Ground Water Management in Metro Rail Project

Vikas Garg[1], Vijay Raj[2]

[1]Professor, [2]Adjunct Professor,
Civil Engineering Department,
University of Petroleum and Energy Studies, Dehradun, India

Abstract

India is the dependent on groundwater for its societal needs. It uses an estimated 230 cubic kilometers of groundwater per year . About 90% of irrigated agriculture and 85% of drinking water supplies are dependent on groundwater. Urban residents increasingly rely on groundwater due to unreliable and inadequate municipal water supplies. Underground constructions including construction of metro tunnels are considered susceptible to depletion of this precious resource. Already, the ground water development has reached alarming levels of over 100% in states like Harayana, Punjab and Delhi. It is therefore imperative to adopt groundwater management practices, when underground construction projects like metro tunnels are being constructed through aquifers. This paper discusses the impact of such constructions on groundwater and suggests remedies adopted to address such situations.

Keywords: *Ground water, Metro tunneling, Tunneling*

1. Introduction

Ground water is very important for the survival of human society as it fulfills the demand of drinking water, agricultural and the industrial sector in both urban and rural India. Unfortunately, Groundwater level storage on earth exists less than 0.3% of total water available on earth. Due to development of construction projects, tunneling work for metro, ground water is extracted day by day which is creating stress on availability of ground water.

In this paper, optimum utilization of extraction of ground water is due to construction projects. A metro railway is considered to be life line for development of any nation. Metro rail system to be designed to provide fast transfer of public from one place to another place. Metro rail also helps to integrate the nation and create a feeling of good bonding among the people. The metro rail project should be so well designed such that it enhances value to community and can contribute to the well-being, health and productivity of society. A good design for the metro tunnel should create an economically, socially and environmentally sustainable transport system that caters to the control of depletion of ground water. It is therefore necessary to develop suitable groundwater management techniques for conservation of ground water while executing such projects.

2. Scenario of ground water in India

In India, 89% of ground water extracted is used in the irrigation sector, making it the highest category user in the country, as agricultural sector contributes to approximately 17% of GDP of India and 70 – 80% of value of production from irrigated lands depends on ground water. This is followed by ground water for domestic use which is 9% of the extracted groundwater. Industrial use of ground water is 2%. 50% of urban water requirements and 85% of rural domestic water requirements are also fulfilled by ground water. Out of the 1,123 BCM/year, the share of surface water and ground water is 690 BCM/year and 433 BCM/year respectively. Due to the increasing population in the country, the national per capita annual availability of water has reduced from 1,816 cubic metre in 2001 to 1,544 cubic metre in 2011.2 This is a reduction of 15% of total storage of water in last 10 years.

Ground water development is a ratio of the annual ground water extraction to the net annual ground water availability. The average stage of groundwater development in the country, as estimated in 1991, was 32 percent. In 2003, the average stage of development had reached approximately 42 percent but in the states of Haryana, Punjab and Rajasthan, the stage of groundwater development was observed to be more than 85 percent

Today the level of ground water development is very high

Statistics regarding water resources in India		
Sn.	Parameter	Unit(Billion meter/yr)
1	Annual Water Availability	1869
2	Usable Water	1123
3	Surface Water	690
4	Ground Water	433

in the states of Delhi, Haryana, Punjab and Rajasthan, where ground water development is more than 100%. This implies that in these states, the annual ground water consumption is more than annual ground water recharge. With this in view a master plan has been presented for artificial recharge of ground water in India by Central Ground Water Board, New Delhi. However, for the success of such programs the involvement of community is very essential as they are the directly affected stakeholders. In this connection the lead taken for water management in Chennai is commendable.

2.1 Description of the problem

The problem of management of ground water in metro rail projects is now described with reference metro projects carried out in India. A number of metro rail projects are being constructed throughout India as well as in various cities of the world. In urban areas there is a limitation of space available on ground therefore large part of metro rail system has to be constructed to underground under space constraints. Many times these may have to be constructed with limited space between and close to existing buildings also.

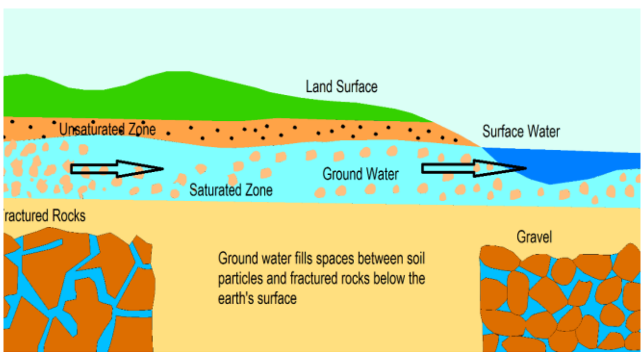

Figure 1a: Undisturbed aquifer

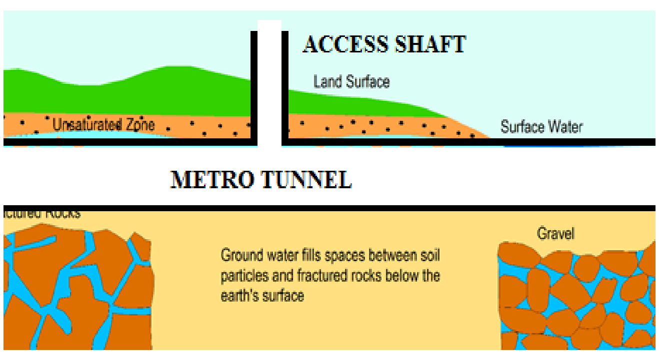

Figure 1b: Underground tunnel causing disturbance to aquifer

During tunneling, lots of water to be extracted from aquifer and it was happened in the past for all the metro projects. Due to extraction of this water, lots of water will be wasted which would affect irrigation as well as domestic supply of water. When ground water will be extracted then existing pore may decrease. This reduced may cause settlement of building foundations and failures of piles etc. During underground construction the water table is completely disturbed leading to large scale depletion of ground water and lowering of ground water table. As shown in figure 1(a&b), tunnel may pass though aquifer water bodies that may cause significant depletion of ground water.

3. Effect of ground water Depletion due to metro projects

The depletion of ground water due to metro tunneling projects can result several serious consequences. The depletion of underground water causes a deformation of the soils and rocks around the excavation area. Such deformations can lead to sudden failures, subsidence and sinking that can damage both the tunnel as well as existing nearby structures on ground surface. The opening of underground works causes a deformation of the soils and rocks around the excavation area. Such deformations may trigger sudden collapses, subsidence and sinking that can damage both the work under construction and pre-existing nearby structures, in particular, if the work is being constructed in developed areas. The sudden collapse with cavity filling (Fig. 2) usually happens in case of limited overburden that can reach, in some particular cases, up to ten times the cavity diameter. The consequences of ground water depletion and the resulted damage cause depends on the impact of groundwater withdrawal and vulnerability of nearby structures on the surface like buildings foundations, industrial structure settlements, underground and surface storage structures etc.

3.2

Figure 2: Examples of surface settlements induced due to tunneling: a Crater of Saint-Laurent Place (Metro Lausanne-Ouchy; Seidenfuß 2006).

4. Possible solution for ground water management

During metro projects huge amount of ground water is to be extracted from aquifer during tunneling. This water could be utilized for fulfilling the domestic, irrigation and industrial requirement. For construction of metro tunnels a number of shafts have to be lowered into the ground for various purposes such as for various special structures and for tunnel boring machine (TBM) access. It is necessary ground water should not ingress into the shafts. The geology of the area plays an important role in controlling the ingress of ground water into the shaft. If there is any impermeable layer is present below the ground water table the ground water that lies above the impermeable layer can be left undisturbed as such. But in case the whole area is filled with aquifer then proper system for extracting the ground water and recharging back in the area surrounding the shaft should be developed (Refer case study I & II). For controlling the flow of ground water proper arrangement are to be made which are as follows.

The area around shaft is to be fenced for isolation & proper traffic control. Several wells will be set up in the vicinity of the shaft for pumping and observation. These wells will be used for extracting the water and monitoring of water level.

4.1 Set up and Installation of observation wells

Several observation wells will be required for continuous monitoring of ground water levels both during construction phase and service phase**.** If existing wells are to be used as observation wells, their construction details and locations must be reviewed. If new wells are to be installed for the purpose of the test, several factors must be considered, including the number of wells, and locations.

Depth of the observation well(s) should be determined by geology: The intake portion of the well must be open to the same aquifer as is the pumping well. However, the intake need not fully penetrate the aquifer, assuming ideal conditions are met (horizontal, laminar flow). If conditions are not ideal, the observation wells should be open to the same portion of the aquifer as is the pumping well.

4.2 Number of observation wells

To monitor ground water level both during construction and service phase a number of observation wells are required. For proper monitoring of ground water level the observation well should preferably reach the stratum located upto the crown of the tunnel.

A number of wells should be used if soil conditions are laterally heterogeneous and an assessment of the degree of heterogeneity is required. In this case, the wells ideally should be situated such that they are the same distance from the pumping well, but in positions where they will reveal the different conductivities as shown in Figure 3(a & b).

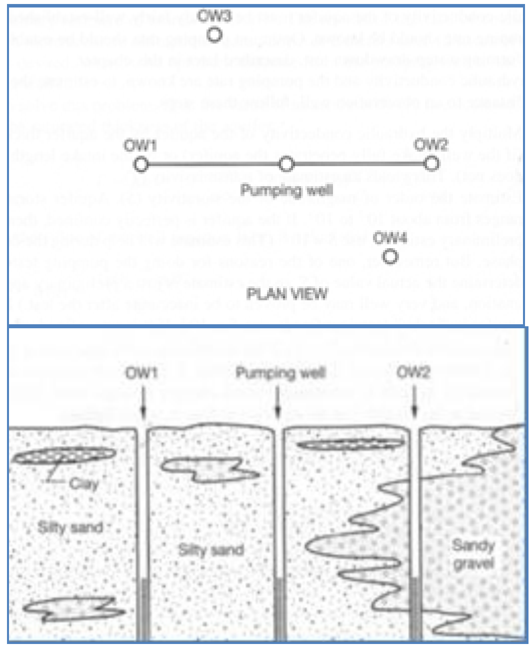

Figure 3(a&b): Number and position of observation wells in plan and elevation.

4.3 Plugging of well

After the shaft has been sealed the pumping and observation wells have to be plugged. After complete checking of shaft the pumping /observation wells can be plugged. All the obstructions from the well should be removed and then casing should be taken out. After this the plugging of the wells should be done as per the procedure described.

Initial well-plugging steps include accurate measurement of the well dimensions of the well which should be recorded and also enquiry will be done for well condition and removal of all obstructions. The wells having diameter more than 200mm will be plugged with material of 1:10 ratio (Cement & Soil/Stone dust) with adequate water cement ratio to maintain workability.

For the wells whose diameter is less than 200mm will be plugged with material of 1:7 ratio (Cement & Soil/Stone dust). If required as per the site conditions bentonite will be used in the mix. Where ever the diameter of the well is more than 200mm in the 150mm size tremie pipe will be inserted and filled with plugging material upto the top of the well as shown in figure 4.

.

ISSN (Online): 2230-7893
www.IJCEM.org

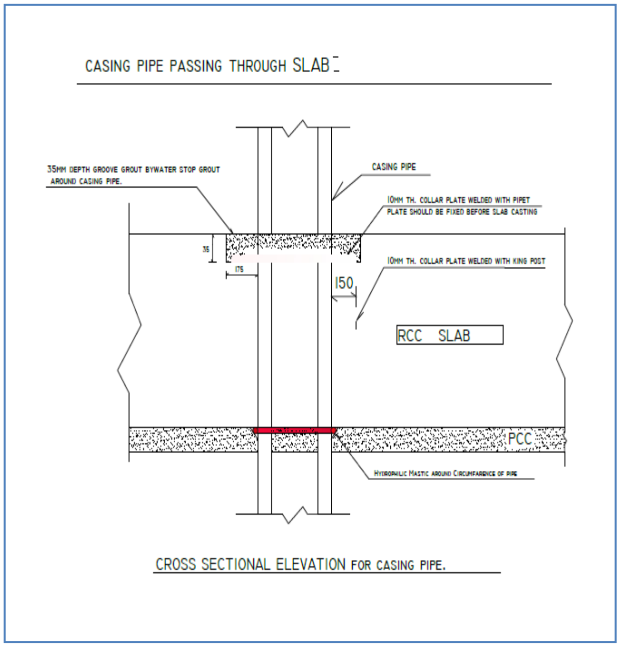

Figure 4: Plugging of observation well

5. Discussion

There is no doubt that disturbance is caused to underground water reserves, as a result of under ground construction activities including construction of metro tunnels. The seriousness of the problem is presented through Case study I in which the alarming condition of ground water reserves has been depicted for the city of Delhi, the capital of India.

The above case study shows that there is need for a prudent management of such construction activities with a view to conserve the scarce ground water resource. There can be several solutions to this issue. One such solution has been presented in Case study II where an intelligent ground water management system developed for the construction of underground tunnel for metro rail project in Copenhagen has been discussed.

5.1 Case Study I - Groundwater scenario during Metro Construction in Delhi

Groundwater level in present conditions have been reached upto 64 m depth in certain areas of Delhi with an average rate of depletion of about 1.44 m per year because of increased extraction.

According to studies carried out by ground water central board in 2012, the availability of ground water level was varying from about 2 m to 20 m in various parts of Delhi as shown in figure 5. (Ground water information booklet of new Delhi district).

When the ground water level crosses 10 metres, sophisticated equipment is required to extract it. In India underground tunnel was made in Delhi for metro project. It is suspected that the rapid fall in ground water level, may be due to various underground construction activities and possibly due to construction of metro tunnels.

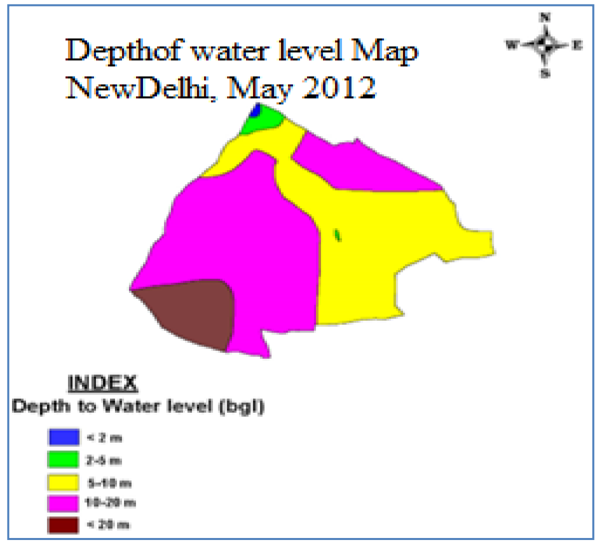

Figure 5: Ground water level in Delhi in 2012

Due to excessive withdrawal of ground water either during tunneling or other reasons, there is a huge loss of ground water storage that could be utilized for potable water. For example the rate of decline of groundwater in Delhi is as high as 1.7 to 2 meters/year in some areas which leads to an overall deficits of about 112 MGD of drinking water. This deficit in drinking water supply of Delhi can be partially augmented through exploitation of groundwater resources. Therefore there is need of hour to conserve ground water to the maximum extent.

In order to avoid similar situations in other underground metro projects, it is necessary to carry out proper water management procedures to recharge groundwater as done for metro Construction in Copenhagen.(Refer case study II)

5.2 Case Study II - Groundwater Management for Metro Construction in Copenhagen

In the new Copenhagen Metro line “Cityringen”, driverless Metro trains will transport up to 240.000 passengers per day through a twin-bore tunnel system (Figure 6). This applies both for the tunnel tubes running at a depth of 25 m below the surface and for a total of 21 required shafts, which reach down as far as 40 m into the Copenhagen limestone. These shafts, averaging 65 x 20 m in size, are required for the underground stations as well as for various special

Inside the shafts, it is necessary to lower the groundwater level –in order to allow shaft sinking and to relieve the shaft floor. As there is no impermeable layer, this entails a drop in the groundwater table in the areas surrounding the shafts. This, however, is prohibited in Copenhagen for specific reasons: its inner city is built on old wooden piles which must on no account be allowed to dry out.

5.2.1 Re-infiltration with treated groundwater

Hölscher Wasserbau from Haren (Ems) in Germany has developed a custom-built groundwater management concept for this ambitious infrastructural project. For the construction of the new Metro line, the experts have developed a system which ensures an unaffected groundwater level outside the shafts by infiltrating treated groundwater back into the aquifer (Figure 7). All in all, the system developed and implemented by Hölscher consists of approximately 500 extraction and recharge wells, around 300 groundwater monitoring wells with radio data loggers, 21 water treatment plants, approximately 25 km of pipeline and a fully automatic SCADA system (supervisory control and data acquisition). The company managed to deal cost-effectively with the geological conditions, which were technically challenging with respect to drilling, by using the DTH (down-the-hole) method.

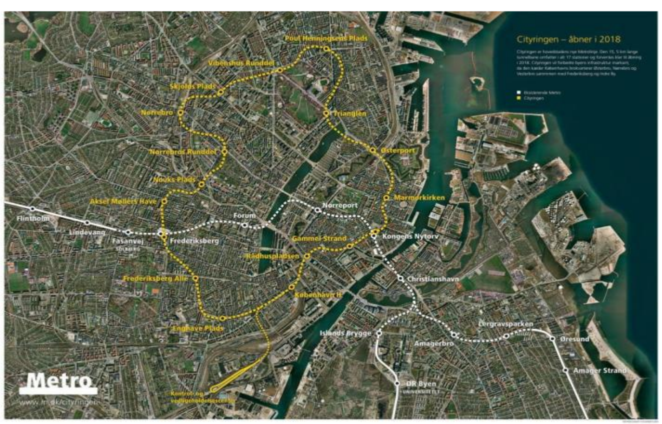

Figure 6: Copenhagen's new Metro line "Cityringen" (yellow line) increases the current network (white line) by approximately two-thirds.

Specifically developed water treatment plants make it possible to infiltrate the extracted and treated groundwater back into the ground. In so doing, large amounts of expensive drinking water can be saved: during the construction phase, a total of around 20 million m3 of groundwater are treated in the water treatment plants and subsequently recharged.

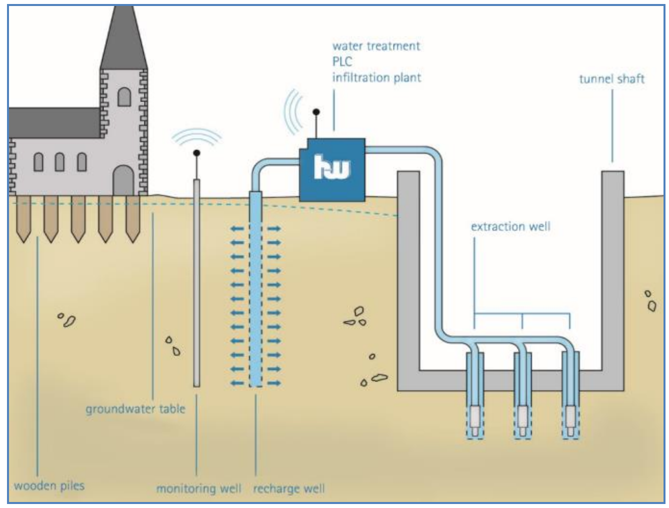

Figure 7: Schematic diagram of Hölscher's groundwater management concept.

6. Concluding Remarks

Metro construction projects are the need of the hour and underground tunnels are often required to be constructed. On the other hand there is a serious situation as far as consumption and replenishment of ground water is concerned. Already India is facing stresses as far as water use is concerned. Therefore the importance of groundwater availability in country's socio-economic development and to meet the environment concerns has to be considered in due prospective.

As urban areas are hotspots of groundwater development activities, it should be the endeavor of project planners to include the recharge activities also. These projects should therefore be constructed judiciously taking care of the conservation of ground water. The ground water management as practiced in Copenhagen is an excellent example. As a number of underground metro tunneling projects are coming up in various cities such practices should be incorporated in these projects in the planning stage itself.

References:

[1] M. Mehta, "Status of Groundwater and Policy Issues for its Sustainable Development in India", Proceedings of IWMI- ITP-NIH International Workshop on Creating Synergy between Groundwater Research and Management in South and Southeast Asia, February, 2005.

[2] Saleem Romani, "National Blueprint for Recharging Groundwater Resources of India", Proceedings of IWMI- ITP-NIH International Workshop on Creating Synergy between Groundwater Research and Management in South and Southeast Asia, February, 2005.

[3] M.E. Varuaa, "Groundwater management and gender inequalities: The case of two watersheds in rural India, "Journal of Groundwater for Sustainable Development, Elsevier, Volume 6, March 2018, Pages 93–100.

[4] S S Nair, "The Chennai Experience" Making Water Everybody's Business, Centre for Science and Environment, Pp193

[5]http://hwdewatering.com/cms/media/kunde_hoelscher/upload/201504/2897_2015_04_20_PM_Metro_Kopenhagen_Englisch.pdf

[6]http://www.prsindia.org/administrator/uploads/general/1455682937~~Overview%20of%20Ground%20Water%20in%20India.pdf

[7]https://www.scribd.com/document/264817934/Ch5-v1-Groundwater