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Modelling Water Demand and Usage Within a Catchment Area Using WEAP

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ABSTRACT

Water is demanded in varied quantities from streams and rivers to meet daily needs in the home, environment or surroundings. This water is fetched by children, women or individuals for drinking, washing, cooking, bathing, cleaning etc. This same water is used for irrigation, hydropower generation, abstracted for treatment and distribution to citizens. It is also used for fishing, used in the industry for cooling and manufacturing purposes and so on. It therefore becomes appropriate to model water demand and usage within a catchment area for decision making when it comes to real time water demand, usage, sustainability and protection of rivers such as River Birim, Supong, Pra, Ankobra, Densu and river Volta for future generation. Using WEAP software, water is modelled by generating scenarios and results to justify that about 90% water demands activities and usage occur within Supong River and River Birim catchment area. And even though water demand is met, a certain level of contamination is attained hence requiring treatment before usage among water users. The research has established that modelling with WEAP software is an effective tool for future scenarios generation towards preparation, planning, awareness creation and effective management of the economic good for the now and future generations.

Keywords: catchment, modelling, demand, WEAP, scenarios, water, runoffs, resources, management.

1 INTRODUCTION

The demand for water for daily activities is unmet in this current Ghana and if met, with certain level of contaminations which requires treatment before usage. The treatment requirement is due to the level of contamination by illegal activities such as illegal gold mining, runoffs from storms carrying varied amount

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of refuse deposited in drains and drained into streams and rivers as runoffs. These runoffs ends up in streams given different degrees of water with contaminants which requires treatment before usage. River Volta has water of varied amount at different locations which is used for different activities depending on needs. Some of these activities includes for irrigation, hydropower generation, for fishing, building construction, drinking etc. Surface water accessibility within the eastern region has now become a problem due to the destruction of surface water bodies by illegal gold mining activities. This has resulted in about 90% dependent on ground water abstraction and usage in most towns and communities in the eastern region. In the 1990's, rivers such as river Birim, river Akrusu and Supong at Osino and Nsutem respectively were used for drinking, cooking, bathing, washing, fishing, irrigation etc to promote daily activities and human existence. With all these uses taking place, illegal gold mining was in place in the towns. This is not same in 2022 as these rivers have been destroyed due to illegal gold mining activities. The demand for water within most communities and towns in the eastern region to meet such water demands is now a big problem which requires serious attention and resolution in saving the future of water for the next generation. The future of surface water in Ghana is poor due to man's quest for riches through gold mining in Ghana hence the need to safeguard it. The interrelationship that exist between ground water and surface water can result in the contamination of ground water if all surface waters are contaminated to a higher degree within these areas. Ground water abstraction for usage in the homes will hence come with contaminants which will pose health treats to all users.

Water is demanded at various points on a river channel for various activities. The demanded activity suggests the quantity, quality and amount of water to be used or abstracted for usage. The amount of water needed for hydropower generation will not be same as for irrigation, drinking, washing or for cooling in industries. Priority characterization plays a major role when looking at water demands on a river channel. Water to meet physiological needs is at a higher priority compared to water for running industries within a locality or community and same as for hydropower generation. Each purpose for water use and the associated demands because of contamination, quality and treatment option for further usage. Water therefore cannot be used to run industry, generate waste and effluents and discharge them back into streams to be used for drinking, washing and cooking by downstream users. If this is done, it will result in sickness of the indigenous or downstream users hence the need for prioritization during demand analysis on streams and rivers. Rivers in Ghana will continue to have varied amount of water running downstream to users. But there is the need to work at quality, avoid illegal activities within the catchment areas of such

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rivers and promote river banks protection to extend the life and future of such river bodies.

Modelling therefore is of utmost importance to obtain scenarios and results which are likely to take place when it comes to the existence, running, operation and maintenance of such river bodies for the future. This will help make knowledgeable decisions on water bodies and water resources for the good management of water resources in Ghana. All water bodies in Ghana are of great importance to the welfare of the country as a natural resource. There is therefore the need for best management practices that will keep and maintain the life and existence of the water body for now and future. Such best management practices can only be generated or obtained through modelling tools to forecast for the future. Forecasting for the future depends on historical data, past results, current state of affairs of the river or water body and readjustment to meet future demands. The readjustment and prediction should be in such a way that, future results are obtained to a higher degree of accuracy with minimal errors. Prediction through modelling cannot be exact but should yield results which will save future negative impacts and promote the well-being of the water resources sector and save our river bodies. This is the reason for the modelling of demand and water usage on our river bodies. Water will be demanded at various points on any river channel and will require right usage or abstraction mindset to obtain the needed amount whiles safeguarding the life of the river for now and generations to come.

2 REVIEW OF RELATED WORKS ON WATER MODELLING

2.1 Water Use and Demand

2.1.1 Water Use

Water use is described in three terms namely withdrawals or abstractions, consumptive water use and non – consumptive water use. Withdrawals or abstractions signifies water taken from a surface or groundwater source, and after use returned to a natural water body, e.g. water used for cooling in industrial processes that is returned to a river. Such return flows are particularly important for downstream users in the case of water taken from rivers (Wallingford et. al., 2003).

Consumptive water use or water consumption represent a withdrawal or an abstraction from a river or stream but in this case without any return flow. Water consumption is the water abstracted that is no longer available for use because it has evaporated, transpired, been incorporated into products and crops, consumed by man or livestock or otherwise removed from freshwater resources. Water losses during the transport of water between the points of abstractions and the point of use, (e.g. resulting from leakage from distribution pipes), are excluded from the consumptive water use figure. Examples of consumptive water use include steam escaping into the

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atmosphere and water contained in final products i.e. it is water that is no longer available directly for subsequent uses by consumers (Wallingford et. al., 2003).

The third water use is the Non-consumptive water use. The is where water use involves the use of a water body for navigation, instream flow requirements for fish, recreation, effluent disposal and hydroelectric power generation (Wallingford et. al., 2003).

2.1.2 Water Demand

Water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water consumption, although conceptually the two terms do not have the same meaning. This is because in some cases, especially in rural parts of southern Africa, the theoretical water demand considerably exceeds the actual consumptive water use (Wallingford et. al., 2003). Water demand is dependent on specific requirements and activity. Water demand points on river channels needs to be ascertained and identified correctly before abstraction for usage in order not to have effect on downstream users. This is not the case on most rivers in Ghana as upstream users on most river bodies like River Birim, river Densu, river Supong, river Akusu generates contaminated water for downstream users. This gives polluted water which cannot support activities like irrigation, washing, drinking etc within the communities. All these negative impacts is as a result of illegal gold mining and deposit of debris and release of effluents into the water bodies. This has reduced the demand points along such river bodies because of the pollution level at various points. This has also increased the cost of production by Ghana Water Company Limited (GWCL) who is one of the main users of these water bodies within the sub – region to produce good quality water for the homes and industries.

2.2 Water management within a catchment area

An important purpose of water management is to match or balance the demand for water with its availability, through suitable water allocation arrangements. Within a catchment and sub-catchment level there is a large number of often conflicting of water uses including; Irrigation, Domestic use in urban centres, Domestic use in rural areas, Livestock, Industrial use, Commercial use, the environment (e.g. instream flow requirements for aquatic life and wildlife), Institutions (e.g. schools, hospitals), Hydropower, Cooling (e.g. for thermal power generation), Waste and wastewater disposal, Fisheries, Recreation, Navigation (Wallingford et. al., 2003). Management of the water within a catchment should be holistically done as contamination of water upstream affects downstream users.

Catchment development in terms of water resources management is only feasible if there is sufficient water to support it. Water resources are often now the limiting factor to future development. The potential for new sources or increased

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storage either within or outside the catchment may also be considered to improve the water resources potential if supported by water managers. The schedule for the development of these and other water resources infrastructure must also be considered to ensure that the infrastructure is in place when needed. This should be part of the planning process when it comes to water resources management within the catchment (Wallingford et. al., 2003). Water demand forecasts are tied directly with catchment planning and their relationship should be cyclical, as the forecasts are based on expected development and growth in the catchment. As part of demand management, the potential for improving efficiency in distribution or otherwise reducing demands must be assessed as this can make significant differences in the resource potential of the catchment. It is necessary to forecast water demand in order to regulate and control abstraction and contamination so that demands will be met all year round (Wallingford et. al., 2003). Once this is done, demands at all demands points along the river channel will be met and then within the catchment area as a whole.

2.3 Demand to supply correlation within a catchment area

Water is demanded in varied quantities within a catchment all year round by different users. Such water is abstracted to meet conflicting uses in order to meet the demand needs. Supply is hence done by the river body to meet these needs. There is the need for a balance between demand and supply so that the water body will not die but will be a sustainable entity to meet demands all year round within the catchment. Water allocation is not generally an issue when water availability far surpasses water demand. In such situations all demands can be satisfied, and in there may be no need for a regulated allocation of water. However, this is not the case for the majority of the catchments in southern Africa. In most catchments in southern Africa water availability is frequently less than the demand for it. It is then necessary to find a suitable allocation of the scarce water to meet demands (Wallingford et. al., 2003).

2.4 Estimating household water demand in other countries

The estimation of household water demand functions in developed countries has been the focus of many empirical papers, starting with the work of Gottlieb (1963) and Howe and Linaweaver (1967). Studies have been made in a large number of countries, including Australia (Grafton and Ward, 2008), Canada (Kulshreshtha, 1996), Denmark (Hansen, 1996), France (Nauges and Thomas, 2000), Spain (Martínez-Espiñeira, 2002), Sweden (Höglund, 1999), and especially the United States (Foster and Beattie 1979; (Agthe and Billings, 1980); (Chicoine and others, 1986); (Nieswiadomy and Molina, 1989); (Hewitt and Hanemann, 1995); (Pint, 1999; Renwick and Green, 2000). One needs to estimate household water demand in order to know the total quantity of water consumed by a family within a period and the total quantity needed to be abstracted, treated, stored and distributed. It also gives an idea about the need for a water

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storage system for the home and the quantity to be stored at a time t in case of power outages, problem with distribution networks. The season (dry or rainy) also plays a role in this regard as rate of evaporation on water bodies is high during this dry seasons reducing quantity of water in the water body. This affects the quantity abstracted for treatment, storage and distribution to homes. In almost of all studies performed in industrialized countries, the residential water demand function is specified as a single equation linking (tap) water use (the dependent variable) to water price and a vector of demand shifters (household socioeconomic characteristics, housing features, climatologic variables, etc.) to control for heterogeneity of preferences and other variables affecting water demand (Whittington et. al., 2010).

2.5 Modelling water demand and use

The selection of analytical techniques for developing estimates of future water withdrawals (plus purchases for resale by public water systems) was dictated by the type of data on actual water quantities and the corresponding data on explanatory variables available for each sector of water demand. The two principal techniques used in this report were the unit-use coefficient method and multiple regression (Scott et. al., 2019). The general approach to estimating future water demand can be described as a product of the number of users (i.e., demand driver) and unit quantity of water as;

$$Q_{cit} = N_{cit} \times q_{cit} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

where:

Q_{cit} = water withdrawals (or demand) in user sector c of study area i in year t; N_{cit} = number of users (or demand driver) such as population, employment, agriculture, or head of livestock; and q_{cit} = average rate of water requirement (or water usage) in gallons per capita-day, gallons per employee-day, and so forth (Scott et. al., 2019).

The unit-use coefficient method assumes that future water demand will be proportional to the number of users N_{cit}, while the future average rate of water use, q_{cit}, is usually assumed to remain constant or is changed based on some assumptions. Modeling of water demand usually concerns the future changes in average rate of water usage, q_{cit}, in response to changing future conditions (Scott et. al., 2019). Water-demand relationships which quantify historical changes in q_{cit} can be expressed in the form of equations, where the average rate of water usage is expressed as a function of one or more independent (also called explanatory) variables. A multivariate context best relates to actual water usage behaviors, and multiple regression analysis can be used to determine the relationship between water quantities and each explanatory variable. The functional form (e.g., linear, multiplicative, exponential) and the selection of the independent variables depend on the category of water demand (Scott et. al., 2019).

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For example, public supply withdrawals can be estimated using the following linear model:

$$PS_{it} = a + \sum_{j} b_j X_{jit} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:

PS_{it} = per capita public supply water withdrawal within geographical area i during year t; X_j = a set of explanatory variables (e.g., air temperature, precipitation, price of water, median household income and others) that is expected to explain the variability in per capita use; and ε it = a random error term (Scott et. al., 2019). The coefficients a and b_j can be estimated by fitting a multiple regression model to historical water-use data. The actual models used in this study were specified as double-log (i.e., log-linear models) with additional variables that served to fit the model to the data and also isolate observations that were likely to be outliers:

$$lnPS_{it} = a_o + \sum_{j} \beta_j lnX_{jit} + \sum_{k} \gamma_k lnR_{kit} + \varepsilon_{it} \ldots\ldots\ldots (3)$$

where:

PS_{it} = per capita public supply water withdrawals (plus purchases) within geographical area i during year t (in gallons per capita per day); X_j = a set of explanatory variables; R_k = ratio (percentage) variables such as ratio of employment to population; ε_{it} = random error; and α_o, β_j, and γ_j = parameters to be estimated (Scott et. al., 2019).

Many econometric studies of water demand have been conducted during the past 50 years. A substantial body of work on model structure and estimation methods was also performed by the USGS (Helsel and Hirsch, 1992). The theoretical underpinnings of water demand modeling and a review of a number of determinants of water demand in major economic sectors are summarized by Hanemann (1998). Useful summaries of econometric studies of water demand can be found in Boland et al. (1984). Also, Dziegielewski et al. (2002) reviewed and summarized a number of studies of aggregated sectoral and regional demand (Scott et. al., 2019).

3 METHODOLOGY EMPLOYED FOR THE RESEARCH

The adopted method for this research work involves the review of related works on modelling of water demand and usage based on historical data. Then the **WEAP** (**WATER EVALUATION AND PLANNING SYSTEM**) software is used to model water demand and usage within a town and at various demand points on a river channel based on experimented data obtained for the analysis. Results are then used to generate and predict scenarios of activities likely to occur in big city on river bodies such as river Birim, river Densu, river Ankobra, river Akusu, and river Supong when dealing with demands and usage within a catchment area in the future.

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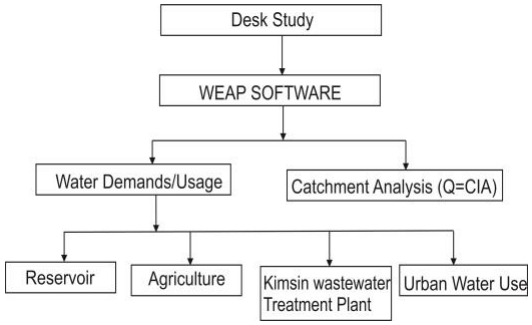


Fig 1: Employed methodology for the modelling

4 RESULTS AND DISCUSSIONS

4.1 Water demand points

Fig. 2 gives the schematic view of the modelling process. It gives a clear picture of the various demand points on the main River. The demand points includes big city, agriculture, Kimsin treatment plant and a reservoir downstream of the main River. Water is needed for domestic use by the big city for (drinking, bathing, cooking) and other purposes such as gardening, building construction, watering of lawns etc. This same water is need for irrigation purposes especially during the dry season by the agriculture sector. Ghana as country experiences two main seasons; rainy season and dry season. During the rainy season, the country receives varied amount of water from irregular daily rainfalls. Homes within the study areas makes use of barrels and cans to store this water for daily usage.

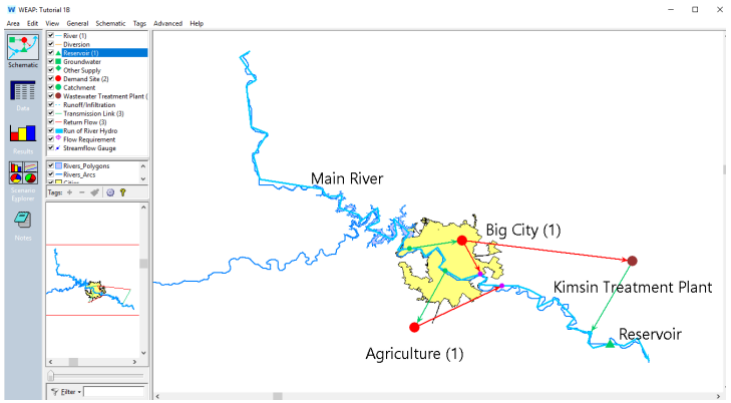


Fig 2: Schematic view of the modelling

Most of the rains goes wasted since homes within a community do not have enough rain harvesting storage facilities to store the rain water. Again, homes have not designed any rain harvesting facility or structure to collect enough water which can be used for about 2 – 3 weeks hence the need to turn to water bodies (Main Rivers) as a source of water and demand point. Irrigation is also identified as a strong demand point especially during the dry season. Farmers have farmlands along rivers and lakes such as along River Birim, Akrusu, Supong, the white and black Volta. Farmers therefore makes use of pumping machines which is usually provided by NGO's and other bodies to pump the water from the river and use it for irrigation. Farmers are usually put in groups to make use of the water pumping machines based on closeness of farmlands along the river. Treatment plant is also sited downstream of the main river to treat all contaminated

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water from the big city and channeled into a reservoir for storage to be used during mean periods of the season.

4.2 water use by big city and for agriculture

Water as an economic good is needed by man within the big city and for agriculture to meet the basic physiological needs in the homes and within the environment. **Fig. 3** gives a clear picture of the monthly water variations when it comes to demand by big city and for agriculture purposes. The monthly variation of water use is from January 2000 to October 2015. The above years are modelled to analyze the monthly water variations when it comes to the use of water by big city and for agriculture purposes. The variation for the big city ranges from 7.5 to 9.6 percentage share. This means that the demand for water by big city is within acceptable range hence will not have a negative repercussion on the main river. The demand for use by agriculture ranged from 0 to 30 (% share) percentage share. Which is also within acceptable demand range hence will not impact the main river negatively. This figures were generated for higher population growth (2001 – 2015). By result analysis, population will increase as the years go by, demanding for pressure from the big city and agriculture on the main river. This calls for strategic use of water from the main river even though a water treatment plant exist downstream of the main river to treat all contaminated water leaving the city. Agriculture demand should also contribute to water obtained for treatment by the Kimsin's treatment plant as can be seen in Fig. 2. It can clearly be seen that, demand by the big city to meet physiological and daily needs is higher than that demanded by the agriculture sector and so will it be as population increases in the future.

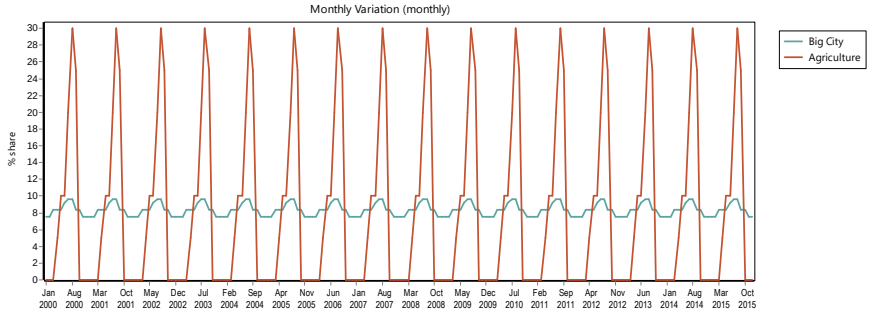


Fig 3: Monthly variation for water use (Demand by big city and agriculture

Fig. 4 and **Fig. 5** gives a fair idea about the annual activity level for water use for Referenced scenario (2001 – 2015) and Annual activity level for water use for Higher Population growth (2001 – 2015) respectively. The annual activity level for water used by the big city for the reference scenario ranges from 891,688.1cap in 2001 to 1,209,276.2cap in 2015. Depicting by the graph below gives a clear indication of yearly increment in the annual activity level for water use for the referenced scenario. This means that, as population increases within communities and in Ghana in the future, the demands for water will increase. This is good statement for the water sectors to look at water resources management for stakeholder participation including community members or beneficiaries. The increment for the referenced scenario is gradual as depicted in **Fig 4**. The same cannot be said

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for the annual activity level for water use for high population growth (2001 – 2015). The annual activity level for water used by the big city ranges from 916,117.9 cap in 2001 to 1,813,850.7cap in 2015. High population growth scenario gives higher annual activity level compared to the referenced scenario. It is justified to say that, internal migration to seek greener pastures will increase population within the big cities in future resulting in an increase in water demand by the big city. The agriculture sector level is expected to see a sharp increase in yearly demand for water especially during the dry season. Farmers need to be cautious in the use of pumping machines in abstracting water from the main river in order to meet household demands.

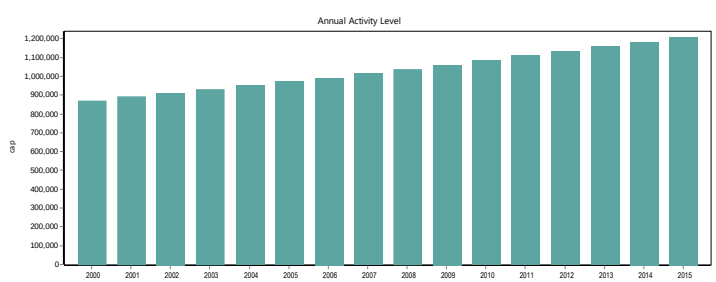


Fig 4: Annual activity level for water use for Referenced scenario (2001 – 2015)

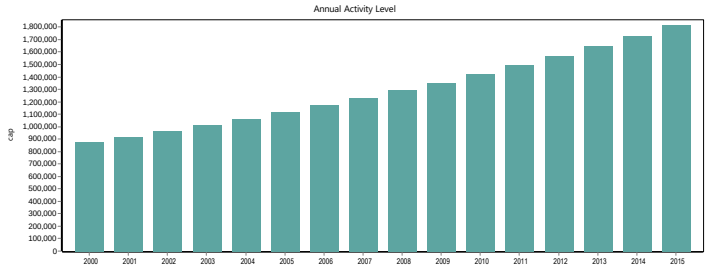


Fig 5: Annual activity level for water use for Higher Population growth (2001 – 2015)

4.3 Kimsin Treatment Plant as a demand point

Every city needs water and so is the big city in this modelling. The big city gets water from the main river and this water is used to meet various water demands in the homes, streets, market and work places. The obtained water is used for domestic purposes, run turbines to produce electricity, run factories and industries in the production of goods and services. All these demand points contribute to water used by the city. The city therefore generates thousand meter cubes of contaminated and pollutant effluents which are released into drains and septic tanks for disposal. All these polluted water are collected and channeled to the Kimsin treatment plant for treatment and recycling. The monthly waste water received ranges from 4,500% share to 8,967.6% share as depicted in **Fig. 6**. Caution needs to be taken in order not to pollute the water upstream as downstream users also need the water to meet daily household's needs. The treated water is released back into the main river whiles some are used for other

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purposes. This is good thing in this modelling and Ghana should research into how to recycle polluted water and channeled back into other streams to increase the amount of water in the river for downstream users. Kimsin's treatment plant ensures that the water is safe and well treated before releasing into the main river. **Fig. 7** indicates the daily capacity of water generated by the big city and conveyed to Kimsin treatment plant for treatment and usage. It gives a clear picture that, water is used in varied amount in different places which generates daily contaminated water hence becoming a source and an input parameter for the existence and sustenance of Kimsin treatment plant.

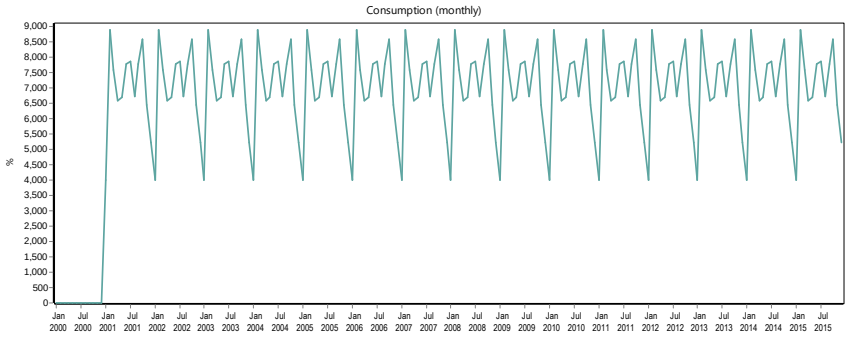


Fig. 6: Kimsin Treatment plant monthly consumption rate

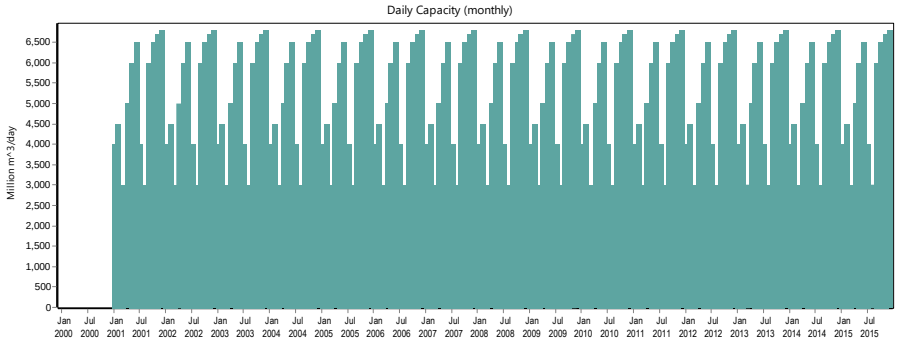


Fig 7: Daily capacity of water for Kimsin Treatment plant

4.4 Domestic, irrigation water needs and water year

Abraham Maslow's theory of needs talks about the first and foremost which is the physiological needs which needs satisfaction before any other need. People in the big city **(Fig. 2)** need water and food before thinking of the other needs. Water therefore becomes a necessity which the big city cannot do without. The big city therefore gets water from the main river to meet this needs and other needs. The domestic and irrigation daily water needs from the river ranges from 450m^3 to 3500m^3 by volume as depicted in **Fig 8**. Daily irrigation needs are met especially during the dry seasons. During the rainy seasons, the big city receives varied amount of water which is collected and stored for days or weeks. This help reduce the pressure on the main river. Abstraction for irrigation purposes also reduces as plants receives water on daily and weekly basis during the rainy season. High volumes of demand for water is usually obtained

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during the dry seasons as can be seen in **Fig. 9** where dry and wet (seasons) have been plotted against normal season.

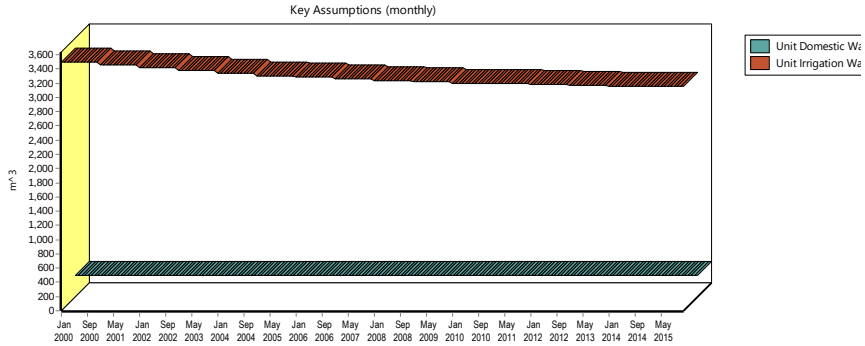


Fig 8: Domestic and irrigation water needs from river

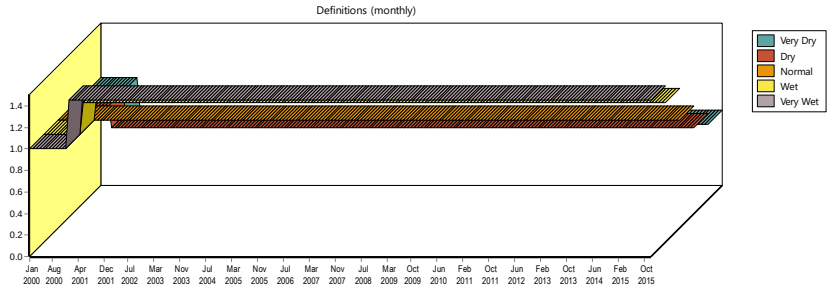


Fig. 9: Water year type relative to normal water year

4.5 River Headflow and storage capacity of Reservoir

By definition, headflow is the flow at the head of the main river. In this modelling, it is assumed that the main river takes it source from somewhere and headflow determined to know the amount of water entering the city for modelling and analysis. The headflow ranges from 4.9m^3 to 108.8m^3. The headflow is very small during the mean periods of the season and high during the rainy seasons as depicted in **Fig. 10**. In WEAP, when one draws a river, it has a place where it starts (as depicted in **Fig. 2**). Headflow in WEAP is the value of the flow in the first reach of the modelled river. Natural rivers trickle into existence in elevated areas, so headflow is usually difficult to measure in real life.

Fig. 11 is a diagram showing the water storage capacity of the reservoir in this modelling. Reservoir is an artificial lake where water is stored for future use. The reservoir in this modelling is formed by constructing a dam across the main river. Reservoirs can also be formed from a natural lake whose outlets has been dammed to control the water level. The dam controls the amount of water flowing downstream to users. People have been creating reservoirs for thousands of years. The oldest known dam in the world is the Jawa Dam in what is now Jordan. It was built in about 3000BCE to store water to be used for irrigation. Since then, different sizes of dams have been constructed to store and distribute water for all kinds of uses worldwide. In this modelling, a reservoir is built on the main river because the amount of water in the main river varies over time. During very wet periods as in **Fig. 9**, the water in the main river rises and sometimes overflows its banks. By limiting the amount of water allowed to continue moving downstream to users, reservoir help control flooding. In this modelling, the reservoir

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storage capacity ranges from 56000Mm^3 to 150000Mm^3. The modelling assumed that, water in reservoir during mean periods should be able to meet the activities within dry season until the wet season begins.

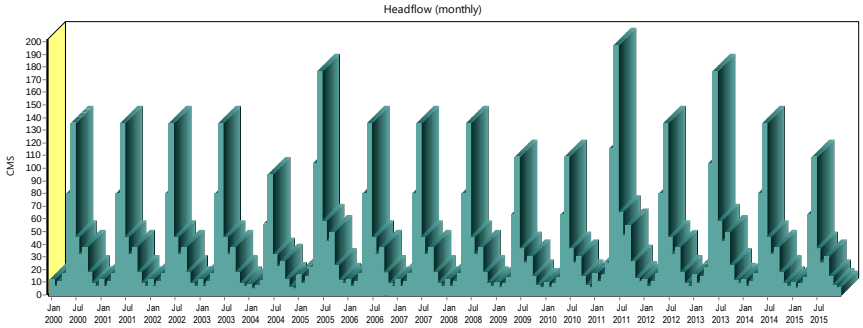


Fig. 10: Main river head flow

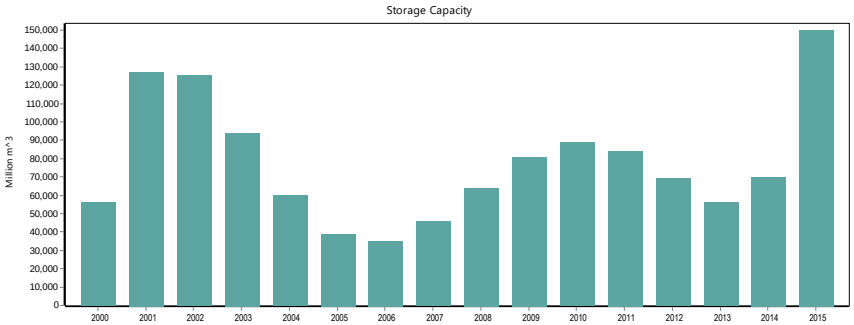


Fig 11: Reservoir Storage Capacity

5 CONCLUSION

Water demand within a catchment is subjective and will continue to soar to high levels as people try to get access to water for effective house management, running of factories and industries, for irrigation, hydropower generation and other needs. Water plays major roles in our daily lives hence the demand for water for all the purposes indicated above will continue. This calls for constant preparation and effective water resources management and practices in order to protect the water body and economic good while using it in an efficient manner for now and the future. This modelling has made it clear that, population will continue to increase as people migrate to inner cities for better job placement and opportunities. Such migrations to cities will put pressure on utilities such as water as established by this work hence pressure on water demands from major water bodies in the cities in Ghana. Once a while it is imperative to simulate and model such activities like water demand and usage within a catchment to get better understanding of the use of water, the various demands points, recycling process and usage of water. The modelling therefore gave a clear sense of direction when it comes to the availability of the resources (water), good management practices, protection and usage. This modelling has made it clear that headflow from rivers such as Birim, Densu, Pra, Akrusu, Supong should be estimated and modeled to know the amount of water flowing into a catchment area as this gives clear understanding of future scenarios which can affect the water sector and its availability for all. Through such modelling, water users, water

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managers and investors will predict or forecast into the future water demand, usage and prepare for it. By this assertion, the research has established that modelling is an effective tool for future scenarios generation towards preparation, planning, awareness creation and effective management of the economic good for the now and future generations.

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REFERENCES

Gottlieb, M. 1963. "Urban Domestic Demand for Water in the United States." Land Economics 39(2):204–210.

Grafton, R. Q., and M. Ward. 2008. "Prices versus Rationing: Marshallian Surplus and Mandatory Water Restrictions." The Economic Record 84: 57-65.

Kulshreshtha, S. N. 1996. "Residential Water Demand in Saskatchewan Communities: Role Played by Block Pricing System in Water Conservation." Canadian Water Resources Journal 21(2):139–155.

Hansen, L. G. 1996. "Water and Energy Price Impacts on Residential Water Demand in Copenhagen." Land Economics 72(1):66–79.

Nauges, C., and A. Thomas. 2000. "Privately-operated Water Utilities, Municipal Price Negotiation, and Estimation of Residential Water Demand: The Case of France." Land Economics 76(1):68–85.

Martínez-Espiñeira, R. 2002. "Residential Water Demand in the Northwest of Spain." Environmental and Resource Economics 21(2):161–187.

Höglund, L. 1999. "Household Demand for Water in Sweden, with Implications of a Potential Tax on Water Use." Water Resources Research 35(12):3853–3863.

Foster, H. S. J., and B. R. Beattie. 1979. "Urban Residential Demand for Water in the United States." Land Economics 55(1):43–58.

Agthe, D. E., R. B. Billings, J. L. Dobra, and K. Raffiee. 1986. "A Simultaneous Equation Demand Model for Block Rates." Water Resources Research 22(1):1–4.

Chicoine, D. L., S. C. Deller, and G. Ramamurthy. 1986. "Water Demand Estimation under Block Rate Pricing: A Simultaneous Equation Approach." Water Resources Research 22(6):859– 863.

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ISSN: 2235-767X

Volume 10 Issue 12

December 2022

Nieswiadomy, M. L., and D. J. Molina. 1989. "Comparing Residential Water Demand Estimates under Decreasing and Increasing Block Rates Using Household Data." Land Economics 65(3):280– 289.

Hewitt, J. A., and W. M. Hanemann. 1995. "A Discrete/Continuous Approach to Residential Water Demand under Block Rate Pricing." Land Economics 71:173–192.

Pint, E. 1999. "Household Responses to Increased Water Rates during the California Drought." Land Economics 75(2):246–266.

Renwick, M. E., and R. Green. 2000. "Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies." Journal of Environmental Economics and Management 40(1):37–55.

Whittington, D., Nauges, C., 2010, Estimation of water demand in Developing countries; Overview, Article in the World Bank Research Observer.

Wallingford H. R. and the Department for Water Development, Ministry of Rural Resources and Water Development (Zimbabwe) 2003, Handbook for the Assessment of Catchment Water Demand and Use.

Scott C. M. P.G., Dziegielewski, B., Zhenxing Z., Abrams D., Walton R. K., 2019, Water Demand in the Rock River Water Supply Planning Region, 2010-2060, Contract Report 2019 -02.

Helsel, D.R., and R.M. Hirsch. 1992. Statistical methods in water resources. Elsevier, Amsterdam, The Netherlands.

Boland, J.J., B. Dziegielewski, D.D. Baumann, and E.M. Optiz. 1984. Influence of Price and Rate Structures on Municipal and Industrial Water Use. U.S. Army Corps of Engineers, Institute for Water Resources Report 84-C-2, Ft. Belvoir, VA.

Hanemann, W.M. 1998. Determinants of urban water use. Edited by D.D. Baumann, J. Boland and W.M. Hanemann. McGraw-Hill, New York, NY.

Dziegielewski, B., S. Sharma, T. Bik, X. Yang, H. Margono, and R. Sa. 2002. Predictive Models of Water Use: An Analytical Bibliography. Department of Geography and Department of Economics, Southern Illinois University, Carbondale, IL.

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