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Availability and trends of water supply Network in sub-Sahara Botswana

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Abstract— *Water is an essential requirement for individuals and is one of the major keys of any financial improvement of the world social orders and a manageable utilization of this asset is of most extreme significance. Water shortage can have extraordinary effects with respect to the economy, advancement and national security of a nation and it is imperative to get a handle on the reason for the issue keeping in mind the end goal to explain it in the most productive way. By breaking down information time arrangement for temperature, precipitation and utilization and additionally playing out a spatial investigation over the catchment range it was conceivable to distinguish the progressions that have happened in the catchment territory, the atmosphere and the household utilization throughout the most recent decade. Poor information determination and an absence of factual noteworthiness imply that no solid conclusions can be drawn. The paper depends on various reports to demonstrate the accessibility patterns of water in the nation on the premise of interest and supply design.*

Keywords— ***water utility, dam, water level, quality, reservoirs.***

I. INTRODUCTION

Botswana is a landlocked, semi-bone-dry nation with a rough zone of 582 000 km² and has a populace of 1,680,863. It is situated in the focal point of Southern Africa. The most minimal parts of the level surface are Ngami territory and marshes of the Okavango River in the northwest, the salty skillet of Makgadikgadi in the upper east and the region between the Shashe and the Limpopo Rivers in the east. The Okavango and Chobe Rivers are the main perpetual streams with their sources outside the nation. A large portion of the streams and valleys are vaporous and normally dry aside from after downpours. In the focal parts of Kgalagadi, there are fossil valleys, made amid times of higher precipitation before. Botswana is a land-bolted nation straddling the Tropic of Capricorn in the focal point of the Southern African Plateau. Botswana is a dry nation endemic to dry spell. The country's capital city, Gaborone, is situated in south-eastern Botswana. A country with a high reliance on surface water, Gaborone is the same with, as of not long ago, the majority of the city's water being preoccupied from the Gaborone Reservoir [1]. Botswana's climate is semi-arid. Though it is hot and dry for much of the year, there is a rainy season, which runs through the summer months. Rainfall tends to be erratic, unpredictable and highly regional. Often a heavy downpour may occur in one area while 10 or 15 kilometres away there is no rain at all. Showers are often followed by strong sunshine so that a good deal of the rainfall does not penetrate the ground but is lost to evaporation and transpiration.

Fig. 1: location of Dams in Botswana

Figure 1 above shows the location of major dams in Botswana and the coverage. The major water supply in the capital Gaborone, the Gaborone Reservoir, has received a failed status during 2014 and 2015 due to diminishing water levels. As a sub-Saharan, semi-arid nation is no stranger to the discourse surrounding a sustainable water future, Water distribution within the country is uneven due to approximately 70% of the nation being covered by the Kalahari Desert, and drought is considered endemic to the country [2]. In summer during the morning period humidity ranges from 60 to 80% and drops to between 30 and 40% in the afternoon. In winter humidity is considerably less and can vary between 40 and 70% during the morning and fall to between 20 and 30% in the afternoon. Pula brings prosperity to the nation

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and the superstitious believes of many Batswana become more prominent during drought years [3]. In Botswana, water is mainly used for human consumption, wildlife, commercial, industry and institutional purpose although it varies per sector.

II. MANAGEMENT OF WATER NETWORK

The Water Utilities Corporation is a legislature possessed enterprise that gives water and waste water administration benefits in Botswana. The WUC was built up in 1970 to deal with a water supply and circulation extend in the Shashe Development Area. Today the WUC gives water to the urban communities of Gaborone and Francistown and the towns of Lobatse, Jwaneng, Selebi-Phikwe and Sowa. The WUC is economically self-sufficient, raising enough revenue from billing and subsidies to cover operational costs, investments and debt servicing.

The WUC is administratively divided into the South region based in Gaborone with Management Centers servicing the Gaborone, Mochudi, Lobatse, Molepolole, Kanye, Gantsi and Tshabong; and the North region based in Francistown with Management Centers servicing Francistown, Mahalapye, Palapye, Serowe, Selebi-Phikwe, Masunga, Maun and Kasane [4]. The WUC supplies bulk treated water to the Department of Water Affairs [5]. The Department of Water Affairs arranges distribution of this water and water from its own sources such as well fields to seventeen major villages. About half of the water delivered to the major villages comes from the WUC [6]. District Councils supply water to more than 200 smaller villages. Table 1 shows the Availability of Groundwater in Botswana as reported in statistics report 09.

Table 1: The Availability of Groundwater in Botswana (2008)

Cumulative			
Wellfield	Developed available resource (m3/d)	Resources developed (m3/d)	**Sustainable Resource (Mm3/yr)**
Dukwi	5700	5700	**0.039**
Palla Road	7500	13200	**1.46**
Ghanzi	1850	15050	**0.68**
Kanye	3950	19000	**1.44**
Letlhakane	1500	20500	**0.06**
Gaotlhobogwe	7500	28000	**5.84**
Palapye	4000	32000	**1.64**
Ramotswa	5000	37000	**1.83**
Serowe	6200	43200	**1.28**
Tsabong	2000	45200	**0.73**
Kang-Phuduhudu	7860	53060	**3.27**
Boteti	8950	62010	**1.96**
Maitengwe	9400	71410	**3.43**
Matsheng	9600	81010	**3.52**
Pitsanyane	1000	82010	**0.37**
Maun	8000	90010	**10.07**
Masama*	20480	110490	-
Botlhapatlou*	14000	124490	-
Bobonong* Cluster*	**3800**	**128290**	-

III. SOURCES AND STATISTICS OF WATER SUPPLY

The nation is provided with both surface and groundwater and the three fundamental water sources in Botswana are Dams, Rivers, and Boreholes. Mostly, Botswana has 10 dynamic dams. Letsibogo dam speaks to a major dam in Botswana as far as mean yearly repository yield. Its entire catchments are inside Botswana and have a territory of around 5 700km² with an expected mean yearly of 57 million cubic meters. The dam has a limit of 100 milion cubic meters and a yearly yield of 24 million cubic meters. One of the biggest dams, Gaborone Dam is a dam on the Notwane River in Botswana with a limit of 141,100,000 cubic metresThe Gaborone Dam became scarce without precedent for March 2015, as water levels dipped under 5 percent, leaving the capital and encompassing ranges dependent on the North-South Carrier and the Molatedi Dam, which gives 16 percent of its needs. Figure 2 shows the capacity of dams in mega liters.

Fig. 3- Comparison of dam levels on different years [15]

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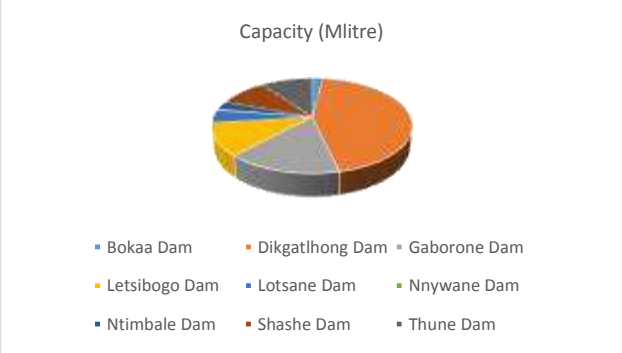

Fig. 2: Capacity wise dams in the counter

The city likewise attracts on wells encompassing towns for 25 million liters of water every day. The soonest that Gaborone can hope to have stable water supply is in 2017, after the finish of another pipeline from the north fit for pumping 120 million liters a day, and the expansion of well fields around the city, as per Mokaila. Longer-term arranges incorporate a Chobe-Zambezi pipeline by 2023 and supplies from the Lesotho Highlands extend, which is expected to be talked about in November by the legislatures of Botswana, South Africa and Lesotho [7]. Some of these incorporate the drafting of the National Water Conservation Policy and its related Strategy. Wide partner and open counsel has started and will proceed in year 2007 to cover all locale and sub-regions in Botswana. This Policy is an essential piece of the usage of the audited Botswana National Water Master Plan (BNWMP) and the National Development Plan 9 (NDP 9) and is a guide to better oversee water assets in the nation. The division has additionally drafted 'Controls for the supply of savoring water Botswana,' a report intended to relieve abuse, wastage and botch of drinking water supply in Botswana [8].

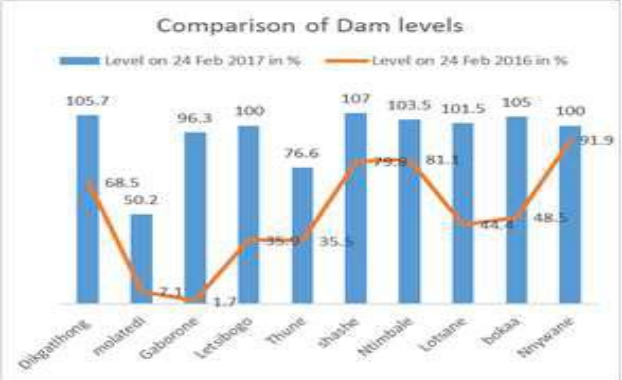

Fig. 3: Comparison of dam levels on different years [15]

According to the Population Projection 2001-2031 WUC served 414,020 (23 percent) of the total population of Botswana with water in 2008 and the population has increased by 11.4 percent from 366,626 in 2001 Population and Housing Census. Groundwater recharge is very limited, thus making the resource finite and non-renewable. Approximately 34 percent of the total water supply is from surface water, whereas the remainder (66 percent) is from groundwater. Figure 3 shows the level trends of dams on two different dates in 2017 & 16.Table 2 shows the Sources of water that supply the greater Gaborone area reported by WUC on 29 October 2015. It shows the peak demand of 145 ML/day, rational demand of 110 ML/day. Two dams were failed, which was the danger situation at that time.

Table 2: Sources of water that supply the greater Gaborone on 29 October 2015

	Dam level(%)	**Available supply**
Bokaa dam	2.0	0 (Failed)
Gaborone Dam	1.2	0 (Failed)
Nnywane Dam	50.00	2 million litres/day
Molatedi Dam	5.7	4.8 million litres/day
North South Carrier scheme I		60 million litres/day
Masama wellfield		20 million litres/day
Ramotswa wellfield		5 million litres/day
Total available supply		92.10 ML/day
Deficit		17.90Ml/Day

However, surface water accounts for 90 percent of the total supply of water in urban areas such as Gaborone, Lobatse, Francistown and Selibe-Phikwe. Apart from major rivers such as Chobe and Limpopo tributaries, the Okavango Delta is one of the most important wetlands in Botswana and forms a major part of the surface water resources in Botswana [9].

IV. WATER QUALITY ISSUES AND CONTROL

Botswana Bureau of Standards (BOBS) has built up furthest breaking points and ranges for substance levels suitable in drinking water. In 2015, United Nations Special Rapporteur on Human Right to Safe Drinking Water and Sanitation, Léo Heller as of late discharged a scorching report throwing defamations on the nature of savoring water Botswana. In 2013 the American Embassy in Gaborone issued an inner update to its staff cautioning them not to drink tap water in Gaborone as it was risky to drink. In a condemning preparatory report, Heller watched that as indicated by authority information gave by the Water Utilities Corporation (WUC), the consistence level of microbiological examination of eight out of 34 observing ranges in the time of July to September this year was beneath 50 percent. He additionally said there was no breakthrough observing information accessible in three

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other checking regions. Heller likewise watched that while the WUC screens the water nature of boreholes not associated with the system, the data of the individual boreholes is not announced or not effectively accessible [10].The Water Conservation and Quality division is one of the technical divisions within department of Water Affairs. It is primarily charged with coordinating and facilitating water conservation, protection and quality issues for the 17 major village water supplies. However, its mandate is extended to other villages throughout the country. It is increasingly becoming evident that additional planning tools and water conservation and protection measures are needed in the quest to safeguard and utilize the scarce water resources in the most beneficial and optimal ways. The continuous water and waste water quality monitoring of our water resources thus proves to be a necessity, coupled by introduction of various technologies to effectively implement the water conservation and protection measures and practices countrywide [8].

Table.3: Chemical Tests Results for and Gaborone by WUC Source-BWS October 2009

Chemical	**Gaborone**		
	Average	Minimum	Maximum
Alkalinity as CaCO3, mg/L	120.53	88.37	156.77
Bromide Br mg/L	<0.05	<0.05	<0.05
Calcium Ca, mg/L	20.31	10.40	41.93
Calcium Hardness as CaCO3, mg/L	42.57	9.22	61.00
Chloride, CI mg/L	7.50	4.16	10.93
Conductivity uS/cm	211.34	134.83	281.50
Fluoride, F mg/L	0.54	0.16	1.03
Iron Fe, mg/L	0.27	0.06	0.49
Magnesium Mg, mg/L	8.46	4.28	19.40
Manganese Mn, mg/L	0.01	0.00	0.03
Nitrate NO3, mg/L	0.43	0.17	0.65
Nitrite NO2 mg/L	<0.1	<0.1	<0.1
pH	7.71	7.26	8.06
Phosphate PO4, mg/L	<0.2	<0.2	<0.2
Potassium K, mg/L	4.96	0.68	9.80
Sodium Na, mg/L	10.34	5.22	16.51
Sulphate SO4, mg/L	3.79	1.96	6.41
TDS	137.37	87.64	182.98
Temperature,Celcius	21.30	3.20	27.20
Total Hardness as CaCO3, mg/L	86.25	63.08	122.72
Turbidity NTU	0.44	0.09	0.90

Table 3 shows the chemical analysis of water for quality measures. It indicated the Alkalinity as CaCO3, mg/L 156.77 maximum value while Calcium Hardness as CaCO3, mg/L is 61.00. Table 4 shows the Gaborone Microbiology Total Analyses Microbiology Results for Water Supplied by WUC. As per the water statistics report 2009, *t*he assessments for both microbiology and chemical contents are done once each week for small cities this is Sowa, Lobatse, and Jwaneng and two times a week for bigger towns and towns particularly Gaborone, Francistown and Selibi-Phikwe. Testing is also finished day by day on the plants. On common they checks approximately 3500 to 4000 microbiological and chemical samples from its distribution network and any other 1500 to 2000 from the vegetation annually, which translates to between 6 to eleven instances the minimum requirement of the BOS 32: 2000.

Table.4: Gaborone Microbiology Total Analyses (source-water statistics 09)

Determinants (count/100 m1)	**Total Analyses**	**BOS 32:2000 4% Max Allowable Compliance**	**Non Compliance with 4% Max Allowance Compliance**	**BOS 32:2000 1% Max Allowable Compliance**
Total Coliform	1602	10	45 (2.8%)	100
Faecal Coliform	1602	1	6 (0.37%)	10
Faecal Streptococci	1602	10	0	100

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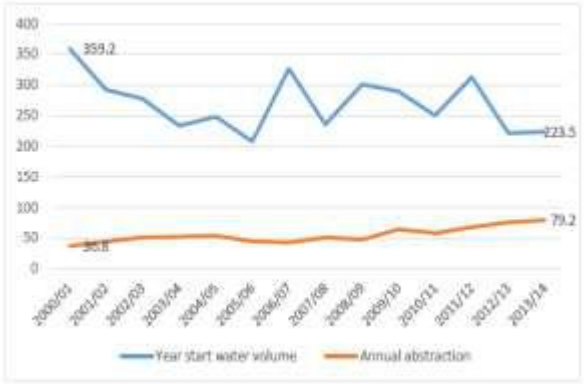

Fig. 4: Water stored in and abstracted from dams (Mm^3)

Figure 4 shows the volume of water stored in major dams at the beginning of the year and annual water abstraction from the dams. The opening volume shows a decreasing trend while abstraction is increasing, putting more pressure on the dams. WUC also faces operational challenges including ageing water supply infrastructure, vandalism, treatment plant deficiencies, weak human resource capacity, poor network maintenance, and poor customer data resulting in poor service delivery and statutory hurdles which affect the pace of capitalization of the system [16].

V. CONCLUSION

Groundwater is a vital water resource for domestic, industrial, mining and livestock needs, and turns out to be much more vital amid dry season when surface water sources go away. Around 60% of water requests are met from ground water sources and potable water from dams. The intense lack of water in Botswana presents open doors for differentiating sanitation. Choices to incorporate dry sanitation with added advantages to the farming part through dry manure. This waterless sanitation choice speaks to a huge greening of the economy. Included advantages incorporate the decrease in expenses to the meat business right now forced by measles and other parasitic veterinary infections brought on by steers coming into contact with human faucal matter in rustic Botswana. Overseeing request makes accessible a similar measure of water at a lower cost in this way making the economy more productive. The water asset administration methodology would be, with or without environmental change, to join both free market activity measures guided by minimum cost. Request measures have a tendency to be less expensive to execute, in this way these could be researched first. On the supply side, water reusing will presumably be the least expensive, most doable choice. Borehole water advancement, combined with desalination are expensive however could be considered in the long haul. Between bowl exchanges and imports are long haul measures which ought not to be discounted, but rather require territorial participation and consequently ought to dependably be considered in the arranging procedure. On the off chance that the water emergency proceeds with, a decrease in endowments might be inescapable as capital must be infused into different divisions, for example, the change of water foundation. This could huge affect country's improvement including the way of life of a large number of its occupants. Due to the scarcity of water and less rainfall pattern, an awareness program to save the water, more use of rain water catchment system, desalination must bring in practice.

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