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Rainwater Harvesting in the Heritage Buildings: A Case Study of Victoria Memorial Hall, Kolkata

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ABSTRACT

Owing to environmental hazards caused by over pumping of groundwater inside Victoria Memorial Hall (VMH) campus led the VMH authority to seal all the tube wells and Kolkata Municipal Corporation (KMC) was directed to supply the required quantity of water to VMH. On the issue of water level decline (5- 15 cm/yr) in KMC area including that of the VMH campus, Central Ground Water Board (CGWB) has carried out a detailed study in the campus and advocated artificial recharge of groundwater at VMH. As a possible recharge source, the surplus water from the lakes was considered. Presence of deleterious compound and coliform bacteria hindered the option of artificial recharge from lake water. Hence, rainwater harvesting has found out the alternative option to solve the water problem. Rainwater harvesting in VMH through a specially designed structures was ruled out in view of handicapping stability and the aesthetic beauty of the monument site. The problem was addressed through the studies include assessment of optimal rainwater harvesting tapping the surplus rainfall runoff. The study also revealed the presence of unique inbuilt rainwater harvesting arrangement in VMH. The recommended design would help to store 8 lakh litres rainwater in the harvesting tank of water, which is equivalent to the volume of water that KMC supplies to VMH every day.

KEYWORDS : Victoria Memorial Hall (VMH), Central Ground Water Board (CGWB), Rainwater harvesting, Artificial recharge, Surplus rainfall runoff.

Introduction

Victoria Memorial Hall (VMH), the landmark of Kolkata city, is situated (22°32′41″N latitude and 88°20′32″E longitude) in the west central part of (Fig-2) Kolkata Municipal Corporation (KMC) limits and in the south of Fort William in West Bengal State. The monument is made of white Makrana marble and its dimensions are 103m x 69m and it rises to a height of 60.9 m. The hall is surrounded by picturesque blooming gardens and lakes occupying an area of 64 acres (26 ha).

The current study unravels, presence of inbuilt splendid rainwater harvesting arrangement and distribution of rainwater, collected through rooftop and landscape, provision for maintenance of level in the water bodies for structural balance is also designed by the British architect.

Its foundation stone was laid in the year 1906 and was inaugurated in 1921.The monument was intended to serve as a tribute to the success of the British Empire in India. Sir William Emerson had prepared the actual plan of the memorial, while its construction was done by Messrs. Martin & Company of Calcutta under the supervision of the Superintending Architect Mr. Vincent J. Esch. The design comprises an amazing fusion of British and Mughal architecture. The monument is made of white Makrana marble and its dimensions are 103m x 69m and it rises to a height of 60.9 m up to the figure of Victory (i.e., the angel).

Based on initial studies, it was suggested that artificial recharge to ground water through rain water harvesting may be taken up in the VMH campus. Subsequent study revealed the presence of oil and grease and also coliform bacteria in the rain water coming from surrounding catchment area into the tank situated inside VMH campus. On these observations, the injection of such polluted water to the ground water was negated. A detailed studies carried out in the line of rain water conservation through the existing set up to solve the water demand of VMH campus. Rain water harvesting for conservation instead of artificial recharge to the ground water was considered as the best possible option..

Hydrogeology of VMH campus and environs

The area incorporating VMH inside Kolkata Municipal Corporation forms a part of Lower Ganga Basin (Fig-2) and represents a flat topography with ground elevation varying from 4 to 5 meters above mean sea level (m amsl). It is underlain by Quaternary alluvium, deposited by southerly flowing Bhagirathi River and its tributaries. The alluvial deposits (Fig-3) principally comprise clay and silts and various grades of sands with occasional gravel beds (Fig-4). The top of the alluvium is in general covered by a thin bed of clay.

Ground water occurs under confined condition below a thick cover of clay blanket of 25 to 30 m thick clay bed. A detailed study by CGWB (Kar, 2013) revealed that the depth to piezometric surface level of water in KMC area is significantly deep and ranges between 13.58 m bgl to 19.38 m bgl in pre-monsoon and 12.66 m bgl to 17.72 m bgl in post monsoon time (Fig–5 & 6). The CGWB study also revealed that the long term trend of water level in and around VMH registers an average fall of 5- 15 cm /yr(Fig-9). The deeper water level and the long term falling trend are the cumulative effects of continuous huge ground water withdrawal for the domestic and industrial uses. Recently at places in KMC area presence of arsenic over permissible limit is reported, which is correlated with the massive decline due to over pumping.

As ground water occurs under confined condition in KMC area, top thick clay bed does not allow direct ground water recharge to the deeper aquifers. The confined aquifer is recharged from the area located around 40-50 km north of Kolkata city. Hence, to replenish the unscientific withdrawal, as envisaged through steady decline of piezometric surface (Fig-7), artificial recharge of groundwater is necessitated through injection of rooftop harvested rainwater through tube wells in such tracts (Fig-8). However, quality of water being recharged is also an issue, which has to be meticulously considered in case of ground water recharge. Rapid urbanization which generates accelerated runoff requires optimum harvesting of rainwater both through rooftop as also by other means like conservation through ponds and landscape, which could be adopted in KMC as also in the entire Greater Kolkata metro city area.

June to October is the monsoon period characterized by heavy shower. Over 80% of the total annual rainfall occurs in this period. Normal annual rainfall of KMC area is 1647 mm. Normal monsoon rainfall is 1282 mm and normal non-monsoon rainfall is 365 mm. The rainfall available at Kolkata is fairly high, which can be used for rainwater harvesting as also for ground water recharge.

Procedure of the study

Immediately after a preliminary visit, detailed studies were undertaken to find out the following:

1. **The presence of inbuilt rainwater harvesting structures in the Victoria Memorial Hall as also their connection with the water bodies and the interconnection of the water bodies.**
2. **Mode of harvesting of rainfall in the landscape.**
3. **Total requirement of water supply inside the campus and its historical review.**
4. **Assessment of garden and pond area and estimation of optimum rainwater harvesting inside the campus.**
5. **Estimation of total surplus runoff spills over annually through storm drain and to recommend the needful structures to divert the surplus water for optimal harvesting to fulfill the water supply requirement as and when needed to satisfy the directive of Hon'ble high court.**

Discussion

This picturesque memorial is made of marble. The entire building was so designed by the British Architects that it is surrounded by number of concrete ponds which are hydraulically connected and possibly the foundation of the memorial structure is in hydrostatic balance with the water bodies encircling the monument. It is also a classic example of management of water inside the pond whose bulk volume comes through rainwater harvesting whose sources are the building structure and the landscape. During the study, the techniques of rainwater harvesting adopted inside the memorial has been examined. The study revealed that there are inbuilt network of rainwater drains from the memorial hall to the ponds (Fig-10 & Fig-11), in between the ponds (Fig-12) and landscape to the ponds (Fig-13). In the design the provision of spillway drain was also kept to pass the excess water from the pond to the adjacent Hooghly river.

Since its opening in 1921, the water level in ponds was maintained through the rainwater. However, subsequently especially after 1970 the arrival of tourist to the Memorial hall started increasing heavily, thus there was necessity for additional supply of water to the premises at a steady rate. The requirement of water in the VMH includes watering the garden, flushing the toilets, drinking water supply for the staffs and visitors and to replenish the water bodies in the campus to maintain an optimum level which in turn may be essential for the stability of the Memorial structure. The water supply in VMH used to be met from the 6 tube wells constructed in depth range of 80 to 130m inside the campus. The tube wells were discharging at a rate 10,000 litre per second (lps) for a period of 12-14 hrs/day. Subsequently, in July, 2003, with the detection of arsenic contamination in the ground water above permissible limit, Hon'ble court, recommended in its report in 2004, that the abstraction of ground water by the VMH authority should be totally stopped and the KMC should ensure and expedite the surface water supply in the VMH campus. At present, tube wells are not in use and the quantum of supply received from the KMC is about 7 lakh litres per day.

Garden and water spread area in the Ponds of Victoria Memorial Hall

The main memorial building is occupying an area of 7159.48 m^2 (77064 sq. ft.) and it is surrounded by the garden, pavement and water bodies (Fig-14). The garden and the paved area in the campus cover an area of 97926.81 $m^{2.}$ There are 6 ponds/lakes of different dimensions exist in the campus. The area of the ponds as per the record of VMH are given in the following table (Table-1).

Table-1 Ponds in VMH and their water area

Sl no	Location of the pond	Area in m^2
1	N. E. Region	18461.70
2	N.W. Region	18461.70
3	S. E. Region	4013.41
4	S. W. Region	4013.41
5	Circular pond on West	803.61
6	Circular pond on East	803.61

Water column in the concrete portion around the bank is 4 feet and in the non concrete portion in the central part is 8 feet. The ponds are interconnected. Water from one pond flows to the next connected pond until similar level is achieved in each pond. Maintenance of water level in the ponds is necessary for the stability of the main memorial building. The topographical survey in the campus indicates that the ground slope converges towards each pond. The ponds receive the surface runoff from the gardens and the pavements and from the main VMH building. However, presently these are regularly fed by the water supply of KMC to maintain the water level, while formerly water balance was regulated through ground water by pumping of the deep tube wells in the campus.

Estimation of Rainwater Harvesting in Victoria Memorial Hall

Study proposes to design water holding structures to conserve the excess runoff from the campus while there is outflow of surplus rainfall during July to December every year.

It was observed that the rainfall received on the main memorial building and on the peripheral area both in upper and lower tiers of the building passes directly or through the rain water pipes to the basement, then to the existing concrete drains surrounding the monument. Water from these drains ultimately flows to the lakes/ponds surrounding the campus.

Considering the average annual rainfall of about 1400 mm, the annual rainfall outpoured in the building is calculated as follows.

Q_1=A_1 X rainfall X Runoff coefficient = 8018 .62 m^3, Where, A_1= area of the building in m^2

Rainfall=1.4 m, Runoff coefficient=0.8

On the other hand, the rainfall runoff from garden and the paved area in the campus are also collected in the respective ponds through the rainwater inlets in the ponds. The volume of annual rainfall runoff collected from the garden is estimated as follows:

Q_2= A_2 X rainfall X Runoff coefficient = 27419.51 m^3, Where, A= area of the garden and the paved area in $m^{2,}$ Rainfall=1.4 m, Runoff coefficient=0.20

Besides that the direct annual rainfall received in the ponds directly is

Q_3 = A_3 X annual rainfall=65178 m^3, where A= Total surface area of the pond = 46556 m^2

Therefore, total annual rainfall collected to the ponds = Q_1+ Q_2+ Q_3= 100616.13 m^3

The ponds are also fed from the KMC water supply to maintain an optimum water level in the ponds throughout the year.

The outflow components from the ponds are the evaporation losses and the outflow of the excess water during monsoon seasons through the storm drain (Fig- 15) that occur in the south eastern part of the campus. The storm drain emerges from the eastern circular lake. The excess water from all the ponds ultimately drains out through the storm drain.

Harvesting of excess runoff from the Storm drain

The storms drain flowing (Fig-15) in north-south direction, discharges the excess runoff in the monsoon season. Studies in various season reveals that the drain is flowing for about 120-150 days in a year. The out flow in various seasons and average volume of water passes through the drain is estimated and enumerated below. It has been observed that the height of flow in the strom drain varies from 30-40 cm in July-August, 15-20 cm in September, 10-15 cm in October, 5-10 cm in November-December and no flow during January-May/June. From the available flow record, the average flow height has been determined and it is considered as 25cm. The average flow velocity was deduced as 0.31m/sec.

Area of the trapezohedral section of the storm drain with average height of 0.25 cm =0.375m^2

Hence, the total daily flow is estimated as = 0.31x0.375=0.11625m^3/Sec=10044m^3

While the total estimated annual flow=120x100044=12, 05,280 m^3

In the present exercise an attempt has been made to divert the excess runoff to the rainwater harvesting reservoir. Adequate measures for desiltation and filtration have been kept in the design. Various assumptions and principles are adopted during preparation of the design.

The study revealed that rainwater harvesting in the VMH campus is feasible through interception of surplus runoff which is passing through the storm drain located in the southern side of the campus flowing westward. For this purpose the following structures may be constructed (a) One check weir with spillway, intake and outlet arrangement of captured water (b) One RCC desiltation chamber (10mx4.5mx3m) with baffle wall (c) One RCC filtration chamber(10mx4.5mx3m) with four filtration units(4.5mx2.25mx2.6m) with inletoutlet drain and wire mesh cover (d) One RCC rainwater harvesting reservoir (20mx10m x4.5m) with outlet facility through 10 cm dia PVC drain.

Conclusion

Total estimated annual flow through trapezohedral section of the storm drain is 12, 05,280 m^3. As per calculation, the recommended design would help to store 8 lakh litres rainwater in the harvesting tank of water, which is equivalent to the volume of water that KMC supplies to VMH every day.

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Fig-1: Victoria Memorial Hall

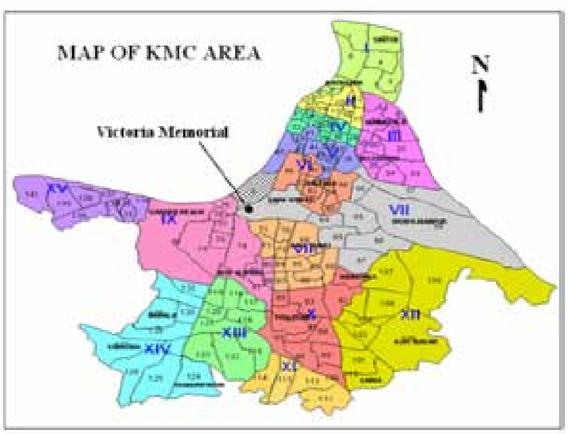


Fig-2: Location map of VMH

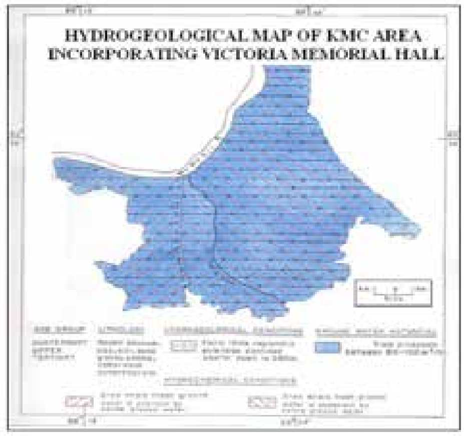


Fig-3

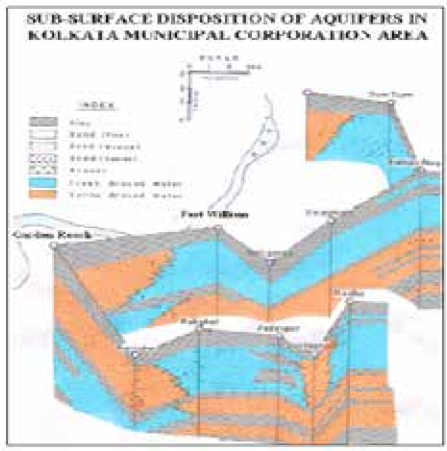
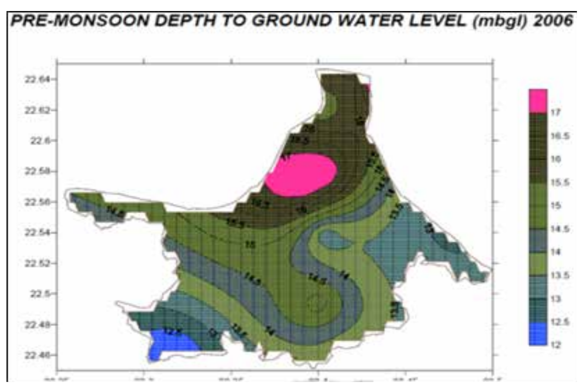


Fig-4



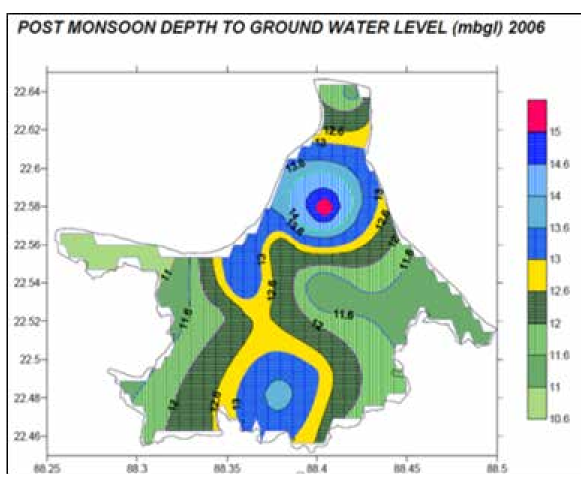


Fig-6

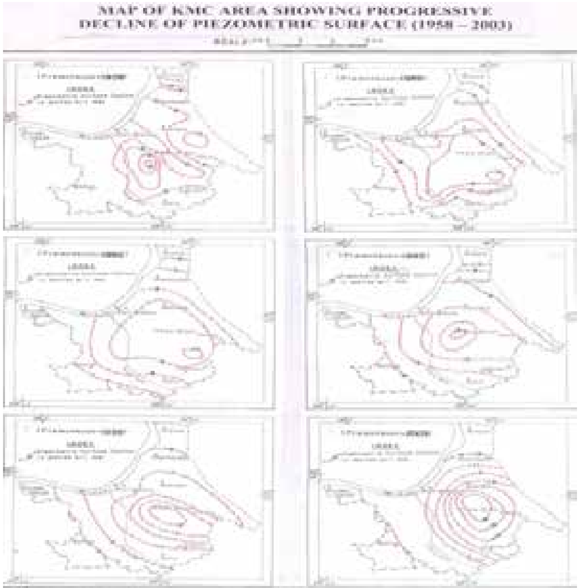


Fig-7

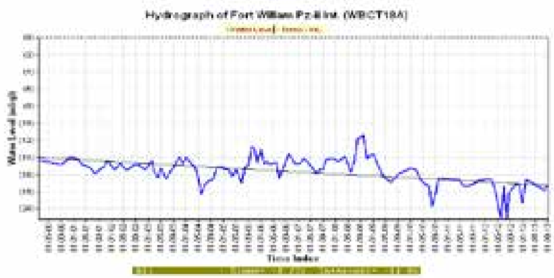


Fig-8

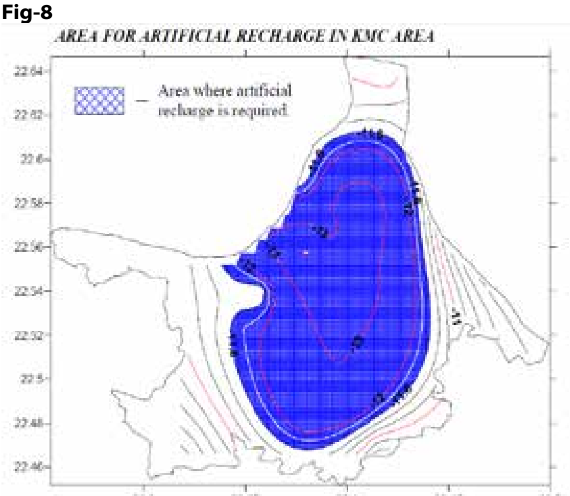


Fig- 9

Figure 3- 9: Hydrogeology of KMC area incorporating VMH. 3- Hydrogeological map, 4- Subsurface disposition of aquifers, 5-Premonsoon depth to water level map, 6- Pre-monsoon depth to water level map, 7- Steady long term decline in piezometric surface, 8- Long term trend of water level in Fort William area, 9- Areas feasible for artificial recharge

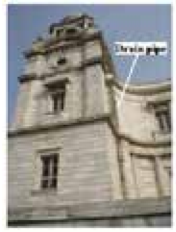


Fig-10: Drain pipe

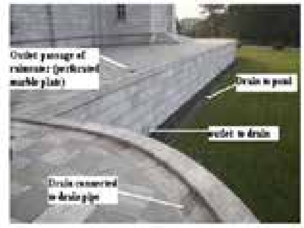


Fig- 11: Interconnection of drain to Ponds

Fig-12: Interconnected pond with inlet/outlet Drain
Fig-13: Inlet connection to convey Land scape Drain rain into the pond

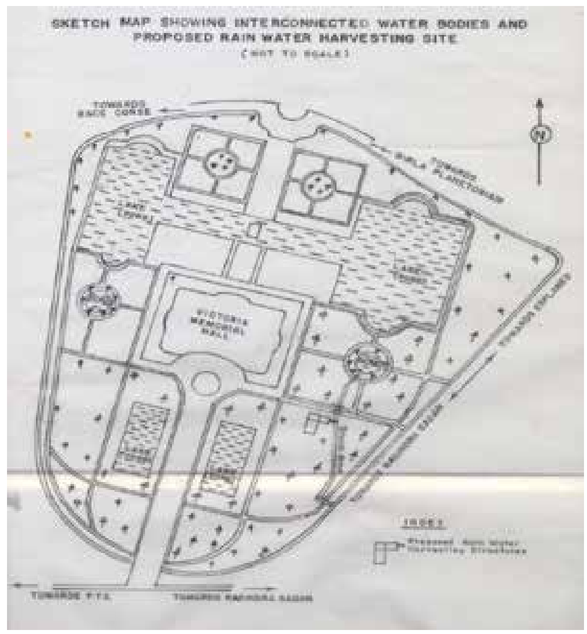


Fig-14: Sketch map showing Victoria Memorial, proposed Rainwater harvesting project site and the adjoining water bodies

Fig-15: Storm drain carries surplus rainfall runoff

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