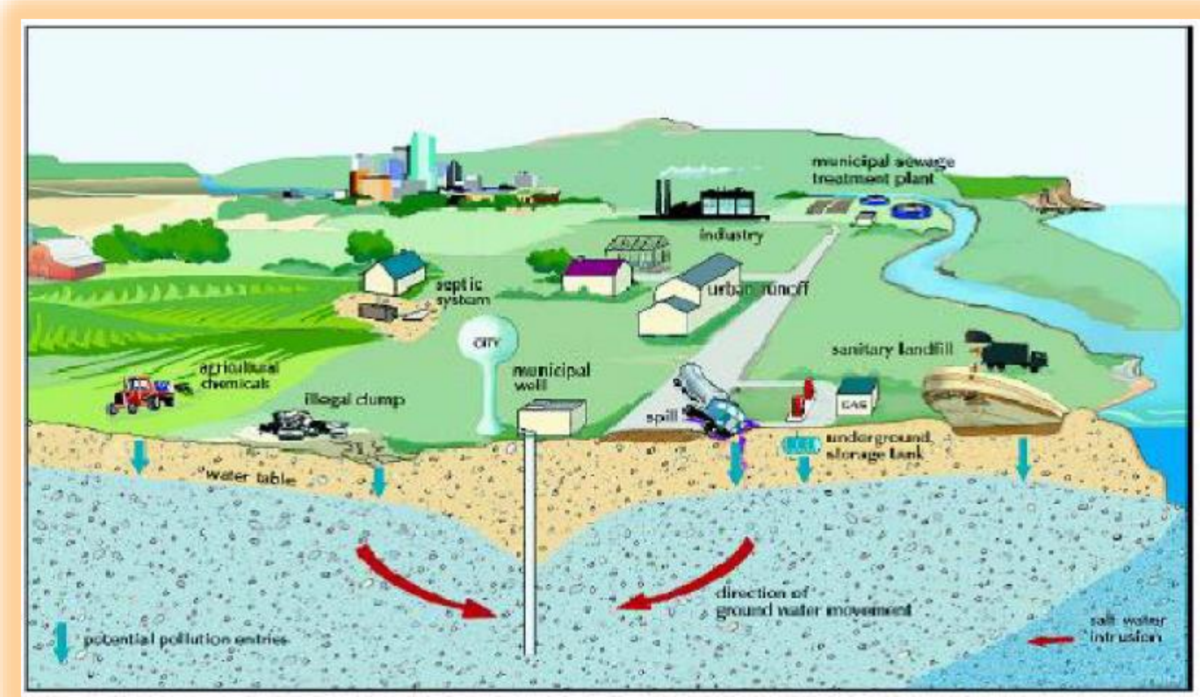
Name of Technology	Relocation of Water Points away from saline, flood and drought prone areas
Sector	**Water Resources**
Sub-Sector	**Water Supply**
Introduction	Salinization and contamination of groundwater systems can be caused by fossil salt water, i.e. water that has remained trapped in the sedimentary layer; salt water intrusion from the sea, as a result of over-pumping near the coast, or by reduced recharge due to reduction in rainfall; and water contamination from surface point sources (e.g. pit latrines, dump sites)(van Dongen, 2014). The Gambian open (80km long) and sheltered (200km of inland estuary) coastal zone is experiencing contamination primarily by seawater intrusion due to overexploitation and reduction in freshwater recharge due to reduced rainfall, occasional flooding of traditionally dug shallow water wells and the use of on-site sewage disposal systems, in particular pit latrines, septic tanks and pumping sewer into the River Gambia. The extend of saline intrusion in the River Gambia is mainly governed by the balance of outward advective transport by freshwater and inward dispersive salt transport from Atlantic side, extended with the rainfall rate, which accounts for the local rainfall and evaporation. (Verkerk and Van Rens, 2005). According to Jarju (2009), annual rainfall amounts have decreased by about 30% from 1950 to 2000. This decrease has been evident in the reduction in the length of the rainy season and also the quantity of rainfall amounts recorded in the month of August, particularly during the period 1968 to 1985, and in 2002. The Gambia NAPA (GOTG, 2007) points out that the combinations of sea level rise, global warming and changes in rainfall patterns, could impact freshwater resources qualitatively and quantitatively. Surface evaporation is expected to increase, whilst groundwater recharge is expected to take the reverse trend and both phenomena enhance advective salt transport in the River Gambia (Verkerk and van Rens, 2005; Njie, 2002; as cited by Jarju, 2009), and place additional constraints on management rules of an upstream reservoir. However, the biggest threat of saline intrusion into the River Gambia and coastal aquifers comes from projected sea level rise (Njie, 2002). Flood events from the late 1980s to date are both riverine floods and flash floods. The flash floods affected mostly the Greater Banjul Area (GBA) where the drainage system is very poor, whilst riverine floods occurred in part of Central River Region (CRD) and areas in Upper River Region (URR). In conjunction with sea level rise, shallow water tables, water logged soils and coastal erosion are also adding to flood risk in settlements, such as Old Jeshwang, Eboe Town, and Fajikunda etc, that are steadily encroaching into wetlands (Jarju 2009). In these areas shallow and uncovered wells are completely flooded and conterminated during the floods and for many months after the floods recede. Over exploitation of the groundwater aquifer is mainly due to increased number of water points (wells and boreholes) due to increased demand for human consumption and for horticultural activities. Gambian irrigation using surface water resources primarily from the Gambia River is used only for rice production while mixed crops (vegetables and fruits) are either rain fed or irrigated by using groundwater resources (Jarju, 2009).
Technology characteristics	Key adaptation measures that are pertinent to addressing the climate change related impacts discussed in the preceeding introductory section on the water resources status and management functions include (a) artificial recharge of groundwater aquifers; (b) improvement of management of urban storm-water runoff; (c) promotion of the collection of rain water (harvesting); (d) resettlement of people or relocation of activities away from the flood plains (Njie, 2002); and (e) relocation of Abstraction Points (water wells and boreholes) to less saline areas (GOTG, 2007; Jarju, 2009). In the Kombo peninsula on the coastal zone of The Gambia, where a large number of production boreholes are concentrated, demand is outstriping renewal

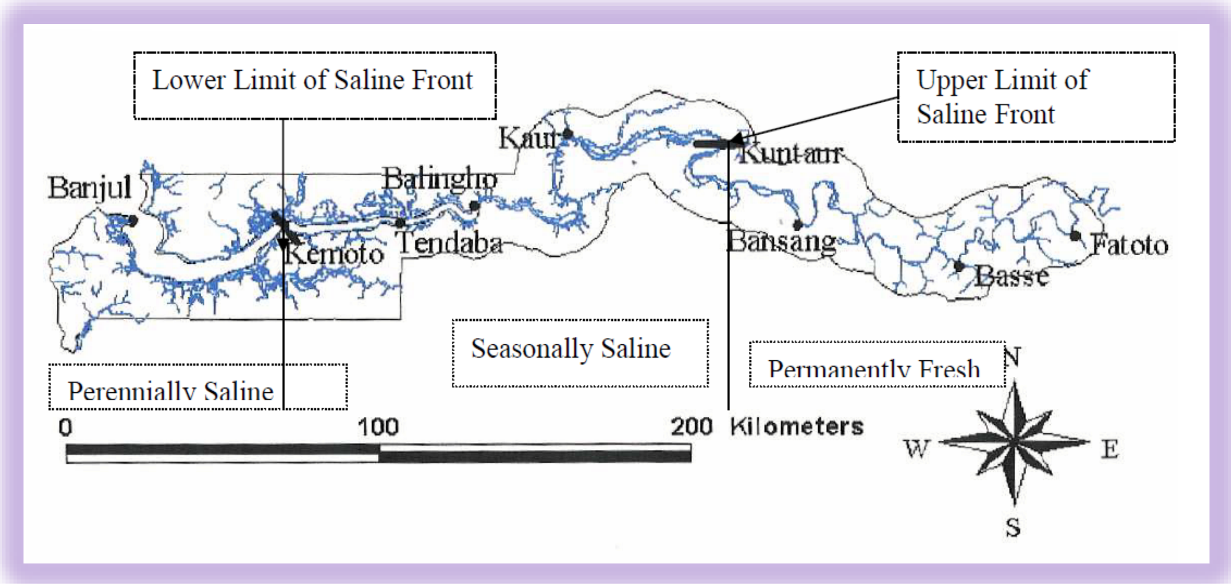
	rates, forcing current and future managers to consider several options including groundwater mining, and long-range transport of water (SNC Lavalin, 2005). According to Manneh (1997), a constant flow of $20m^3/s$ are required to arrest saline intrusion in the estuary at 195km upstream of which 15,000 ha have been identified for irrigation development. Water wells and boreholes that have been found to be too saline for human consumption and crop and livestock watering need to be plugged and abandoned. Replacement boreholes need to be relocated and drilled within a safe distance of the abandoned saline locations and sources such as the sea and the shoreline. Pieter G van Dongen (2014), found that in the coastal zone of Dar-es-Salaam, fresh water (< 150 mg/l) is present beyond 2 km from the sea, but within 1 km from the sea, many boreholes/wells are brackish (300-1,000 mg/l) to brackish-salt (1,000-10,000 mg/l). Funda Dökmen, (2012) also found that seawater intrusion was found within a 1 km radius of the coastal line. This evident relation to distance from the sea clearly points to seawater intrusion as the cause of salinity. Ofcourse, the situation is exacerbated by reduced groundwater recharge due to reduced rainfall amounts and infilration rates into the ground. Applying a 2Km distance from the source of seawater intrusion as the safe distance may also take into consideration future climate change scenarios. Relocation will include drilling the same number of water points or lesser number landward of the safe distance of 2KM. Relocation of water points will also meet the water supply side adaptation measures identified in the national strategic documents (INC, 2003; Jarju, 2009); GoTG/NAPA, 2007), SNC, 2013) which include (a) the construction of new systems such as well fields and hand-dug wells; (b) modification of existing physical structures such as conversion of diesel powered water pumping systems to solar powered systems and (c) developing alternative management of existing water supply system, for example by changing operating rules, coordinating water supply/demand systems or conjuntive use of surface and ground water supplies. Relocation and modification of technologies will meet the water demand adaptation measures that include (a) conservation and improving efficiency, (b) technology change such as the use of solar power water supply systems in the rural communities and (c) market or price driven transfer activities. For examples, policies which involved metering, water pricing, as well as use of conservation methods, will improve efficiency and promote water loss through demand. In rural Gambia, the communities have service contract with the companies for the operation and maintenance of solar water supply systems. Under this arrangement, community taps are metered and payment is based on the volume of water consumed. This has resulted to efficiency in water use because communities use pipe water supply for drinking and water from traditional wells for laundry and other domestic purposes. This reduces the stress on water withdrawals from the aquifers.
Costs, including	Cost is an important factor to consider in the relocation of water wells and boreholes away from flood-prone and saline areas. From the planning and design stages, climate change issues will be factored in the new structures to make them flood and saline proof. The adaptation scenario is to plug and adandon and then relocate deep wells and boreholes while maintaining the shallow garden wells which do not reach the depth of the saline wedge and are are only used for horticultural practices.
• Cost to implement adaptation options[10]	Based on the scenario above, estimated unit cost of drilling one borehole, installing solar powered pumping and distribution systems and running the pipe network for a community of one thousand residents is about US$42,000, for two thousand residents is about US$56,000 and for five thousand residents is about US$120,000, respectively. For a population of less than 500 residents a drilled or hand-dug well fitted with one handpump is estimated to cost about US$10,000 and for a population of 500 to 1000 residents a dug or drilled well when fitted with two handpumps is estimated to cost US$14,000.
• Operations and maintenance	The operations and maintenance
Potential financing and markets:	Donor partners such as Saudi-Sahel Programme, the IDB, the AfDB, UNICEF and the EC are always available to support provision of water supply to communities. There has been an increasing number of Small Business Enterprises (SMEs) engaged in the installation and management of water supply technologies such as Hand Pumps, Solar Panels, pipes and taps. The market is growing.
Potential development impacts, benefits	A global warming trend will have serious impact on agricultural production since the resilience of the agricultural system depend heavily on strategic approaches to water management capable of addressing climate change impacts on future renewal rates of groundwater resources, flow and salinity regime of the River Gambia. Cultivation though irrigation with saline water impacts on crop productivity. Salts transmitted into the soil by water affects the growing plants. The osmotic pressure of the soil solution increases because of accumulation of salts in the soil. For this reason, physiological drought occurs because plant roots take in water with difficulty. Salt accumulation within the root zone negatively affects yield and quality of plants over the time (Dokmen and Kurtulus, 2008). Flooding has both direct and indirect impacts on society in terms of loss of assets (physical infrastructure, raw materials, etc.) and indirect impacts in terms of goods and services (lower output of damaged or destroyed factories, cost of medical expenses and lost of productivity arising from increase of diseases, injury or death).
Economic	Relocation of water points from flood and saline prone zones will promote and facilitate adaptation to the negative impacts climate change enumerated above. The technology will reduce the chances of households failing to access potable safe water supplies during floods. It will reduce the time lost traveling long distances to access good drinking water when the water point gets either damaged, contaminated or cannot be accessed because of the floods. Avoiding such loss of time prevents disruption in productive activities and the negative implications this entails. Time loss to morbidity or taking care of a sick relative especially by women due to water borne disease from contaminated water points is also reduced. In the end, there would be a healthy community able to pursue livelihood objectives of its own choice. Relocating the water wells and boreholes to freshwater zones and then backed by adopting appropriate policies and technologies of exporting water for agricultural and domestic use in the saline zones will increase agricultural productivity and reduce pollution from saltwater.
Social	Areas of concern are domestic dwellings, farms and industry with private supplies. The potential for

[10] *Data and information based on personal communication with the Acting Principal Hydrogeologist of the Department of Water Resources*

	downward migration of contaminated flood water is high in water abstraction boreholes meaning the spread of illness through the water supply is possible.
Environmental	Relocation of deep wells and boreholes from saline areas will minimize intrusion of saltwater into freshwater zones. However, construction activities will cause damage to soils and vegetation cover.
Status	There is no information regarding the status of the proportion of boreholes and protected wells that can be regarded as resilient to climate change hazards. However, given that awareness to this need has only began to emerge slowly in the last decade, it can be envisaged that a big proportion of the boreholes and wells in flood prone area are vulnerable to contamination and damage due to flooding.
Advantages and disadvantages of relocation of water points from flood and saline prone zones.	Overall the technology will reduce disruptions in access to safe water during flooding. The floodwaters will not only contaminate drinking water sources but also lead to the destruction of water and sanitation systems, increasing the risk for water-borne diseases such as cholera during the rain season. Flooding can lead to contamination of drinking water wells and can also prevent physical access when floodwaters are high enough. Community health and economic activity require continuity of safe water supply. Ensuring continuous access to drinking water decreases the likelihood that populations will be displaced during moderate flooding.
Acceptability to local stakeholders and feasibility of implementation	Both rural and urban water supply are based on policies and regulations that promote and facilitate good practice for digging wells, drilling boreholes and installation of solar powered reticulation systems. Good practice entails that water points are located away or protected from burial sites, pit latrines, runoff water, waste disposal, etc. On top of this, the water affairs department has been encouraging the communities to site the wells in locations which are not prone to flooding.
Endorsement by experts	The water resources experts and managers endorsed the relocation of water points away from saline and flood prone areas of the coastal zone and the estuary of the River Gambia. This endorsement is manifested in the National Communications and the NAPA of The Gambia by inscribing it as one of the adaptation options. The National TNA Adaptation Working Group has also “voted” and prioritized the relocation of water points as viable adaptation option with the accompanying technologies.
Timeframe	The relocation of water points from the planning, designing and implementation phases will take a minimum of 7 years.
Institutional capacity	The Hydrogeology Division of the Department of Water Resources has a wealth of knowledge and skills on water supply technologies particularly as they relate to digging of wells, drilling of boreholes and the procurement and installation water lifting, pumping and distribution systems. The Water Quality Division of the Department of Water Resources and the Water and Sanitation Working Group that includes the Public Health Services of the Ministry of Health and Social Welfare and the Local Councils have knowledge and skills related to public health principles. These institutions are capable of undertaking basic survey and analysis of population distribution; and water point location, elevation and maping. A training or certification program may be necessary for staff of the Hydrology and Water Quality divisions of the Department of Water Resources to enable the determination flood-prone and saline areas under current and projected climate change. Some institutional capacity is necessary to determine if, where and how public funds should be allocated for constructing or retro-fitting wells.
Adequacy for current climate	Plugging and abandoning water points that have become saline and are in flood prone areas have been practiced at a smaller scale but have proved to be inadequate in addressing the water stress caused by the contamination of water by salt and other bacteriological and chemical components of pollution.
Size of beneficiaries group	Considering that the Kombo Peninsular is defined as the Coastal Zone of The Gambia, it is estimated that the population that will benefit from relocation of water points will be about 53% of the population of the Gambia (GBoS, 2013, http://www.accessgambia.com/information/population.html)



Sources of groundwater contermination are numerous and are as diverse as human activities (Zaporozec abd Miller, 2000, and Zaporozec, 2004; as cited in Pieter G van Dongen, 2014)



Zonation of the River Gambia Estuary Source: Njie & Corr 2006