Evaluating the Change of Water Table Position for Sustainable Development: "A Case Study of Ghazi Barotha Hydropower Project"

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Abstract

The primary objectives of this study was to evaluate the effects of the construction and subsequent operationalization of 1450 MW power generation facility "Ghazi Barotha Hydropower Project", on water table position in the surrounding areas. To assess the effects, the data comprising of elevation values of water column in open wells set up at different locations in vicinity of the facility have been collected. For a precise and comprehensive analysis, the study area was divided into 12 clusters. The hydrograph of each cluster between average water column elevation values and years (from 1997 to 2008) have been analysed. By comparing the values, before and after building the facility, it has been concluded that there are significant effects on positions of water table on some area, whereas in other areas, no substantial effects have been observed.

Keywords: Ground water, Ghazi Barotha Hydropower Project, Hydropower, Water depth, Dam, Water Table.

1. INTRODUCTION:

Hydropower is the dominant source of renewable energy generation globally which is producing 71% of all renewable generation with having total installed capacity 1064 GW in year 2016 (WEC,2016). It is 16.4% of total electricity produced in the world from all the sources. At the end of the 20th century, about 45000 large dams (above than 15 m) with a total reservoir area of about 500,000 Square km have been constructed to produce hydroelectricity, irrigation purposes, and for drinking water storages (Gleick, 1998; WCD, 2000). These dams contribute a major source of economic growth of industry with addition of progress of rural countries, and are considered as “sustainable hydropower” or “green hydropower” (Truffer et al., 2003).

The sustainable practices in development of hydropower projects have significant advances. These elements have added to enhance the willingness and acceptance for financial donor and policymakers to encourage the development of hydropower by providing the investment and giving suitable atmosphere by policymakers. Research have been extended widely to access the effects of dams or hydropower projects on water table position of their adjacent area. Some of the researchers have focused on positive effects of micro dams on water table encashment, whereas, some have studied effects of dams or reservoir on groundwater quality. The possible effects have been explained as follows;

a) Impacts of hydropower projects on groundwater

The dams and hydropower may change groundwater quantity, its flow pattern or its quality. The building and operationalization of hydropower project is connected with a serious environmental issues such as diversions of flows, interruption to migration of fisheries, hydro-cresting, flushing of reservoirs and flooding of lands and changes in bio-geochemical cycling (Friedl et al., 2002). Seepage has been observed the main impact on the adjacent areas of the reservoir. Consequently, the hydraulic grade line of the area goes up, considerably, imposing acute impacts on crop growing, drinking & irrigation water demand and hydraulic structure’s foundations. The groundwater levels before and after the construction of dam is best indicator to understand the effects of dams on groundwater. It has been observed that groundwater levels are increased after the impounding of reservoir. About 1.5 m increase in level of groundwater in North of Chennai has been observed after the completion of the check dam (Parimala Renganayaki et al., 2013). The recharge of aquifers boost ups due to seepage and elevated rate of infiltration. Moreover, the zones, which primarily was infertile, get their volume of recharge and becomes fertile. Similarly, over-recharge has also observed lead to water logging, the observed phenomenon in the vicinity of Tarbela dam (Tariq, 1993).The water table of the surrounding area of Khanpur dam is 75 feet deep and it goes to 150 feet as go away from dam site. Due to khanpur dam, the groundwater aquifer of the close area is sustained (Naeem et al., 2012). These dam structures can facilitate the recharge of ground water aquifer above 80% under the variable conditions of flood events, magnitude of storage and specific conditions of site. Further, some of the studies have also revealed that aquifer re-charge can be attained up to ninety five percent (Haimerl, G. 2000). It has been observed that groundwater quality is increased by increasing the levels of reservoir. The ground water inflow and outflow quantity was 2.5 times greater of Budush dam when reservoir level was 307 m.a.s.l. as compared when the reservoir stage of 245.5 m a.s.l. (A. Adili., 2014).

b) Impacts on groundwater flow pattern

The hydraulic head is caused to flow groundwater upward, downward or horizontally. The rivers, streams, precipitation and reservoirs are main source of groundwater recharge. With increase in infiltration the groundwater moves within soil having low permeability region. The excess seepage from dams not only increase the level of groundwater but also it caused the reason of change of flow pattern of groundwater. The variation in flow pattern is mainly due to the upsurge of water elevation of the reservoir, which in fact, creates the raised difference in hydraulic gradient amid the storage and the neighbouring aquifer. The groundwater direction was towards the river side before the construction of Budush Iraq dam and after the construction of dam, the reservoir gained net recharge to the aquifer (A. Adili, 2014). The construction of any structure that changes the groundwater regime can have potentially un-expectable results to the structure itself and the local hydrology (Milanovic, 2002).

c) Impacts on groundwater quality

Dams and hydropower also create impact on groundwater quality by infiltration of reservoir water into groundwater. The quality may be evaluated based on the values of total dissolved solids quantum or ionic concentrations of the ground water (Kunkle, G. R. 1965).The infiltrated water from the dams contain 0.4 to 47 mg per litre of zinc (Zn), 1100 to 1800 mg per litre of sulphates and up to 7.4 mg per litre of lead (Pb) (Adamczyk el al., 1994). The process of Eutrophication occurred in reservoir water and that contaminated water infiltrated to the groundwater. The pore water have found containing contaminants fractions and dissolved organic carbon infiltrated to the ground water (Wildi et al., 2004).

Literature review reveals that there are long term effects of change in water table position on lives of people in the area of the project, their living & housing, agriculture, livestock, social & health, ecology, environment and communication. Therefore, it is important to evaluate the change in water table position in the "Ghazi Barotha Hydropower Project (GBHP)" vicinity areas for sustainable development.

This case study may facilitate in future, at planning and designing phases of similar kind of hydropower projects, in early stage assessment of impacts, keeping in view the impounding effects on the position of ground water table. This may be helpful to mitigate the possible adverse impacts on the ecology of the area. Further, it may also help to add remedial measures against the possible impacts at the planning phase in the projects.

2. SCHEME OF STUDY:

2.1 General Scheme:

The GBHP utilizes the available head of mighty Indus in the middle of the downstream of Tarbela Dam Hydropower Station and the joining point of the River Indus with River Haro. The facility is of 1,450 MW installed generating capacity, comprising of 5x290 MW generating units.

There are three major components of the Project.

a) **The Barrage;** Located near Ghazi in the downstream of the Tarbela Reservoir at distance of 7 km, regulates the discharge from Tarbela.

b) **RCC Power Channel;** measuring about 52 km long intakes discharge from Head Regulator at barrage of 1600 cumecs.

c) The Power Complex; Located near Barotha, Operates under the discharge from Tail Regulator.

2.2 Methodology:

The groundwater was extracted from open wells manually and by Persian Wheel operated through diesel pumps . The Unconfined Aquifers were the Principal aquifers and variation in hydraulic grade line i.e water table position (depth) was taken as an indication for the study of the impacts. The depths of water table was recorded on a regular basis, the data was comprised of water column depths. The change in water table position was identified through the aforementioned data by comparison of levels of wells before and after the construction and operationalization of the Project.

2.3 Wells Inventory:

Identification of a number of wells was made with the help of authorities at the Project. Out of total of 127 wells, 37 and 39 were located along the left and right bank of Indus River respectively. The remaining were near power channel/complex and at barrage. The following information was collected from the wells;

a) Well ID No.
b) Well Location Coordinates
c) Well Type

2.4 Mapping of wells and Data Collection:

Mapping of the wells was carried out to get an overview of the area. The mapping done on base map of the project is as shown in Figure 1 & 2. The average water column of each well was calculated from 1997 to 2008 for each season i.e. summer and winter season of a year. The hydrograph was then plotted between the average water column depth of wells and time series on seasonal basis from 1997 to 2008 .The average rainfall intensity recorded in mm was also added on secondary axis in the hydrograph to observe the results that how much changes in water columns depth in wells were varied with respect to rainfall. The changes in groundwater depth before and after the construction of project can be accessed by variation in hydrograph. The color variation in hydrograph was used to distinguish the pre and post construction periods; grey color is used for 1997 to 2002 period whereas blue color was used in hydrograph for year 2003 to upward which is pounding year of the project. The wells were categorized into different clusters (groups) to get the better understanding of the effects of project on surrounding plain.

The clusters arrangement is designated in Figure 2.

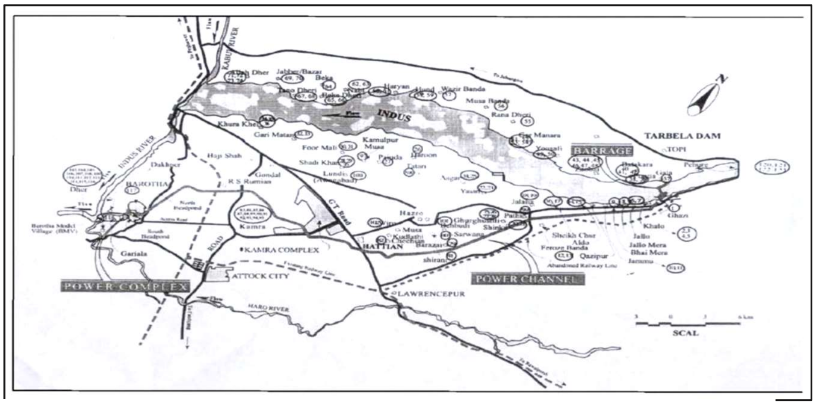


Figure 1: Mapping of the Wells

The detail of clusters is as under:

Sr. No	Location	Cluster Name	Area	Quantity of Wells
1	**Indus River** (Left Bank)	Left Bank-01	Ghaziabad to Qazipura	14
		Left Bank-02	Aladowa to Asgharabad	12
		Left Bank-03	Shaaddi khan to Haroonabad	11
2	**Indus River** (Right Bank)	Right Bank-01	Gallaya and battakara	06
		Right Bank-02	Zaryabi and Hyndalla	18
		Right Bank-03	Hyriana and Allah Dheira	15
3	**Power Channel** (Right /Left Bank)	Power Channel-01	Ghurghushti to Chechian	08
		Power Channel-02	Shadi khan to Wiro&Barotha	10
4	**Barrage Zone**	Barrage Zone-01	Pehoore hammleyt	04
5	**Power Complex** (Right & Left Bank)	Power Complex-01	Dher Wells	06
		Power Complex-02	Dher special wells	08

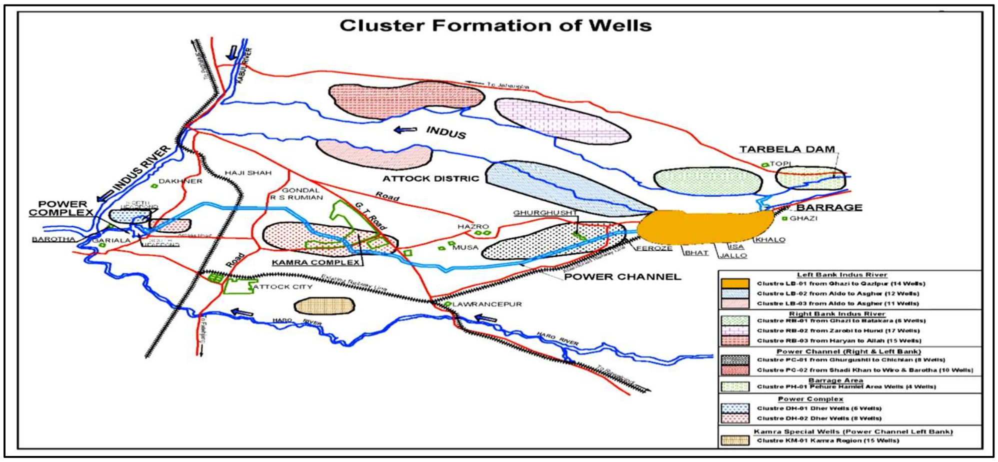


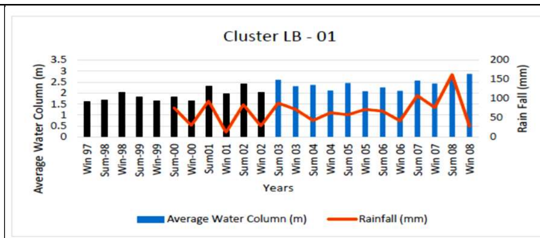
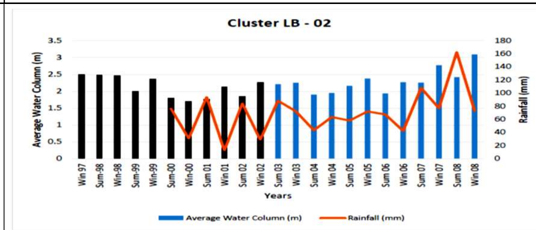
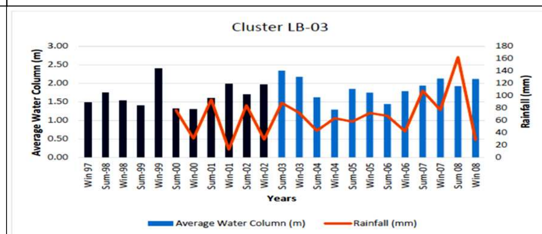
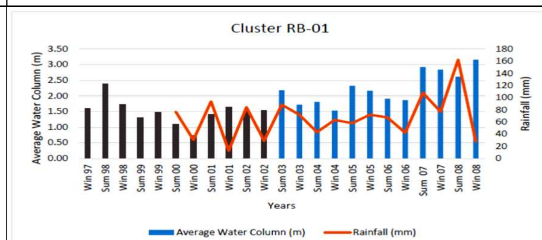
Figure 2: Layout of Clusters

3. RESULTS:

3.1 Results and Discussion:

Average seasonal water column depth of all wells in a Cluster is calculated and then graph is plotted against time series to determine the impact of GBHP on water table depth. The observations are tabulated here along with the graphs for the presentation of status of the water column in each cluster.

Cluster	Observation	Graphical Presentation of Results

<table>
<tr><td>Left Bank-01</td><td>Significant Rise in the water column after construction of GBHP. The rise may be mainly due to increased rainfall and seepage effect.</td><td>
</td></tr>
<tr><td>Left Bank-02</td><td>A minor change in water table position has been observed before and after construction of GBHP.</td><td>
</td></tr>
<tr><td>Left Bank-03</td><td>A very little effect on position of water table observed in this area after completion of GBHP.</td><td>
</td></tr>
<tr><td>Right Bank-01</td><td>Water table of the area has been observed slightly raised after the completion of the project.</td><td>
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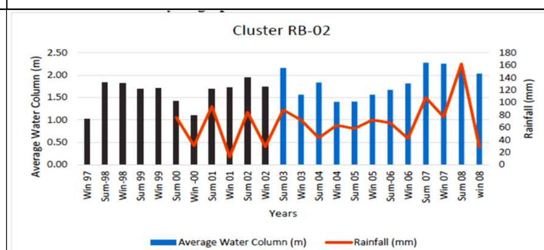
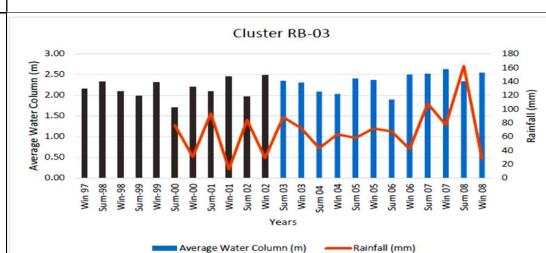
<tr><td>Right Bank-02</td><td>No significant effect has been measured on groundwater level.</td><td>
</td></tr>
<tr><td>Right Bank-03</td><td>No significant effect has been measured on water table position in this area.</td><td>
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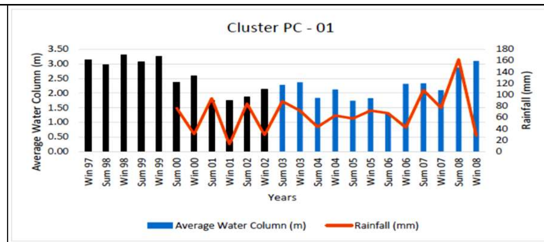
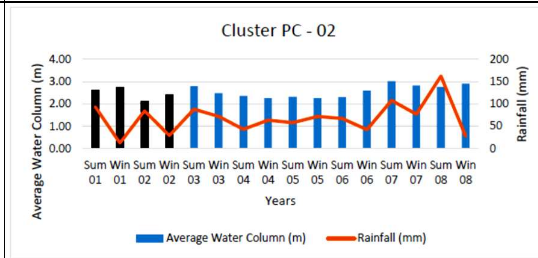
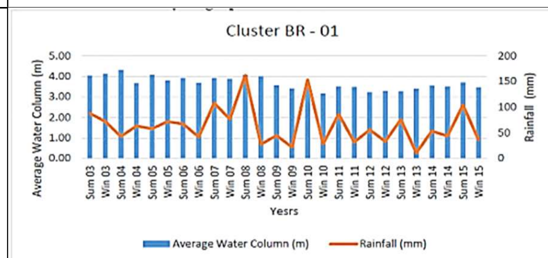
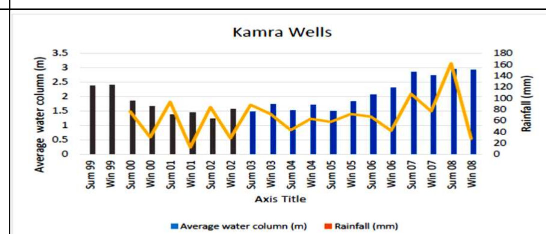
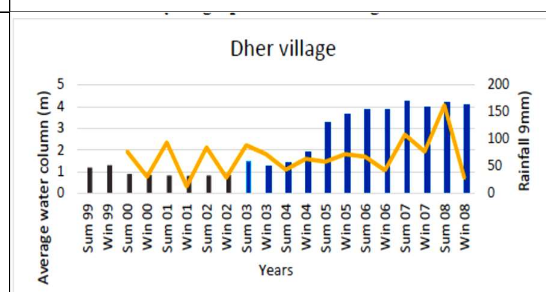
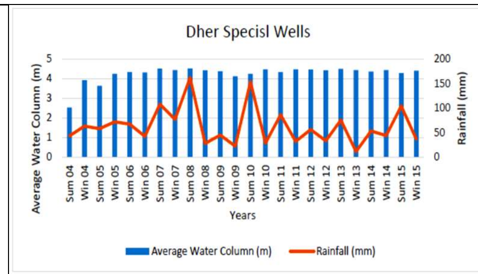
Power Channel-01	No significant effect has been measured on water table position in this area.	
Power Channel-02	No significant effect has been measured on water table position in this area.	
Barrage Zone-01	Season by season fluctuation have been observed in conjunction with barrage level. The position of water table increases as the level in barrage increases.	
Power Complex-01	Constant increasing trend in water table position due to seasonal effects have been observed.	
Power Complex-02	Significant rise in the water table position of the area has been observed.	

Power Channel-01	Minimum fluctuation has been observed.	

CONCLUSIONS:

Based on the analysis of the graphs presented above, it may be concluded that there are different effects for different portions of the project vicinity areas, on water table position. On some portions, the water table of the area has raised significantly which may be mainly associated with the better monsoon and seepage effects. Whereas, on other portions there is minor or no effect. Some portions like the Cluster PC-01 keeps the highest water table position in comparison to other cluster which may be due to continuous impounding effect. Ghazi, Kkalo, Barrage areas of Project, Dher and Kamra Village are the most affected areas, where water table depth rises after the construction of project due to increased seepage effect.

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