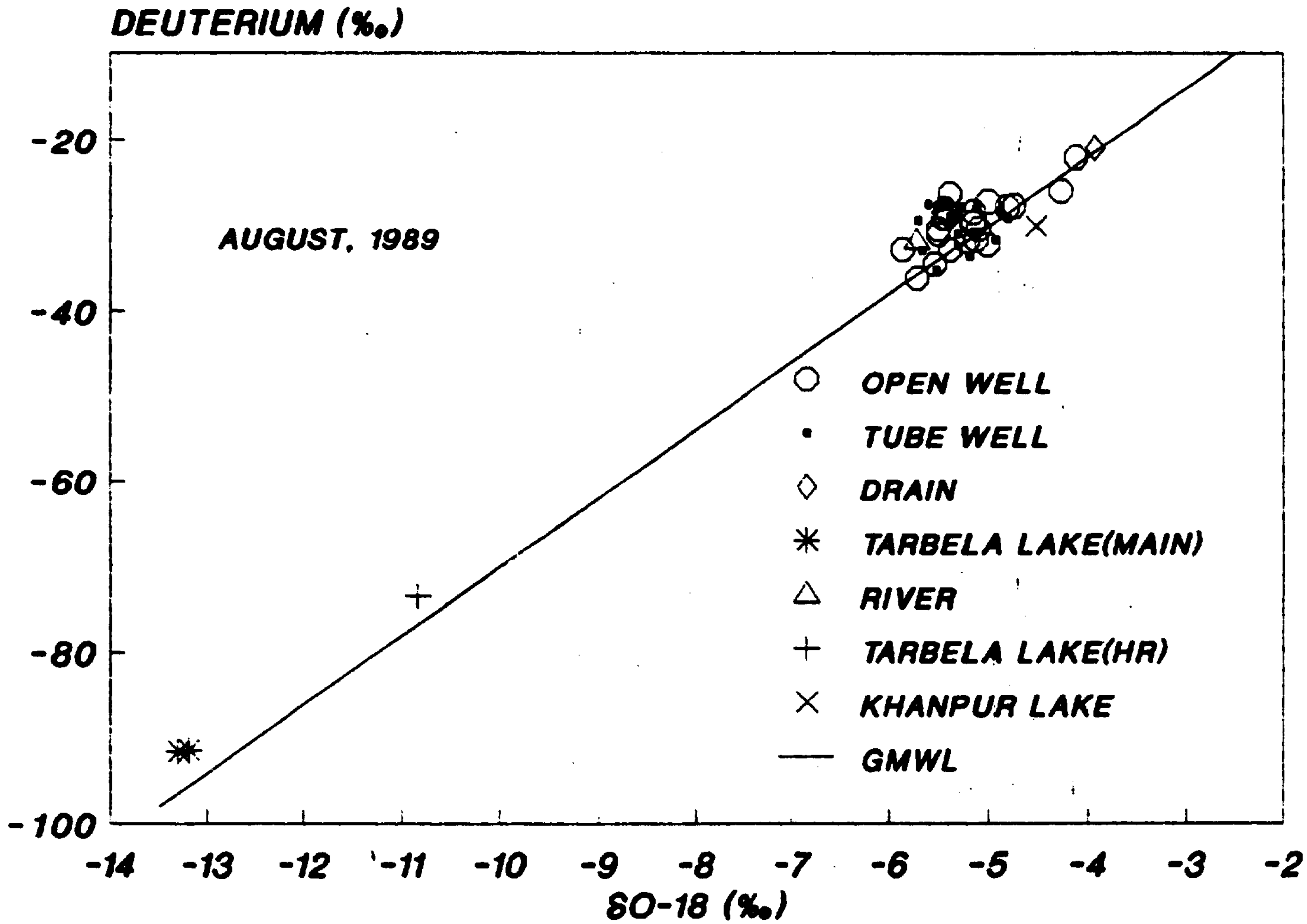

FIG. 8: δO-18 VS DEUTERIUM OF WATER SAMPLES

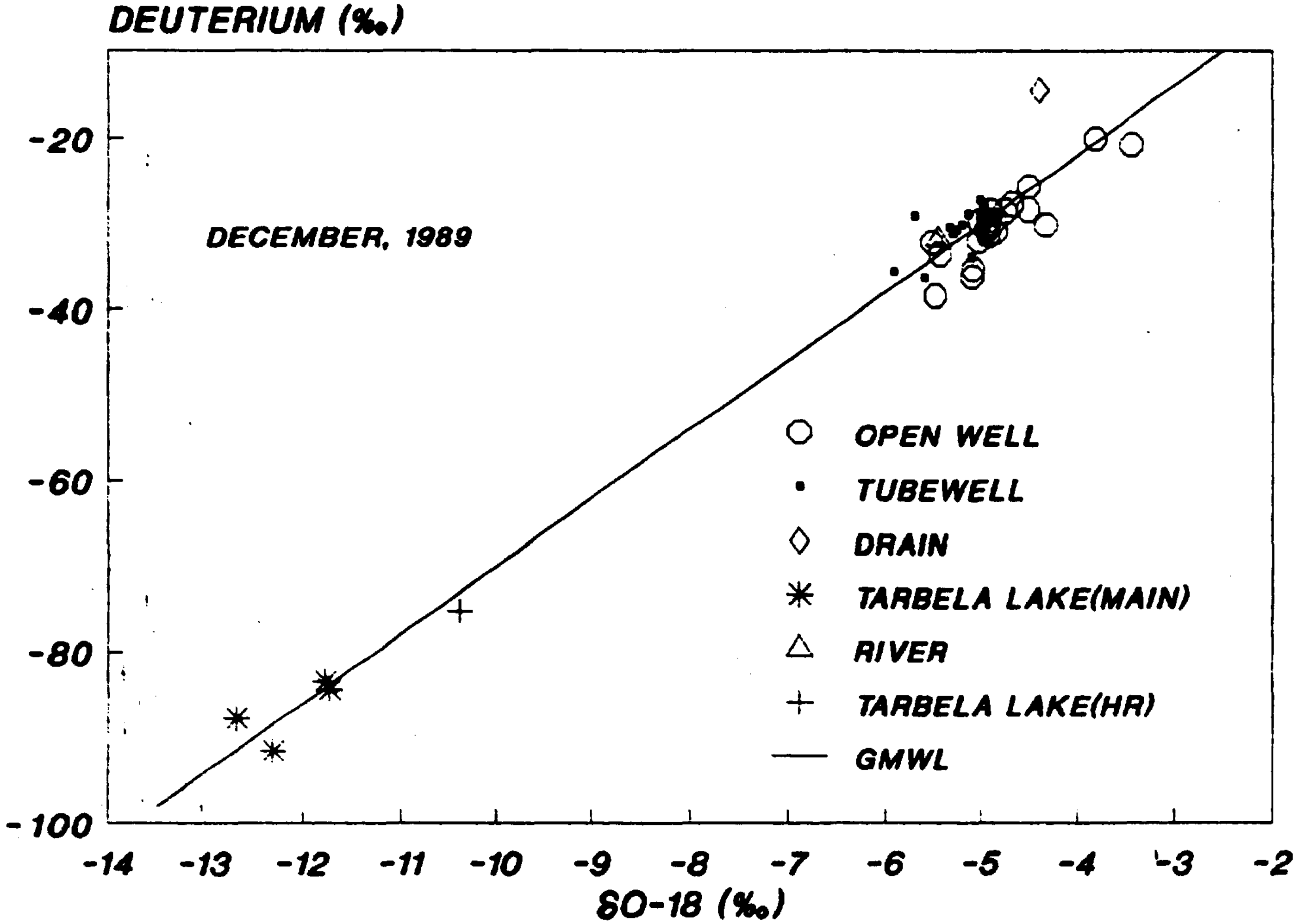

FIG. 9: δO-18 VS DEUTERIUM OF WATER SAMPLES

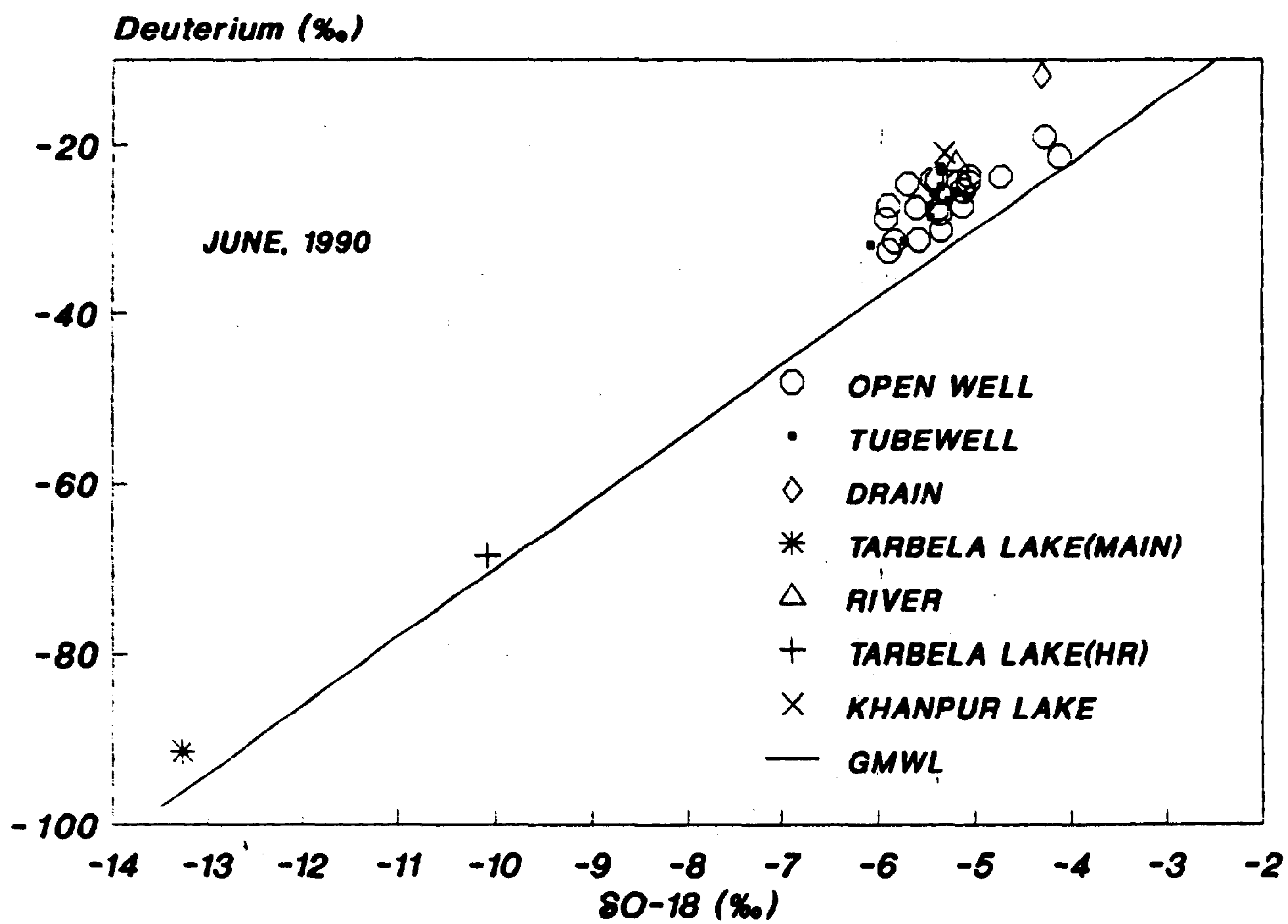

FIG. 10 δO-18 VS DEUTERIUM OF WATER SAMPLES

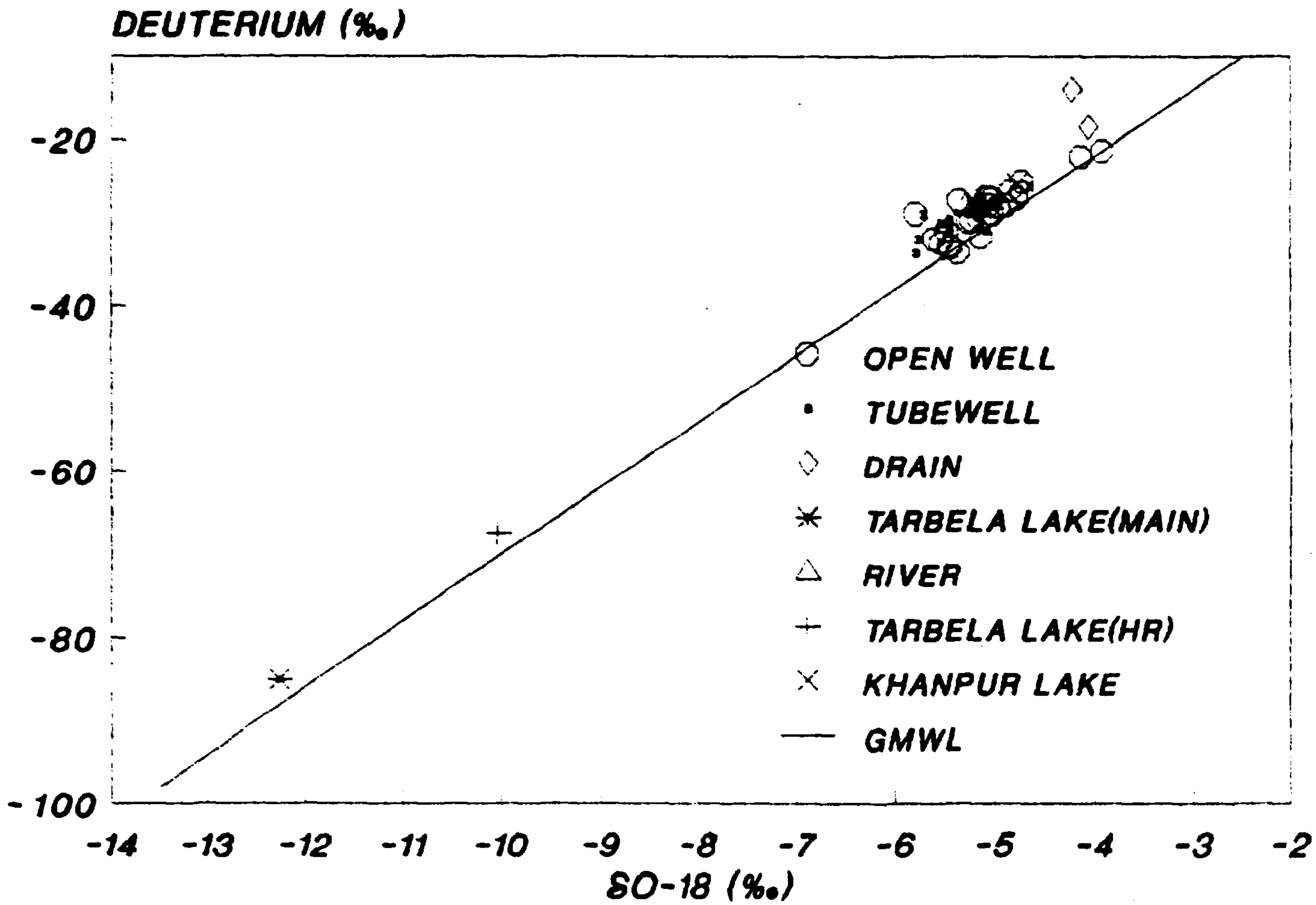

FIG. 11: δO-18 VS DEUTERIUM OF MEAN VALUES

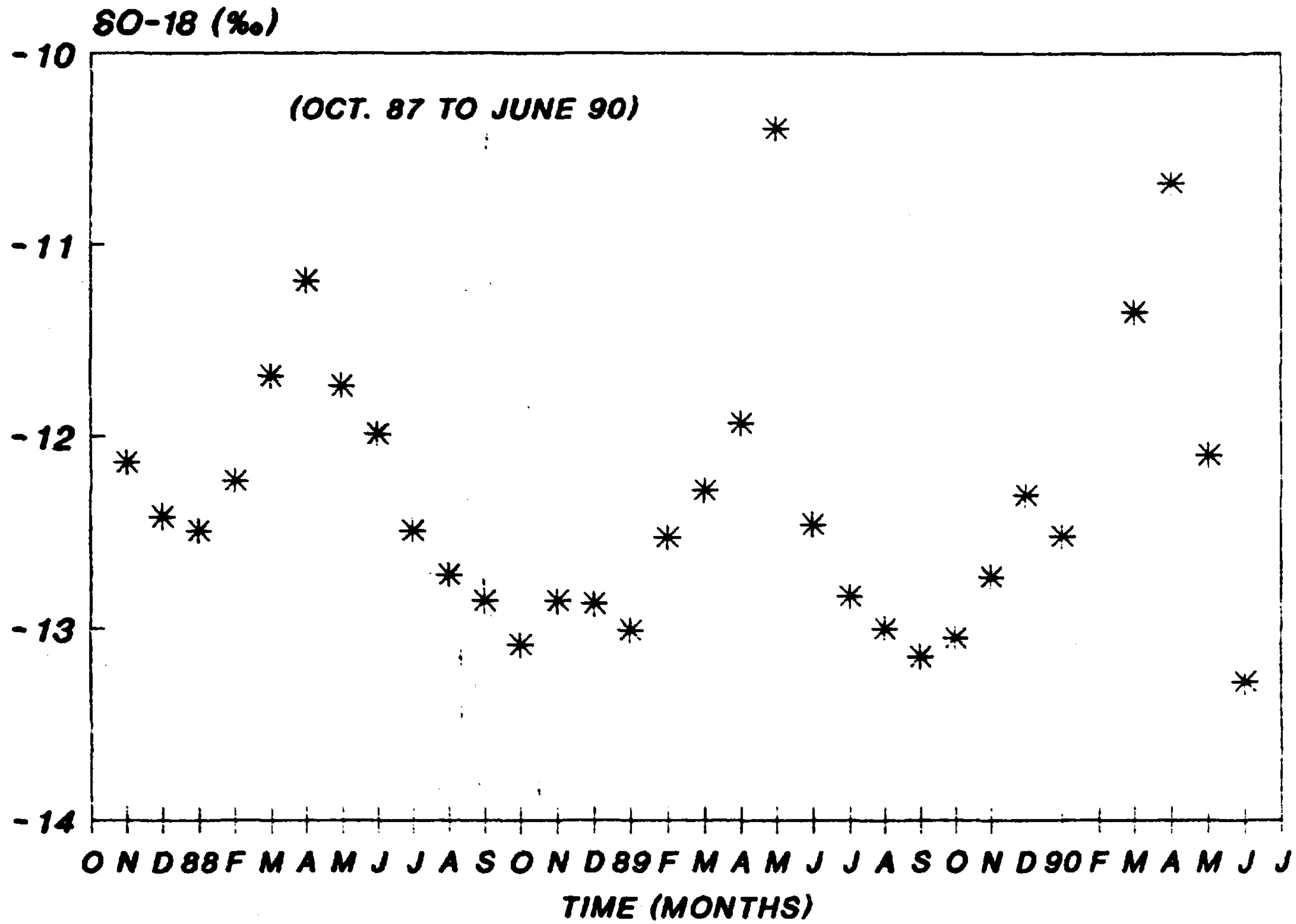

FIG. 12: VARIATION OF δO-18 OF TARBELA LAKE

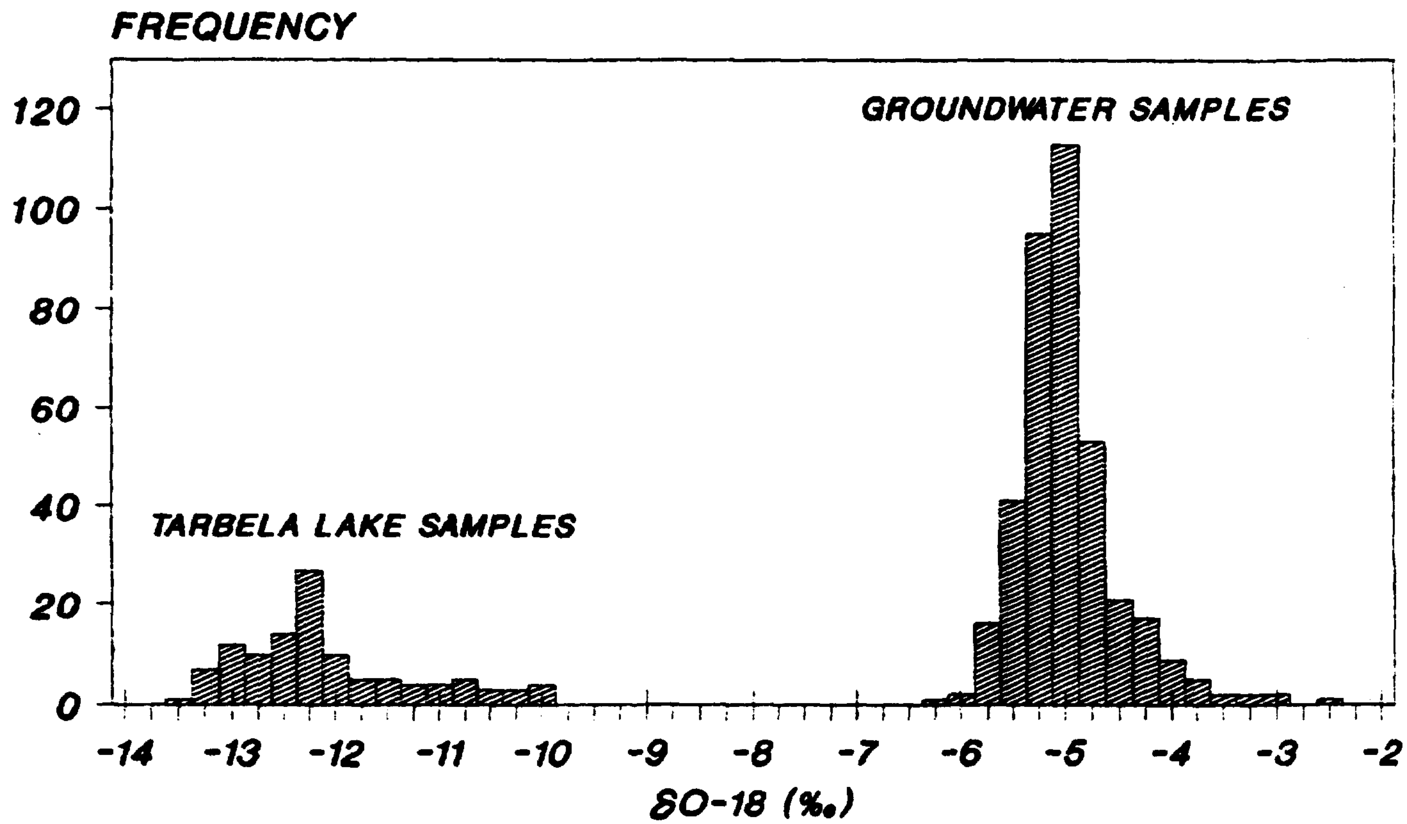

FIG. 13: FREQUENCY DISTRIBUTION OF δO-18

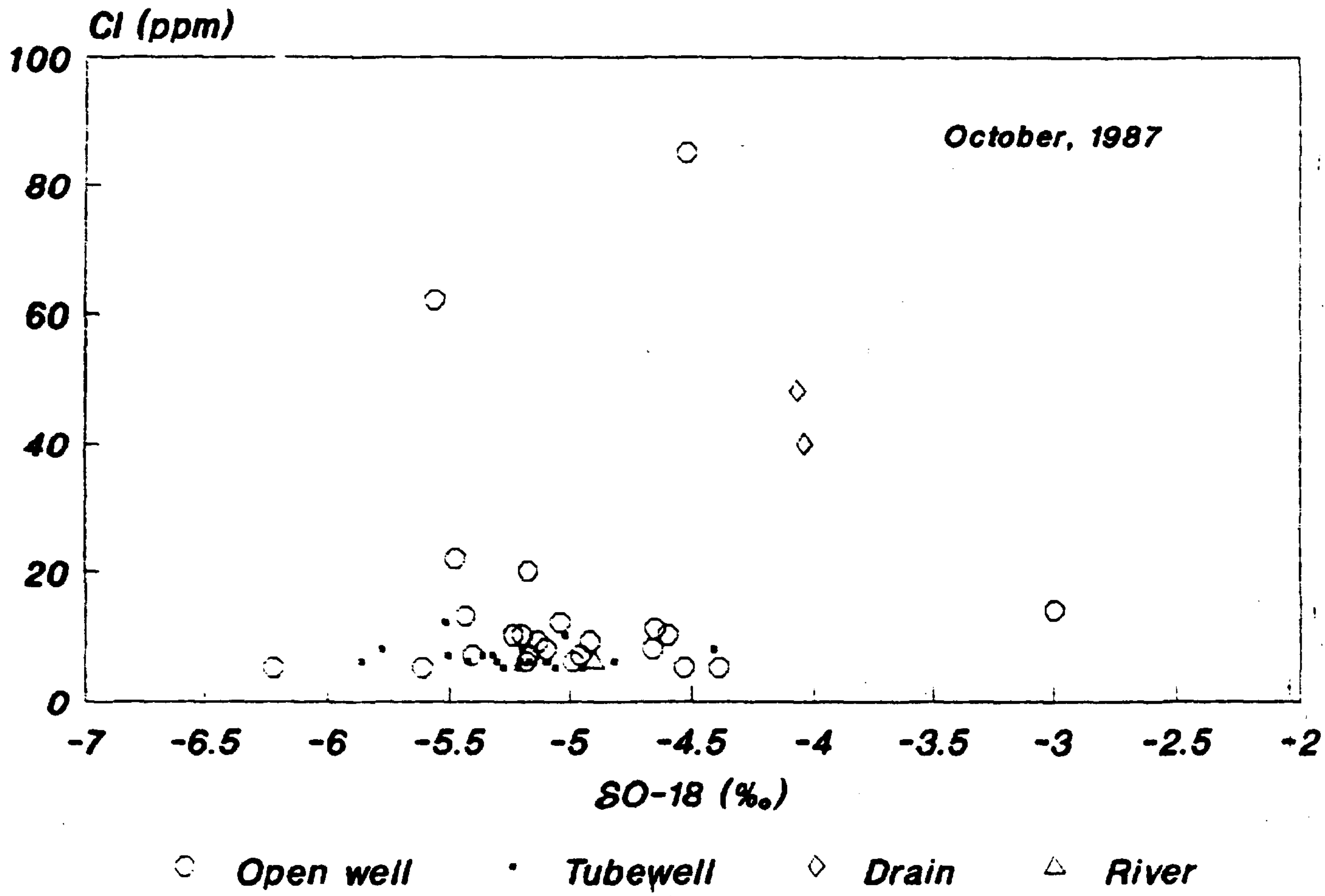

FIG. 14: δO-18 VERSUS CHLORIDE OF WATER SAMPLES