Impact of Climatic Change on Groundwater Resources and Potential Adaptation Measures

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Abstract

Rural communities depend on the shallow regolith aquifers for domestic and small scale agricultural by means of dug wells or agro wells. These communities experienced droughts causing tremendous hardship to the people and livelihood with deficiency of rainfall for shorter periods compare to that of the past.

Therefore to understand the causes of the frequent drought, impact of the long term climatic variables on the frequent drought and introduce possible adaptation measures for the resilience of the communities the study was carried out covering selected area at Galagamuwa D.S. division in Kurunegala, district which is more vulnerable to drought.

Cumulative rainfalls of the district do not show any significant changes except the seasonal variation. Increasing of temperature shows influence precipitation amount, timing and intensity rates and the increase of evapo-transpiration which leads to the soil moisture deficiency affect to the groundwater potential. Groundwater resources of the studied areas are related to climate change through the direct interaction with surface water and indirectly through the recharge process was evident by the water level fluctuation of dug wells within the study area.

However, as in many other sectors groundwater regime is vulnerable to climate change either directly or indirectly. Therefore downscale global climate model has to be coupled with hydrological models which are capable to quantify the output such as groundwater recharge which will benefit to introduce the adaptation strategies on climate change.

Introduction

Climate Change is defined as statistically significant variation in either mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2001). The second assessment report of the Intergovernmental Panel on Climate Change (IPCC) made comment about groundwater research as "***Despite the critical importance of groundwater resources in many parts of the world, there have been very few direct studies of the effects of global warming on groundwater recharge".*** Further the third assessment report highlighted ***"Groundwater as the major source of water across much of the world, particularly in rural areas in arid and semiarid regions, but there has been very little research on the potential effects of climate change***", following the fourth assessment conclusion as ***"Despite its significance, groundwater has received little attention from climate change impact assessments, compared to surface water resources"*** highlighting the potential impacts of climate change on water resources have long been recognized, although there has been comparatively little research relating to groundwater. This global assessment is highly fit to the Sri Lankan context too as the groundwater-resource sensitivities to climate change have not been addressed within the country's research agenda.

Over the past few years, much of Sri Lankans live in dry zone as well as wet zone have experienced increasing pressure on water resources due to a drier climate and increased scarcity of surface water and groundwater. In recent years Sri Lanka agriculture, which account for the major part of the gross national product as well as other livelihood suffered badly from the abnormal weather conditions. Consequently agriculture and other livelihood output declined drastically followed by the extreme water deficit and excessive rainfall conditions, which has resulted a sudden decrease in export earning followed by the massive increase for relief distribution (Figure 01) causing severe damage to national economy. Further analysis of recent records Figure 01, indicated, drought occurred not only in the drought-prone dry zone of the country but also throughout the intermediate and wet zone too with few dry consecutive days, lowering the potential of the shallow regolith aquifer which is used by the majority of the rural population for domestic water consumption by means of dug wells or shallow tube wells.

The degree of vulnerability to frequent drought in the country has also expanded as a challenging issue, manifold due to global phenomena such as climatic change.

Analysis of the impact of drought and the trends of drought in the country shows that the drought is mainly due to seasonal scarcity of water in localized areas. Although the most noticeable impacts of climate change could be fluctuation in surface water levels and quality, greatest concerns has to be paid to the groundwater management to overcome the water scarcity and the related issues as most of the rural population depend on groundwater for domestic use.

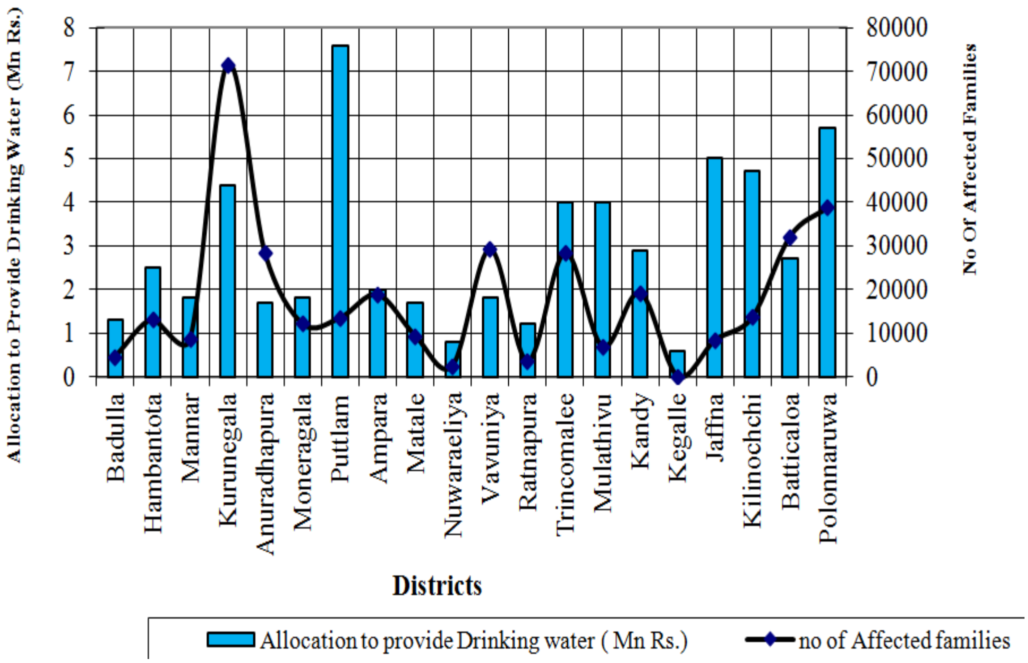

Figure 01 Impact of Drought in Sri Lanka within Year 2012

Objective

Main objective of this attempt is to introduce a sustainable community based groundwater replenishment measures as adaptation techniques for the resilience of drought and study the impact of the adaptation to the shallow regolith aquifer system.

Methodology

Padipanchawa Cascade System located at Galgamuwa D.S. Division in Kurunegala district was selected and five small scale abundant tanks were developed with water diversion canals as shown in Figure 02 to combat frequent drought experience in the area.

Apart from the rehabilitation of abundant tanks, construction of anicuts and diversion canals, introducing soil conservation measures, planted traditional area specific varieties in the cascade system were implemented under the project with the support of communities. Moreover to get the scientific information on the climate change in particular area weather stations were established to measure the climate variability such as rainfall, temperature, wind speed, sunshine etc. through Agrarian Services Department and school children's support were obtained to monitor the water level of the 15 no of dug wells selected based on the landuse and the morphological features of the area as given in table 01 .

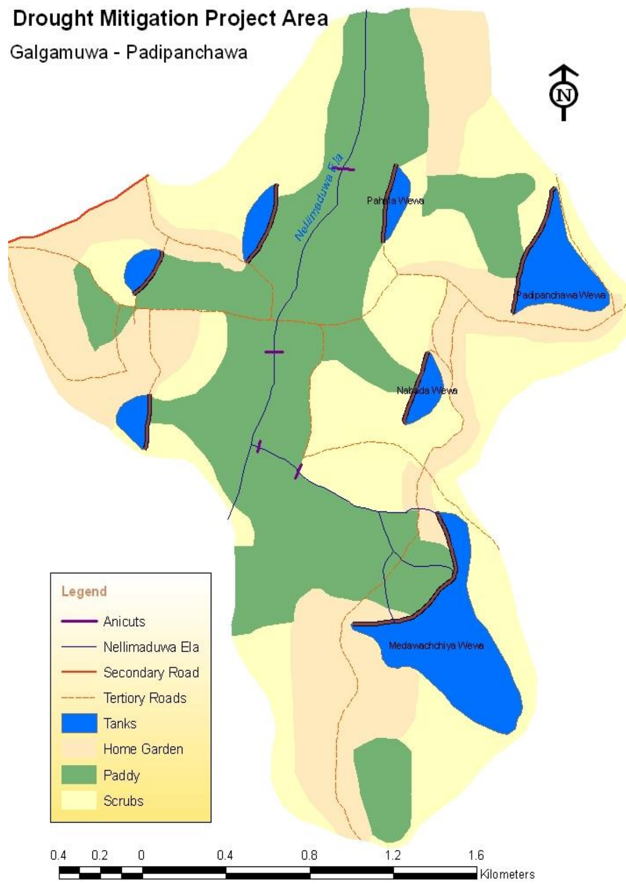

Figure 02 Cascade Development as Climate Change Adaptation Strategy

Table 01 Details of the Dug Wells in monitoring Network

Well No	Diameter (m)	Depth (mbgl)	Details
PD-DW-01	1.2	8.60	Located in home garden
PD-DW-02	1.5	5.80	Located at home garden
PD-DW-03	1.8	4.40	Located in scrubs
PD-DW-04	0.8	2.05	Located close to tank
PD-DW-05	2.0	4.55	Located in scrubs
PD-DW-06	2.2	3.80	Located close to tank
PD-DW-07	1.5	2.70	Located close to tank
PD-DW-08	1.6	3.90	Located close to tank
PD-DW-09	1.3	4.50	Located close to Paddy field
PD-DW-10	1.6	5.20	Located in scrubs
PD-DW-11	1.8	3.60	Located close to tank
PD-DW-12	1.5	4.96	Located close to Paddy field
PD-DW-13	1.6	7.33	Located in home garden
PD-DW-14	1.3	4.65	Located close to Paddy field
PD-DW-15	1.4	8.87	Located in home garden

Climate Change in Sri Lanka

Evidence is mounting that we are in a period of climate change brought about by increasing atmospheric concentrations of greenhouse gases. Researchers have proved that atmospheric carbon dioxide levels have continually increased since the 1950s. The continuation of this phenomenon may significantly alter global and local climate characteristics, including temperature and precipitation. Climate change can have profound effects on the hydrologic cycle through precipitation, evapotranspiration, and soil moisture with increasing temperatures. Although Sri Lanka is a negligible contributor to global warming, being an island nation close to equator highly vulnerable to the impacts of climate change, which include: increases in the frequency and intensity of disasters such as droughts, floods and landslides, variability and unpredictability of rainfall patterns, increase in temperature, sea level rise, etc.

Sri Lanka receives 1860mm per year on average (1961-2010 rainfall average) and this is equal to 122Km3 in volume. Based on rainfall the annual rainfall cycle in Sri Lanka can be divided into four seasons namely, Southwest Monsoon (May – September), Northeast Monsoon (December – February), First Intermonsoon (March – April), Second Intermonsoon) (October – November). The country is divided in to three climatic zones, considering the rainfall pattern as wet zone (average annual rainfall 2350mm), dry zone (average annual rainfall 1450mm), intermediate zone (average annual rainfall between 2350mm and 1450mm)
Analysis of the rainfall variation of Kurunegala districts illustrated in Figure 03 shows no any significant changes in the cumulative rainfall over the last 30 years.

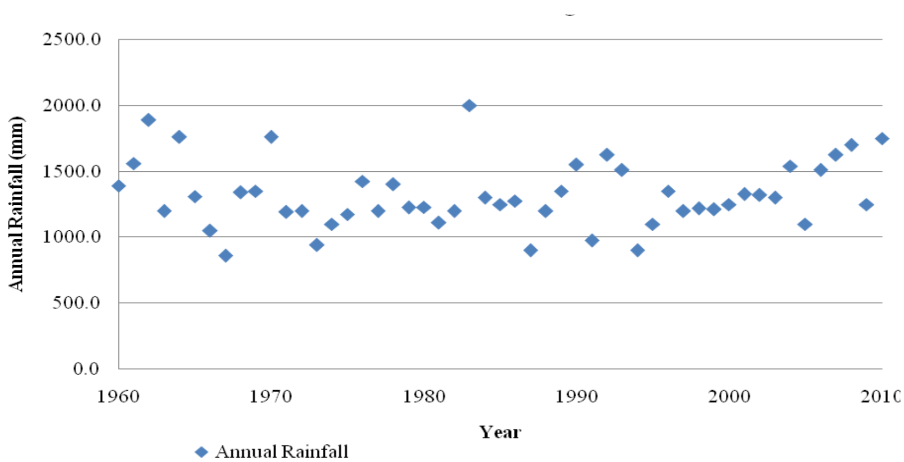

Figure 03 Annual Rainfall Variation in Kurunegala District

Study carried out by the Department of Meteorology on Variability of all Sri Lanka seasonal rainfall during the period of 30 years from 1931 to 1990 is given in **table 02** depicts no any significant changes except erratic distribution of rainfall within the season without change in cumulative rainfall.

Table 02 Variability of all Sri Lanka seasonal rainfall from 1931-1990(Sources Meteorological Department)

Season	**CV (1931-1960) %**	**CV (1961-1990) %**
North East monsoon	31	42
First Inter monsoon	23	27
Southwest monsoon	21	16
Second Inter monsoon	22	23
Year	11	14

According to the results of General Circulation Models, the paramount issue in changes in precipitation will be the increase in extremes rather than a long-term change in average precipitation. That means high intense rain can be expected within a short period. This will lead to accelerating of soil erosion process: already 33% of the land area of Sri Lanka is affected by soil erosion. Also the process of silting the reservoirs will be accelerated.

The Intergovernmental Panel on Climate Change (IPCC) estimates that the global mean surface temperature has increased 0.6 ± 0.2 ^{o}C since 1861, and predicts an increase of 2 to 4 ^{o}C over the next 100 years. Analysis of the annual average maximum and minimum temperature in Kurunegala district shows the increasing trend as shown in Figure 04 and Figure 05 respectively.

With the temperature increase more evaporation can be expected and this will substantially affect irrigation withdrawals: higher temperatures, hence higher crop evaporative demand, mean that the general tendency would be towards an increase in irrigation demands. Due to higher temperature people tends to use more water and therefore high demand for water, ultimately heading to water scarcity. Apart from that high evapo-transpiration directly cause the depletion of groundwater especially in the shallow regolith aquifer. Also the projected temperature increase would degrade water quality by means of degradation.

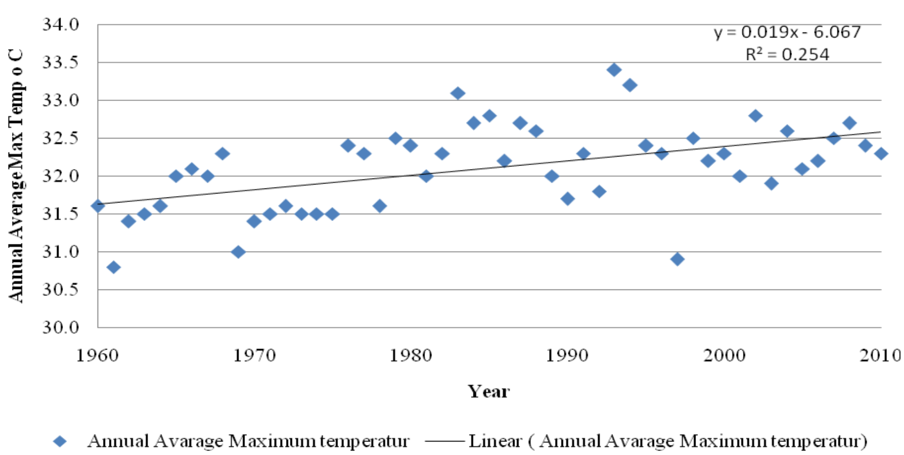

Figure 04 Annual Average Maximum Temperature Variations in Kurunegala District

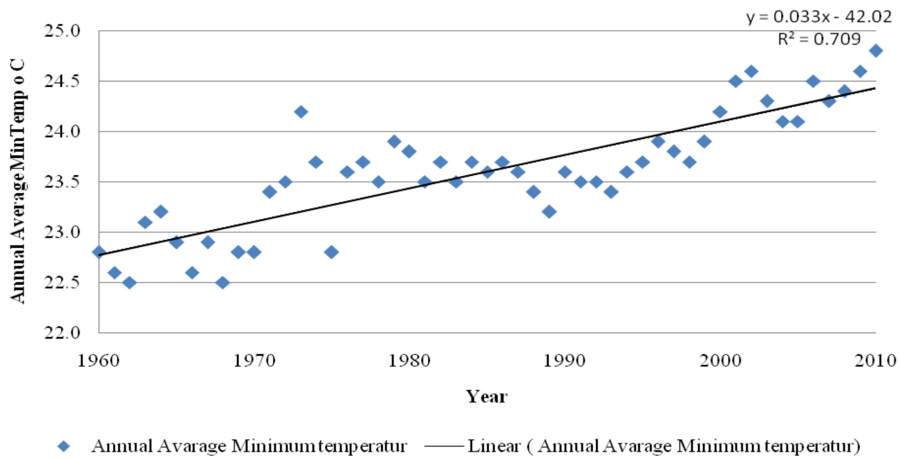

Figure 05 Annual Average Minimum Temperature Variations in Kurunegala District

Results & Discussion

Groundwater extracted from an aquifer that receives recharge from rivers, tanks, rainfall or from other aquifers. It also refers to the total amount of groundwater replenishment through the annual hydrological cycle, and therefore has significant dependency on the climate and its variability such as rainfall, temperature, evaporation, transpiration, and the processes of hydrological cycle such as runoff, infiltration, percolation etc.

It has been shown that rainfall is the most important climate parameter influencing recharge, followed by rainfall intensity and temperature (McCallum et al. 2010). Furthermore, changes in recharge induced by changes in CO_2 concentration, solar radiation and vapour pressure deficit are relatively minor. Increases or decreases in recharge generally reflect increases or decreases in rainfall (Allen et al. 2004; Serrat-Capdevila et al. 2007), but there are enough exceptions to preclude relying solely on change in rainfall as an adequate predictor of change in recharge. Change in the frequency and seasonality of rainfall may also influence changes in recharge. Water level fluctuation of the selected dug wells at Padipanchawa cascade system at Kurunegala district located in the dry zone of Sri Lanka prominently depicts the increase of water level with the seasonality of rainfall as shown in Figure 06

The next most sensitive factor to influencing recharge is temperature. It was found that recharge increased as rainfall increased up to a 3°C temperature increase. For larger temperature rises, however, evapotranspiration increases lead to reductions in recharge (Crosbie et al. 2010c; Doll 2009; Rosenberg et al. 1999)

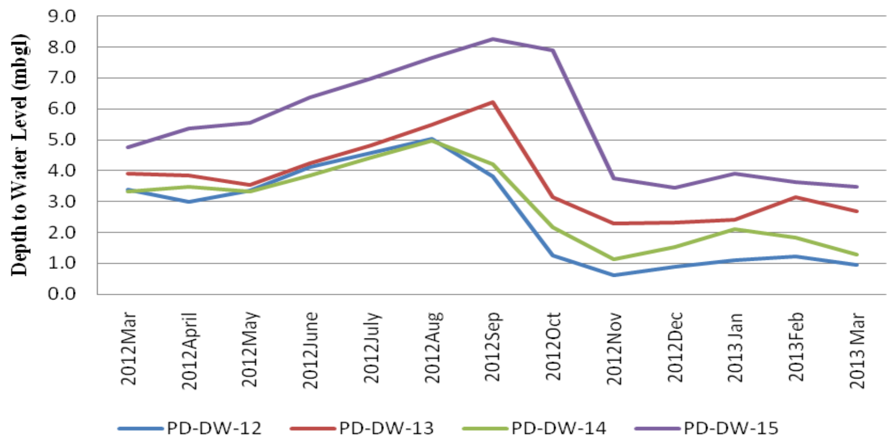

Figure 06 Seasonal Fluctuation of Depth to water level

Climate change adaptation strategies has shifted from an impacts-led approach to a vulnerability-led approach and therefore future human exposure to climate hazards based on different climate change scenarios get more attraction rather than the hazards of climate change to introduce the adaptation strategies. However, in the past, many structural, physical and institutional adaptation mechanisms, implemented through conventional top-down approaches, lacked community participation and livelihood focus. This paper will discuss the top down and bottom up integrated approach practised as adaptation measures in Galagamuwa D.S. division of Kurunegala district.

Development of tank cascading system extensively traps silt and harmful material and act as sponge for storm water. Further it acts as a wind barriers surrounding the area, and control evaporation, harvesting rainwater and replenishes ground water in the surrounding area.
Increase of the groundwater level of the dug wells located in the proximity of the tanks depicts the refurbishment of abundant tank help to retain more water and feed groundwater aquifer.

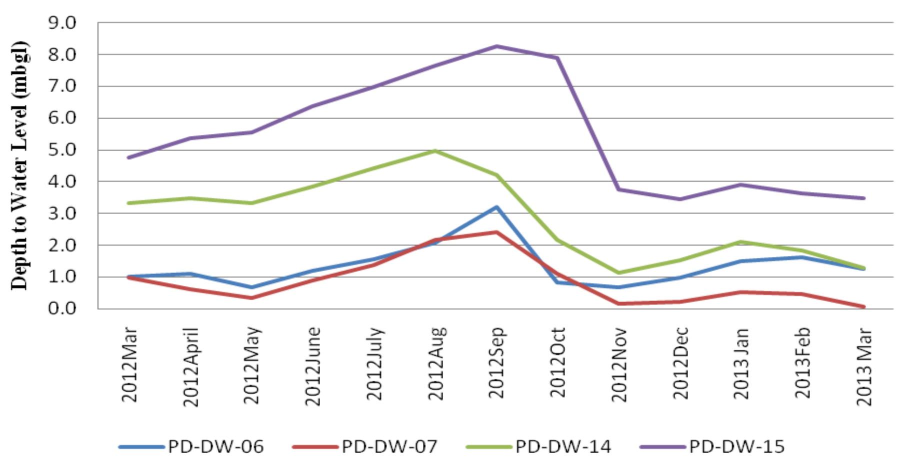

Figure 07 Variation of Depth to Water Level based on Distance to the Tank

However the water level data of the wells located in agricultural areas and the non agricultural areas of the cascade system reveal, groundwater recharge of shallow regolith aquifer is generally much greater in areas of annual crops than in areas of trees and shrubs.

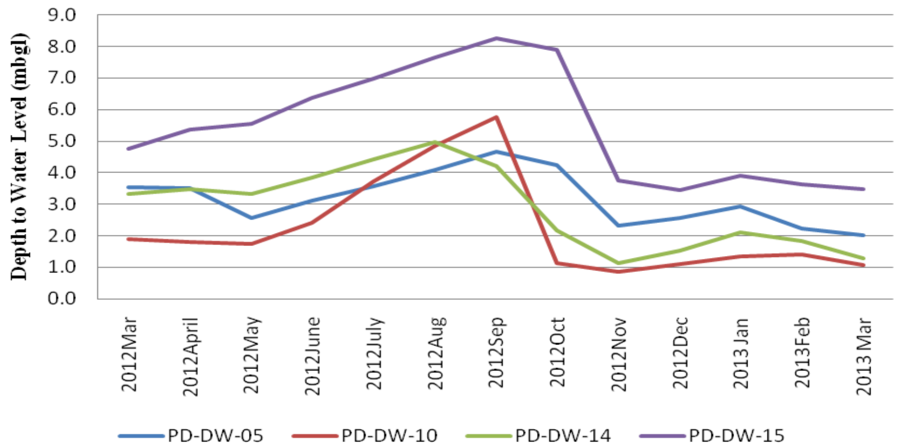

Figure 08 Variation of Depth to Water Level in agricultural and Non agricultural areas

Water level fluctuation of dug wells located in vegetated areas, non vegetated areas were compared. The recharge of the dug well located in non vegetated area is higher than that of the vegetated area. As the water diversion also took place within the cascade system

The impact of vegetation on recharge is evident in Padipanchawa cascade, where the dug well located in deep-rooted native trees with shallow-rooted crops resulted in recharge increases. This may be due the high evapo-transpiration of deep rooted trees due to temperature increase.

Additional aquifer attributes that may influence localized recharge sensitivity to climate include the level of tank cascade and aquifer connectivity, the proportion of localized recharge relative to diffuse recharge to an aquifer, geomorphic setting and mechanisms that promote rapid recharge, and this was clearly demonstrated by the water level of the dug wells located closer to the tanks compare to the water level of the wells located away from the tank.
However the study evidences the positive impact of water diversion to the groundwater replenishment of the surrounding area. Further it reveals that the catchment preservation to control soil erosion and to increase soil moisture retention followed by the traditional methods enhance the groundwater potential of the area and so that the community can fulfill their domestic water requirement through the dug wells at home gardens.

As in many other sectors groundwater regime is vulnerable to climate change either directly or indirectly. Therefore downscale global climate model has to be coupled with hydrological models which are capable to quantify the output such as groundwater recharge which will benefit to introduce the adaptation strategies on climate change.

Moreover followings can be recommended based on the experience gain through the implementation of the project with the support of the community in the area.

- Groundwater uses should be responsible for understanding the implications of climate change and its impact on the aquifer system or systems they manage. It is the foundation for developing adaptation options. Effective communication of impacts, implications and response strategies is essential for groundwater utilities to achieve the public support needed to implement the required adaptation strategies.
- Adaptation takes place on the local level are more effective but regional and national initiatives are necessary in order to assess the impacts of, and maintain a coordinated response to, climate change.
- Traditionally, water utilities have relied upon a variety of decision analysis methods to inform long term planning decisions in the context of uncertainty. Climate change factors should also be included in decision support analyses in order to enable the development and implementation of appropriate adaptation options.
- Instead of waiting for truly actionable science or preparing for one of many possible climate change impacts, groundwater utilities should consider preserving and developing adaptation options that can be implemented in the future when more is known about the timing and/or magnitude of actual impacts .

Reference

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