# HILLTOP IMPOUNDING RESERVOIRS FOR RAIN WATER HARVESTING, A CASE STUDY FROM GARHWAL HIMALAYA

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## ABSTRACT

In Garhwal Himalaya, water resources are inadequate. Most of the villages are located over the spurs between the river valleys, these spurs and ridges, because of uncontrolled deforestation and rapid soil erosion, lack of vegetation cover and consequently have few springs as only source of water. Since the rivers are far away such springs are generally drying up. As a result, the villages located on these spurs are facing acute scarcity of water. This problem further aggravates, as the rock formations are generally metamorphosed in nature viz. phyllites, schists and quartzites, there is hardly any possibility for underground water except along the valleys.

The data collected for precipitation in this area suggest that the altitudes between 1,200-2,000 m a.s.l. receive a high rainfall viz. over 400 cm per annum. But because of low infiltration capacity of the ground, due to thin soil cover, impervious rocks and lack of vegetation, this water flows away down the slopes into the valleys. Therefore, a scheme was envisaged to collect this rainwater into some hilltop impounding reservoirs.

Geomorphological studies carried out in the Pauri district, revealed that there are several hill tops lying between 1,800-2,000 m a.s.l. Such hilltops are some times flat with adequate soil cover. Three such hilltops were chosen viz. Ghandiyaldhar near Pauri, Tarakund near Chakisain and Gurkhal near Pokhra. Small ponds were dug up over such hilltops, and compacted mud pebble linings were made using locally available stones and sticky clays.

During rainy season, it was noticed that such reservoirs are able to store adequate water. The loss of water on evaporation was checked by planting trees around the ponds. Some seepage through the floors and sides of the reservoirs was permitted. It was noticed that such seepage reactivate the springs located on the down slopes. In this way, a successful attempt was made to provide some additional source of water to the villages, mainly for irrigation purpose.

## 1.0 INTRODUCTION

This work was carried out in the Pauri district of Garhwal Himalaya, U. P. (figure-1), where water resources for drinking and irrigation purposes are quite inadequate. There are few perennial rivers, which have sufficient flow throughout the year. These are:

(i) Alaknanda (Ganga) that forms the northern and western boundary of the district.

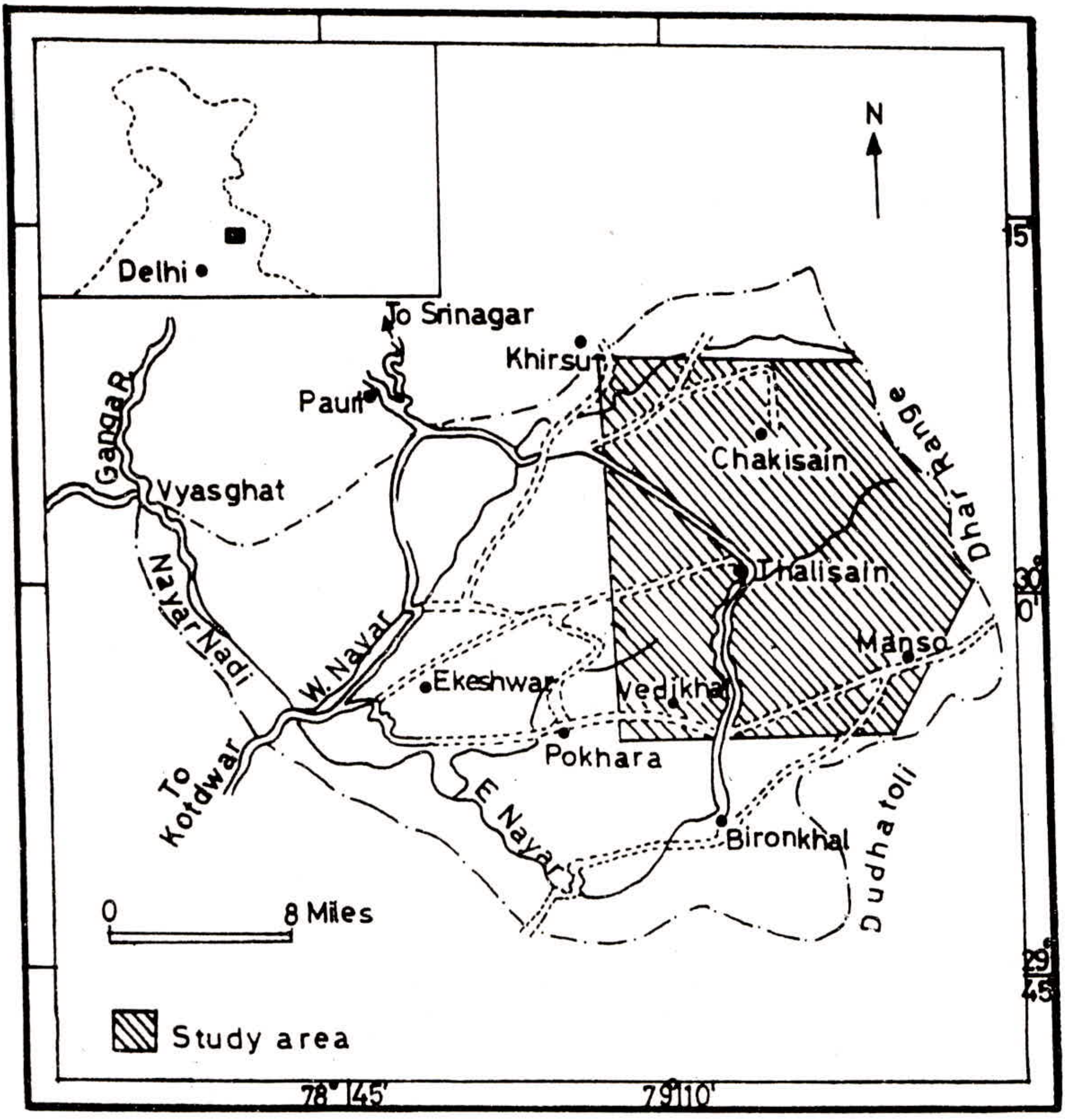


*Fig. 1 : Location map of the study area*

(ii) Nayar river, a tributary of the Ganga, which rises from the Dudhatoli hills forming the eastern margin of the district. Two major streams rises from the northern and southern flanks of this range viz. the western and eastern Nayar respectively.

(iii) Khoh river rises from the Lansdowne hills and flows southwards towards Kotdwara, this river has less flow in comparison to the other two.

Apart from these three rivers, there are some springs on the sides of the river valleys. However, only few of these are perennial, and most of them are erratic and activate only after rains. Even the perennial springs are in the process of rapid depletion, because of slope failures, deforestation etc.

The problem of water scarcity multiplies as most of the human settlements and the cultivated fields are located over the ridges and spurs, far away from the perennial rivers. Such settlements get water from few springs that are also being depleted. Moreover such ridges and spurs are poised in such way that most of the rain water falling over them, flows away. The distribution of rainfall is also very peculiar. The rainfall is mainly received from the Southeast monsoon that strikes the Himalaya from south. In this way only south facing slopes receive adequate precipitation, whereas the north facing slopes constitutes the shadow zone and receive very little precipitation (Kharkwal, 1977). The rainfall is also controlled altitudinally (Purohit, 1977). The areas located below 1,000 m a.s.l. receive very low annual rainfall, between 1,000-2,000 m a.s.l., the rainfall is high to moderate, whereas above 2,000 m a.s.l. it goes on decreasing and above 3,000 m a.s.l. there is hardly any precipitation.

In order to supplement the inadequate water resources, a plan was envisaged to store this rain water falling over the ridges, and for this purpose the construction of impounding reservoirs was planned at suitable places in the Pauri Garhwal district, for rain water harvesting.

## 2.0 COLLECTION OF RAINFALL DATA

The data for rainfall was collected annually for different places by using rain gauges at different altitudes, Following table gives annual rainfall data at different altitudes on south facing and north facing slopes in Pauri district.

These data show an adequate annual rainfall in the altitudinal zone 1,200-1,800 m a.s.l, specially over the south facing slopes.

For collecting rain water it is necessary to calculate the gross water yield from the stream flow data (Remson, 1978) using the following formula

| | | |
|---|---|---|
| Let annual rainfall be | = | X cm |
| Area of the given catchment | = | Y sq. m |
| Loss during surface runoff is | = | Z cm |
| Therefore, the gross water yield will be | = | (XY) – Z |

In this way, on the basis of collected data the gross water yield was calculated for several catchments. Since the plan was to collect water for local use, only smaller micro-catchment (3rd order basins) were selected, and their gross water yields were calculated. The micro-catchments were chosen after thorough geomorphological and geological investigations.

*Table 1 : Annual rainfall at various altitudes on the south and north facing slopes*

| Altitudinal zones in m a.s.l. | Annual rainfall in cm (approximate) | |
|---|---|---|
| | South facing | North facing |
| <600 | 310 | 195 |
| 1200 | 410 | 220 |
| 1800 | 370 | 205 |
| 2400 | 130 | 60 |
| >3000 | 35 | 10 |

## 3.0 GEOMORPHOLOGICAL INVESTIGATIONS

These investigations were carried out on the basis of the field observations aided by the study of landsat imagery for this area (figure 2).

The area is full of a number of ridges and their related spurs. A map of ridges and spurs is given (figure 3). The most imposing landmark in this district is the Dudhatoli range, which is disposed roughly in a NW-SE trend, rising to the height of over 3,000 m a.s.l. This range shoots out a number of oblique ridges and spurs which act as water divides and catchments for various streams. Generally, such ridges have steep escarpments on the upper and talus cones on the lower parts. The top parts of such ridges are gently sloping with natural depressions at some places. The prominent oblique ridges are:

(i) **Mandakhal-Patoli ridge :** On the western side of western Nayar and south east of Pauri, it trends roughly north-south rising upto 2,000 m a.s.l. The top part of this ridge gently slopes towards east and south-east. A gently south-east sloping micro-catchment at 1,800 m a.s.l. altitude was located near Ghandiyaldhar.

(ii) **Bharsar-Chaurikhal ridge :** It is also a north-south trending ridge located on the eastern flank of western Nayar, west of Thalisain village. This rises upto 2,500 m a.s.l., the top part generally slope towards north and north-east and thus no suitable micro-catchment could be found.

(iii) **Binsar ridge :** This is an east-west trending ridge, located on the southern flank of eastern Nayar, south-east of Thalisain. This ridge rises upto 2,800 m a.s.l. The top parts gently slope towards north as well as south, but all the micro-catchments are located well above the high rainfall zone.

(iv) **Dikhaldhar ridge :** It is northern most off shoot of the Dudhatoli range trending NW-SE, located in the east of village Chakisain. This ridge rises upto 2,400 m a.s.l., and top parts gently slope towards south-west and north-east. Only one south-west facing micro-catchment could be located within the high rainfall zone, viz. Tarakund.

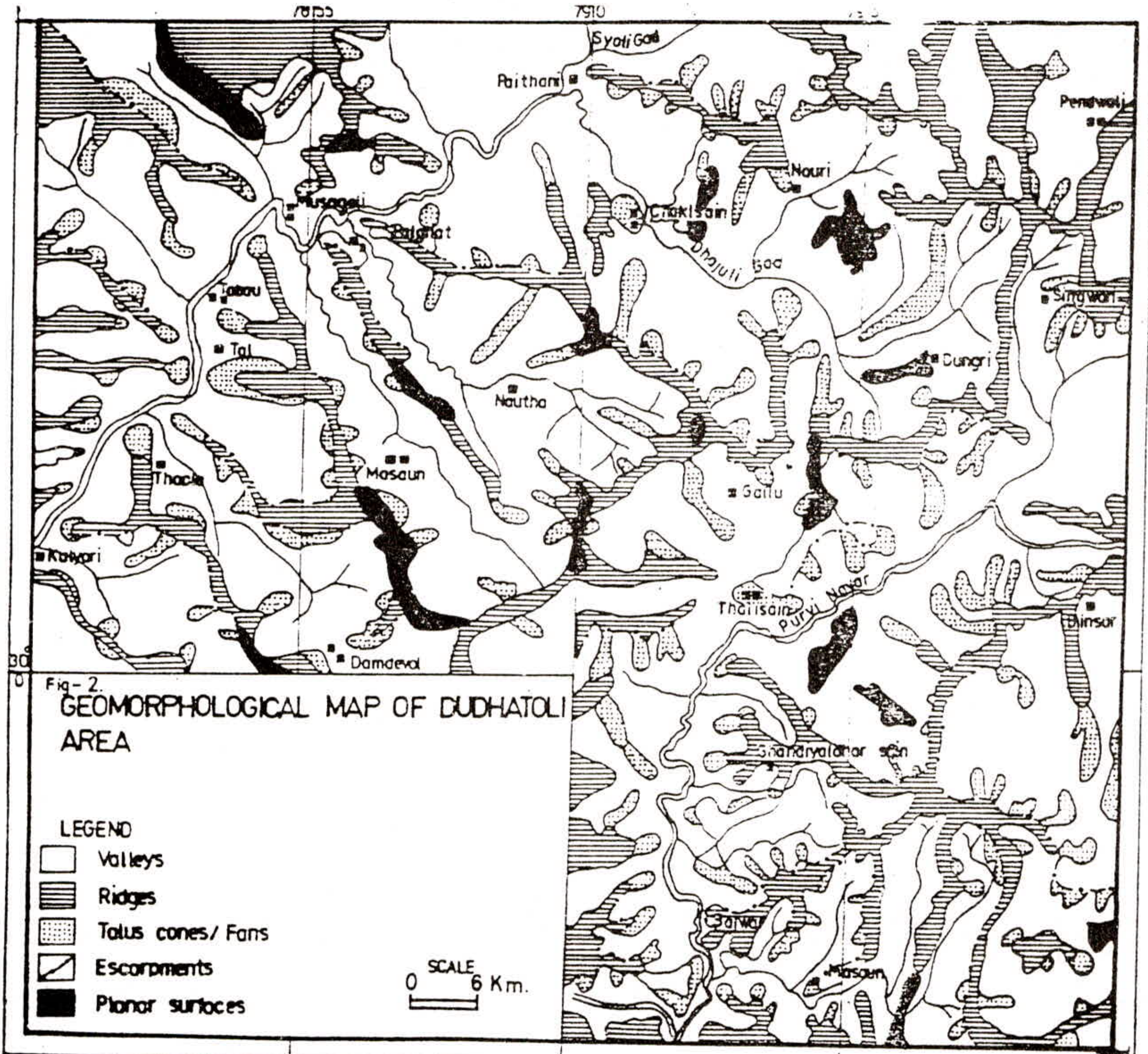


*Fig. 2 : Geomorphological Map of Dudhatoli Area*

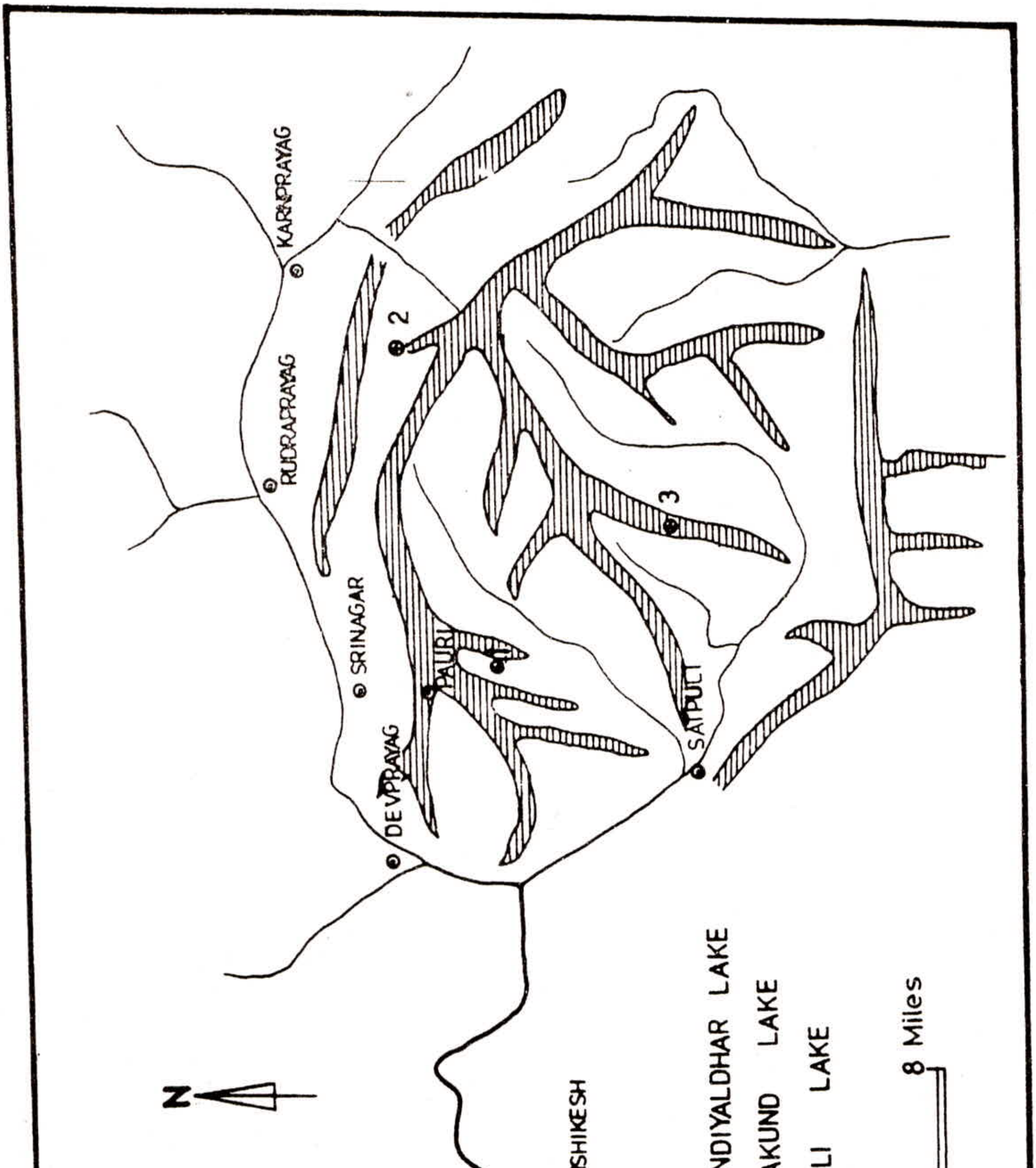


*Fig. 3 : Map showing water divides ridges and location of Hill-Top Reservoirs*

(v) **Damdeval ridge :** This is an east-west trending ridge forming the catchment for river Machhald a tributary of Eastern Nayar. The eastern part of this ridge turns southwards forming the Pokhra spur. It rises upto 2,500 m a.s.l. on western side, while the Pokhra spur rises upto 2,000 m a.s.l. A south facing gently slopping micro-catchment was located over the Pokhra spur, viz. Gurkhal.

## 4.0 GEOLOGICAL INVESTIGATIONS

The geological investigations were carried out on the basis of field observations. The broad geological framework is depicted in figure 4.

Auden (1949) described the Dudhatoli crystallines as a thrust block composed of schists, gneisses and granitoids. He (Auden, 1949) included the phyllites of Pauri-Pabau area in the Chandpur group, and thought that Dudhatoli crystallines constitute the base of Krol unit. Mehdi et al. (1972) interpreted a normal succession from Chandpur to Dudhatoli-Almora crystalline.

The geological mapping of the area was carried out on a 1:50,000 scale. Stratigraphically the entire area comes under Kumaon Super Group (Kumar et al., 1974). The stratigraphic-tectonic sequence is given in Table 2.

*Table 2 : Stratigraphic-tectonic sequence of the area*

| Age | Stratigraphy | | Tectonic unit |
|---|---|---|---|
| Pre-Cambrain (Proterozoic) | Nagthat Formation | Quartzite with intercalated phyllites and slates | Jaunsar Group |
| | Chandpur Formation | Mainly phyllites and slates | |
| Pre-Cambrain (Archean) | Dudhatoli-Almora crystalline Formation | Dudhatoli Granites-gneisses (high grade metamorphics) | Dudhatoli Almora Thrust sheet (Kumaon Super Group) |
| | | Dudhatoli schists (low grade metamorphics) | |
| | | Manilla phyllites | |

Detailed geological investigations were also taken up at the selected sites for the construction of impounding reservoirs.

## 5.0 SITE SELECTION FOR IMPOUNDING RESERVOIRS

For this purpose, suitable sites were selected with help of field observations aided by the study of aerial photographs. Suitable hilltops were chosen within the zone of high rainfall (1,200-2,000 m a.s.l.), with gentle south facing slopes having sufficient micro-catchment areas. Such sites have sufficiently thick soil cover, with a considerable quantum of clayey soil, underlying less fractured rocks in order to avoid seepages etc. The locally available clayey soil may also be used as construction material. Detailed surveys also revealed the presence of natural depressions over such hilltops. It was also noticed that such depressions are located along the boundaries of two lithological units, generally between quartzites, phyllites and schists, created on differential erosion.

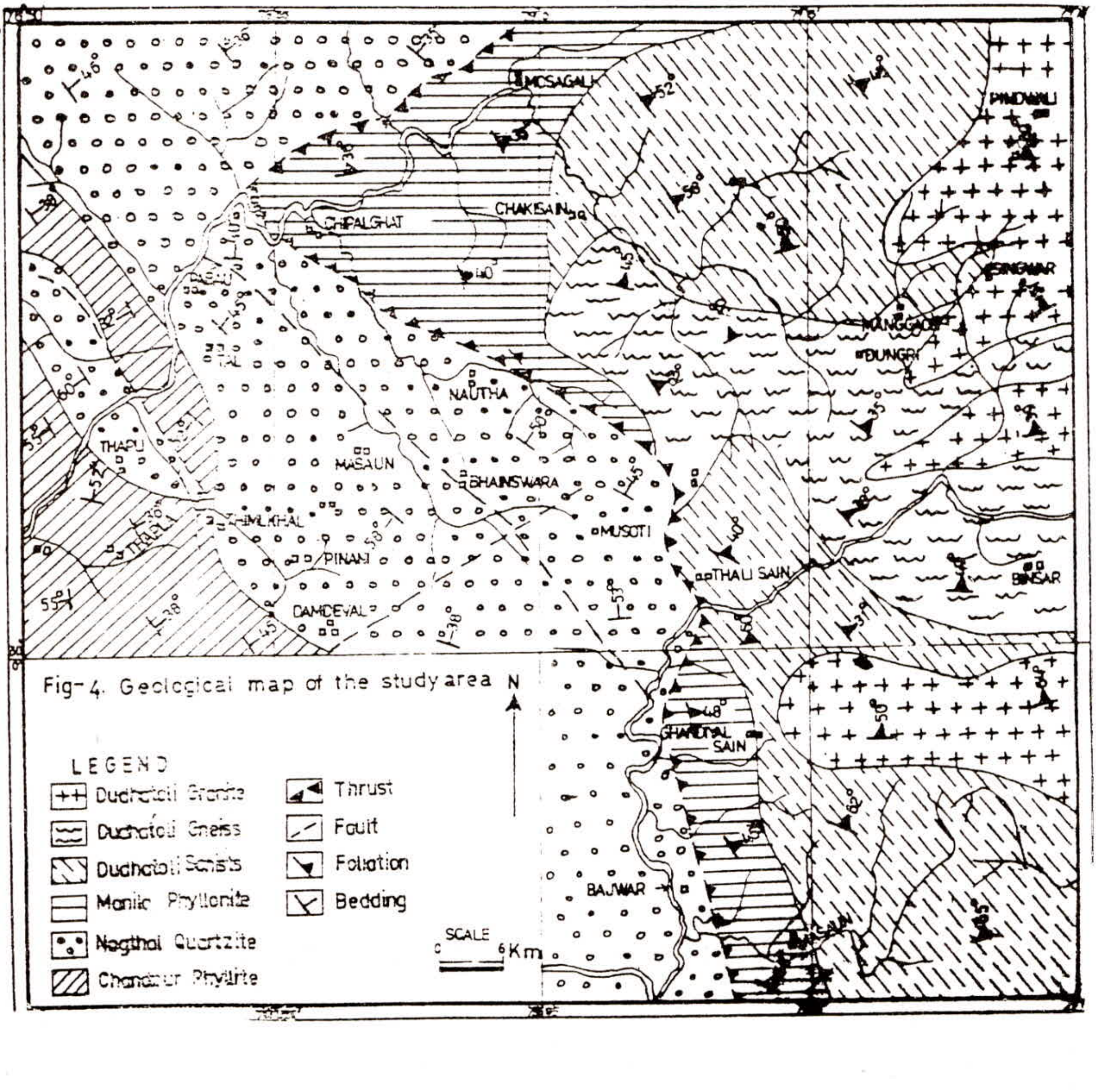


*Fig. 4 : Geological map of the study area*

As a result of these investigations, three suitable sites were selected. These sites are:

(i) **Ghandiyaldhar :** Located about 12 km south-east of Pauri town, over the Mandakhal-Patoli ridge, west of the western Nayar, at an altitude of about 1,850 m a.s.l., the natural depression was located between the Pauri phyllites and Devithonk quartzites.

(ii) **Tarakund :** Located about 10 km north-east of the village Chakisain, over the Dikhaldhar range, the catchment for the western Nayar. The site is located at an altitude of 2,000 m a.s.l., and the depression is along the boundary between quartzites and schists.

(iii) **Gurkhal Tal :** Located about 3 km west of the Pokhra village, over the Pokhra spur of the Damdeval ridge, forming the catchment of the river Machhald, a tributary of eastern Nayar. The altitude here is 1,750 m a.s.l. and the depression is located between Pauri phyllite and Maithana quartzite.

All these three sites are shown in figure 3. The three natural depressions were converted into small reservoirs, by deepening and enlarging the depressions in order to store more water. All these three sites had the presence of good quality clayey soil, which could be utilized for plastering the sides of reservoir in order to check seepage. On the sides of reservoirs a 60 cm thick layer of compacted pebbles was filled followed by a 40 cm thick layer of mud. At the floor of the reservoir about 1 m thick layer of compacted pebbles cemented with mud were laid down.

In this way, it was contended that rain water can be stored locally involving very little expenditure.

## 6.0 DESCRIPTION OF THE IMPOUNDING RESERVOIRS

(i) **Ghandiyaldhar Reservoir :** Investigations revealed that this site has micro-catchment area of about 3,000 sq. m. The annual rainfall measured is about 350 cm. Therefore the gross water yield calculated is:

3,000 X 350 = 10,50,000 cubic cm or 10,500 cubic m
Less 10% on run-off loss (including infiltration and evaporation)

In this way the net gross water yield shall be around 9,000 cubic m annually. The initial natural depression has an approximate area of around 800 sq. m.

The geological investigations revealed that the northern and eastern parts of the area is occupied by light brown and yellow quartzites that are hard and compact having a general NNW-SSE strike and dip towards NE viz. away from the depression (figure 5). On the other hand the southern and western parts of the depression are occupied by light gray phyllites having general strike NW-SE and dip towards the depression viz. NE. These rocks appear to have been overlain by clayey alluvial soil.

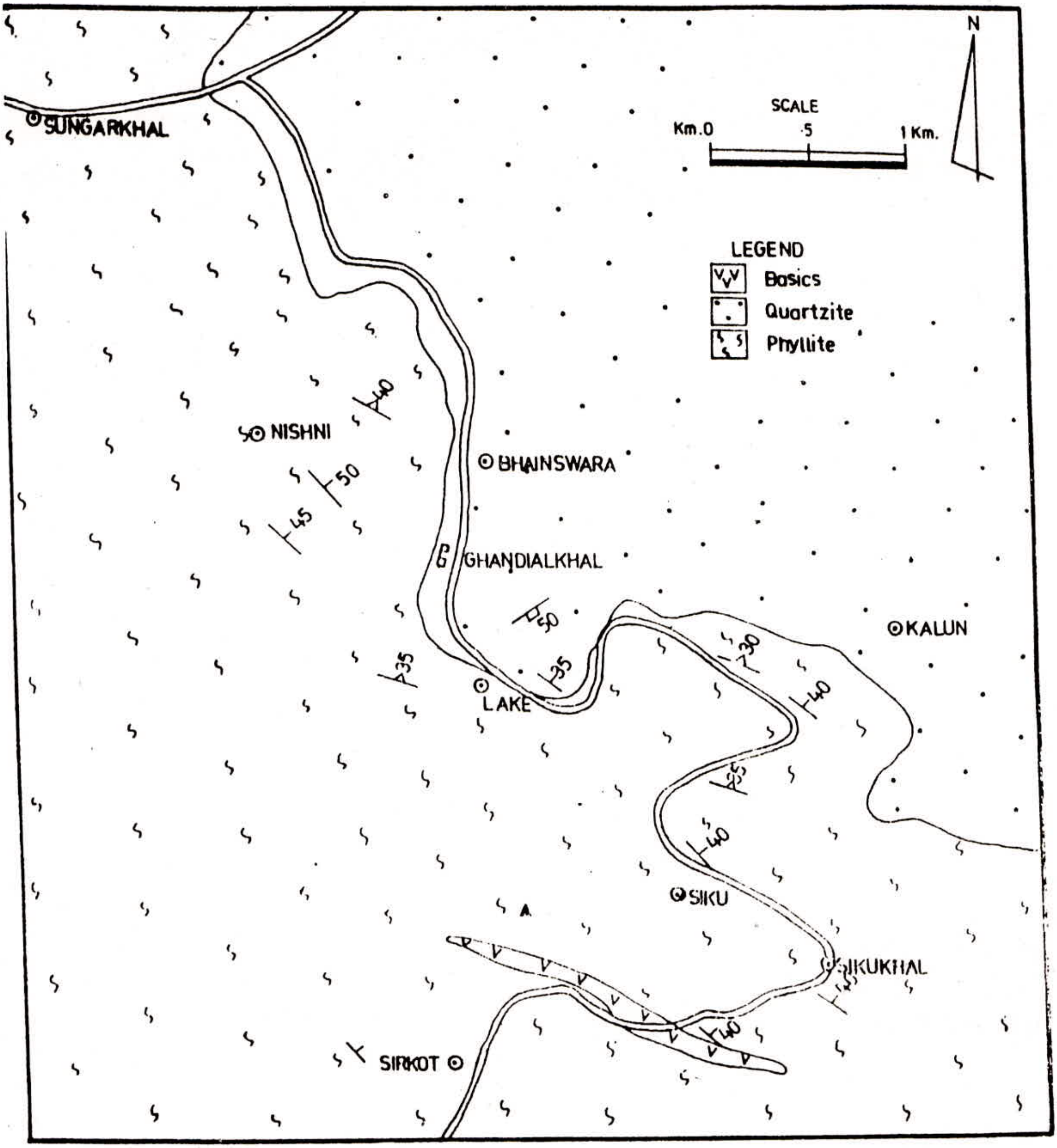


*Fig. 5 : Geological map of the Ghandiyaldhar lake*

The soil characters were studied on the basis of laboratory analysis. The samples were analyzed with respect to their size characters and chemical compositions. These data are given in Table 3 and 4.

*Table 3 : Size analysis of the samples of Ghandiyaldhar lake*

| Locality of sample | Sample No. | Coarse sand % | Sand % | Silt % | Clay % |
|---|---|---|---|---|---|
| East | $L_1$ | 9.81 | 50.35 | 29.30 | 10.34 |
| North | $L_2$ | 6.53 | 51.75 | 29.98 | 11.75 |
| Centre | $L_4$ | 6.35 | 45.45 | 31.70 | 6.50 |
| West | $L_6$ | 35.09 | 35.41 | 22.50 | 7.00 |

*Table 4 : Chemical analysis of the samples of Ghandiyaldhar lake*

| Locality of the sample | Sample No. | PH | % of organic carbon | % of Nitrogen | Potash (ppm) | Phosphate (ppm) |
|---|---|---|---|---|---|---|
| East | $L_1$ | 5.3 | - | 0.0679 | 104 | 13.684 |
| North | $L_2$ | 5.4 | 0.585 | 0.0690 | 108 | 14.388 |
| North | $L_3$ | 5.2 | - | 0.0882 | 160 | 3.158 |
| Centre | $L_4$ | 6.2 | - | 0.0567 | 160 | 19.281 |
| Centre | $L_5$ | 5.2 | - | 0.0882 | 155 | 3.281 |
| West | $L_6$ | 5.8 | - | 0.0399 | 120 | 40.789 |
| West | $L_7$ | 5.0 | 0.130 | 0.0568 | 160 | 21.380 |

The result of analysis reveals that the soil of this area is largely silty but becomes more clayey in the central part of the depression. The soil is generally acidic viz, having low pH, low organic carbon, nitrogen and potash.

It was planned to convert this natural depression into an impounding reservoir by enlarging and deepening it and sealing the sides to prevent any possible seepage. Locally available clay and quartzite pebbles were utilized for this purpose.

The depression was enlarged on digging, giving it an oval shape, and the dug up area was about 1,090 sq. m. The depth of the reservoir was kept variable, on the sides it was 2 m and in the centre 4 m (figure 6). The longer eastern and western sides were made sloping in order to avoid any landslip etc.

Three feeder $2^{nd}$ order streams were located for the reservoirs, which carry water from the catchment. These stream channels were also deepened and joined to the excavated site.

**(ii)** **Tarakund Reservoir** : Here the natural depression is roughly 1,800sq. m in area with a catchment of 5,500 sq. m. The annual rainfall calculated is about 260 cm. In this way the gross water yield will be :

5,500 X 260 = 14,3000 cubic cm or 14,300 cubic m
Less 10% run-off loss (including infiltration and evaporation)

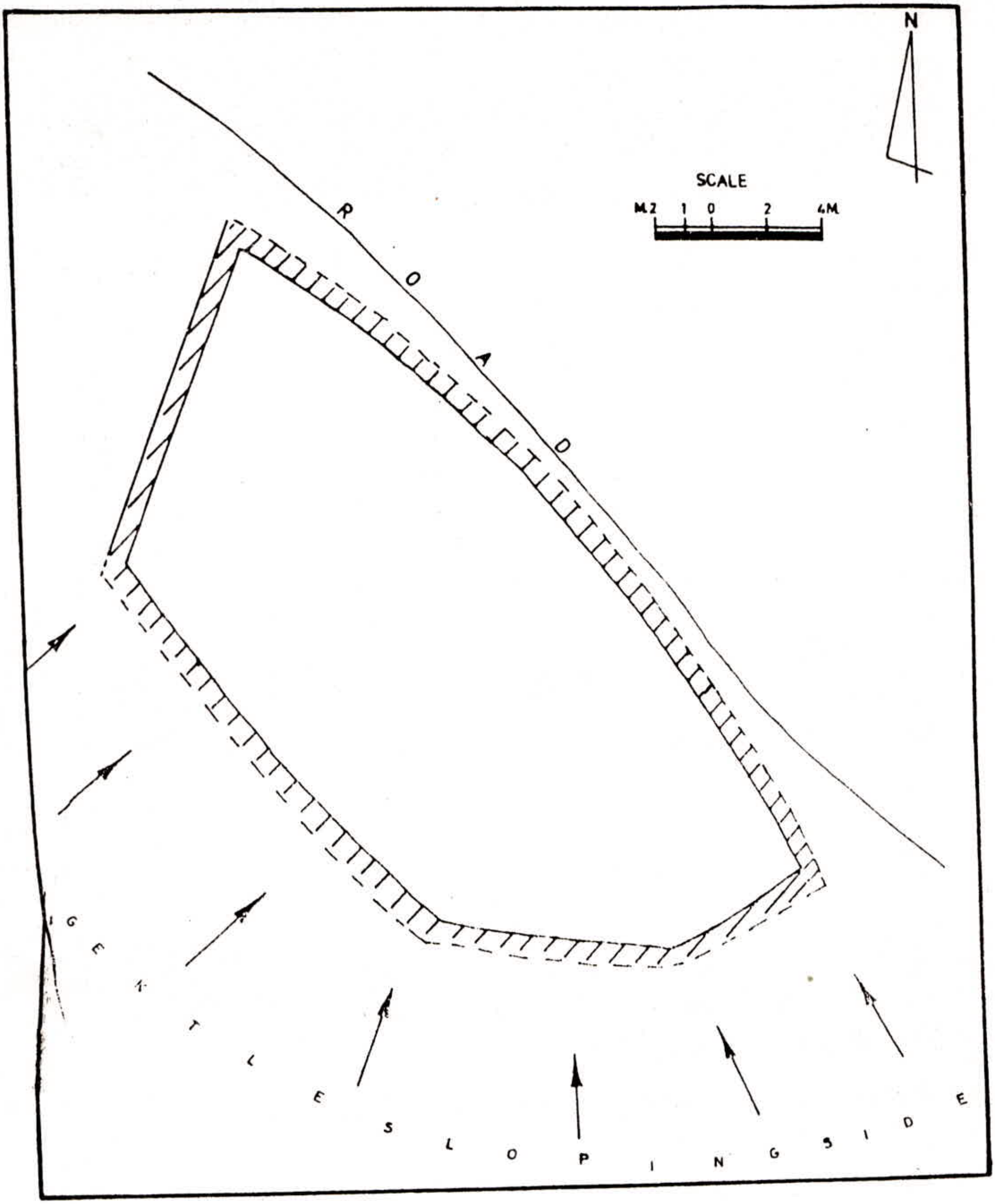


*Fig. 6 : Surveyed Plan of Hill-Top reservoir at Ghandiyaldhar*

In this way the net gross water yield will be around 1,300 cubic m annually. It was planned to construct an impounding reservoir by deepening this depression, with 4 m in the central part and 1 m on the sides. The northern side of this depression is occupied by schistose quartzites striking east-west and dipping southwards and the southern side by sericite schists dipping southwards. The impounding reservoir here is yet to be constructed.

(iii) **Gurkhal Reservoir :** The natural depression here has an area of about 1,100 m. and catchment area of about 4,000 sq. m, whereas the annual rainfall is about 380 cm. In this way the gross water will be :

4,000 X 380 = 15,20,000 cubic cm or 15,200 cubic m
Less 10% run-off loss (including infiltration and evaporation)

The net gross yield will be about 14,000 cubic m. It is planned to deepen this depression 4 m deep in the centre and 2 m on the sides. The geological investigations revealed that the eastern part of the depression is occupied by brown quartzites and western part by grey phyllites, both having eastward dips. A reservoir is yet to be constructed at this site.

## 7.0 CONCLUSION

Only one reservoir could be constructed at Ghandiyaldhar, which stored water sufficient for the use to the local villages for irrigation purposes. The impounding of water not only helped to lessen the water scarcity, but also improved overall ecology of the surrounding areas. It was noticed that some of water seeps through the sides and goes underground. It was noticed that the dormant springs located on the downslope, were activated, and also it was possible to create a horticultural belt around this reservoir.

## ACKNOWLEDGEMENTS

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