Chapter V

GROUNDWATER SURVEYS

Based on the background information, as given in the foregoing chapters (II and III), the area under study has been classified for the purpose of the groundwater surveys into three categories:

(a) Basaltic hilly region
(b) Basaltic valley plains and
(c) Basaltic plains, influenced by underlying Vindhyanas.

The basaltic hilly areas characterised by flat tops, are generally found to be occupied by the massive zone of flow No. 6. The conical and dome-shaped hills occurring on the flat tops, generally consist of the vesicular zone and the upper jointed zone of the flow No. 7 along with the remnants of the flow No. 8. Steep slopes are characteristically found to occur at the bottom massive parts of the flow No. 6.
me shaped Ama Khurd Hill
Showing flow No. 8.

Farm lands of flow No. 4 at Sangaot.
The flow No. 5 occurs at the foot hills of these flat-topped hills, especially in the vicinity of Saugor town. The vesicular horizons and the upper jointed and fractured parts of the flow No. 4 give rise to undulating topography at the bottom slopes of these hills. This undulating ground has a limited areal extent, and it merges with the valley plains. These valley plains are very extensive around Saugor and support good farmlands. In these low grounds, there occur meandering streams which are cutting through the massive zone of the flow No. 4. The stream courses and directions appear to be controlled by the local relief. These plains have very low gradients, and gradually merge with the areas occupied by the flow No. 3 without any noticeable break in the slope.

At the beginning of the groundwater survey work, twenty-four villages were selected on the basis of lithological units and topographic features during the field season of the year 1967. Based on the experience gained from these studies, groundwater surveys were then extended to forty-nine more villages, during the field seasons of the years 1968 and 1969. These investigations were planned on the watershed basis, in addition to lithological considerations.

Most of the farmlands in the area under investigation occur on the flow Nos. 1 to 4. On the hill flats practically no farmlands exist, but for a few patches of the forest lands which had been cleared recently for agricultural purposes to
accommodate the landless farmers. One such farmland occurring on the hill flat (flow No. 6) is the Shyampura Orphanage farmland. This has 4 dug wells, out of which two are meant for irrigation. This farmland was selected for groundwater studies to determine the groundwater occurrences in the higher flows. The dug wells of the farmlands of Makronia, Rajakheri, Baheria, and Gamharia villages have been selected for study, as these wells depend upon the groundwater body occurring within the weathered and interflow zones of flow Nos. 4 and 5. Similarly, in order to determine the occurrence and behaviour of groundwater in the porous zones of flow No. 4, groundwater surveys were taken up in as many as 28 villages. These villages are Bhapail, Phutera, Biharipura, Chakroda, Bamori, Amoni, Kaneradev, Piparia, Bhainsa, Pagara, Kudari, Patkui, Bararu, Bachlon, Jinda, Bamora, Sidqawan, Bamori Tudar, parts of Sanoda, Semria-Angad, Lalepur, Jetpur, Pararia, Khareerabhan, Ghureta, Bhonhari, Pamakheri, and Lidhorahot.

The dug wells of the parts of the villages Rusalla, Tilakhari, Sairkhera, Simaria, Dharkheri, Paten, Masurhai, depend for their groundwater on the interflow zones of flow Nos. 3 and 4 and these villages were also selected for surveys.

The village areas which depend upon water-bearing zones of the flow No. 3 have been selected for groundwater surveys. Those surveyed are Semra-Kala, Joharia, Hasrai, Mohasa,
Dhagrania, Telabuzurg, Manesia, Basaiganj, Sihora, Sumredi, Jerai, Jarara, Lidhorakhurd and Kerwana.

The wells of the villages which tap the interflow porous zones of flow Nos. 2 and 3 were also taken up for similar studies. These villages are Ramchhahri, Machhi, Khaira-Salaiya, Kisanpura, Pachpipra, Basia-Bhansa, Kanchri, Dungasara, Piparia Karkat, Chauwra and Bannad.

The dug wells occurring in parts of the flow No. 2 belong to the villages Mothi, Gadholi and Madanpura. These were taken up for groundwater surveys. In this category, the villages Lohari, Barodia-Gusai, Devri and Sewara-Sewari are such, which depend for their groundwater not only on a thin cover of flow No. 2 but also on the underlying quartzitic sandstones. Such groups of villages have been surveyed separately.

Finally the villages Berkheri Khuman, Richhawar, of which the dug wells tap the water-bearing interflow zones of flow Nos. 1 and 2 have been taken up for studies of groundwater bodies.

Groundwater Survey Technique

Water levels of the dug wells, during the rainy season, do not represent the true static groundwater levels, for they
do not reach stability conditions, on account of rainwater falling directly into them, in addition to the continuous recharge from the influent seepage* areas (Tolman 1937). This results in fluctuations in the groundwater levels. It has been observed that after a heavy cloudburst, the groundwater levels in the dug wells suddenly rise and, after a few hours, the water levels go down. In some cases, the water levels rise even without rains. It has been realised during the reconnaissance work, that it takes at least 10 to 15 days after the cessation of rains for the groundwater to have stable static water levels in the dug wells. Therefore the water level measurements have been made in the dug wells of the villages under study only after the rains have stopped and the stability conditions are reached. Measurements of water levels have also been made during the summer season, that is, before the on-set of rains. These data were utilized for preparation of groundwater level maps to determine the occurrence of groundwater, its movement and direction, including the extent of groundwater bodies in the area under investigation. The data on the groundwater levels for the villages under investigation have been tabulated, and are given in the Appendix III. From these data groundwater level maps have been prepared, and the general movement directions for the groundwater studies have been shown within the village boundaries, as shown in the Plate No. 7.

* Influent seepage as defined by Tolman (1937) in his textbook on "Ground Water" on page 163.
For the preparation of groundwater level maps, the village Revenue maps (Khasra maps) were used. These are available on 16 inches-to-a-mile scale. The location of existing dug-wells is already shown on these maps. Wherever they do not show all the existing wells, the wells that were not marked were located on the map with the help of a chain and compass. Then the wells in each village were numbered. A temporary bench mark for every village was then located, and a value was assigned. The information about the location of this bench mark and its value (generally 100') was passed on to the village head man for future reference. With reference to the bench mark of a village, the reduced levels of the ground surface of the wells existing in that village were determined with the help of a Dumpy level. Care had been taken to measure the reduced levels of the natural ground surface at each well by avoiding the raised grounds surrounding a dug-well. The depths to groundwater surface in the dug-wells were measured with reference to the reduced ground surface levels of wells. Wherever possible, the data were also given to the owner of the well for safe keeping. Then the reduced groundwater levels were determined. These data were then noted on the revenue map against the individual wells. With the help of these data, groundwater level contours at one foot vertical intervals were drawn. Adopting the above procedures, groundwater level data for as many as 73 villages had been collected. These data are presented in the Appendix III. Based on the data, groundwater level maps were
prepared and studied. Out of these maps, only the representative ones were selected for use in the text for they were found to be adequate to bring out the hydrogeological conditions of the aquifer zones of the flows on which the farmlands occur.

In addition to the groundwater level surveys in the villages, water samples from 26 dug-wells occurring in flow Nos. 3 and 4 were collected in Polythene bottles provided with airtight caps to prevent escape of dissolved gases. On each bottle, the location, day and date were mentioned, and these were sent for chemical analysis to the Soil Survey Laboratories of the Department of Agriculture, Government of Madhya Pradesh located at Jabalpur.

**Basaltic Hilly Region:**

**Shyampura Village:**

The Shyampura village is situated on a narrow hill flat and is about 110 feet above the surrounding valley plains. There are four dug-wells over the hill flat with depths of 27, 29, 69 and 70 feet from the ground surface. Out of these four wells, two wells end in the weathered zone of the flow No. 6, whereas the remaining two wells, not only penetrate through the massive zone of the 6th flow and pass through the
intertrappean occurring below it, but finally end in the upper part of flow No. 5. It is interesting to note that the wells having depths of 27 and 29 feet meet the entire drinking water requirements for about 200 villagers during the summer months, whereas the other two deep dug-wells get completely dry during the early part of the summer season. The latter two wells act just like inverted wells, through which the groundwater in the weathered zone of the sixth flow is drained into the lower flows. It has been further noted at this hill flat that, after rains have completely stopped, seeps and springs are found to occur on the hill sides at the contacts of the individual flows. These springs and seepages continue even up to the end of the winter season. This is due to the groundwater leaking out from the hill sides through the interflow zones.

As the existing wells are only four in number, and the density of wells in this area is insufficient, the groundwater level maps for this village were not prepared.

In order to study the behaviour of groundwater levels in the dug-wells of the foot-hill plateau areas of the valley plains where farmlands occur, the groundwater level measurements were made in the existing dug-wells of the villages Makronia, Rajakheri, Baheria and Gamharia; the groundwater level data are given in the appendix. Only the groundwater level maps of the village Makronia are produced in the text.
VILLAGE MAKRONIA

GROUNDWATER LEVEL MAP

INDEX
Bench Mark 100' Bm
Dug Wells 0
Streams L
Village L
Contour Interval 1'

SCALE
Yds 440 220 0 440 880 Yds

(Reduced from 16" to a mile Scale)

Water level on 26.6.67 (Before rains)
North, but in the south-eastern portion of the map the direction of movement is towards east. The average groundwater gradient is 39 feet in a mile.

The groundwater contours in a major part of the area are medium-spaced, but for a small portion in the central part where the groundwater contours have become closer. The local gradient in this area of closely spaced contours is 45 feet in a mile, whereas the local gradient in the south-eastern portion of the area where closely spaced contours are also found to occur, is 120 feet in a mile.

The rise in the groundwater levels after the rainy season varies from 14 to 27 feet from that of summer groundwater levels.

The groundwater contour maps prepared for the other three villages, namely, Rajakheri, Baheria and Gamharia indicate that the conditions observed in the Makronia village area are more or less repeated in these areas but for the following differences:

(1) The village Rajakheri and Gamharia areas have continuous single groundwater bodies during summer.

In the
(2) Baheria village area due to the occurrence of streams and gullies, the groundwater levels soon fall down to stream bed level. The wells in a part of this village have widely
spaced contours, as the dug-wells tap the vesicular part of the fourth flow.

(3) In the village Rajakheri, the average gradient of groundwater bodies is 45 feet in a mile during summer and 64 feet in a mile after the rainy season.

A well at the Police Lines situated at the Makronia village used to tap the water-bearing weathered zones of flow No. 5. This well had a total depth of 30 feet with a column of 12 feet of water during the month of March 1967.

In order to increase the yield, an attempt was made by the owner of the well to convert the well into a dug cum bore well. A 3 inch diameter hole was drilled from the bottom of the dug-well to a depth of 110 feet. This drill hole penetrated the entire thickness of flow No. 4, and it ended in the massive part of flow No. 3. However, the drilling had an adverse effect and even the 12 foot column of water of the dug-well was completely lost. Thus the drilling converted this well into an inverted well through which the stored water within the aquifer interflow zones of flow Nos. 4 and 5 leaked down to contribute to the porous dry zones occurring below.

In order to study the hydrological characters of the flow No. 4, groundwater level maps were prepared for as many
as 28 villages, occurring in different watersheds. A study of these maps indicates that the areas have more or less similar water-level contour patterns. Therefore, only representative groundwater level maps for villages were selected for illustration and description, as they are found to be quite adequate to bring out the groundwater conditions of this flow. The villages Patkui, Bararu, Semrabag and Jinda occur adjacent to one another and more or less in continuation with the villages already described in the foregoing paragraphs. Other villages which tap the groundwater body of flow No. 4 selected for illustration are the Saugor town area (occurring on the eastern side of the Saugor lake), Piparia, Bchainsa and Pagara villages.

**Patkui Village:**

The dug-wells of this village area tap the vesicular zones and fracture parts of the flow No. 4. The terrain is sloping towards east with a gradient of 40 feet in a mile. The main stream forms the eastern boundary of the village. The total number of existing dug-wells is 29.

In this village, the summer season groundwater level measurements were made on the 18th of June, 1967 before the commencement of the rainy season. Based on the data, the groundwater level map (Plate No. 9, A) was prepared. A study
of the groundwater contours brings out that the groundwater movement direction is due north-east in the western part of the village area. In the eastern part of the area, the movement of groundwater is towards south-east. The average groundwater gradient is 33 feet in a mile. The groundwater contours show uniform spacing in the entire farmland area of the village, and are widely spaced and regular. They represent a single groundwater body, but in the south-eastern portion, a small groundwater basin is found. The trend of recession of the groundwater levels during summer is found to be towards the main stream.

In the same area, groundwater levels were measured on the 30th of September, 1967 immediately after the rains had stopped. The groundwater contours prepared from these data (Plate No. 9, B) show that groundwater moves due south-east. The average groundwater gradient is found to be 50 feet in a mile. The groundwater contours in this map are medium-spaced and uniform. These are regular in most of the area, but in south-eastern part, the groundwater contours show depressions surrounding the dug-wells. This is due to pumping. The water levels in all the wells are found very near to the ground surface. The rise in the groundwater levels after the rainy season is 30 feet above that of the summer season.

The general groundwater direction is more or less the same
VILLAGE PATKUI
GROUNDWATER LEVEL MAPS

Water level on 18-6-67
(Before rains)

Water level on 6-12-67

Groundsurface contour map

INDEX
Bench Mark 100' Bm.
Dug Wells
Streams
Village
Contour Interval 1'

SCALE
Yds. 440 220 0 440 880 Yds.

(Reduced from 16'' to a mile Scale)
in both the maps. In order to bring out the relationship of groundwater movement to topography, surface (ground) contours were drawn (Plate No. 9, C). These indicate that the slope of the ground surface and the groundwater movement are more or less in the same direction.

Bararu Village:

The dug-wells of the village Bararu tap the weathered part of the massive zone of flow No. 5. The area lies adjacent to the Shyampura foot hills, and is surrounded by Patkui, Bachlon and Kapuria villages. The area is more less a flat terrain, and the ground surface has a south-easterly slope with a gradient of 27 feet in a mile. The total number of dug-wells is 65.

In this village, the summer groundwater level measurements were made on 22nd June, 1967, before the advent of rains. Based on the data, the groundwater contours (Plate No. 10, A) have been prepared. A study of the groundwater contours shows that the groundwater movement direction is due south-east, that is, towards the Semrabaj village. Considering the general gradients of groundwater from north-east to south-east, it has been found that the groundwater levels fall 18 feet in a distance of one mile. Groundwater mounds and basins are also found locally around the dug-wells. When the
groundwater level maps of the village were reduced from 16 inches to-a-mile scale to 4 inches to-a-mile scale for illustration in the text, the one foot vertical contours became so closely spaced that only 5 feet contour intervals could be shown (Plate No. 10). Around the dug-wells in the south-western part of the map, the groundwater mounds occur at three places. The groundwater within the dug-wells maintain higher column and the adjoining areas slowly get recharged by these wells.

In order to interpret the groundwater basins and domes surrounding the dug-wells, the topographic contours have been drawn, and these are shown along with the groundwater level maps (Plate No. 10, C). The comparative study of the two maps shows that it is a local topographic feature which has been reflected in the groundwater contours.

In the same village, the groundwater level data after the rainy season were collected on 29th September, 1967. The groundwater level contours prepared from these data, have been shown in the map (Plate No. 10, B). The groundwater contours show that the general movement direction of groundwater is towards south-east. Average groundwater gradient is 20 feet in a mile. The groundwater contours in a major part of the area of this village are medium-spaced and uniform. The data on the groundwater levels of the dug-wells after the rainy
season show that the groundwater levels in most of the dug-wells are 7 to 10 feet below the ground surface. The rise in the groundwater levels after the rainy season is 30 feet.

Semrabag Village:

The village Semrabag is surrounded by the villages Patkui, Bararu on the north-west side and, on the southern side, it occurs adjacent to the village Rajakheri. The dug-wells of this village Semrabag tap the groundwater bodies from the upper fractured zones and weathered parts of the massive zone of flow No. 4. The terrain slopes in general towards north-east with an average topographic gradient of 30 feet in a mile. The total number of existing wells in this village is 90. The groundwater level data could be collected for 53 dug-wells only.

The summer groundwater measurements were made on 20th June, 1967. The groundwater level contours prepared from the data (Plate No. 11, A) shows that the general groundwater level gradient is towards north-east. The groundwater contours show that small groundwater domes occur in the eastern part, whereas in the east-central part and north side, groundwater basins of smaller size are found surrounding the dug-wells. The groundwater level contours are medium-spaced.
VILLAGE SEMRABAG

GROUNDWATER LEVEL MAPS

BARARU

JINDA

PATKUI

RAJAKHERI

CANTT.

Water level on 20.6.67 (Before rains)

Water level on 30.9.67 (After rains)

INDEX
Bench Mark 100' Bm.
Dug- Wells 
Streams 
Village
Contour Interval 

SCALE
Yds 440 220 0 440 880 Yds

(Reduced from 16" to a mile Scale)
VILLAGE SEMRA BAG
GROUNDWATER LEVEL MAP

INDEX
Bench Mark 100' Bm
Dug-Wells O
Streams
Village Contour Interval 1'

SCALE
Yds 40  220  0  440  880 Yds

(Reduced from 16" to a mite Scale)
The groundwater level map shows the presence of low hydrostatic head.

In this locality, immediately after the rainy season, groundwater levels were measured on 22nd September, 1967 in 53 wells. These levels are very near the ground surface. The groundwater contours (Plate No. 11, C) show that the general groundwater movement direction is towards north and the average gradient is 20 feet in a mile. The groundwater domes are found to occur surrounding the dug-wells as shown by the contour patterns. The contours in the north-eastern part of the area are found to be curved upstream and this contour pattern indicates that the groundwater body is recharging the stream flow (effluent part of the stream).

As some of the water levels in the dug-wells had not reached static conditions, the groundwater levels were once again measured on the 30th of September, 1967, that is, about 8 days after the cessation of rains. The groundwater level contour map now prepared (Plate No. 11, B) for the same area shows variation in the groundwater contour patterns from the earlier one (Plate No. 11, C). The contours are more regular and uniform. The water levels in the dug-wells have fallen 7 to 12 feet below the ground surface and the groundwater conditions are more or less stabilized. The rise in the groundwater levels from that of the summer levels varies from
11 to 15 feet.

**Jinda Village:**

The area of this village lies adjacent to the villages Makronia, Semrabag, Bararu and Bachlon. The terrain slopes towards north-east. The local surface gradients are towards the stream, which flows in a north-easterly direction. The total number of existing wells in this village is 15. The wells of the locality tap the bottom fractured part of the flow No. 4.

In this village the summer groundwater levels of the dug-wells were taken on 15th June, 1967. Based on the data, the groundwater contours (Plate No. 12, A) have been drawn. A study of the summer position of the groundwater contours indicates that the groundwater movement direction is due south-east in the north-western part of the village, and towards north-east in the south-central portion, where the streams occur. The average groundwater level gradient is 7 feet to a mile in the south-east direction, whereas it is only 2½ feet in a mile in the north-east direction. The groundwater contours are widely spaced and uniform. A fairly large depression is found to occur in the south-central portion and this seems to have effected all the groundwater contours. The patterns of the groundwater contours of the
VILLAGE JINDA

GROUNDBWATER LEVEL MAPS

BACHLON

BARARU

SEMRA BAG

BAMORA

GAMMA RIA

MAKRONIYA

Water level on 15-6-67
(Before rains)

Water level on 20-9-67
(After rains)

INDEX
Bench Mark 100 ft
Dug- Wells  O
Streams
Village  L
Contour Interval 5'

SCALE
Yds 440  220  0  440  880 Yds

(Reduced from 16' to a mile Scale)
summer bring out their tendency to recede side ways towards the stream and, at the same time, towards the downstream side. After the rainy season, the groundwater level data of the dug-wells were collected on the 20th September, 1967. The groundwater contours (Plate No. 12, B) show that groundwater movement direction is due south-east in the north-western part of the village, that is, towards the stream. In the south-central part of the area of the village, the movement is towards north-east. The groundwater contour patterns show a large depression. The groundwater gradient is towards south-east, and is 12 feet in a mile in the north-western part of the village, whereas in the south-central portion, it is 4 feet to a mile in the north-east direction. The contours are medium-spaced. After rains, groundwater levels come very near to the ground surface.

The rise in the groundwater levels after the rainy season is found to be 5 to 7 feet in the south-central part of the area, and 18 feet in the north-western part of the village.

**Saugor Town Area:**

The farmlands occurring to the east of the Saugor town adjacent to Saugor lake (not considered for additional dug-wells) were selected exclusively for studying the relationship of the groundwater with that of the surface storage of the
The groundwater levels in the wells are very near to ground surface. The annual fluctuation which has been reflected from the comparative study of groundwater levels before and after rains is 10 feet in the northern part, whereas in the southern part, it is 40 feet. The groundwater contour patterns bring out the fact that the entire area is recharged by the surface storage of the tank during the summer season, and this has been found to be entirely changed after the rains, and the groundwater body recharges the tank. The direction of groundwater movement after the rains follows the direction of topographic gradients.

Piparia Village:

The dug-wells of the village Piparia tap the thin weathered parts of massive zone of flow No. 4. The village area lies adjacent to Udaipur, and Tilimafi village. In the south-western part of the area, ground surface slopes towards west and north-west directions. The average gradient is 36 feet in a mile. The total number of existing wells is 57. In this village, the summer season groundwater level measurements were made on 26th June, 1967. Based on these data, the groundwater contours (Plate No. 14, A) were prepared. A study of the groundwater levels in the dug-wells show that most of the wells are dry. The water levels have receded towards west. Only 7 wells occurring in the south-western
VILLAGE PIPARIA

GROUNDWATER LEVEL MAPS

PLATE 14

Water level on 26-6-67
(Before rains)

Water level on 21-9-67
(After rains)

INDEX
Bench Mark 100' Bm
Dug Wells  o
Streams  L
Village  
Contour Interval 1'

SCALE
Yds 440 220 0
440 880 Yds

(Reduced from 16" to a mile Scale)
part have water columns of 2 to 4 feet. In this part, the contours are medium-spaced.

In the same area water level data were collected on 30th September, 1967 after the rainy season. The groundwater contours (Plate No. 14, B) drawn from these data show that the general direction of movement of groundwater is towards north-west. The average gradient of groundwater level is 52 feet in a mile. The contours are closely spaced. They present regular and uniform patterns. In the southern portion of the area, small domes have been formed. The rise in the water levels after the rainy season is found to be 10 to 40 feet above the summer levels.

Bhainsa Village:

This village not only occurs in the basaltic valley plains of flow No. 4 but it is also situated adjacent to the Vindhyan hill. The dug-wells of the village tap the upper fracture zones and massive part of the flow No. 4. The village area is surrounded by streams from three sides. In the central portion, a minor surface water divide has been formed. The terrain is more or less flat. The total number of existing wells is 15. In this village, the groundwater level measurements were made on 23rd April, 1968. The groundwater contours (Plate No. 15) show that
the groundwater movement direction is towards south-west. In the south-west portion of the area, a minor groundwater divide occurs as indicated by the groundwater movement, that is, towards south as well as towards north-west. The contours are regular, and are widely spaced. The contour patterns indicate the occurrence of a continuous groundwater body. The groundwater level gradient is 15 feet in a mile towards south-west.

The contour patterns reflect the recession of groundwater body towards the streams side ways as well as towards downstream side.

**Pagara Village:**

This village exists in the valley plains of the flow No. 4. The valley plain area of this village is surrounded from three sides by Vindhyan ridges. In the north-central part of the village, the Vindhyan inlier has been found protruding through basalts. The dug-wells of this village area tap the water-bearing vesicular zones, fractured zones and weathered zones of flow No. 4. The total number of existing wells is 54.

The groundwater level measurements for this village were made only once, on the 25th April, 1968. The groundwater contours (Plate No. 16) show that the direction of movement
of groundwater is towards south-east and in the central part of the village, the groundwater movement direction is due west. The contours are medium-spaced and uniform. The gradient of groundwater level is 30 feet in a mile.

Groundwater movement is found to be influenced by the topographic gradients. From the influent seepage grounds occurring towards north-east of the village area (Deccan Trap hilly areas) the groundwater moves in a south-eastern direction and, during the course of its movement through the weathered zone of the flow, the groundwater changes its direction of movement towards east. The contour patterns show truncation of groundwater body, and the movement of groundwater first due south, and then due south-west. This truncation in contour pattern is on account of the presence of the Vindhyan ridge inlier, which disappears near the truncation point. The groundwater bodies on either side of the Vindhyan unite to give rise to a single groundwater body.

The groundwater level maps, prepared for six villages, namely Rusalla, Telakheri, Siakhera, Simaria-Dharkheri, Paten and Masurhai, show more or less similar groundwater contour features. (The dug-wells of these villages tap the interflow zones of flow Nos. 3 and 4.) Only one map, for the village Rusalla has been included here for description, and the groundwater level data for all the villages are included in the appendix.
Rusalla Village:

This village is surrounded by Baheria, Sidgwan, Kerbana and Khiria villages. The wells of this village, though occurring on the farmlands of flow No. 4, generally end in the disintegrated interflow zone of flow Nos. 3 and 4. The total number of the existing dug-wells is 25. The farmlands are deeply dissected by the streams, and are surrounded by them on all the sides. The terrain is sloping in the north-easterly direction. The local surface gradients are towards the north-west, that is to say, towards the main stream. In the north-easterly direction, the gradient is 21 feet in a mile, whereas to the north-west direction, the surface gradient is 60 feet in a mile.

The summer groundwater levels were taken on the 28th of June, 1967. The groundwater contours (Plate No. 17, A) show that the movement of the groundwater is towards the north and north-east. The groundwater level contours are medium-spaced in the southern and the northern parts of the map whereas, in the central part, the contours are widely spaced. The groundwater level gradient, occurring in the northern and southern portion of the map, is 80 feet in a mile whereas, in the central part, the groundwater level gradient is 15 feet in a mile. The groundwater contours show a uniform pattern.

In the same area, after the rains, groundwater level
VILLAGE RUSALLA

GROUNDWATER LEVEL MAP

MOHLI

SIDGAWAN

BAMORA

Water level on 20-9-67
(After rains)

INDEX

Bench Mark 100' Bm
Dug Wells 0
Streams
Village L
Contour Interval 1'

SCALE

Yds 440 220 0 440 880 Yds

(Reduced from 16" to a mile Scale)
measurements were made on the 20th of September, 1967. The groundwater level contours prepared (Plate No. 17B) show that groundwater movement is towards the north and north-east. The groundwater contours are closely placed in the upper and the lower parts of the map whereas they have a medium spacing in the central part. The groundwater levels are three feet below the ground surface. The rise in the groundwater levels after the rainy season is 30 feet above the summer groundwater levels.

The villages Tilakheri, Sainkhera, Simaria, Dharkheri, Paten and Masurhai bring out similar features. The groundwater contours have been found very closely placed in parts of the areas of these villages, the dug-wells of which depend upon the flow No. 4. Whereas, they are found to become medium to widely placed in the lower level areas of the same villages, the dug-wells of which depend upon the third flow.

The groundwater level data for as many as 14 villages whose dug-wells tap flow No. 3, were collected. These data have been given in the appendix III. The maps prepared from these data show similar patterns of groundwater level contours as discussed above for the higher flows. Only one map for a part of the village Kewana has been included here for showing the contour patterns and their behaviour.
Kerwana Village:

The farmlands of the village occur on basaltic flow No. 3, and are surrounded by the farmlands of the adjacent villages Sidgawan, Majhgwan and Bamori Tudar. The wells of this village occur in the weathered and vesicular part of flow No. 3. The local surface gradients are towards the north-west, that is, in the direction of the main stream which is flowing in a north-easterly direction. The total number of dug-wells is 70. The summer groundwater level measurements in these wells were made on the 27th of June, 1967. The groundwater contours prepared from these data (Plate No. 18, A) show that the general groundwater movement direction is due west, and the groundwater level gradient is 35 feet in a mile. The groundwater contours are uniform and regular.

Once again the groundwater levels were measured on the 28th of September, 1967, that is, after the cessation of the rains. The groundwater contours prepared (Plate No. 18, B) show that the general groundwater movement direction is due west, and has a gradient of 43 feet in a mile. The groundwater contours are medium-spaced, and are regular and uniform. The rise in the groundwater levels after the rains is 14 feet above the summer levels.

The groundwater level measurements in the dug-wells,
which depend upon the interflow zones of the 2nd and the 3rd flows could be made only once, and that too during the winter season spread during the months December to March, in the year 1969. All these maps show similar contour features. Out of these, the map for the village Pamakheri has been selected for description and illustration.

Pamakheri Village:

This map also brings out contour features similar to the others. The groundwater levels of the dug-wells of the village were taken on 27th January, 1970. The groundwater contours prepared (Plate No. 19) show that the general movement direction for groundwater is towards east-northeast in the southern part; and, in the northern part, the direction of groundwater movement is due south-west. The contours give rise to groundwater depressions surrounding the wells. In the northern part, the one foot contours are so closely placed that they appear to interfere with one another. Therefore, when reduced to 4 inch-to-1-mile scale from a 16 inch-to-a-mile scale map, groundwater contours could be drawn only at intervals of five feet. The groundwater contours show peculiar shapes surrounding the dug-wells.

Groundwater level data have been collected in the dug-wells of the villages Berkheri Khuman and Richhawar. These
areas are occupied by flow Nos. 1 and 2. The data have been included in the appendix. The groundwater level contours bring out similar contour pattern features. Only one map, of the village Richhawar, has been taken up for description and illustration.

**Richhawar Village:**

The village area lies adjacent to the river Bewas. It is surrounded by the village areas of Ramakheri and Khejra-Budhu. The terrain slopes are south-easterly with an average gradient of 10 feet in a mile. In the central part of the terrain, the ground slopes are towards the north and south, that is, in both the directions. The Bewas river which forms the eastern side boundary of the village is flowing in a north-easterly direction. The total number of the existing wells in this village is 21.

The groundwater level measurements were made on the 27th of December, 1969. The groundwater level contours (Plate No. 20) show that the direction of the groundwater movement is due SE in the western half of the portion of the village, whereas, in the other half, towards the river bank side, the movement direction is towards south-west. The northern part of the map shows that depressions are present around the wells and that these have peculiar shapes
and the contours get closer. A groundwater trench is found in the southern part of the area, which has a south-westerly trend.

_Basaltic plains influenced by underlying Vindhyan:_

As many as four villages, namely Lohari, Barodia-Gusai, Devri and a part of Sewara-Sewari were taken up for groundwater surveys, during the winter season of the year 1969. The groundwater level data of the dug-wells occurring in these villages are given in the appendix (No. III on pages 66-72). A study of the cross-sections of the dug-wells indicate that most of the wells have met the Vindhyan quartzitic sandstones at shallow depths varying from 10 to 15 feet. These wells occur in the synforms of the Vindhyan, where a thin cover of Deccan Traps still covers the Vindhyan. The wells in the farmlands of these villages go dry, during the month of January and, as such, the wells neither have winter nor summer irrigation potentials. During this month, once the water is removed from the well, the well does not recuperate even for weeks, suggesting that the groundwater bodies within the synforms are seasonal (rainy) and local.

_Controls of Groundwater Movement:_

The studies of groundwater level maps bring out interesting
features about the controls to the groundwater movement in the basalts. They show that the direction of movement of groundwater in the basaltic flows is influenced by the topographic gradients, as shown by the groundwater level maps of the villages Patkui and Bhainsa (Plate Nos. 9 and 15) which occur on either side of the main topographic divide, where the groundwater moves in opposite directions giving rise to a groundwater divide. The trend of recession of the groundwater levels, during the summer months, is towards the streams and the groundwater body also recedes downstream. It has been noted in the above villages that in the higher grounds occupied by the grassland areas, the groundwater levels in the dug-wells rise immediately after a storm break, on account of quicker effluent seepage. As the dry season advances, the water levels in the wells of these areas fall down faster whereas in the farmland areas occurring in the areas of in situ weathered basalts, there is a gradual rise in water levels during the rainy season and, once the water levels attain their maximum static levels after the rainy season, the levels fall gradually from October till the following June. The drop in levels, from the start of the dry season up to its end, varies much from place to place, but the average fluctuation is 35 feet in the area. The study of the maps shows that the dug-wells occurring on minor surface water divides go dry during the summer due to the recession of the groundwater bodies. In the deeply
dissected areas, the groundwater occurring on either side of the streams is robbed by the streams and the contour patterns curve to form a 'V' shape towards the upstream side of a stream, showing that these parts of the stream are effluent.

If the 'V' of the curves of groundwater contours points downstream side, it indicates that, that part of the stream is influent, that is to say, a losing stream. The groundwater contours show the presence of groundwater mounds and depressions commonly; and small trenches are also found occasionally. Groundwater ridges are not commonly found in the groundwater level maps of the area under study. It has been noted that even a small change in the topography has been reflected by the groundwater contours. The directions of groundwater level gradients and ground surface gradients appear to be more or less the same practically in all the maps. The groundwater level maps prepared for the villages Samrabag and Bararu (Plate Nos. 10 and 11) show that immediately after the rains, the groundwater bodies do not any more reflect the minor surface water divides and unite to become a single groundwater body. However, as the summer season progresses, the groundwater body splits into smaller bodies reflecting the surface divides. The groundwater contours also reflect the nature of the permeable zones. For example maps prepared for the fourth flow indicate that
parts of the area have comparatively closely spaced groundwater contours, whereas, in other parts the contours are found to be medium to widely spaced. A study of the lithological characters of the vertical cross-sections of the dug-wells occurring in the closely spaced groundwater contour areas of this flow revealed the occurrence of dug-wells in the jointed zones and massive parts of the flow, whereas, similar studies with respect to the widely spaced groundwater contours revealed that the dug-wells penetrated either through the thick weathered zones of the flow or the vesicular parts of the flow. Therefore the widely spaced contours indicate that the area covered by that part of the flow has better permeability than the part of the flow having closely spaced contours. Todd (1959) states that the portions having wide groundwater contours (flat gradients) will have higher permeability than those with narrow spacing. It has been also mentioned by him that under steady state conditions, the elevation at any point on water table equals the energy head and as a consequence the groundwater flow lines lie perpendicular to water table contours. It has been noted during the study of the water levels that in a horizontal distance of 1 mile, the head loss of groundwater varies from 5 to 40 feet in a mile during the summer, the average head loss being 35 feet. Based on the contour interval space features, areas within flow No. 4 have been classified into two categories. Thus the poor zones and good
zones have been selected for locating dug-wells on the basis of closely placed and widely placed summer groundwater level contours. On account of better homogeneity in porosity and permeability characters of weathered and vesicular parts of the flow than the fractured and jointed zones of the same flow, water table conditions appear to be predominant in the vesicular disintegrated parts of basalts, whereas semi-confined conditions appear to occur exclusively in the fractured jointed zones. Further, the water table conditions (gravity flow) generally govern the movement during the rainy season when the static groundwater level surfaces have risen up into the weathered parts of the flow and, as the groundwater levels gradually fall in depth below the vesicular zones during summer, the semiconfining conditions (pressure gradients) begin to govern the movements. Due to such mixed conditions of groundwater movement within the water-bearing zones of the basalts, it has been preferred to describe the groundwater contour maps as groundwater level maps rather than water table or pressure surface maps.

The groundwater level maps of the Kaneradev and Gadholi villages (occurring on either side of the basaltic hill) show that the groundwater bodies occurring in the valley on either side of that hill become one single body immediately after the rains. This body, however, gets separated into different groundwater bodies along the divides as the dry
season advances. In the valley areas of basaltic flows occurring on either side of the Vindhyan hills, the groundwater bodies on either side of the valley never unite to form a single groundwater body even after the rainy season, as the Vindhyan hills act as a barrier. This feature has been brought out by the groundwater level maps of the farmlands of the villages Kudari and Makronia Kurd, which occur on one side of the Vindhyan hill, and the farmlands of the villages Sirwai and Berkhera occurring on the other side of the Vindhyan hill but at a lower elevation. The Vindhyan hill barrier is leaky, and the upper groundwater body of the flow leaks through the openings in the Vindhyan quartzitic sandstone, giving rise to springs on the lower valley side (as at Barra Ramjhira, see plate No. 3). A study of the Kagara and Richora groundwater level maps shows that, wherever the Vindhyan quartzitic sandstone hills lose their heights and, hence, disappear below the basaltic rocks in the valley plains, the adjacent separate groundwater bodies on either sides of the Vindhyan merge into a single groundwater body, immediately after the rains. But the Vindhyan quartzitic sandstones that occur below the ground still continue to act as a barrier for the groundwater bodies occurring at deeper levels. From these observations it is clear that, apart from climate, influent seepage (recharge) and lithological controls, there are topographic controls, drainage pattern controls and pre-basaltic topography controls.
over the movement and occurrence of groundwater in this terrain.

During the rainy season, the contours are more or less uniform in geometrical pattern, and are more closely spaced when compared with the contour spacings of the same flow just before the rains have started. The close spacing of contours appears to be due to greater quantities of water trying to pass through the permeable zones of the flows, on account of better influent seepage (recharge) conditions than are available during the summer season. Therefore the summer groundwater level contours appear to be more useful for determination of permeable zones in a flow. The shapes and sizes of groundwater bodies are controlled by the thickness and the extent of weathered pockets of basalts, fractured zones and their interconnections, vesicular zones and, finally, the thickness and extent of water flow zones. Apart from the above, the withdrawal of water by pumping results in a change in the uniform shapes. The change in the direction of the flow lines in the perched groundwater bodies is controlled by the presence of lateral impermeable boundaries which perhaps do not interfere during and immediately after the rainy season; when the groundwater levels in the water-bearing zones rise high. As the groundwater levels fall, with the advance of the dry season, the patches of massive zones interfere with the lateral flow of groundwater, and
bring out changes in the shapes of the contour patterns accordingly. During summer, the groundwater bodies are more localized, and get bounded by impermeable massive parts.

**Tank and Spring Surveys:**

The gully, stream and river courses of the area under investigation, ultimately pass through one or the other Vindhyan gaps existing in the Vindhys of the area under investigation. As stated in Chap.II, p.34, some of the stream and river courses have achieved surface hydraulic connections from one side of the valley to the other, that is, the streams and rivers flow through the Vindhyan gaps, whereas in some gaps the hydraulic connections have been partially achieved through the gap, resulting in the ponding of run-off water. As soon the depression behind the Vindhyan gap gets filled with water due to rainfall, the excess water flows over the gap towards the lower valley side. After the cessation of rains, cascading of surface water over the Vindhyan gap stops, and the pool of water in due course of time dries up. In some of the gaps, hydraulic connections are yet to be established.

Wherever the present day streams and rivers have established surface hydraulic connections from one side of the valley to the other side, through the Vindhyan gaps,
there occur excellent sites for the construction of small dams. This feature had already been taken into consideration by the Bundela Kings of the eighteenth century to build a tank, known as Motital near Kanchmahal, by constructing a thick wall (dam) across the Vindhyan gap. Incidentally the closure acts as a free overfall weir. The Saugor lake is itself a monumental example of artificial closure by means of 300 feet long masonry wall with a height of 20 feet. Sites for constructing small dams in the area under investigation still occur. For instance, one can construct a large tank by closing the Kanchmahal gap to a height of 30 feet near the road cutting on the 7th milestone occurring on the Saugor-Jhansi national high way. A huge tank, thrice as large as the Saugor lake, can be built by closing the Satgarh gap occurring at about 5 miles to the NW of Saugor on the Karan stream.

Wherever the surface hydraulic connections have not yet been established from one side of the valley to the other through the Vindhyan gaps, the groundwater bodies of the basaltic rock formations (Deccan Traps), occurring on the higher valley sides of the Vindhyan gaps give rise to perennial springs on the lower valley sides. The springs known as Bada Ramjira and Chota Ramjira (Plate No. 3) are the best examples. The Vindhyanus actually act as underground barriers, separating the groundwater bodies of
the basaltic rock formations occurring on either side of the valleys. Springs of this type do not seem to fit perfectly in any one of the standard classifications of springs given in textbooks (like *Groundwater* by Tolman), for the waters of the springs of the area under investigation neither belong to the formation (Vindhyans) through which they flow, nor are the springs contact springs.

These springs are of non-thermal type and perennial. Their yields are at the maximum after the rainy season. The quantity of water issuing from one such spring, namely Bada Ramjira was found to be more than 100 gpm. during the last week of February 1970.

**Pumping Tests:**

The groundwater bodies within the basaltic flows are comparable to "perched confined groundwater bodies" (Newcomb, 1959). The basaltic flows are not at all of isotropic media, and are largely made up of impermeable layers with zones of horizontal permeabilities; the vertical permeabilities are limited only to the porous zones of a flow. In spite of these conditions, Leniger (1968), a Dutch Geologist, working for India Foundation, Indore, has carried out 40 pumping tests in Tube Wells systematically in the basaltic rocks of the Malwa Plateau (Middle Traps), to determine the hydrological
characters like coefficients of Transmissibility and Storage. He states that "The groundwater levels never reached the previous static levels after the test has been performed. This means the recovery is incomplete. The groundwater during the pumping test is in a state of non-steady flow. The water-bearing interflow zones, being anisotropic in nature, made the interpretations difficult. The drawdowns in the pumped well as well as in the observation wells were small and no equilibrium state could be reached". Under these conditions, the formational parameters that have been calculated by him for the Fort and Sanwer areas, Indore, with the help of Theis non-equilibrium formula (Theis, 1935) are reproduced below:

\[
\begin{align*}
  kD &= 1700 \text{ m}^2/\text{day} \\
  S &= 4 \times 10^{-4} \\
  kD &= 1500 \text{ m}^2/\text{day} \\
  S &= 2 \times 10^{-4} \\
  kD &= 4000 \text{ m}^2/\text{day} \\
  S &= 4 \times 10^{-4}
\end{align*}
\]

for well No. 49

for well No. 51

for well No. 52

"The figures for wells Nos. 49 and 51 coincide very good. Well No. 52 gave regarding kD a different result. This kD value is probably not reliable (distance of the well to the pumped well too big, drawdown too small). For the pumping tests in the Fort area the results of the calculation are given in the Table below:"
## FORT AREA

<table>
<thead>
<tr>
<th>Observation well</th>
<th>Pumped well</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>49</td>
</tr>
<tr>
<td>49</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>( k_D = 1600 )</td>
</tr>
<tr>
<td></td>
<td>( S = 0.003 )</td>
</tr>
<tr>
<td>51</td>
<td>( k_D = 3100 )</td>
</tr>
<tr>
<td></td>
<td>( S = 0.001 )</td>
</tr>
<tr>
<td>52</td>
<td>( k_D = 4000 )</td>
</tr>
<tr>
<td></td>
<td>( S = 0.001 )</td>
</tr>
</tbody>
</table>

\( k_D = \) Coefficient of Transmissibility  
\( S = \) Coefficient of Storage

For the Sanwer Road area the results are as follows:

<table>
<thead>
<tr>
<th>Observation well</th>
<th>Pumped well</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37</td>
</tr>
<tr>
<td>37</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>( k_D = 553 )</td>
</tr>
<tr>
<td></td>
<td>( S = 0.0004 )</td>
</tr>
<tr>
<td>42</td>
<td>( k_D = 614 )</td>
</tr>
<tr>
<td></td>
<td>( S = 0.0005 )</td>
</tr>
<tr>
<td>43</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( k_D = \) Coefficient of Transmissibility  
\( S = \) Coefficient of Storage
On the basis of the above data, some of the conclusions arrived at by him are interesting, and these are given below:

1. The anisotropy and inhomogeneity of the strata are clear from the boreholes and pumping tests.

2. The anisotropy and inhomogeneity of the water-bearing strata cause big differences within very short distances. Prediction of good well sites is hence difficult.

Under the above conditions, the existing field methods (Wenzel, 1942) for determining either the coefficients of Transmissibility and Storage or the coefficient of Permeability and Specific-yield of aquifer formations do not suit the hydro-geological conditions existing in the basaltic rock formations of the area under investigation, as these principles are applicable only to those aquifers which are homogeneous with isotropic permeabilities and have infinite areal extents. In this connection, Newcomb (1971*) states that in the case of basaltic formations *the value of coefficient of storage (S) is usually close to the coefficient of elasticity of water; apparently this is because the aquifers are rigid and groundwater is almost entirely confined much of it is perched but that is also confined. The coefficients of transmissibility range from more than a million down to as little as 20,000; this depends on how

* Personal communication to K.N. Das.
much a permeable zone has been tapped by the well. We get a higher 'T' value when we calculate it from the drawdown in a separate observation well than we do when we use the drawdown or recovery in the pumped well. All this suggests to us that the use of 'T' and 'S' are not very important in the Columbia River Basalts. Basalts are certainly not a isotropic medium; they are largely made up of impermeable layers but include some horizontal permeability at the tops of some of the flows".

Before attempting to determine a technique suitable for predicting the quantities of water that can be pumped safely from the dug-wells during different seasons, a dug-well requires to be defined. A dug-well is one which functions as a storage tub receiving groundwater percolating through the pervious zones from the sides of the well on account of groundwater level gradients surrounding the well. It is not a point source like a tube well. During pumping, the water already present in the well and the water which infiltrates into the well during pumping are both removed, as the water in the well is normally pumped out at a higher rate than the rate of infiltration. For this reason, the
modified Slichter's formula as used for testing open wells by Narasimhan (1965) is also not applicable. In these circumstances, the groundwater level contour maps are used as base maps. Out of the winter and summer season maps, the summer season maps are used, for, during this time, the recharge to the groundwater body does not occur from any source except tanks. As earlier stated (Chap. V, pp. 84–104) the groundwater level contour patterns are different for different seasons. In addition, the contours may be closely and/or medium or widely spaced in the same area. Taking the nature of spacings of contours into consideration, dug-wells fitted with pumps are selected for pumping tests such that a few wells occur in closely spaced contour areas, and others in medium-spaced and widely spaced contour areas. For conducting recuperation (recovery) tests the villages Bararu (closely spaced contours with a groundwater level gradient more than 60 feet in a mile) Somrabag and Patkui (medium-spaced contours with a groundwater level gradient 20 to 60 feet in a mile) and Jinda (widely spaced contours with a groundwater level gradient 6 to 20 feet in a mile) were selected, for the density of existing dug-wells in these villages is found to be adequate for preparing accurate groundwater level maps, and, moreover the wells are equipped with pumps. Four dug-wells were selected in these villages; the wells occur in the weathered and fractured and jointed zones of flow No. 4. During the last week of April, 1968,
the static water levels in the wells were recorded and then the wells were pumped dry. The recuperation of water levels with respect to time were noted up to a period of 10 hours after the pumping stopped. The volume of water in each dug-well at the end of this period, was calculated by measuring the diameters of the wells at different depths. The results of the test are tabulated below:

Table No. 5

<table>
<thead>
<tr>
<th>Name of the village and the well numbers</th>
<th>The approximate yields of dug-wells in closely spaced contour areas at the end of 10 hour recuperation time, given in imperial gallons</th>
<th>The approximate yields of dug-wells in medium-spaced contour areas at the end of 10 hour recuperation time, given in imperial gallons</th>
<th>The approximate yields of dug-wells in widely spaced contour area at the end of 10 hour recuperation time given in imperial gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bararu Well No. 1</td>
<td>3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Bararu Well No. 2</td>
<td>5000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Semrabag Well</td>
<td></td>
<td>8000</td>
<td></td>
</tr>
<tr>
<td>4. Patkui Well</td>
<td></td>
<td>5500</td>
<td></td>
</tr>
<tr>
<td>5. Jinda Well No. 1</td>
<td></td>
<td></td>
<td>9500</td>
</tr>
<tr>
<td>6. Jinda Well No. 2*</td>
<td></td>
<td></td>
<td>12000*</td>
</tr>
</tbody>
</table>

*This well occurs near an effluent pocket of stream, though the water quantity of water occurring in the pocket is negligible.
The above Table indicates that at the end of every 10 hours, the farmer can begin pumping again, and, with a proper irrigation schedule, even from the Bararu well No. 1, he can pump as much as 6000 gallons in a day, during summer.

It has been further noted that the rate of recovery of water levels in the dug-wells decreases with increase of time, after pumping stopped. The Table No. 6 for the university well (diameter of 22 feet and a depth of 24 feet) brings out this point.

The data given in the Table can be used to determine a proper irrigation schedule, such that the farmer would begin pumping at the end of a particular time, and need not wait for the water level to reach the seasonal static level.

Studies conducted in a few other wells tapping the flow No. 4 with closely spaced groundwater level contours indicated that the water levels in these wells took as many as 6 days to recover their seasonal static level positions during summer. Some of the large diameter (30 feet) dug-wells existing in the same flow yield as much 40,000 gallons a day during the month of June. Such wells are found to occur in thick weathered vesicular zone of the flow and the groundwater level contours of the area for the summer season are widely spaced. The average yields of wells occurring in the medium-spaced groundwater level contour areas can be assumed to be about 12,000 gallons per day during summer for the flow.
<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>I</th>
<th>M</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 hrs. 30 mts.</td>
<td>9 hrs. 30 mts. to 9 hrs. 30 mts.</td>
<td>9 hrs. 30 mts. to 10 hrs. 30 mts.</td>
<td>10 hrs. 30 mts. to 11 hrs. 30 mts.</td>
<td>11 hrs. 30 mts. to 12 hrs. 30 mts.</td>
</tr>
<tr>
<td>12 hrs. 30 mts. to 13 hrs. 30 mts.</td>
<td>14 hrs. 30 mts. to 15 hrs. 30 mts.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recuperation in Imperial Gallons:
- 0*
- 2156
- 2058
- 1910
- 1870
- 1000
- 1200
- 1000
- 900

Total quantity in the well in imperial gallons:
- 8000**
- 10156
- 12214
- 14024
- 15094
- 16094
- 17294
- 18294
- 19094
- 19094@

* The test started at 8.30 a.m. on 9th May, 1970.

** Before the recuperation test started, the water could not be emptied fully with a diesel pump for want of suction length.

@ Static water level reached.
As most of the dug-wells are still equipped either with rahats (persian wheels) or motes (a local method of removing water with the help of a pair of bullocks), recuperation studies in the dug-wells occurring in other flows were limited to one or two wells in each flow. With this data along with the data gathered by questioning the owners of wells, the yields of the dug-wells occurring in the interflow zones of flow Nos. 1 and 2 can be roughly estimated, and the yields vary from 15,000 to 20,000 gallons per day during the month of March (beginning of summer) and the yields are much more during the month of November (after rains).

Similar studies for flow No. 3 indicated that the dug-wells occurring in this flow yield about 15,000 gallons per day during the months of December, January, and February; but the end of March, the yields fall to 3,000 to 4,000 gallons a day. The dug-wells existing within the weathered zones of the basaltic flow No. 5 yield as much as 20,000 gallons a day during the month of December and their yields during summer, vary from 6,000 to 9,000 gallons a day.

Though the recuperation data of dug-wells, occurring in differently spaced summer groundwater level contour areas of different flows of the area under investigation are meagre, as a test measure, as many as 60 well sites were located in the farmlands under the Agriculture Refinance Corporation loan scheme, Government of India, in such a manner that no
well site occurs within the closely spaced groundwater level contour area. The following Table shows the distribution of new wells in different villages.

**Table No. 7**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the village</th>
<th>Number of new wells under A.R.C. Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kerwana</td>
<td>17</td>
</tr>
<tr>
<td>2.</td>
<td>Rusalla</td>
<td>11</td>
</tr>
<tr>
<td>3.</td>
<td>Bararu</td>
<td>13</td>
</tr>
<tr>
<td>4.</td>
<td>Jinda</td>
<td>3</td>
</tr>
<tr>
<td>5.</td>
<td>Patkui</td>
<td>3</td>
</tr>
<tr>
<td>6.</td>
<td>Bachlon</td>
<td>2</td>
</tr>
<tr>
<td>7.</td>
<td>Barkhera</td>
<td>1</td>
</tr>
<tr>
<td>8.</td>
<td>Sidgawan</td>
<td>5</td>
</tr>
<tr>
<td>9.</td>
<td>Rajakheri</td>
<td>1</td>
</tr>
<tr>
<td>10.</td>
<td>Semrabag</td>
<td>3</td>
</tr>
<tr>
<td>11.</td>
<td>Bamora</td>
<td>1</td>
</tr>
</tbody>
</table>


|                      | **60** |

All these wells were commissioned during the summer of the year 1969. Most of the wells have penetrated the entire thickness of aquifer zones, and ended within one or two feet of the massive zone of a flow. The depths vary from 30 feet to 40 feet and their internal diameters range from 13 to 20
feet and the diameters are more or less maintained throughout their depth. All the wells, except for one, irrigate more than 5 acres of high-yielding variety of Mexican wheat during winter and not less than ½ acre of vegetables during summer, whereas the exceptional well irrigates 3 acres of high yielding Mexican wheat and about half an acre of vegetables during summer. The acreage under irrigation from this well, in different seasons has been taken, as a standard for determining the economic potentialities of a well for preparing schemes for construction of dug-wells in the area under investigation, for, if a well fails, the farmer having mortgaged his land to obtain the loan to construct the well, gets ruined. The cause of the low yields of this well during different seasons (when compared with the other wells) is on account of the farmer shifting the well site to a higher level of his farmland, for taking full advantage of the ground slope for movement of irrigation water from place to place on his farmland. As a consequence, the well site now occurs on the closely spaced contour area.

Suitability of groundwater for irrigation:

Water samples were collected from as many as 26 dug-wells that were newly constructed under the Agriculture Refinance Corporation Scheme in the villages Kerwana, Bararu, Sidgawan and Rusalla in order to find out the suitability of these
waters for irrigation. The major constituents such as Sulphates, Chlorides, Carbonates, Bicarbonates and Calcium were determined. The results of the analyses are tabulated below.

**Table No. 8**

**CHEMICAL ANALYSIS OF THE WATER SAMPLES COLLECTED FROM THE DUG-WELLS**

<table>
<thead>
<tr>
<th>Village</th>
<th>Well location (field nos.)</th>
<th>T.D.S</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>pH</th>
<th>Conductance in M.M. Mohs.</th>
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The above Table also includes the pH values, conductance in milli micromhos, and total dissolved solids. The traces of minor constituents like Boron etc., along with Sodium and Potassium are not reported in the analyses.

The total dissolved solids range from 90 ppm. to 395 ppm. in different samples. There is a considerable variation in the relative amounts of chemical constituents present in the groundwater samples of different wells. The analyses also show that the groundwater is moderately hard with low salinity. The pH value of different samples vary between 8.1 to 9.4. The groundwater is slightly alkaline. Calcium is the principal constituent that contributes to the hardness, which is largely of carbonate (temporary) type, as the bicarbonate is the principal anion. The carbonate and bicarbonate ratio is more, due to the moderately high pH values of groundwater. The concentration of soluble salts in groundwater is not so excessive as to make the water injurious to plant growth. The sulphate in natural waters are recycled from the atmosphere, and its absolute concentration is less than 2 ppm. in atmospheric precipitation; but the analyses of groundwater in this terrain, give very high values for sulphate, ranging from 40 to 246 ppm. It is probably due to the use of fertilizers like ammonium sulphates etc. The groundwater of the Deccan Traps in the area under investigation is quite suitable for irrigation purposes.