Groundwater Development in Hilly Terrain: Case Studies in and around Kohima, Nagaland

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Abstract: Significant increase in developmental activities in the State are considered as a factor responsible for scarcity of water during lean periods in most of the townships in hilly areas. With a view to ease partially the water scarcity during lean period, the State DGM has formulated strategies to harness groundwater resources in problematic rugged hilly terrains of the State which constituted almost 95% of total area. Kohima, the Capital township of Nagaland, is a fast growing urban centre broadly located on linear ridge covering an area of about 20 sq. km and has a total population of about 95,000. Highest elevation in the vicinity is 2364 m above msl and the area receives heavy rainfall during monsoon. The township is established within semi-consolidated formations comprising shale, claystone, siltstone and fine-medium sandstone belonging to Disang and Barail Group of rocks ranging in age from Upper-Cretaceous to Recent. These geological formations had undergone various phases of deformations and tectonic processes resulting to development of secondary geo-structures, which facilitates groundwater development.

Exploratory drilling of four successful shallow tube wells within 120 m depth in and around the township provided subsurface geo-hydrological data with ample scopes for judicious development of groundwater resources in hilly terrain. Static water level varies from 5 m to 39 m bgl with discharges ranging from 6000 to 9000 lt/hr for a drawdown within 7 m. Construction of dug/ring wells has proved to be feasible at a specific geo-structural set-up.

Generation of integrated data information system of groundwater, efficient management along with artificially recharging groundwater from rain water during monsoon period will achieve sustainable and eco-friendly development of groundwater resources in hilly state of Nagaland. Lack of geophysical inputs, high contents of iron, inaccessibility and caving at weak geologic zones are some of the constraints for development of ground water in the state.

INTRODUCTION

The State of Nagaland, occupying the easternmost part of the country, comprises hilly terrain which constitutes almost 95% of the total area of the State. The remaining part comprises fringing alluvial plains as well as inter-mountain valley areas. Geologically, the State is covered by rocks ranging in age from Upper-Cretaceous to Recent. Secondary porosity like fissured media, cleavages and weathered/

sheared zones in consolidated and semi-consolidated formations are identified as potential geo-structures for harnessing ground water in hilly terrain.

In view of complex geology and various constraints, groundwater development in the problematic hilly areas of the state remained unexplored till recently. Sustainable development of ground water in hilly urban areas of the State is becoming inevitable, as the demand for water in various sectors is increasing manifold due to significant increase in developmental activities and fast population growth in urban areas coupled with drying up of surface water sources.

CASE STUDIES OF KOHIMA TOWN

Kohima, the State Capital of Nagaland, is broadly located in the southern part of the state and lies between Latitudes 25° 37′30″ and 25° 42′32″N and Longitudes 94° 04′40″ and 94° 07′43″E covering an area of about 20 sq. km with total population of 95,000 (2001 census). The maximum and minimum temperature varies between 28.0°C to 5.2°C.

The town is established all along the linear ridge trending NNW-SSE, with highest elevation of 1528 metres above msl (within town area) with moderate slopes on either sides of the ridge having gentle depression at places. Highest elevations in the vicinity are Polubadze 2364 m and Japfu peak of 3015 m above msl with general elevation increasing towards south. The area receives heavy rainfall ranging from 1500 mm to 2200 mm during monsoon with consequential heavy discharge through perennial rivers, rivulets and other seasonal drainage systems resulting in scarcity of water during lean period.

The main drainage systems controlling the hydro-geological conditions in and around town area are Dzutre Ru (a tributary of Duzuza N) and Dzuna Ru on the western side and on the eastern side of the town, whereas Sanu Ru and Rhe Ru are the main drainages system on the northern side. The tributaries of these drainages developed the radial type of drainage pattern. The streams and drainages are deep and narrow which are controlled by joints and fractures associated with lineaments.

HYDROGEOLOGY

Hydrogeologically, Kohima Town area is predominantly occupied by consolidated to semi-consolidated rocks of Disang and Barail Series (Tertiary Period) comprising shale, siltstone, mudstone and fine to medium sandstone. These rock formations being a part of Kohima Synclinorium had undergone various phases of deformations and tectonic processes, forming complex geological structures with innumerable joints, fractures and fissures through which groundwater development is facilitated.

Disang Rocks

Major portion of Kohima town is occupied by argillaceous Disang group of rocks consisting of shales, claystone/siltstone, mudstone and sandstone. At places shale becomes highly carbonaceous forming black/carbshale. Geohydrologically, Disang rocks exposed in and around Kohima town may be further sub-divided into the following units.

Splintery Shales

The typical dark grey and splintery shale is exposed in many places of the town area, sometimes intercalated with thin bands of siltstone and sandstone. Spheriodal weathering with concretionary nodules and crinkle surface is a common feature of this shale. At places, specially at weak/sheared zones, this shale becomes pulverized into blackish shale and swells in contact with water, susceptible to slide and mudflow associated with blocks/boulders of hard shale/siltstone/sandstone etc. Well developed joints and fractures, fine to medium grained sandstone bands occur as intercalation with this shale. Thin bands of sandstones intercalated with shale becomes more ferruginous, through which iron oxides are leached out, particularly sandstone bands which are associated with pulverized shale.

This shale, intercalated with fine to medium sandstone bands, is found to be potential for harnessing ground water in hilly area as evident from the four shallow tube wells constructed to a depth of 60 to 120 m bgl within this shale. Khaki/buff colour shales are mostly found at the nose of ridges, showing distinct bedding planes and are characterized by presence of numerous joints and fractures, broad warps and are quite susceptible to breakage into rectangular shapes. Greenish colour phyllitic shale with fully developed schistosity occurs at lower contours as sheets and flaggy form. This zone is found to be feasible for construction of dug/ring well to tap ground water for domestic purpose.

Siltstone/Claystone

Siltstone bands in varying thickness, greyish in colour, intercalations with thin bands of fine and hard sandstone and phyllitic shales are mostly exposed in nalla sections. The dark grey shale, wherever present in between the siltstone bands, often appears as claystone bands. The siltstone are very hard and massive, usually forms small water falls wherever it occurs across the nalla/streams. Since this siltstone has less porosity and poor development of fissured media, it is found to be not feasible for development of ground water.

Barail Rocks

Barail group of rocks occurs overlying the Disang predominantly araneceous and consists of well bedded sandstone intercalated with sandy shale. Sandstone are usually fine to medium grained, fairly cemented, hard and compact and are well jointed and fractured some of which are deep seated through which ground water is discharged as perennial springs. Barail group of rocks is present at the top of synformal ridges on the southern part of the town dipping towards the hill. No exploratory drilling has been carried out in these areas. However, a few dug/ring wells constructed revealed high potential for groundwater development.

High Level River Terrace Deposit and Soil Cover

Elongated outcrops of high level river terraces occur along NH-39, 300 m south of police check gate while entering Kohima town from Dimapur and about 15 km towards Imphal from Kohima. They occur at the higher contour elevation above 1300 m msl. Various sizes of pebbles and boulders of Disang and Barail rocks are cemented by clay with shale matrix and fragments.

Top soil cover at different contours of neighbouring town areas are being developed as terrace cultivation by constructing micro/check dams to divert flow of spring/stream water along contour channel through gravity towards lower level terrace.

GROUND WATER CONDITION

Groundwater development in hilly area of the state has not been able to achieve a desired level due to various constraints except exploratory drilling in and around Kohima town and a few dug wells constructed for domestic purposes. The typical sandstone present in the area are fine, highly cemented, hard and compact along with steep slopes which further facilitates easy and fast draining out of surface water as run-off during rainy season. However, the rocks are fairly jointed and fractured through which ground water is recharged through infiltration and percolation. Barail rocks at the higher elevation act as "Re-charging as well as discharging Zone" whereas the Disang terrain at the lower contour act as "Discharging zone". Ground water is manifested in the form of springs wherever water table is intersected by the surface/slope. The discharge of springs in Barail is found to be higher (ranging from 200 to 500 lts/hr) than in Disang (varying from 150 lts to 300 lts/hr).

Springs are of gravitational type and are mostly found concentrated on the scrape slopes of landslide and hill slopes close to the lithological contacts, fractures and weak zones. Thus the spring are associated with two sets of fractures/joints as well as sheared/weak zones. In many localities people have constructed reservoir to collect water discharging from these fractures/joints. Water level recorded from dug/ring wells in and around Kohima town varies from 3 to 5 m whereas water level recorded from the four tube wells constructed by the Department varies from 4 to 26.80 m bgl.

Ground Water Structures

Dug/Ring Well

Dug/ring well is one of the most economic and convenient structure for withdrawing ground water for domestic purposes in hilly areas. In view of scarcity of water, in recent times, a number of dug wells are being constructed by an individual or in colonies. The depth of these wells ranges from 8 to 15 metres with about 1 m dia which are lined with concrete/cemented rings all along the depth. In the lean period, 1000 to 3000 ltrs of water is withdrawn daily from these wells. It has been observed that construction of shallow dug well is feasible mostly in paleo landslide zones, splintery shale and at the contacts between Disang and Barail litho-facies.

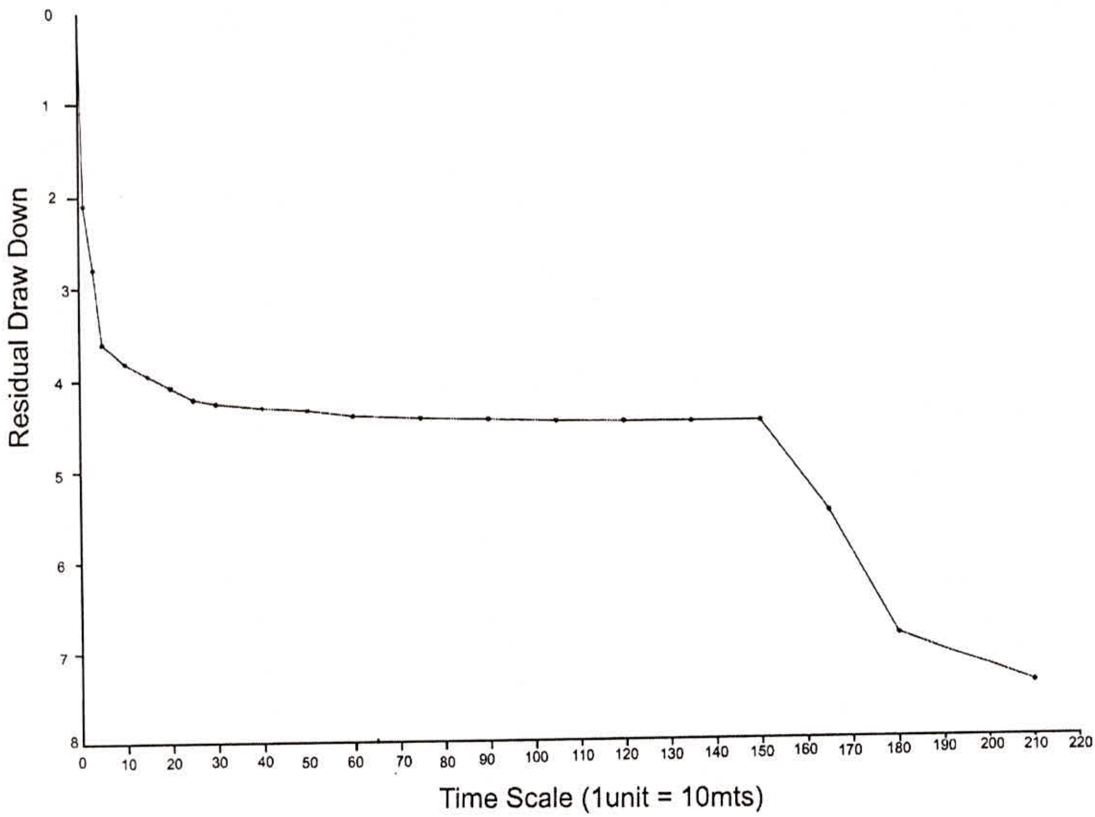
Tube Well

Like in valley/plain areas, construction of tube well for harnessing of ground water is quite promising in hilly areas too. The exploratory drilling and successful development of tube wells in and around Capital township of Kohima has provided information about subsurface geohydrological data, which may help in judicious development of groundwater resources in hilly terrain to cater water supply during lean period.

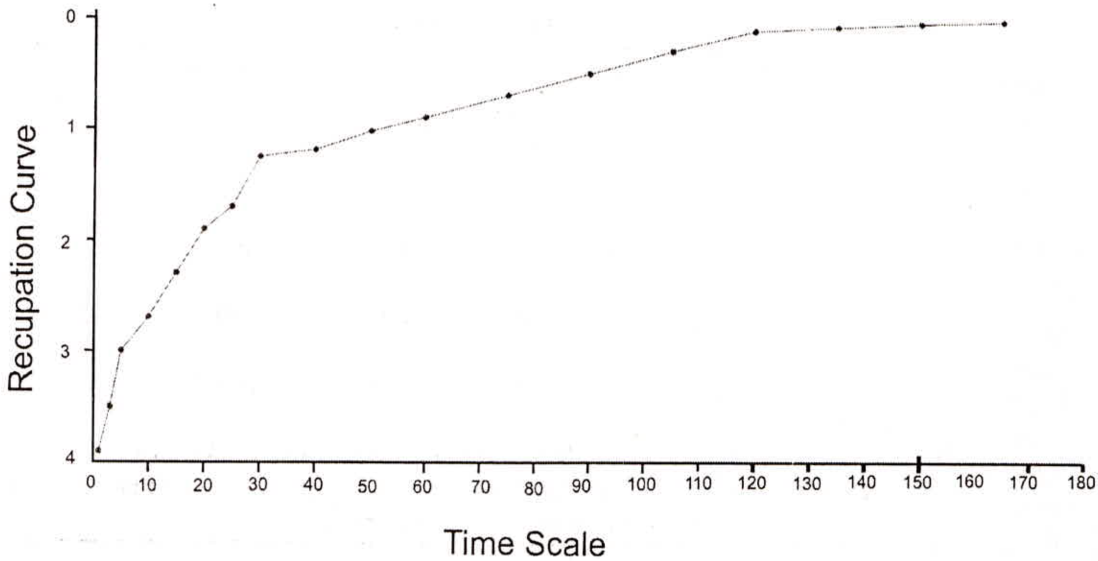
The tube wells were drilled and developed within dark grey colour splintery shale to a depth ranging from 60 to 120 m bgl having discharge of 6000 to 9000 lts per hour with minimum drawdown of 5.98 m. Subsurface geo-hydrological data generated from these wells have further led to delineation of prospective secondary porosity in hilly Disang terrain for development of ground water. Step drawdown test (Graph 1) and recuperation test (Graph 2) was conducted on one of the locations. Geohydrological parameters generated from these five wells are shown in Table 1.

Table 1. Geohydrological parameters generated from five wells

Sl No.	*Locations*	*RL*	*Depth (m)*	*Static water level (m)*	*Drawdown (m)*	*Discharge lt/hr*	*T values m^2/d*
1.	Raj Bhavan Complex	1510	58.37	39.80	5.98	7000	
2.	Indira Gandhi Stadium	1439	62.00	26.46	6.88	7500	
3.	Planning & Co-ordination Residential Complex	1306	59.50	27.30	7.40	9000	10.987
4.	Nagaland Assembly Secretariat Complex	1310	120.00	4.30	28.50	6000	
5.	Administrative Training Institute	1410	113.00	Pilot hole was drilled within siltstone/ claystone with thin bands of dark grey shale but abandoned due to poor development of fissured media.			



Graph 1. Step draw down of well at residential complex of Planning and Co-ordination Department, Kohima.



Graph 2. Recuperation curve of well at residential complex of Planning and Co-ordination Department, Kohima.

Quality of Ground Water

Detailed studies on groundwater quality have not been carried out so far to determine its quality for various uses. However, iron content in ground water in most of the areas is seen to be high which should be properly treated before it is used. Water sample collected from Kohima village (KV_2) analysed at RRL, Jorhat shows slightly high contents of $CaCO_3$, Mg, and total solids which will be required to be treated so as to bring down within permissible limit before it is used. Analytical result of the said sample is given in Table 2.

Table 2. Analytical result of water sample

	KV_2TW	*IS:1050, 1983*
1. pH	7.51	6.5 to 8.5
2. Turbidity (NTU)	1.00	10 NTU (max)
3. Total Hardness as $CaCO_3$	270.00	300 mg/lt (max)
4. Calcium as $CaCO_3$	172.00	75 mg/lt (max)
5. Magnesium as Mg	97.00	30 mg/lt (max)
6. Iron as Fe	0.36	0.12 mg/lt (max)
7. Sulphate as SO_4	4.83	250 mg/lt (max)
8. Chloride as Cl	24.80	150 mg/lt (max)
9. Phenolphthalein Alkalinity	ND	—
10. Methyl Orange Alkalinity	280.00	—
11. Residual Chlorine	ND	0.2 mg/lt (max)
12. Total Solids	6746.00*	500 mg/lt (max)
13. Fluoride as F	ND	0.6 to 1.2

Various Constraints

Lack of geophysical data, which is the primary requisite for groundwater development, high iron content in ground water, inaccessibility for transportation of machinery and equipments to desirable locations as well as frequent caving while drilling are some of the inherent problems for groundwater development in hilly areas.

CONCLUSION

1. There is an imperative need for generation of an integrated groundwater information system to assess precisely its availability in hilly terrains. Development of groundwater resources will supplement the availability of water resources in various sectors, specially during lean period.
2. Exploratory drilling and development of shallow tube wells proved the presence of potential secondary porosity within 50 to 200 m depth bgl in hilly areas.
3. For efficiency and longevity of well, properly designed well assembly should be lowered throughout the entire length of the well.
4. Potability of ground water must be confirmed through analytical studies before it is used.
5. Creating public awareness for groundwater management and development based on scientific information with appropriate technologies as well as to manage conjunctively with surface water resources will ensure indiscriminate development of ground water.

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