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NBI Technical Reports: Water Resource Management Series

Projection of Municipal and Industrial Water demands for the Nile Basin

WRM-2020-08

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Document Sheet

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The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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Executive Summary

Municipal and industrial demand projection for the Nile Basin countries

Like many regions across the globe, the Nile Basin countries face an increasing challenge of water resources allocation for their growing and competing supply needs in different sectors: agricultural, municipal and industrial, hydropower, navigation, water quality as well as meeting environmental needs to mention some. In addition, climate change induced rising temperature and reduction and/or shifting rainfall patterns across much of the basin will exacerbate the challenge.

While traditionally most of the efforts have focused on assessment of adequate water supply and understanding its spatial-temporal changes, an integrated basin wide management cannot be considered without understanding water demand for different sectors and characterizing the gap between supply and demand. Often times these gaps are not trivial.

This project aimed at developing a robust framework to estimate municipal and industrial water demand across cities in the Nile Basin countries.

The specific objectives were to:

- Develop/refine baseline water demand for municipal and industrial water use for 2016
- Develop projection of water demand for municipal and industrial sectors for the Nile Basin through the year 2050
- Develop viable scope for water saving from the municipal and industrial water use sectors through employment of various measures, such as demand side management, adoption of water efficient technologies and reduction of losses.

To fulfil these key objectives the project team worked closely with Nile Basin Initiative (NBI)staff, technical staffs representing the Nile Basin countries, and national consultant that were retained for data collection in each of individual countries, wherever possible.

The methodology that is used in this project started with extensive desktop research that provided background information on methods and tools for demand projection as well as coordinating with NBI staff through virtual meeting to set the framework. The project team presented its initial findings to a wider group of Nile Basin technical experts during the 5th Regional Expert Group workshop in Kigali, Rwanda that was held from February 23rd through 25th, 2019. Breakout sessions were formulated to elicit specific inputs from workshop participants.

One of the most challenging aspects of the project was lack of data that was necessary for estimation of baseline water use as well as projection to the 2050-time horizon. To help alleviate some of these challenges, NBI retained the service of national consultant from most of the basin countries to collect required data[1]. Accordingly, in collaboration with NBI staff, the project team designed an extensive survey document to capture information from municipalities, cities, and regions in the Nile Basin countries.

[1] Project team worked with National consultants to collect specific data used for database deign, demand forecast, and demand management efforts. Data were obtained from cities and municipalities in Burundi, Ethiopia, Kenya, Rwanda, South Sudan, and Uganda.

This information was used as a basis for database design and implementation (Technical Note I), demand forecasting methodology development and implementation (Technical Note II), and assessment of demand management/water conservation measures (Technical Note III).

These technical notes are summarized in the next section.

Through this project, the team accomplished the following:

- Developed an extensive survey and database collection framework for use with this project as well as accommodate ongoing activities.
- Designed, implemented, and populated the first unified Nile Basin level database in Structure Query Language (SQL) frame for municipal and industrial water use collection, monitoring and modeling
- Produced an estimate of industrial and municipal water demand through 2050.
- Developed an assessment framework for water saving through implementation efficient technologies and alternative water sources

Key findings

- Demand for municipal and industrial water is expected to increase significantly across Nile Basin countries in all sub-sectors
- An average of 376% (266% to 461%) increase in water use is expected under high economic scenario across Nile Basin countries
- Significant offset can be achieved through passive measures. This needs to be accounted in water demand model projections
- There is a significant potential for alternative water supply (e.g., rainwater harvesting and greywater reuse) that should be quantitively assessed and implemented, if found cost effective.
- Regular database update through implementation of Nile Basin wide annual water use reporting need to be in place to better assess current demand and produce reliable forecast going forward

ES. 1. Technical Note I: Database design and implementation

This technical note provides documentation on the design and implementation of SQL database that is meant to be a living document and associated database. The database is designed to have two major components (Figure ES.1): 1) historical database which is a repository of raw data as collected by national consultants and was used as a basis for estimating baseline demand for water use. The database is designed in such a way that it can be upended or expanded as new water demand category is identified and/or new data are collected; and 2) projected demand for water use. This data set is based on subset of the raw data and additional data that was collected by the project team from literature, national reports and databases (e.g., population growth for each of the Nile basis countries, GDP, price, etc.).

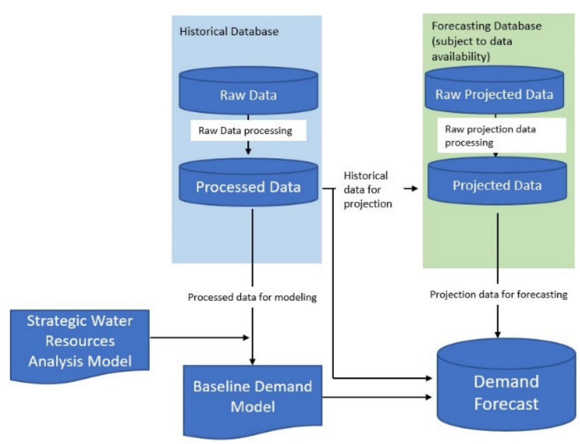

Figure ES. 1.1. Database structure

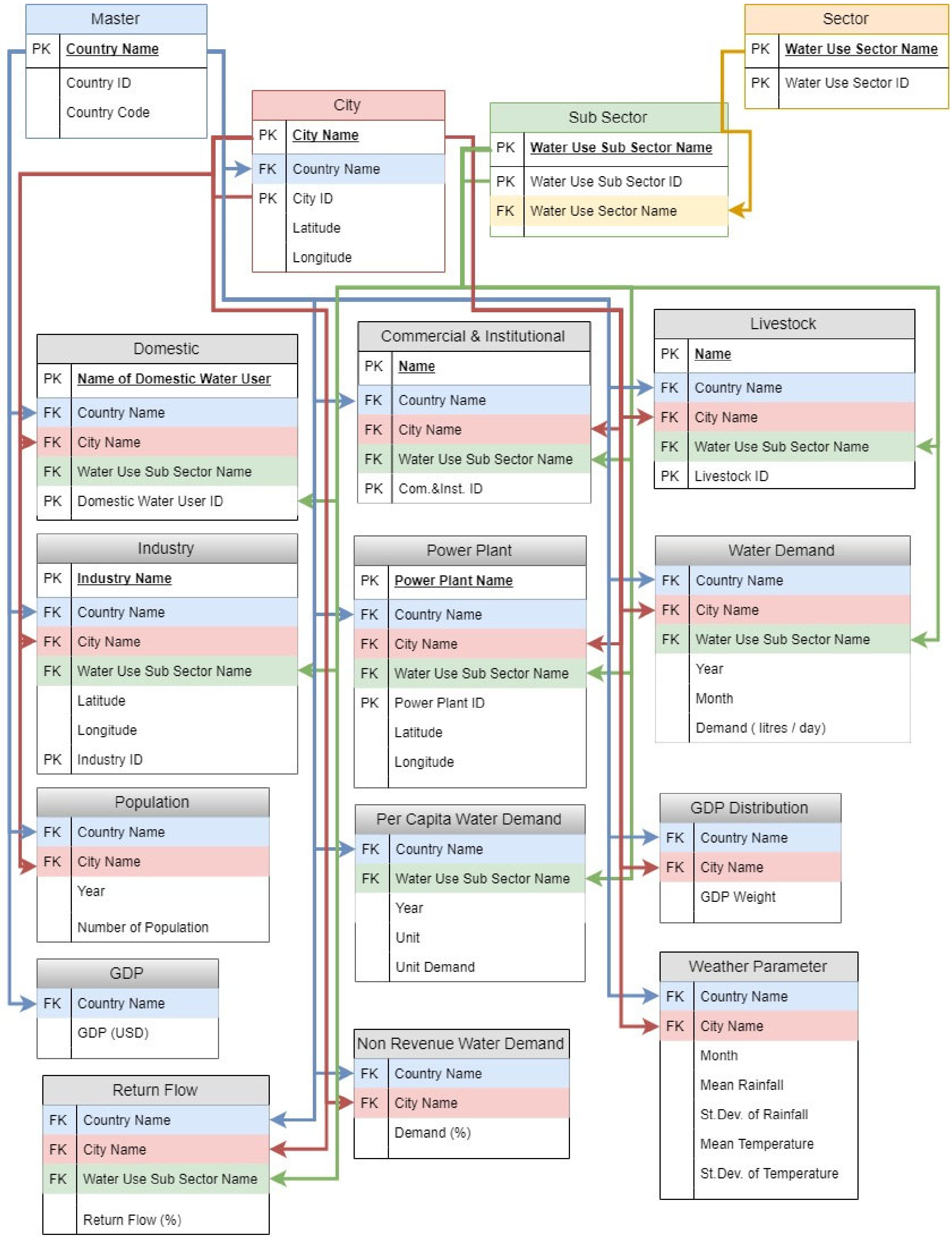

Figure ES.1.2. Relationships of the historical water demand database. PK and FK denote Primary Key and Foreign Key, respectively.

The database allows to query information and generate model input parameters and/or data analysis. For example, demand can be queried by city, country, sector, subsector, and so on. The historical database contains a total of sixteen tables with relational links as shown in Figure ES.2.

ES. 2. Technical Note II: Methodology and forecast results

The project team conducted an extensive desktop research on methods of demand forecast available in literature that was initially considered for their applicability in the Nile Basin countries. Several factors play a crucial role in estimating demand for municipal and industrial water uses. These are population, ability to afford water (this can be reflected as personal income or overall Gross Domestic Product of a region), price of water (subsidized or "true" cost), whether there are implemented efficiency measures/products, and weather (rainfall and temperature). All these factors, except population, can be aggregated into a single metrics called "per capita" water consumption. Per capita consumption provides what a "single" person would consume. Where data availability justifies it, per capita consumption can be further disaggregated into different modes of water supply.

Initial efforts taken by the project team looked at different socio-economic groups and estimation of their current water use as well as projection of the groups' water use into the future. These grouping included low, middle, and high-income groups served by: 1) in-house connection; 2) yard tap (external connection); 3) standpipe/ water kiosk; and 4) water trucks (at a community level). This approach would have allowed a much more granular estimation of the percentage of consumers in each socio-economic group as well as per capita water use for each group. After data collection by national consultants, it became clear that data availability did not support this approach.

Regardless of the mode of water connection, water consumption would depend on ability to afford and price of water. These two factors were found to be major drivers of water use in the Nile Basin countries. Per capita water uses were then projected into the future through the planning period of 2050 using difference GDP and price growth scenarios. Figure ES.2.1 shows expected per capita municipal water use for each of Nile Basin countries for three GDP growth scenarios (1%, 5%, and 10% annual increase). Spread for each of the counties represent price differences across cities, where this information is available. Once future per capita values were estimated, an adjustment was made to incorporate non-revenue water (unbilled fraction). Non-revenue water for each country was estimated based on a function of total water production versus water delivered to customers.

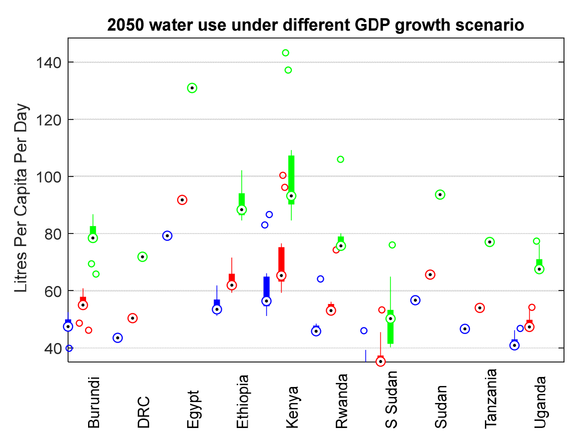

Figure ES.2.1. 2050 projected percapita water use for different GDP growth scenario. (Blue @1%, Red @5%, and Green @10% GDP growth rate).

Total water use for each country was estimated for two scenarios of population projection (high and medium). In addition, a technology factor was included to account for passive efficiency measures.

Table ES.2.1 shows demand growth in the Nile Basin countries under high population and GDP growth scenario with and without technology factor. Population growth is expected to vary from country to country with Egypt showing a low growth of 77% and Uganda showing a high growth of 172% through the planning period. A mean growth of 130% was found across the ten countries. Under such scenario demand for water would significantly increase from a low of 266% to a high of 461% under high population and GDP scenario for the ten NBI countries. Some of these increases in demand for water could be offset with introduction of high efficiency fixture and other technological advances to values that would range from 209% to 374%. While there is significant saving through technological advances, it still cannot compensate for the growing water demand as it is mainly driven by population growth and increased per capita water use that comes with higher GDP (ability to pay for the service) growth. The current low water use pattern is expected to grow exponentially before the curve starts to flatten out.

Figure ES.2.1. 2050 Demand increase (as multiplier) compared to current water use under high population and GDP growth.

Country	Population Increase	Demand Increase (High Econ Growth)	Demand Increase (High Econ w/Tech)
Burundi	1.59	4.36	3.52
DRC	1.66	4.50	3.64
Egypt	0.77	2.66	2.09
Ethiopia	1.04	3.22	2.56
Kenya	1.15	3.44	2.75
Rwanda	1.01	3.14	2.50
South Sudan	1.24	3.62	2.90
Sudan	1.18	3.51	2.81
Tanzania	1.66	4.49	3.63
Uganda	1.72	4.61	3.74
Mean	1.30	3.76	3.01

ES. 3. Technical Note III: Water Conservation Measures

Demand side managements approaches are key components of an integrated water resources planning that one needs to look at in order to manage a scarce resource.

Two main categories for demand side management are passive and active water conservation measures. Passive measures are relatively easier to implement and quantify the savings compared to active measures. However, if properly practiced and funded, active measures can result in much better outcomes and accelerate the natural replacement of efficient fixtures. Some examples of demand side measures with high water savings potential include: installation of water sense rated fixtures, weather-based irrigation controller systems, incentives through rebates for water saving units, grey water retrofits and rebates, high- efficiency appliances and process units, retrofits in schools, industries and large institutions. The level of water saving that can be achieved is significantly influenced by the level of market penetration of efficient water use fixtures such as low volume flush toilets, water saving shower heads, appliances, and efficient systems in irrigation and industries.

Passive measures. These are driven by natural replacement of fixtures that have either reached their service life or that need to be replaced. This requires assessment of market penetration of water-efficient fixtures (assess the technology being imported or implemented in each country) and identification of regulations (plumbing and building codes). This also requires information on the modality of water supply (in-house connection, yard tap, etc.), distribution of the socio-economic groups (high and middle income) and information on age of buildings. This information is useful to estimate how much water can be saved when old water fixtures are replaced by water efficient ones.

Active measures. Active conservation measures include changes in practices and behaviors of users typically through implementation of incentives provided by utilities or governments. Active measures are designed to expedite the replacement of standard or inefficient water fixtures with more efficient ones through rebates or other incentives. This scenario includes measures for indoor and outdoor water uses. It requires information on utility and government programs in each city or country. The selection of the applicable measures (rebates/incentives) will depend on the cost of implementation to the users and the utilities/government. It is essential for decision makers to identify potential deferment plans of new infrastructure development, which might otherwise be needed due to the growing demand for water.

Water saving measures assessment in NBI

In order to understand the potential of passive and active water conservation measures in each of the Nile Basin countries and to determine the amount of water that can be saved, the project team included relevant questions in the survey for the national consultants (See details of questions for water demand management in Appendix A of Technical Note III).

Questions related to the passive and active measures include information on market penetration of the major water saving fixtures and appliances (toilet, shower heads, urinals and washing machines) and whether utilities or government have water conservation programs and incentive/rebate plans for efficient system installation. These were used to determine the feasibility of passive and active water conservation measures.

A summary of survey results from national consultants can found in Technical Note III. The results indicate that in most cases, water saving fixtures and appliances are widely available in the market. This is an indication that passive measures are being implemented in new and old buildings. As a result, a technology factor was included in the water demand projection model that represented passive water conservation measures. This was applied starting the current year all the way to 2050.

Projected water savings

Incorporation of passive measure implementation into demand forecast results in a significant water saving by 2050. Based on the projection for the selected cities, it is clear that the total amount of water saved due to water conservation measures will achieve significant reductions in water demand from the Nile River. This is important in terms avoiding or delaying additional infrastructure requirement to meet the high-water demand and to reduce the stress on the river.

For example, for the largest 10 cities in the Nile Basin, the amount of water demand reduction from passive measures by 2050 is presented in Table ES.3.2. This amounts to about 16% of the water demand. This is a significant reduction that needs to be taken into consideration in future water demand assessments. Additional reductions in water demand can also be achieved through active water conservation measures if utilities/governments implement financial incentive (rebates) and other water conservation programs to expedite the installation of high efficiency fixtures and appliances. This amount can be estimated in the future during the regular update of the forecasting model.

Table ES.3.2 Impact of water conservation measures on the 2050 water demand projection for selected cities in the Nile basin.

City, country	Population	Water demand in, m3/day		Water saving,	
		Without conservation measures	With conservation measures	m3/day	m3/year
Gitega, Burundi	14,585	12,390	10453	1,853	676,345
Rustshuru, DRC	164934	11,854	10001	339,316	123,850,340
Cairo, Egypt	16574884	2,170,441	1831125	9,558	3,488,670
Gondar, Ethiopia	661625	61,134	51576	65,458	23,892,170
Bungoma, Kenya	4503826	418,702	353244	23,450	8,559,250
Kigali, Rwanda	2,063,032	150,002	126,552	20,429	7,456,585
Juba, S. Sudan	1,789,183	130,675	110,246	89,150	32,539,750
Khartoum, Sudan	6,339,660	570,248	481,098	4,858	1,773,170
Musoma Tanzania	403273	31,073	26215	81,980	29,922,700
Kampala Uganda	7,157,012	524,380	442,400	1,853	676,345

Alternative water supply potential

Although quantitative estimation of the amount of water that can be saved from all alternative supply side management measures is outside of the scope of this project, the potential and applicability of the different measures in each of the Nile Basin countries is identified based on current practices, climate conditions and advances in technology. The survey results from the national consultants were used to support assessment of supply side management practices (leakage, rainwater amount and temporal distribution, greywater reuse and groundwater use) and possible reduction in water supply needs for countries where data was provided. Qualitative information on the potential application of the different alternative water supply sources in the different Nile Basin countries is shown in Table ES.3.3. The relative potential of water savings is represented by the number of "+" signs. ("+" indicating lowest potential and "++++" indicating highest potential). The assignment of relative water saving potentials for each case has been made based on a very limited information extracted from survey results of the national consultants, reports, databases and the literature (many of which are not consistent).

Table ES3.3. Potential water saving options from alternative water supply options in each of the Nile Basin country

Country	Water loss reduction[2]	Rainwater harvesting[3]	Greywater reuse[4]
Burundi	++++	++++	+
DRC	+++	++++	++
Egypt	+++	+	+++
Ethiopia	+++	++	++
Kenya	++++	++	+++
Rwanda	++	+++	++
South Sudan	+++	++	+
Sudan	+++	+	+
Tanzania	+++	++	+
Uganda	+	+++	+++

Next steps

- Building on this project, NBI should implement a framework for continual data collection and model update at annual to biennial timeframe.
- Contribution of seasonal weather (precipitation and temperature) should be investigated. This would help assess impact of climate on municipal and industrial water demand.
- Quantitative assessment of alternative water supply potential should be performed.
- Regular market and socio-economic survey data should be implemented
- Maintain and update centralized database.

[2] Savings in this category depend on current water lose levels, Repair & Replacement capital availability and the target non-revenue water set by cities.
[3] Savings potential in this category depend on specific climate/seasonal weather pattern as well as end water use that could be substituted with harvested rainwater.
[4] Savings in this category depend on current level of water supply and sewer systems coverage in each of the cities, existing practices of greywater reuse and end water uses such as toilet flushing and landscaping/gardening.

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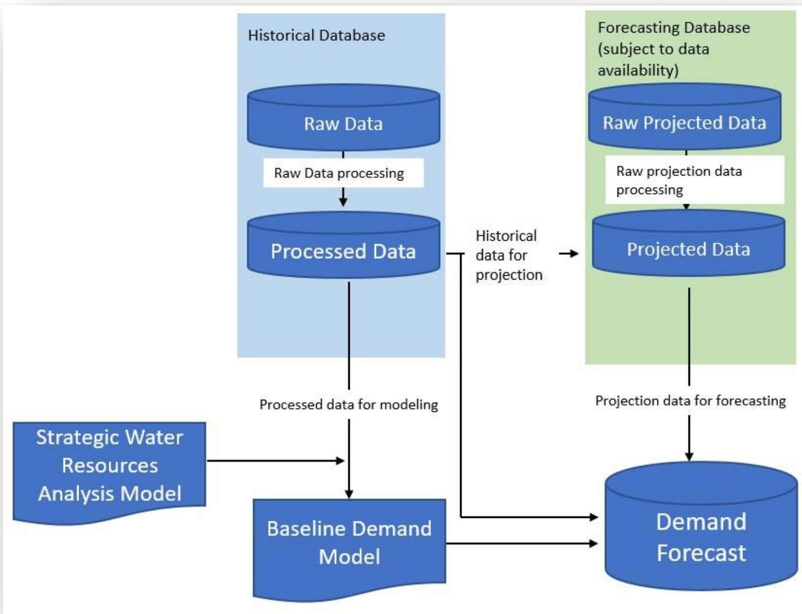
Municipal and industrial water projection for Nile Basin countries



NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

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Technical Note I: Database Design and Implementation

Prepared for

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CONTENTS

1 INTRODUCTION

This document describes the data for the development of the Nile Basin water demand forecast model and the associated database. Detailed description of the database is presented, including the database structure which incorporates possible water demand influencing factors and potentially available data in the Nile Basin. Figure 1 presents the envisioned database framework with tables and their linkages. Having such level of detail provides enough information to estimate water demand.

A questionnaire was developed to collect as much data as possible with the help of national consultants hired by the Nile Basin Initiative from the basin countries. See sample questionnaire attached in Appendix 8.1. All the collected data are stored in the database as raw data. Model development relevant data are then processed, and quality assured for possible errors and inconsistencies and stored in the processed database. Details of the data processing are presented in section 5.

Populating all the tables as initially envisioned with data across the ten Nile Basin countries was a huge challenge. This was because the data collected by national consultants significantly varied in quality and completeness despite using the same survey questions. This discrepancy limits the level of detail and completeness of model input data across the basin countries. In few extreme cases, data from countries like Egypt, Sudan, Democratic Republic of Congo and Tanzania, were not available from the national consultants. The missing data were filled from literature and the water supply plans, and design guidelines provided by Nile Basin Initiative.

The subsequent sections will describe the database framework in detail. The descriptions include for data tables already populated for baseline model development and for the remaining tables where data was not currently available. The detailed descriptions will guide the Nile Basin Initiative to expand the database and improve the demand forecast model when data is available in the future.

2 DATABASE STRUCTURE

The database broadly comprises of two major components, historical and forecast as shown in Figure 1. The historical database is a repository of raw data as collected by the national consultants as well as the processed model data. This database will also be the repository of tables where data is yet to be collected in the future. The consultant developed the database framework based on the nature of data initially collected from the basin countries, anticipated sources from literature and consultant's own experience. The database framework is developed in such a way that it can be appended or expanded as new water demand category is identified and when data is available from a given country. This framework will allow Nile Basin Initiative to focus its future efforts of data collection and streamline the process in such way that forecast updates at regular intervals could be performed going forward.

Data could be added or removed from this designed database as needed to make sure all water use data from all the Nile Basin countries are incorporated without redundant information. This process, however, will not affect the overall database structure. The tables in the database can be updated as more information is gathered, and even new sets of explanatory variables to build the demand forecast model can be generated/ updated regularly.

The historical database is a basis for determining the baseline water demand as it contains water demand explanatory and driver parameters for model development. The water demand baseline model is a primary tool of estimating the baseline water demand and the future water demand. The demand forecast model parameters could be expanded by incorporating additional water demand forecast explanatory variables that explain the future states of water demand in the Nile Basin. The final form of the forecast database and the tables therein are described and shown in the processed database. It is important to note that the accuracy and complexity of the demand forecast model is dependent on the available data. See Technical Note II for details on demand forecast model.

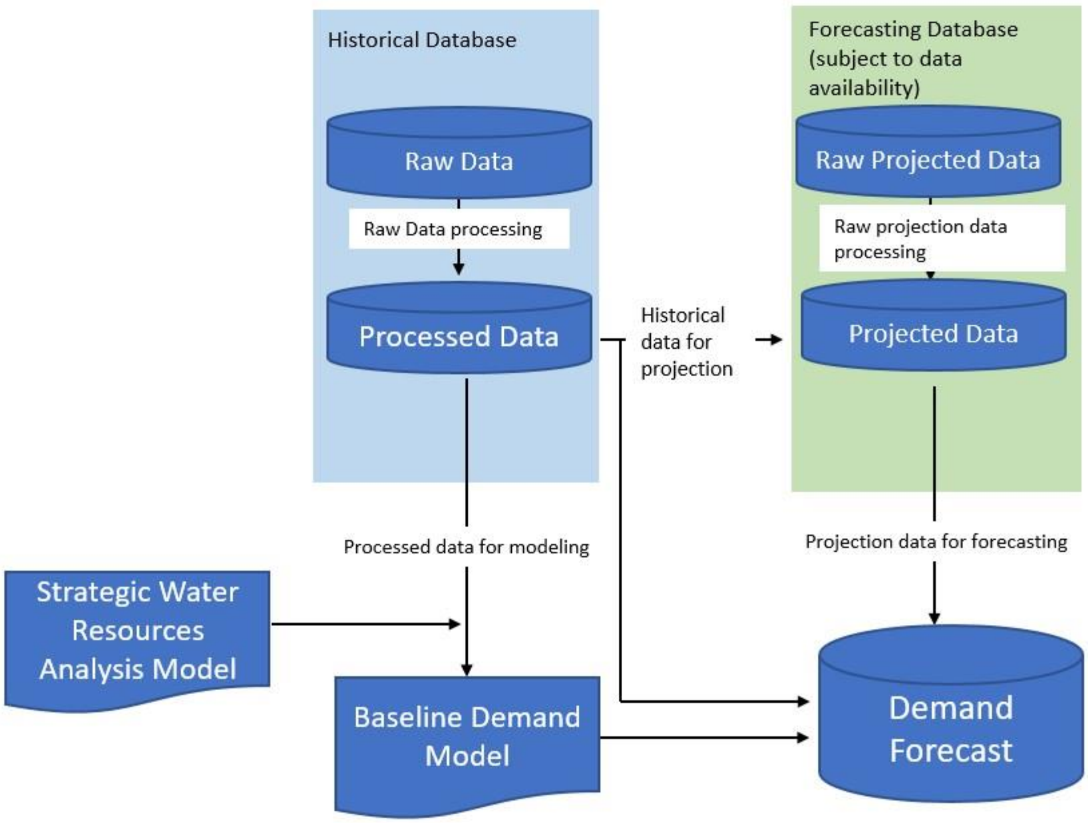


Figure 1: Database structure

3 FUNCTIONALITY

Components of the water demand forecast database are designed/structured to accommodate multiple records of water demand data. The populated database are transferred to the client as a Microsoft SQL database backup files. The database has the ability to query for generating model input parameters and even data analysis for other purposes. For example, demand can be queried by city, country, sector, sub sector and so on. Since the database is SQL based, it is easier to update regularly as new data becomes available. The logical diagram of the database structure is shown in Figure 2 and recommended sample tables are attached in Appendix 8.2

4 DATABASE DESIGN PROCESS

This is the most important part of the water demand model development. The historical database contains a total of sixteen tables with relational links as shown in Figure 2. The level of detail presented in the database structure is key for developing a water demand model for estimating the demand accurately. Tables are color coded to identify relationships of tables and readability. For example, the Master table, which uniquely identifies countries, is shown in blue and so are its links to relevant tables.

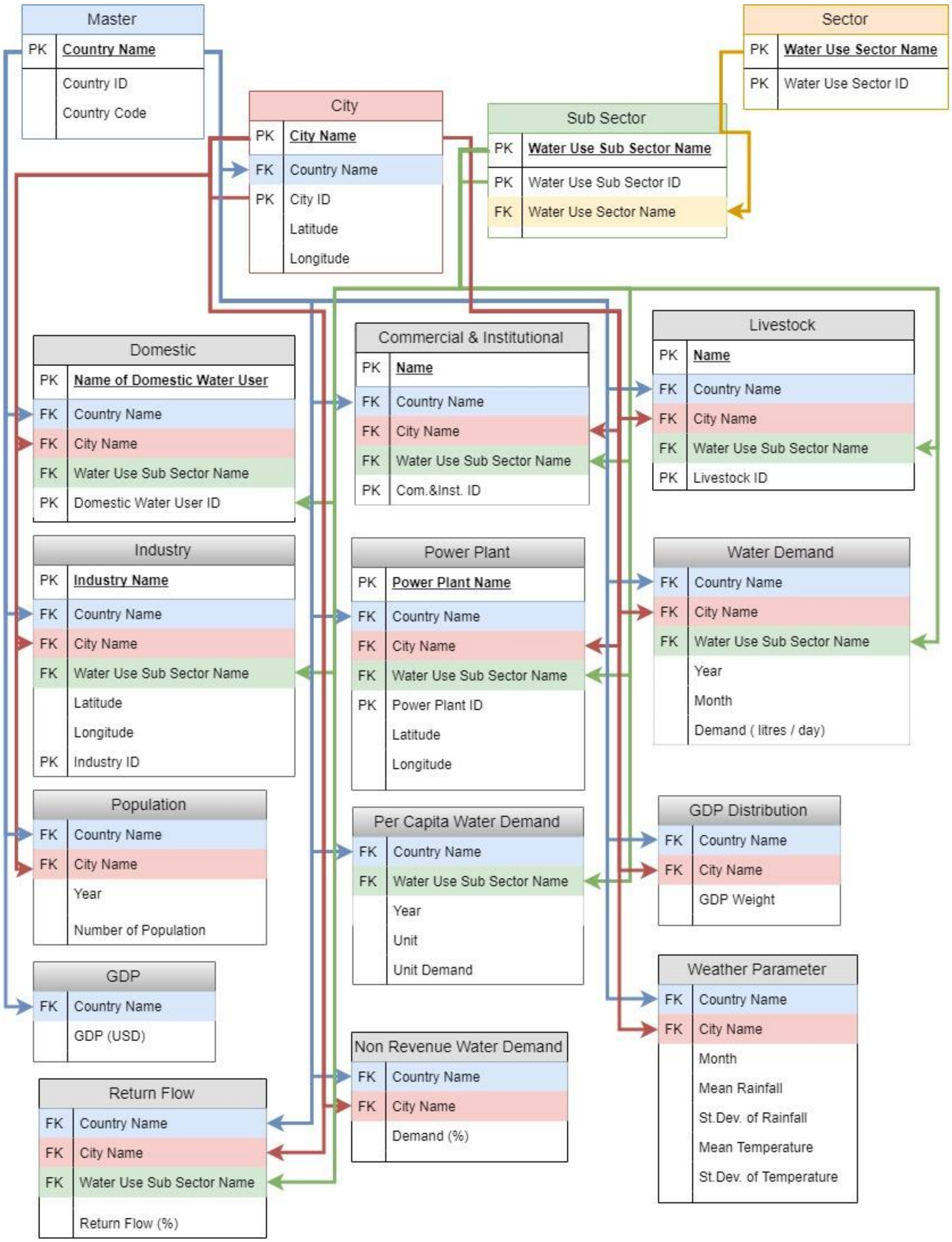


Figure 2: Relationships of the historical water demand database. PK and FK denote Primary Key and Foreign Key, respectively.

The Master and Sector tables are the only two independent tables. Water sector such as domestic water demand is not country dependent and need not be restricted by geography. A more specific water demand, for example, water demand of a city, is linked to the Master table for linking to the relevant country. The link between the Master and Sector tables are established via specific sectoral tables with attributes containing both the country and sector information. Description of the tables in the database structure are provided below. Not all of the tables in the descriptions are incorporated in the demand model development, but descriptions are presented for all of them. The actual model input parameters for model development are briefly described in the model input data section, section 5.

4.1 Master Table

The Master table consists of three fields: Country name and Country code. The main purpose of this table is to assign a unique identifier to each country in the Nile Basin. The Country ID is designated as a two-digit number. as shown in Table 1. The Master table is linked to all tables except the Sector and Sub Sector tables as they are country independent.

Table 1 Master table

	CountryName	CountryCode
1	Burundi	01
2	Democratic Republic of Congo	02
3	Egypt	03
4	Ethiopia	04
5	Kenya	05
6	Rwanda	06
7	South Sudan	07
8	Sudan	08
9	Tanzania	09
10	Uganda	10

4.2 City Table

A City table is a country dependent table with five attributes. It contains name of the country, name of the city, city ID, and its geographic location represented by latitude and longitude coordinates. The City ID is a four-digit identifier constructed by taking a two-digit number from the Country ID and additional two digit number for a city which is assigned for cities after listing alphabetically. For example, Adwa, alphabetically is the first city in Ethiopia, will have a City ID of 0401. The first two-digit number (04) denotes the country, Ethiopia as specified in the Master table. The next two-digit number 01 represents the city of Adwa and identifies it from other cities in Ethiopia. Since cities are represented as nodes for water demand purposes, latitude and longitude coordinates are included as unique location identifiers. The location coordinates sources include google geocoding and data collected by the national consultants. A sample city table from the processed database is shown below.

Table 2 City Table

CountryName	CityName	CityID	Latitude	Longitude
Ethiopia	Adwa	0401	14.1678574	38.8131711
Ethiopia	Ambo	0402	8.9557367	37.9221073
Ethiopia	Assosa	0403	10.0660064	34.5076697
Ethiopia	Axum	0404	4.1326933	38.67655
Ethiopia	Bahir Dar	0405	11.5819977	37.2403369
Ethiopia	Debre Bi...	0406	9.6713202	39.4942181
Ethiopia	Debre M...	0407	10.3307485	37.6969664
Ethiopia	Debre T...	0408	11.8566387	37.9794138
Ethiopia	Gambella	0409	8.2481849	34.5556919
Ethiopia	Gondar	0410	12.601286	37.3864075
Ethiopia	Mekele	0411	13.4974703	39.3536173
Ethiopia	Metu	0412	8.2934783	35.5450363
Ethiopia	Mizan T...	0413	6.99467	35.5684088
Ethiopia	Nekemte	0414	9.0903938	36.4805719
Ethiopia	Shire	0415	14.0944442	38.2143089

4.3 Sector Table

The Sector table is defined by two fields, the Water Use Sector name and the Water Use Sector ID. This table uniquely identifies the five water use sectors: Domestic, Commercial & Institutional, Livestock, Industry and Power. A unique Water Use Sector ID is assigned for each of the five sectors by using a two-digit number that range from 11 to 15. Each of the Water Use Sectors is represented by a separate table (See tables in Appendix 8.2)

4.4 Sub Sector Table

The Sub Sector table further classifies the Sectoral Water Use into a different and more focused water use categories inherited from the Sector table. These categories are defined based on the mode of service delivery. For example, the domestic water use sector is divided into house tap users, private yard tap users, neighborhood yard tap users, public tap users etc. A House Tap User (HTU) is a classification name and it is not geographically restricted, and it is not directly connected to the Master and City tables unless a more specific water use is desired to be represented. A Water Use Sub Sector ID is assigned by taking a two-digit number from the Sector table followed by a two-digit number for mode of service delivery. For example, Sub Sector ID for a HTU will be 1101.

4.5 Domestic, Commercial & Institutional, Livestock, Industrial and Power Water Demand

These sector dependent tables have typically four fields. Name of the actual Water Use Sub Sector has a primary key identifier followed by the country, city and sub sector names and a unique ID. In addition to the four fields, Power and Industry tables include additional location identifiers using latitude and longitude coordinates.

For example, an HTU in Adwa is more specific and needs to be represented uniquely by an ID and location identifier. Therefore, it is represented by a 10-digit number, a concatenation of City ID, Sub Sector ID and the two-digit identifier to the specific water user within the water use sub sector. Table 1 shows nomenclature for a city HTU demand.

Table 1: Example nomenclature for a HTU in Adwa city (Ethiopia)

City ID	Sub Sector ID	Two-digit identifier for HTU
0401	1101	01

The resulting unique identifier for a HTU in Bahirdar, Ethiopia is 0401110101. Similarly, a Private Yard Tap User will be identified as 0401110103

4.6 Population

This table is a repository of city population in each of the basin countries. It is represented by six fields: Year, City ID, Water Use Sector Name, Water Use Sub Sector ID, Sub Sectoral Population and Sectoral Population. The City ID tracks the country and the city and is a key geography identifier. The Water Use Sector name is included to visually identify errors. The first two digits of the Water Use Sub Sector ID should match the sector ID. For example, if the sector is Domestic, then the Sub Sector ID should start with 11. The sub sectoral and sectoral population fields, as the name indicates are to record the population at these two resolutions. The sectoral water use demand was not available. For this reason, this table was populated with the available data that represents the total water use of all sectors combined. Table 3 shows the total water demand of cities.

Table 3: Total Population and those served by the utility in the Nile Basin cities

City	country	TotalCityPopulation	PopulationServedByWaterUtility
Gitega	Burundi	72606	65998.85
Karuzi	Burundi	19185	17439.17
Kayanza	Burundi	43595	39627.85
Kirundo	Burundi	24490	22261.41
Muramvya	Burundi	21311	19371.7
Muyinga	Burundi	17909	16279.28
Mwaro	Burundi	6206	5641.254
Ngozi	Burundi	78171	71057.44
Cankuzo	Burundi	5628	5115.852
Ruyigi	Burundi	18404	16729.24
Kirumba	Democratic Republic of Congo	39035	39035
Kituku	Democratic Republic of Congo	49788	49788
Oicha	Democratic Republic of Congo	55924	55924
Rutshuru	Democratic Republic of Congo	62016	62016
El Minya	Egypt	5393010	5393010
Qena	Egypt	3104367	3104367
Asyut	Egypt	4300293	4300293

4.7 Water Demand

Water consumption data collected from member countries is stored in this table. The table is designed to store the water demand data with six attributes including Year that will help track the water demand by time. The next field is the City ID that represents the country and city to which the demand belongs. The third and fourth fields are Water Use Sector Name and Water Use Sub Sector ID to track water demand by sector and sub sector when available. The fifth attribute is for the daily Sub Sector water demand and the final filed is for Sectoral daily demand. Some water demand data such as the industrial demand comes at the sectoral level while the domestic and commercial & Industrial demands are at the sub sectoral level. However, enough data was not available to represent the sectoral demands as a timeseries. The total city water demand is stored in the processed database as shown in Table 34.

Table 4 Sample total water demand of cities (m3)

country	City	AverageDailyProduction
Burundi	Cankuzo	271109.589041096
Burundi	Gitega	4938783.56164384
Burundi	Karuzi	290772.602739726
Burundi	Kayanza	331386.301369863
Burundi	Kirundo	391890.410958904
Burundi	Muramvya	240591.780821918
Burundi	Muyinga	751435.616438356
Burundi	Mwaro	195419.178082192
Burundi	Ngozi	1099273.97260274
Burundi	Ruyigi	727484.931506849
Democratic Republic of Congo	Kirumba	1092980
Democratic Republic of Congo	Kituku	1394064
Democratic Republic of Congo	Oicha	1565872
Democratic Republic of Congo	Rutshuru	1736448

4.8 Per Capita Water Demand

Data collected from basin countries indicate that the per capita water demand is one of the main components for demand forecasting. For this reason, this table is designed to store the per capita water demand of the different Sub Sectors of water users by five attributes: Country name, Water Use Sub Sector Name, Year, Unit and the Unit Demand. Because of lack of sectoral demand data, the full attributes of this table were not populated. The per capita water demand, as an aggregate of all sectors, is shown in Table 5. The NaN in the city column are missing data. The values in the lpcd column are collected from literature.

Table 5 The per capita water demand of cities (liters per capita per day)

City	CountryCode	lpcd
Cankuzo	01	52.99
Gitega	01	74.83
Karuzi	01	16.64
Kayanza	01	8.36
Kirundo	01	17.6
Muramvya	01	12.42
Muyinga	01	46.16
Mwaro	01	34.64
Ngozi	01	15.47
Ruyigi	01	43.49
NaN	02	28
NaN	03	178
Adwa	04	67.9
Ambo	04	20.9

4.9 GDP and GDP distribution tables

The GDP and GDP distribution tables are included in the database to store country specific GDP data. Per capita GDP are one of the explanatory variables for the demand forecast model. The GDP (or per capita GDP) distribution table will be a repository of GDP weights calculated for each of the cities in a given country. Currently, the demand forecast implementation assumes similar GDP for a city as that of the country. But the database implementation allows for a potential difference in GDP between a city and a country. The weighting process will account for variations in per capita GDP among different cities within a country when data is available in the future. Planned GDP distribution table is shown in the Appendix 8.2. Enough data was not available to weight the economic conditions of cities in the country. However, the per capita GDP per city were derived to explain the water demand in each city. Table 6 shows the per capita GDP stored in the processed database.

Table 6 The per capita GDP per city and country

City	CountryCode	perCapitaGDP
Cankuzo	01	0.8
Gitega	01	0.8
Karuzi	01	0.8
Kayanza	01	0.8
Kirundo	01	0.8
Muramvya	01	0.8
Muyinga	01	0.8
Mwaro	01	0.8
Ngozi	01	0.8
Ruyigi	01	0.8
NaN	02	1.29
NaN	03	9.53
Adwa	04	1.95
Ambo	04	1.95
Axum	04	1.95

4.10 Weather Parameter Table

Weather information (climatological temperature and precipitation) for each of the Nile Basin cities included in the database will need to be collected and stored in this table. Demand projection will use this information to provide within year demand variability and capture seasonal fluctuations. The modeling effort will identify how best to include this information in the forecasted water demand. The table comprises of seven fields to store within year variabilities of rainfall and temperature represented as mean and standard deviation values with a total of 12 rows (one row per month). The first two fields are location identifiers, which include country name and city name. The third field is time of the year to identify the month. The remaining four fields store the mean and standard deviation values of rainfall and temperature, respectively.

4.11 Non-Revenue Water Demand

This table is represented by three fields to store the percentage of non-revenue water for each city of the basin countries. The first two fields will store country and city names and the third field will store the non-revenue water as a percentage of the water demand. Table 7 shows the non-revenue water demand fraction.

Table 7 The unbilled Fraction of water

City	CoutryCode	UnbilledFraction
Cankuzo	1	51.05
Gitega	1	29
Karuzi	1	59.7
Kayanza	1	65.7
Kirundo	1	53.6
Muramvya	1	67.09
Muyinga	1	64.16
Mwaro	1	44.41
Ngozi	1	49.8
Ruyigi	1	64.83
Kirumba	2	21
Kituku	2	21
Oicha	2	21
Rutshuru	2	21
El Minya	3	21
Qena	3	21
Asyut	3	21

4.12 Return flow

This is a repository of return flow measured as a percentage of water demand. This table uniquely keeps record of percentages of return flows for each of the cities in the Nile Basin countries. The table further categorizes the return flow percentage based on the sectoral use of water since the return flow is not of the same percentage across all sectors.

4.13 Price of Water

Price is one of the principal variables that explains the demand of water (see equation 1). The national consultants provided price information for most of the basin countries. For countries with missing data, this information was collected from the African development Bank. Table 8 shows the price data for some of the basin cities stored in the processed database.

Table 8 Price of water of cities (US dollars/ liter)

City	Coutry_Code	Price_dollars_per_liter
Kayanza	01	0.000348
Kirundo	01	0.000426
Muramvya	01	0.000502
Muyinga	01	0.000479
Mwaro	01	0.00069
Ngozi	01	0.000376
Ruyigi	01	0.000524
Kirumba	02	0.0003
Kituku	02	0.0003
Oicha	02	0.0003
Rutshuru	02	0.0003
El Minya	03	9E-05
Qena	03	9E-05
Asyut	03	9E-05
El Giza	03	9E-05
Cairo	03	9E-05
Alexandria	03	9E-05
Adwa	04	0.000134625
Ambo	04	0.00012

5 DATA COLLECTION FORMAT

The section on database design identified the conceptual framework of database, associated tables, and attributed based on current data that was gathered and an understanding of data that can be gathered in the Nile Basin countries in the future. The database is a generic platform that accommodates data collected from each of the countries and allows a systematic expansion. Data from national development reports, design manuals, and/or literature review of prior work as well as primary and secondary data collected by national consultant are used to populate this database as a starting point.

The initial framework of the database is primarily driven by anticipated availability of data to fully populate tables that could support model development. The actual collected data is less than anticipated. The response from the national consultants for the same survey significantly vary in terms of content and completeness and in some cases, they also differed in format. This variation triggered the need to standardize the collected data to the same format. The standardization process includes unit conversion, data generation from the collected data to fill the data gap and create a uniform data format that fits the model data requirement as detailed in the questionnaire. This process was one of the most time-consuming activities to create a uniform data format that can easily be imported to a SQL database so comparison of available data can be made consistently. Sample raw data from the database is shown in Table 9

Table 9 Sample raw data

Category	Description	Data
DF-1	Data Source	NULL
DF-1	a) Country:	Ethiopia
DF-1	b) City/town:	Adwa
DF-1	c) Utility Name:	Water supply and Swerage Service Office
DF-1	d) Website address, if any:	NA
DF-1	e) Type of Utility: [1 if it applies 0 if not]	NULL
DF-1	i) Water	NULL
DF-1	ii) Wastewater	NULL
DF-1	iii) Storm Water	NULL
DF-1	iv) Reuse	NULL
DF-1	v) Other, please specify	NULL
DF-1	f) Contact Information of of a person whao ...	NULL
DF-1	i) Name of person	NA
DF-1	ii) Email	NA
DF-1	iii) Telephone	NA
DF-2	Population	NULL
DF-2	a) Total population of city	NULL
DF-2	b) Population served by water utility	56.13%
DF-3	Source of water supply [1 if it applies 0 if not]	NULL
DF-3	[ ] Groundwater	NULL
DF-3	[ ] Surface water	NULL
DF-3	[ ] Both (Ground water and surface water)	NULL

The gap between the anticipated and collected data from the national consultants was significant which forces the consultant to focus on factors that significantly explain water demand in developing countries in particular – socio-econometric variables. The demand forecast model is thus focused on these parameters.

The database framework developed during the course of this project will be used as a guide to continuously gather and populate the missing data. The continued collection of data, database update, and forecast outlook will help NBI to refine model and outlooks in a consistent manner and provide key feedback where improvement should be made.

5.1 Data processing

The data collected by the national consultants in the database is referred as "raw data". The raw data comes with different sorts of errors. Errors such as inconsistent use of units, use of a comma in place of a decimal point and a decimal point in place of a comma. In few instances, unrealistic numbers were presented. For example, the maximum capacity of the water supply utility is presented to equal or smaller than the average capacity.

Since the information in the raw data is not consistent, data analysis is performed to fill the gap. For example, in some countries the total population served by the utility is not available in the raw data set which requires an estimate based on the available data and assumptions when necessary.

The processed data tables follow the formats presented in the database framework developed during this project (Figure 2). the raw data basically has the same format as presented by the national consultants.

As the data collection is completed, the type and format of demand forecast model become clear to identify what variables should be used to develop the demand model. Model parameters that significantly explain the per capita use of water are processed from the collected data. The driver variable, population, is also used to determine the total water demand. Some derivative products such as the per capita GDP that serves as a surrogate for income and price are generated. It was initially proposed to apply the per capita GDP at the city level. However, data was not available for all basin countries and hence average national GDP values were used in the model.

The processed data mainly comprises of the demand forecast model input data that was processed from the raw data. These include:

1. Price of water
2. Per capita water demand
3. Per capita GDP
4. Assumed unbilled fraction, and
5. Population

These processed data are stored in the processed database.

5.2 Data Output

Primary output data is the demand forecasts for each of the cities selected to be covered by the project. Output data includes other derived data as tables within the database that houses the supporting database for demand forecast. This way updates to primary data as well as model output are stored in a consistent framework and can be tracked over time.

6 MODELLING DATA

6.1 Data for Baseline model development

As explained earlier, extensive data requirements were identified to best represent regional water demand in the Nile Basin. Such modelling effort to estimate the future water demand in time and space (in the Nile Basin countries) plays a key role in the regional water resources modelling efforts. Most of the presumed modelling input data were not available from all countries and some with limited information. Since we are developing a single basin wide model common to all the Nile Basin countries, a complete and accurate modelling input data must be available to reasonably represent the state of the Nile Basin Municipal and Industrial water demand.

Identification of a common data across all the riparian countries was necessary for model development. Previous modelling efforts show that income and price took the lions share in explaining the water demand variability in a region, especially in developing countries. Based on the collected data and the likelihood of obtaining water demand explanatory variables, it was found beneficial to put efforts on the socio-economic variables. The GDP and price of water per country were found to be the two explanatory variables found complete for most of the basin countries. GDP is a surrogate for income and available from different sources. The other major driver for water demand is population. The baseline model data are processed and stored in the processed database. The combination of the driver and explanatory variables determines the water demand model as a product of population and unit water use. The unit water use representation by the explanatory variables is expressed mathematically as shown in equation 1.

$$WU_c = \propto GDPC^{\beta 1} * Price^{\beta 2} * Tech * Seas\ Adj \qquad \text{Equation 1}$$

Where GDPC is per capita GDP, *Tech* represent technology adjustment to passive water use efficiency, Seas Adj representant seasonal adjustments because of weather. α, β1, and β2 are calibration parameters relating per capita water use to independent the per capita water uses explanatory variables.

For details of the water demand model development see Technical Note II (Asefa et al., 2020). The application of technology factor for water saving estimation is discussed in Technical Note III (Ghebremichael et al., 2020)

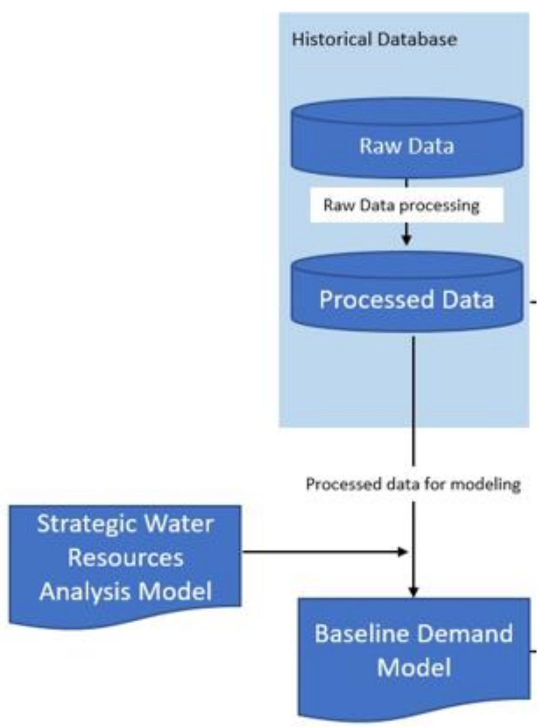


Figure 3 Schematic showing quality assured data for baseline model development

6.2 Demand Forecast data.

The demand forecast input data is the same data type as the base line model explanatory variables. These input variables are projected into the future through 2050. Figure 4 shows schematically the demand forecast.

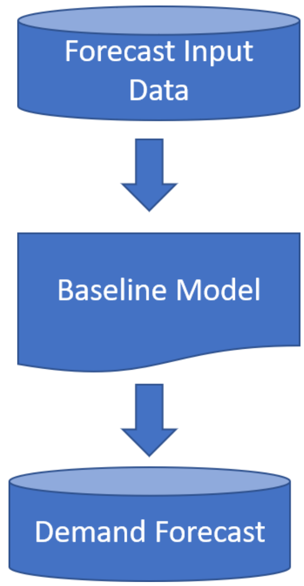


Figure 4 Schematic showing the demand forecast process.

The forecast input variables include scenarios to capture the future water use in the Nile Basin. High and medium population growth scenarios and several GDP growth and price growth rates were considered. The forecast input data and the forecasted water demand through 2050 are stored in the Forecast database. Detailed model results are presented in Technical Note II (Asefa et al., 2020).

7 FUTURE SECTORAL WATER DEMAND ESTIMATE

This section was proposed during the initial phase of the demand forecast model development phase. As explained in the previous sections, the quality and completeness of data varies from country to country. Information on sub sectoral water demands was available for some countries through survey and reports provided by the Bile Basin Initiative. But the available data to cover the Nile Basin countries were too small. Some sample tables are presented by collecting data from documents provided by the Nile Basin Initiative. Sample tables are also presented to show the proposed sectoral water demand in the basin.

The database provides a platform to document water demand for municipal, industrial and power sectors. These are disaggregated into sub sector water demand categories that are practically defined for planning, design and data collection. The different tables for each water demand category have attempted to include most of the classifications used by all Nile Basin countries. The water demand categories have been identified from reports provided by NBI and from national design guidelines of some Nile Basin countries. In cases where additional water use sub-sectors are identified the database offers flexibility to include them later. The approach used to estimate water demand for each sector and sub sector are described below.

7.1 Municipal Water Demand

Municipal water demand includes consumption by domestic (households), commercial & institutional facilities and livestock users. In addition to this, unaccounted for water is included to estimate the total water supply from municipal sources.

7.1.1 Domestic Water Demand

The per-capita domestic water demand in different countries varies depending on the size of the town and the level of development, the type of water supply scheme, the socioeconomic conditions and the climatic condition of the area.

Domestic water demand is an aggregate demand from different groups of users that are served by different modes of service delivery and that have different economic status. In this case five categories of service delivery modes are considered: i) House tap user for high income (HTUH), ii) House tap user for medium income (HTUM), iii) Private yard tap users (YTUP), iv) Neighborhood yard tap users (YTUN), and v) Public tap users (PTU). In some places traditional water users (TSU) such as from truck tankers or direct use from rivers, lakes, or springs can be considered as one of the modes of service delivery. The database will provide options to add this category as one of the modes of service delivery.

The domestic water users are also grouped based upon the socio-economic status of the users as: low income, medium income, and high-income categories. The mode of service delivery for low income categories will include all the different water supply options except the house tap connection. The medium and high-income residents will use house tap connection that will have different water use rates. The classification of low, medium and high-income groups depends on the income ranges defined by respective country and the per capita water consumption of each income group may differ from country to country. Table 10 shows an example of the different modes of service delivery along with the socioeconomic classifications. Depending on the availability of data, each country may decide to use the modes of service delivery with or without the socio-economic classifications.

Table 10: Modes of water supply services for domestic water use category

Income Category*	Mode of Service Delivery	Remarks
Low income	Public tap users (PTU)	The minimum level of water supply service
Low income	Private yard tap users (YTUP)	Low income housing with no inside installation.
Low income	Neighborhood yard tap users (YTUN)	Low income housing with no inside installation.
Medium income	House tap users (HTUM)	Medium income group housing, with sewer or septic tank.
High income	House tap users (HTUH)	Medium income group housing, with sewer or septic tank.

*Classification of high, medium and low-income categories will be based on income range and may differ from country to country

Total domestic water demand can be estimated as weighted average values that takes into consideration the distribution of the socio-economic groups (percentage of population in each income category) as well as the proportion of users under each service delivery. The respective per capita water demand for each service delivery group for base year will be obtained from water supply plans of cities.

Future water demand projections of domestic water demand will consider the changes in socio economic groups and service delivery modes. As the economy grows the income ranges of each socio-economic group may change, and the categories used in the baseline year will be revised to reflect the new classification for future time horizons. Table 11 can be used to estimate future proportions of population in each income category.

Table 11: Distribution of socio-economic groups based on income ranges

	Low Income		Medium Income		High Income	
Year	Income range	Population, %	Income range	Population, %	Income range	Population,%
2015						
2020						
2030						
2040						
2050						

7.1.2 Commercial & Institutional Water Demand

This category refers to the water demand of institutional facilities and commercial enterprises such as schools, hospitals and health centers, churches and mosques, hotels, public offices, shops, prisons, abattoir and recreational parks.

The water demand for each facility may vary depending on the size of facility, activities involved and the level of service provided. Water demand estimation will be based on unit water demand and number of units in each facility. Examples of unit water use for the various commercial and institutional sectors are shown in Table 12.

Table 12: Units of water demand for commercial and institutional sector

Name of Facility	Unit of Water Use
Restaurants	L/seat
Schools*	L/student
Public offices	L/employee
Workshop/shops	L/employee
Mosques & Churches	L/worshipper
Cinema house	L/seat
Abattoir	L/cow
Hospitals	L/bed
Hotels	L/bed
Recreational parks	L/visitors
Public latrines	L/seat

*Schools may further be classified as boarding schools and day schools since they have different amounts of water demand

7.1.3 Livestock Water Demand

Water demand for livestock is estimated based on water requirements for adult livestock in a breeding facility. Table 13 shows the water demand per unit animal counts. The per capita consumption does not include water demand for processing of the product (meat). This value assumes that the water is supplied from municipal line.

Table 13: Unit of per capita water demand for different animals

Livestock type	Unit of water demand
Cattle, Donkeys, Horses	Lit/head/day
Sheep, Goats	Lit/head/day
Camels	Lit/head/day

7.2 Industrial Water Demand

For water demand estimation purposes, industries may be grouped into small manufacturing units and medium or large industries. Large scale industries are expected to have their own water supply system, usually from groundwater sources whereas small to medium industries would be connected to the municipal water supply line.

Unit water demand for manufacturing industries is associated with the unit product as shown in Table 14. In some cases, industrial products can be measured in weight of product (tons) or volume of product (cubic meter).

In the absence of detailed information on industrial facilities, water demand for small or medium scale industries can be estimated on the basis of their land area and their water use intensity (M^3/ha/d). In some cases industries with the same area can have different water demand depending on whether they include water intensive or non-water intensive processes.

Table 14: Unit of water demand measurements for different small manufacturing industries

Industry type	Unit demand in m^3/unit/day
Steel	M^3/ton
Tannery	M^3/ton
Garment, confectionery	M^3/ton
Biscuits, pasta similar	M^3/ton
Rubber and synthetics	M^3/ton
Concrete products	M^3/ton
Soft drinks	M^3/M^3 product
Beer	M^3/M^3 product
Canned food	M^3/can

7.3 Power Generation Water Demand

Water demand for power generation is estimated based on energy production capacity in cubic meters per Mega Watts (MW). Two types of power generation facilities are considered in this category: hydropower generation and non-hydropower (Thermoelectric) generation.

A hydropower plant diverts water from reservoirs to produce power and returns water back to the system downstream of reservoir location. The consumptive water demand for power generation comes from the water loss due to evaporation in reservoirs. Estimates of evaporation from reservoirs is dependent on climatic conditions and reservoir surface area. Net losses will be calculated as the difference between evaporation and precipitation.

Water demand for thermoelectric power generation is mainly for cooling purposes. About 98% of the water withdrawal is assumed to return back to the source if proper water quality (especially temperature and dissolved matter) is maintained. The consumptive water use is mainly attributed to the evaporation loss in cooling towers. Thermoelectric power generation facilities can be either of once-through (single pass) or closed loop (recirculating) systems. In a close loop system, the water remains in circulation for multiple cycles and significantly reduces the amount of water withdrawal from the source. In a once-through system, however, the cooling water is discharged to the source (with a deteriorated quality) and needs to be replaced from the source. If the discharge water quality does not meet the receiving water body requirements it may not be allowed to return to the source. As part of water conservation measures, many thermoelectric power generation facilities are changing from once-through to closed loop systems by including proper water treatment processes to reduce scaling and fouling issues of the cooling water.

7.4 Non-Revenue Water

Non-revenue water includes water losses in the water supply system, illegal connections overflow from reservoirs, improper metering and losses in treatment plant. The amount is expressed as percentage of the sum of domestic, commercial & institutional and industrial water supplied from the municipal system. The percentage usually varies from 15 to 50 percent depending on the age of the water distribution infrastructure, asset management and complexity of the system. For a summary of non-revenue water and target values from the Nile Basin countries see Technical Note III (Ghebremichael, et al., 2020)

In projecting future percentage of non-revenue water, it is assumed that the water infrastructure will be properly rehabilitated to reduce water loss to a reasonable value. With proper technical and financial management utilities can be expected to achieve the economic level of leakage over time. Economic level of leakage is the point at which the cost of producing water is equivalent to the investment required to reduce unaccounted for water.

7.5 Return Flow Estimation

Return flow is the difference between water withdrawals from the source and consumptive use. Estimation of return flows is important to determine the net withdrawal of water from the Nile River. Consumptive use is the amount of water that is consumed by people or incorporated in products. These values may vary from place to place and have different values for the different sectors. Consumptive water uses expressed as median percentage water supplied for the different sectors in the US are provided in Table 15.

Water that is supplied to users: (1) can be returned to the local water cycle by way of a wastewater collection and treatment system; (2) can be returned to the local water cycle directly as return flow to the environment; or (3) it is consumed by users and not returned to the local water cycle. The last option represents the consumptive use. Return flow from municipal and industrial users may come from those covered by municipal wastewater service and those that depend on onsite wastewater management. Return flows in towns with municipal services are usually piped to a stream or in some cases discharged to groundwater. For customers that depend on onsite system return flow is discharged to groundwater through a septic system and leach field.

Calculation of return flows requires estimation of return flow coefficients, which is a percentage of the demand. Return flow is the product of the coefficients and the supply amount.

Table 15 Example of median return flow coefficient in the Great Lakes Basin USA

Water use category	Consumptive use, percent	Return flow coefficient, percent
Domestic	12	88
Institutional and commercial	10	90
Livestock	83	17
Industrial	10	90
Thermoelectric power	2	98

7.6 Seasonal Water Demand Adjustment

Weather (temperature and precipitation) has an impact on water demand. While typically long-term demand forecasts are made on annual time scale, seasonal disaggregation (by month) is needed to capture the difference in water use driven by climate beyond the socio-economic factors. The approach that will be followed in this project will identify base climatological data for each of the cities and provide an adjustment "weight" to account for weather variations throughout the year.

7.7 Water Demand Peak Factors

The average daily municipal water demand is the sum of the domestic, commercial & institutional, industrial and unaccounted for water. It is used for planning purposes over longer periods and to estimate economic analysis of projects over their lifetime. For operational and design aspects of infrastructure maximum day and peak hour values need to be estimated.

The maximum day water demand is considered to meet water consumption changes with seasons and days of the week. It is used for sizing of infrastructure such as transmission and pumping stations. The ratio of the maximum daily consumption to the mean annual daily consumption is the maximum day factor. The proposed maximum day factor usually varies between 1.0 and 1.3.

The peak hour demand is the highest demand of any one hour over the maximum day. It represents the daily variations in water demand resulting from the consumption patterns of the customers. The peak hour demand is used to size infrastructure components such as reservoirs and pipelines. Hourly peak factors vary depending on population size and usually small size population experience higher peak factors. Recommended peak factors for population ranges are shown in Table 16.

Table 16: Hourly peak factors for different population sizes (Ministry of Water Resources of Ethiopia, 2006)

Population range	Peak hour factor
Less than 20,000	2.0
20,001-50,000	1.9
50,0001-100,000	1.8
More than 100,000	1.6

7.8 Example of Baseline Water Demand

From the database it is possible to generate several tables with any combination of attributes using SQL queries. This will allow users to present data that are grouped according to the purpose they want to share. For example, tables can be generated to show aggregate values of water demand at national level, city level, and at sector or sub sector levels. Table 17 shows an example of a 2017 baseline sectoral water demand grouped by city in Ethiopia. The table consists of attributes that include year, country name, city ID, and sector name.

Table 17 Water demand by city and sector

Year	Country Name	City ID	Water Use Sector Name	Sectoral Daily Demand (m^3/d)
..	..	..	..	..
2017	Ethiopia	0401	Domestic	8256.80
2017	Ethiopia	0401	Industrial	1623.09
2017	Ethiopia	0401	Commercial &Institutional	7284.28
2017	Ethiopia	0401	Livestock	36972.06
2017	Ethiopia	0401	Power	0.00
2017	Ethiopia	0402	Domestic	10385.41
2017	Ethiopia	0402	Industrial	1545.18
2017	Ethiopia	0402	Commercial &Institutional	11334.34
2017	Ethiopia	0402	Livestock	9243.02
2017	Ethiopia	0402	Power	2755.56
2017	Ethiopia	0403	Domestic	10489.26
2017	Ethiopia	0403	Industrial	3016.19
2017	Ethiopia	0403	Commercial &Institutional	22215.31
2017	Ethiopia	0403	Livestock	0.00
2017	Ethiopia	0403	Power	6768.48

…	…	…	…	…

The sectoral and total water demand at national levels are shown in separate tables. These values are the sum of sectoral and total water demand for each country. The total demand is calculated by incorporating the necessary correction factors such as percentage of unaccounted for water, adjustment for weather and adjustment for socio economic conditions. Please note that the numbers shown in the table are only examples and do not represent actual water demand in 2017.

Table 18: Municipal, Industrial and Power generation water demands by country

Year	Country	Municipal Water Demand (m^3/d)	Industrial Water Demand (m^3/d)	Power Generation Demand (m^3/d)
2017	Burundi	81396.05	4332.83	6672.54
2017	Democratic Republic of Congo	78604.81	4184.25	6443.73
2017	Egypt	341251.13	18165.30	27974.49
2017	Ethiopia	180079.75	9585.91	14762.27
2017	Kenya	155768.98	8291.81	12769.36
2017	Rwanda	117592.08	6259.60	9639.76
2017	South Sudan	36015.95	1917.18	2952.45
2017	Sudan	252111.65	13420.27	20667.17
2017	Tanzania	201689.32	10736.22	16533.74
2017	Uganda	116691.68	6211.67	9565.95

Table 19: Total baseline municipal, industrial and power water demand of Nile Basin countries. (Note: Total demand includes correction factors for non-accounted for water, weather and socio-economic conditions)

Year	Country	Total Demand (m3/d)
2017	Burundi	92401.42
2017	Democratic Republic of Congo	89232.79
2017	Egypt	0.00
2017	Ethiopia	204427.92
2017	Kenya	176830.16
2017	Rwanda	133491.43
2017	South Sudan	40885.58
2017	Sudan	286199.09
2017	Tanzania	228959.28
2017	Uganda	132469.30

References

Asefa, T., K. Ghebremichael and S. Tassew (2020). Municipal and Industrial Water demand projections to 2050. Technical Note II: Methodology and forecast results. Prepared for Nile Basin Initiative Secretariat (Nile-SEC), Entebbe, Uganda. May 2020.

Ghebremichael, K, Asefa, T., and Tassew, S (2020). Municipal and Industrial Water demand projections to 2050. Technical Note III. Prepared for Nile Basin Initiative Secretariat (Nile-SEC), Entebbe, Uganda. May 2020.

USGS (2008)

Appendix

7.9 Data collection Questionnaire

Category	Description
DF-1	Data Source a) Country: b) City/town: c) Utility Name: d) Website address, if any: e) Type of Utility: **[1 if it applies 0 if not]** i) Water ii) Wastewater iii) Storm Water iv) Reuse v) Other, please specify f) Contact Information of a person who be reached or further information i) Name of person ii) Email iii) Telephone
DF-2	Population a) Total population of city b) Population served by water utility
DF-3	Source of water supply **[1 if it applies 0 if not]** [ ] Groundwater [ ] Surface water [ ] Both (Ground water and surface water) [ ] Other sources of water, specify
DF-4	Water production capacity of the water supply system a. Maximum daily water production [liters/day] b. Average daily production for most recent year[liters/day]

	c. Average unaccounted for water (Percentage of the daily production) d. Total water consumed by customers (liters/day)
DF-5	Residential water use – water supply method Total water use in Households (liters /day) a. In-house connection [No of connections, no of people and water use in this category] i. Number of total connections ii. Total number of people served by in-house connection iii. Total water use in this category (liters/day) b. Yard tap external house [No of connections, no of people in this category and water use in this category] i. Number of total connections ii. Total number of people served by yard pipe iii. Total water use in this category (liters/day) c. Stand pipe/water kiosk [No of stand pipes/kiosk, no of people and water use in this category] i. Number of total connections ii. Total number of people served by stand pipe/kiosk iii. Total water use in this category (liters/day) d. Water truck [number of people, no of trucks in month, and truck volume in use in this category] i. Number of total waters truck delivered in a month ii. Total number of people served by water trucks iii. What is the average truck volume (liters) e. Other supply method, specify [type, number of people and average water use in this category] i. What method? f. Rusengo infrastructures springs managed i.Number of Rusengo insfrastructures ii. Total number of people served by this method iii. What is the average water in this method (liters/day) g.Streams ,rivers,lakes or springs non managed iTotal number of people served by this method ii.what is the average water in this method (lietrs/day) h. Other source i.Total number of people served by this method ii.what is the average water in this method (lietrs/day)
DF-6	Water rate structure a. Type of structure/households Flat fee [in US $] First tier [0 up to XX liters]

	Second tier Third tier Fourth tier Add rows if needed more c. Is there a different billing structure for residential, commercial, industrial water users? If yes, provide billing information in liters water use for each category. commercial and industrial water users Flat fee [in US $] First tier [0 up to XX liters] Second tier Third tier Fourth tier Add rows if needed more d.Administration e. Stand pipe/water kiosk f.collectives customers g. When was the last time water rate prices adjusted? ? in households First tier i. By how much (in US $) ii. How much percentage increase at the time? second tier i. By how much (in US $) ii. How much percentage increase at the time? Third tier i. By how much (in US $) ii.How much percentqge increase at the time h. What is the expectation for future rate increase? (if you know) i. When? ii. How much percentage?
DF-7	Number of city population in the following socio-economic groups? a. No of Low income Population Income range (in US $) b. No of middle income Population Income range (in US $) C. No of High income Population Income range (in US $)
DF-8	Number of home owners in each socio-economic group in range identified in Question 8 a. Low income

	b. Middle income c. High income
DF-9	Number of renters in each socio-economic group identified in Question 8 a. Low income b. Middle income c. High income
DF-10	Number of houses with water meters
DF-11	Sanitation system a. Number of houses connected to sewer system b. Number of houses using septic tanks c. Number of house using dry toilets
DF-12	Water distribution system
DF-12	a. Total length of water distribution system [km]
DF-12	b. Pipe length by size category (diameter) [km, m]
DF-12	Add rows if needed more
DF-13	Residential water use[including single and multifamily such as condominiums] a. Single family (stand alone house without sharing wall) i. No of accounts ii. Average water use (literss/day) iii. Source of water [surface or ground water] b. Multi family i. No of accounts ii. Average water use (literss/day) iii. Source of water [surface or groundwater]
DF-14	Non-residential [such as schools, commercial buildings, hospitals, hotels, government offices, worship places. For each type provide the following information] Fill each column for the establishment a. Name:Government b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. Name:Religious confessions(churches) b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. Name:city and commune b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. Name:general b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. name :industrials (no precision) b. Average water use (liters/day)

	c. Source of water (surface or groundwater)] a. name :state societies b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. name :Administration personalised b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. name :Diplomatics mission b. Average water use (liters/day) c. Source of water (surface or groundwater)] a. name : self consumption by compagny of water supply (REGIDESO) b. Average water use (liters/day) c. Source of water (surface or groundwater)]
DF-15	Industrial [such as manufacturing, mining, construction]. For each type provide the following information. Add information in each column i. Name of industry ii. Average water use (liters/day) iii. Source of water (surface or groundwater)
DF-16	Power [hydro power and non-hydropower generation]. For each type provide the following information i. Name of power plant ii. Power plant location (Latitude and Longitude) iii. Type of plant (hydropower or non-hydropower) iv. Power production capacity v. Average water use (liters/day) vi. Source of water for non-hydro power plants (surface or groundwater, fresh or saline water)
DM-1	What is the percentage of water sourced from surface water, ground water, salt water or other sources?
DM-2	Does the city has water conservatin policy or program? **[1 if it applies, 0 if not]**
	What type of water conservation measures are practiced **(indicate that apply)**
	i) Efficient water fixture replacements programs with rebate
	ii) Water conservation awareness raising programs
	iii) Outdoor water use reduction and efficient landscape irrigation
DM-3	If the city or utility has a rebate program, which ones are in place? [**1 if it applies, 0 if not**]
	i) High efficiency toilet toilets
	ii) Water saving shower heads
	iii) Efficient washing machines
	iv) High efficiency urinal
	v) Efficient cooling towers
DM-4	Does the utility practice the following [**1 if it applies, 0 if not**]
	i) Rain water harvesting

	ii) Greywater reuse
	iii) Water loss reduction program
DM-5	If the city has water conservation program
	i) when was it implemented (year)
	ii) What is the water conservation goal for the city (percentage reduction of demand)
	iii) Does the utility have staff working on water conservation effort?
	iv) Does the utility have water audit program?
	v) Does the utility or municipality has annual budget for water demand management?

7.10 Sample tables that describe the database framework

Sample tables representing the different components of the database framework diagram are provided below.

Table A-8.2-1 Master Table

Country Name	Country Code	Country ID
Burundi	BI	01
Democratic Republic of Congo	CD	02
Egypt	EG	03
Ethiopia	ET	04
Kenya	KE	05
Rwanda	RW	06
South Sudan	SSD	07
Sudan	SD	08
Tanzania	TZ	09
Uganda	UG	10

Table A-8.2-2: City Table

CountryName	CityName	CityID	Latitude	Longitude
Ethiopia	Adwa	401	14.16786	38.81317
Ethiopia	Ambo	402	8.955737	37.92211
Ethiopia	Assosa	403	10.06601	34.50767
Ethiopia	Axum	404	4.132693	38.67655
Ethiopia	Bahir Dar	405	11.582	37.24034
Ethiopia	Debre Birhan	406	9.67132	39.49422
Ethiopia	Debre Markose	407	10.33075	37.69697
Ethiopia	Debre Tabor	408	11.85664	37.97941

Ethiopia	Gambella	409	8.248185	34.55569

Table 8.2-3: Sector Table

Water Use Sector Name	Water Use Sector ID
Domestic	11
Commercial & Institutional	12
Livestock	13
Industry	14
Power	15

Table A 8.2-4: Sub Sector Table

Water Use Sub Sector Name	Water Use SubSector ID	Water Use Sector Name
House tap users (HTUM)	1101	Domestic
House tap users (HTUH)	1102	Domestic
Yard Tab Users	1103	Domestic
Neighborhood Tab Users	1104	Domestic
Public Tab Users	1105	Domestic
Restaurants	1201	Commercial & Institutional
Boarding school	1202	Commercial & Institutional
Day schools	1203	Commercial & Institutional
Public offices	1204	Commercial & Institutional
Workshop/shops	1205	Commercial & Institutional
Mosques & Churches	1206	Commercial & Institutional
Cinema house	1207	Commercial & Institutional
Abattoir	1208	Commercial & Institutional
Hospitals	1209	Commercial & Institutional
Hotels	1210	Commercial & Institutional
Public Bath	1211	Commercial & Institutional
Railway & Bus station	1212	Commercial & Institutional
Military Camps	1213	Commercial & Institutional
Public latrines (with water facility connection)	1214	Commercial & Institutional
Prison	1215	Commercial & Institutional
Commercial	1216	Commercial & Institutional
Swimming Pool	1217	Commercial & Institutional
Recreation (Parks)	1218	Commercial & Institutional
Recreation (sport center)	1219	Commercial & Institutional
Dairy Farm and Fattening Production	1220	Commercial & Institutional
Cattle, donkeys, horses etc	1301	Livestock
Goats/Sheep	1302	Livestock
Camel	1303	Livestock

Steel	1401	Industry
Tannery	1402	Industry
Garment	1403	Industry
Biscuits, pasts, etc	1404	Industry
Rubber and synthetic	1405	Industry
Concrete products	1406	Industry
Soft drinks	1407	Industry
Beer	1408	Industry
Canned Food	1409	Industry
Thermal	1501	Power
Hydro	1502	Power

Table A 8.2-5: Domestic Table

Name of Domestic Water User	**Country Name**	**City Name**	**Water Use Sub Sector Name**	**Domestic Water Use ID**
Bahirdar City HTUH	Ethiopia	Bahirdar	House tap users high income (HTUH)	401110101
Bahirdar City HTUM	Ethiopia	Bahirdar	House tap users medium income (HTUM)	401110201
Bahirdar City YTUP	Ethiopia	Bahirdar	Private yard tap users (YTUP)	401110301
Bahirdar City YTUN	Ethiopia	Bahirdar	Neighborhood yard tap users (YTUN)	401110401
Bahirdar City PTU	Ethiopia	Bahirdar	Public tap users (PTU)	401110501
DebreMarkos City HTUH	Ethiopia	DebreMarkos	House tap users high income (HTUH)	402110101
DebreMarkos City HTUM	Ethiopia	DebreMarkos	House tap users medium income (HTUM)	402110201
DebreMarkos City YTU	Ethiopia	DebreMarkos	Private yard tap users (YTUP)	402110301
DebreMarkos City NTU	Ethiopia	DebreMarkos	Neighborhood yard tap users (YTUN)	402110401
DebreMarkos City PTU	Ethiopia	DebreMarkos	Public tap users (PTU)	402110501
…	..	..	..	..

Table A 8.2-6: Commercial & Institutional Table.

Name	**Country Name**	**City Name**	**Water Use Sub Sector Name**	**C&I ID***
Restaurants	Ethiopia	Bahirdar	Restaurants	0401120101
Boarding school	Ethiopia	Bahirdar	Boarding school	0401120201
Day schools	Ethiopia	Bahirdar	Day schools	0401120301
Public offices	Ethiopia	Bahirdar	Public offices	0401120401
Workshop/shops	Ethiopia	Bahirdar	Workshop/shops	0401120501
Mosques & Churches	Ethiopia	Bahirdar	Mosques & Churches	0401120601
Cinema house	Ethiopia	Bahirdar	Cinema house	0401120701
Abattoir	Ethiopia	Bahirdar	Abattoir	0401120801
Hospitals	Ethiopia	Bahirdar	Hospitals	0401120901
Hotels	Ethiopia	Bahirdar	Hotels	0401121001
Public Bath	Ethiopia	Bahirdar	Public Bath	0401121101
Railway & Bus station	Ethiopia	Bahirdar	Railway & Bus station	0401121201
Military Camps	Ethiopia	Bahirdar	Military Camps	0401121301
Public latrines (with water facility connection)	Ethiopia	Bahirdar	Public latrines (with water facility connection)	0401121401
Restaurants	Ethiopia	DebreMarkos	Restaurants	0402120101
Boarding school	Ethiopia	DebreMarkos	Boarding school	0402120201
Day schools	Ethiopia	DebreMarkos	Day schools	0402120301
Public offices	Ethiopia	DebreMarkos	Public offices	0402120401
Workshop/shops	Ethiopia	DebreMarkos	Workshop/shops	0402120501
Mosques & Churches	Ethiopia	DebreMarkos	Mosques & Churches	0402120601
Cinema house	Ethiopia	DebreMarkos	Cinema house	0402120701
Abattoir	Ethiopia	DebreMarkos	Abattoir	0402120801
Hospitals	Ethiopia	DebreMarkos	Hospitals	0402120901
Hotels	Ethiopia	DebreMarkos	Hotels	0402121001
Public Bath	Ethiopia	DebreMarkos	Public Bath	0402121101
Railway & Bus station	Ethiopia	DebreMarkos	Railway & Bus station	0402121201

Military Camps	Ethiopia	DebreMarkos	Military Camps	0402121301
Public latrines (with water facility connection)	Ethiopia	DebreMarkos	Public latrines (with water facility connection)	0402121401
…	..	…	…	..

*Commercial & Institutional

Table A 8.2-7: Livestock Table

Name	**Country Name**	**City Name**	**Water Use Sub Sector Name**	**Livestock ID**
Cattle, donkeys, horses etc	Ethiopia	Bahirdar	Livestock	0401130101
Goats/Sheep	Ethiopia	Bahirdar	Livestock	0401130201
Camel	Ethiopia	Bahirdar	Livestock	0401130301
Cattle, donkeys, horses etc	Ethiopia	DebreMarkos	Livestock	0402130101
Goats/Sheep	Ethiopia	DebreMarkos	Livestock	0402130201
Camel	Ethiopia	DebreMarkos	Livestock	0402130301
…	…	…	…	…

Table A 8.2-8: Industry Table

Industry Name	**Country Name**	**City Name**	**Water Use Sub Sector Name**	**Lat**	**Long**	**Industry ID**
Steel	Ethiopia	Bahirdar	Steel			0401140101
Tannery	Ethiopia	Bahirdar	Tannery			0401140201
Garment	Ethiopia	Bahirdar	Garment			0401140301
Biscuits, pasts, etc	Ethiopia	Bahirdar	Biscuits, pasts, etc			0401140401
Rubber and synthetic	Ethiopia	Bahirdar	Rubber and synthetic			0401140501
Concrete products	Ethiopia	Bahirdar	Concrete products			0401140601
Soft drinks	Ethiopia	Bahirdar	Soft drinks			0401140701
Beer	Ethiopia	Bahirdar	Beer			0401140801
Canned Food	Ethiopia	Bahirdar	Canned Food			0401140901
Steel	Ethiopia	DebreMarkos	Steel			0402140101
Tannery	Ethiopia	DebreMarkos	Tannery			0402140201
Garment	Ethiopia	DebreMarkos	Garment			0402140301
Biscuits, pasts, etc	Ethiopia	DebreMarkos	Biscuits, pasts, etc			0402140401
Rubber and synthetic	Ethiopia	DebreMarkos	Rubber and synthetic			0402140501

Concrete products	Ethiopia	DebreMarkos	Concrete products			0402140601
Soft drinks	Ethiopia	DebreMarkos	Soft drinks			0402140701
Beer	Ethiopia	DebreMarkos	Beer			0402140801
Canned Food	Ethiopia	DebreMarkos	Canned Food			0402140901
..	…	…	…	..	…	..

Table A 8.2-9: Power Plant Table

Powerplant Name	**Country Name**	**City Name**	**Water Use Sub Sector Name**	**Powerplant ID**	**Latitude**	**Longitude**
Tis Abay	Ethiopia	Bahirdar?	Power	0401150101		
Tis Abay	Ethiopia	Bahirdar?	Power	0401150102		
Tis Abay	Ethiopia	Bahirdar?	Power	0401150103		
Thermal	Ethiopia	Bahirdar?	Power	0401150201	NA	NA
Hydro	Ethiopia	DebreMarkos	Power	0402150101		
Thermal	Ethiopia	DebreMarkos	Power	0402150101		
…	….	….	….	….	….	….

Table A 8.2-10: Water Demand Table

Year	**City ID**	**Water Use Sector Name**	**Water Use SubSector ID**	**Sub Sectoral Daily Demand**	**Sectoral Daily Demand**
2009	0101	Domestic	1101,1102,1103,1104,…		
2009	0101	Commercial &Institutional	1201,1202,1203,1204,…		
2009	0101	Livestock	1301,1302,1303,1304,…		
2009	0101	Industry	1401,1402,1403,1404,…		
2009	0101	Power	1501,1502,1503,1504,…		
2009	0102	Domestic	1101,1102,1103,1104,…		
2009	0102	Commercial &Institutional	1201,1202,1203,1204,…		
2009	0102	Livestock	1301,1302,1303,1304,…		
2009	0102	Industry	1401,1402,1403,1404,…		
2009	0102	Power	1501,1502,1503,1504,…		
2009	0103	Domestic	1101,1102,1103,1104,…		
2009	0103	Commercial &Institutional	1201,1202,1203,1204,…		
2009	0103	Livestock	1301,1302,1303,1304,…		
2009	0103	Industry	1401,1402,1403,1404,…		

2009	0103	Power	1501,1502,1503,1504,…		
2009	0201	Domestic	1101,1102,1103,1104,…		
2009	0201	Commercial &Institutional	1201,1202,1203,1204,…		
2009	0201	Livestock	1301,1302,1303,1304,…		
2009	0201	Industry	1401,1402,1403,1404,…		
2009	0201	Power	1501,1502,1503,1504,…		
2009	0202	Domestic	1101,1102,1103,1104,…		
2009	0202	Commercial &Institutional	1201,1202,1203,1204,…		
2009	0202	Livestock	1301,1302,1303,1304,…		
2009	0202	Industry	1401,1402,1403,1404,…		
2009	0202	Power	1501,1502,1503,1504,…		

Table A 8.2-11: Population Table

Year	**City ID**	**Water Use Sector Name**	**Water Use Sub Sector ID**	**Sub Sectoral Population**	**Total Sectoral Population**
2009	0401	Domestic	1101	34,378	197054
2009	0401	Domestic	1102	48750	197054
2009	0401	Domestic	1103	98527	197054
2009	0401	Domestic	1104	10800	197054
2010	0401	Domestic	1101	36320	206124
2010	0401	Domestic	1102	51504	206124
2010	0401	Domestic	1103	103062	206124
2010	0401	Domestic	1104	10800	206124
2015	0401	Domestic	1101	51893	254037
2015	0401	Domestic	1102	77228	254037
2015	0401	Domestic	1103	112258	254037
2015	0401	Domestic	1104	12658	254037
2020	0401	Domestic	1101	72673	306887
2020	0401	Domestic	1102	113507	306887
2020	0401	Domestic	1103	106165	306887
2020	0401	Domestic	1104	14542	306887
2025	0401	Domestic	1101	101571	369991
2025	0401	Domestic	1102	166496	369991
2025	0401	Domestic	1103	85251	369991
2025	0401	Domestic	1104	16673	369991
2030	0401	Domestic	1101	137353	431591
2030	0401	Domestic	1102	236293	431591
2030	0401	Domestic	1103	39449	431591
2030	0401	Domestic	1104	18496	431591
…	…		…	…	….

Table A 8.2-12: Per Capita Water Demand

Country Name	Water Use Sub Sector Name	Year	Unit	Unit Demand
Ethiopia	House Tap Users	2016	--	
Ethiopia	Yard Tab Users	2016	--	
Ethiopia	Neighborhood Tab Users	2016	--	
Ethiopia	Public Tab Users	2016	L /person	
Ethiopia	Restaurants	2016	L/seat	
Ethiopia	Boarding school	2016	L/Student	
Ethiopia	Day schools	2016	L/Student	
Ethiopia	Public offices	2016	L/employee	
Ethiopia	Workshop/shops	2016	L/employee	
Ethiopia	Mosques & Churches	2016	L/employee	
Ethiopia	Cinema house	2016	L/seat	
Ethiopia	Abattoir	2016	L/cow	
Ethiopia	Hospitals	2016	L/bed	
Ethiopia	Hotels	2016	L/bed	
Ethiopia	Public Bath	2016	--	
Ethiopia	Railway & Bus station	2016	--	
Ethiopia	Military Camps	2016	--	
Ethiopia	Public latrines (with water facility connection)	2016	L/seat	
Ethiopia	Cattle, Donkeys, Horses	2016	Lit/head/day	
Ethiopia	Goats/Sheep	2016	Lit/head/day	
Ethiopia	Camel	2016	Lit/head/day	
Ethiopia	Steel	2016	M^3/ton	
Ethiopia	Tannery	2016	M^3/ton	
Ethiopia	Garment	2016	M^3/ton	
Ethiopia	Biscuits, pasta, etc	2016	M^3/ton	
Ethiopia	Rubber and synthetic	2016	M^3/ton	
Ethiopia	Concrete products	2016	M^3/ton	
Ethiopia	Soft drinks	2016	M^3/M^3 product	
Ethiopia	Beer	2016	M^3/M^3 product	
Ethiopia	Canned Food	2016	M^3/can	
Ethiopia	Thermal	2016	M^3/MW	
Ethiopia	Hydro	2016	M^3/MW	

Table A8.2-13: GDP Table

Country Name	GDP
Burundi	
Democratic Republic of Congo	
Egypt	
Ethiopia	
Kenya	
Rwanda	
South Sudan	
Sudan	
Tanzania	
Uganda	

Table A 8.2-14: GDP Distribution Table

Country Name	City Name	GDP Weight
Ethiopia	Bahirdar	W1
Ethiopia	Debre Markos	W2
Ethiopia	Gondar	W3
…	…	…

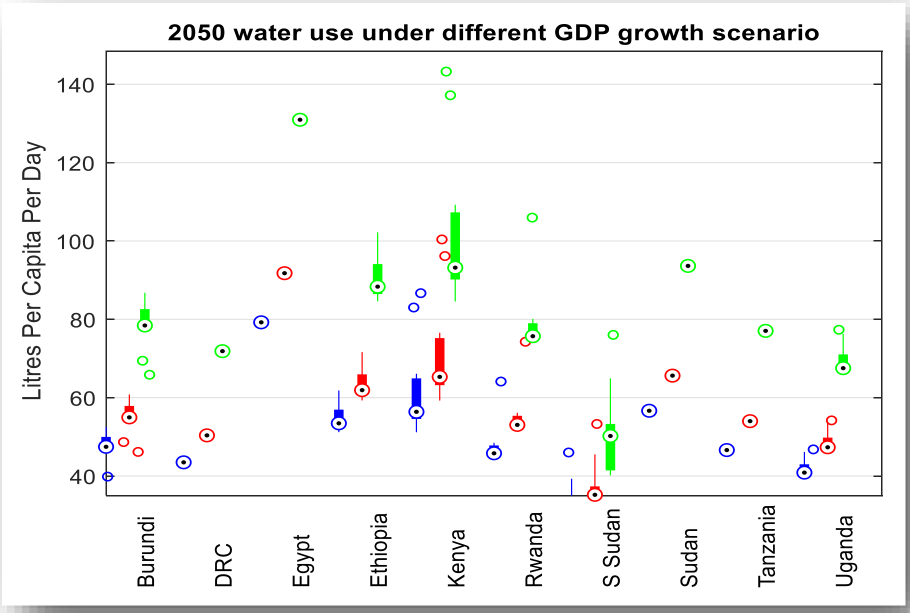
Table A 8.2-15: Non- Revenue Water Demand Table

Country Name	City Name	Demand %
…	…	…
Ethiopia	Bahirdar	
Ethiopia	Debre Markos	
Ethiopia	Gondar	
Ethiopia	Mekele	
…	…	…

Table A 8.2-16: Weather Parameter Table

Country Name	**City Name**	**Month**	**Rainfall mean**	**Rainfall Standard Deviation**	**Temperature mean**	**Temperature Standard Deviation**
Ethiopia	Bahirdar	Jan				
		Feb				
		Mar				
		Apr				
		May				
		Jun				
		Jul				
		Aug				
		Sep				
		Oct				
		Nov				
		Dec				
Ethiopia	Debre Markos	Jan				
		Feb				
		Mar				
		Apr				
		May				
		Jun				
		Jul				
		Aug				
		Sep				
		Oct				
		Nov				
		Dec				
..	..	..	..	..	..	..

Municipal and industrial water projection for Nile Basin countries



NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

MAY 2020

Technical Note II: Methodology and forecast results

Prepared for

Nile Basin Initiative

Prepared By:

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Contents

Introduction

Sustainable water resources planning, and management requires adequate understanding and accounting of available water resources at present and in the future. Such information that is estimated based on rigorous study and the right modelling tools is crucial to make sure that adequate water is available to meet the growing demand due to population growth, economic development and climate change. This is also useful to ensure proper allocation of water to the various sectors. In the case of the Nile Basin countries, this is important as they transition to middle income economies.

Typically, regional demand projections are used to support a decision about the timing and the needed scale of supply projects that may require significant investment to bridge the gap between demand and supply (Figure 1). As shown in Figure 1a, available supply will fail to meet projected demand at time T*. New supply must be planned to meet this demand, if one wants to avoid significant stress in the region that may have consequence. Figure 1b shows the time at which an additional capacity should be brought online in order to meet the growing demand. Identifying when to bring new supply sources to meet demand is a significant investment. In making such investment decisions, it is important not to under- or overestimate future water demands. For this, one needs to develop a robust system of forecasting demand and it should be able to track current demand in a meaningful manner.

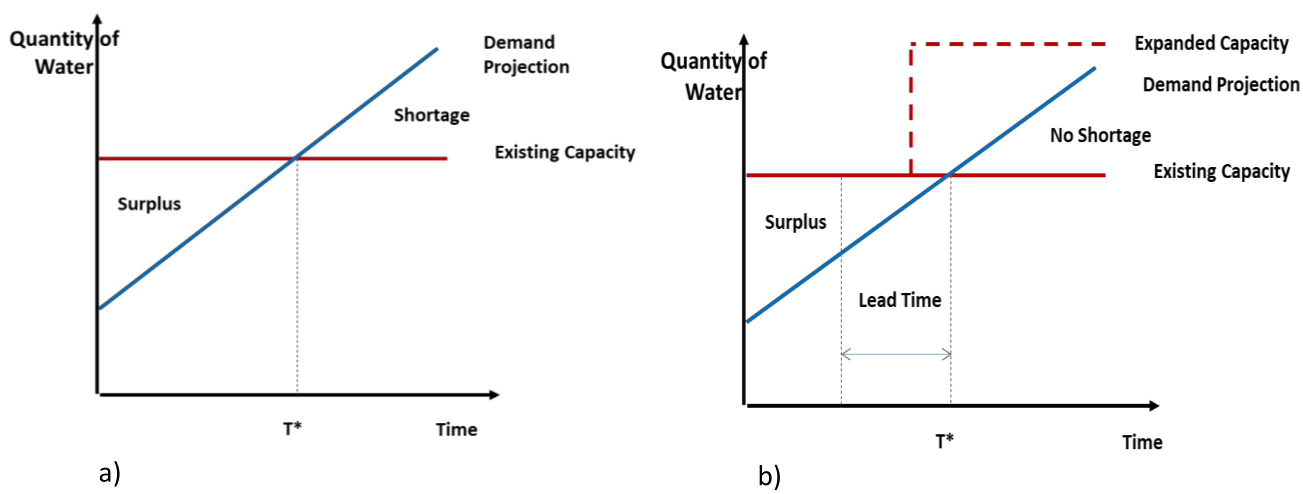

Figure 1. Typical water supply planning. Demand forecast helps the timing and scale of additional supply a region may need. a) when existing supply runs out to meet demand, beyond T*, there will be a shortage b) shows "lead time" needed to bring new supply source. Once new supply source come online (dotted red), possibilities for shortage will be avoided.

Factors Influencing Demand Forecast

Several factors influence water use in residential, commercial, or industrial sectors. Such factors include demographic, economic situation, climatic conditions, technological advancements and water use practices including customer behaviors. Future demand of a region is primarily driven by population growth and increases in sectoral water uses. Municipal demand is primarily driven by population and per capita use.

Demographics and economic development

Growth of water demand is closely associated with the Gross Domestic Product (GDP) of a country. This also applies to industrial water uses. Economic activities dictate the amount of water consumption as the standard of living of communities evolves and the region attracts different types of industries. As the population transitions to middle- or high-income society, the per capita water consumption increases. In the case of industry, water use would be impacted by the type of industry, industrial population, and type of products in the economy.

Climate

Climatic factors significantly impact water demand estimation. Typically, temperature and rainfall are the key weather factors influencing water use. In general, higher temperature is correlated with increased water use, whereas high precipitation may help modulate seasonal water use. Where appropriate (signal is detectable), weather impacts result in differences in seasonal water use across different sectors.

Technological advancements

Water demand can be significantly influenced by the level of market penetration of efficient water use fixtures such as low flush toilets, water saving shower heads, appliances, and efficient lawn irrigation systems and industries.

It is important that when developing a robust water demand forecast model all these variables are taken into consideration. Moreover, information contained in the demand forecast may need to support additional analyses with respect to price sensitivity, water conservation potential, and segments of demand that may be effectively served by non-potable sources of supply. If operational costs of supply alternatives vary geographically, for example due to differences in types and specific conditions of an NBI country, then the demand forecast may also need to differentiate between projected demand across different parts of the region.

Topology of water demand forecasting models

A variety of approaches are used in practice to estimate demand forecast for a region (Billings and Jones, 2008; Donkor et al., 2014). Table 1 presents a summary of approaches including their limitations from simple to more complex approaches. Brief description of each methods is provided below.

Table 1 Demand forecasting topology

Approach	Description	Data Requirement	Limitations
Trend extension and univariate models	Projects past observation into the future	Past water use	Limited predictive ability. Doesn't account future socio-economic condition

Unit water demand (e.g., per capita)	Forecast is based on projected unit water use multiplied by the number of users in the sector	Unit water use and projection of the number of users	Doesn't account changes in unit water use. Socio-economic factors not explicitly handled
Regression/Econometric Models	Demand forecast based on regression, typically linear in transformed space	Sectoral socio-economic, weather data	Needs extensive data that may not be readily available in certain regions
Multi-variate Statistical Models	Demand forecast based on multi-variate relationship, cross correlation in time-space considered	Sectoral socio-economic, weather data	Needs extensive data that may not be readily available in certain regions

Trend Extensions and Univariate Time Series Models

Trend extrapolation and univariate time series techniques forecast water demand as a function of its past values. Trend extrapolation fits a trend line through an historical time series of observed water use pattern and uses this line to extrapolate future values. Trend lines are easily fit in modern spreadsheet programs and also provide some options for fitting nonlinear curves. The underlying assumption of trend extrapolation is that water use can be explained by the passage of time and forecasts of future demand rely only on the value of a time counter or index.

Univariate time series models can be significantly more refined and statistically complex than simple trend extrapolation. As a class of models, they stem from the work of Box and Jenkins (1976). Although these approaches are seldom used in a long-term forecasting context they are technically adaptable to any forecast horizon. The time series literature is highly developed and specialized. In general, time series models can be described by the three component parts of what is known as ARIMA: Auto-Regressive, Integrated, Moving Average. A purely auto-regressive (AR) model predicts water use based on a statistical weighting of its past values. If considered necessary, adding a moving average (MA) component weighs past prediction errors of the AR component to improve predictions. Finally, if differencing of historical observations is necessary to make the original series stationary (that is, of constant mean and variance), the order of integration reflects how many times the series must be differenced. Asefa and Adams (2007) and Tian et al. (2016) used such type of models for urban water demand forecast. Also, House-Peters and Chang (2011) present a review of concepts and estimation methods used for water demand modeling.

Fixed Unit Use Coefficient Models

Unit use coefficient models reflect a class of models where average rates of water use are differentiated from total water use. In general, unit use coefficient models can be expressed as

$$Q_t = U_t * k = U_t \left(\frac{\bar{Q}}{U}\right)\Big|_H \qquad \text{Equation 1}$$

where for a given time period t, Q represents a measure of water use, U represents a count of units associated with the measure of water use, and k denotes an average of water use per unit evaluated over a set of historical observations (H). A traditional application of this type of model is the per capita water use method, where forecasts of population are substituted for the term U and an assumption for average liter per capita is substituted for the term k. In this case, a forecast of future water use depends on both projections of population and estimated per capita use at some future time. There are several possible variations in fixed coefficient methods, depending on the measure of water use that is being forecasted. The term for counting units (U) typically specifies variables that are believed to strongly influence (or drive) long-term trends in water use. In residential water use classes, this variable may often be specified as housing units or households. In nonresidential classes, employment and square footage of structures are often specified as drivers of demand. For agricultural classes, land size or irrigated land size are often used. Land use is also used in cases where future zoning might be considered, for example in association with comprehensive land use plans. A disaggregated unit use model may forecast future demand as the sum of individual sectors (s), which have their own unit counts and water use coefficients:

$$Q_t = \sum_{s=1}^{S} U_{s,t} * k_s \qquad \text{Equation 2}$$

This approach can easily accommodate other data disaggregation to reflect the desired dimensions of the forecast. For example, adding the indices m to represent month, and g to indicate geographic areas, and assuming the time step of the forecast (t) is an annual period, the following specification represents a sectorally, temporally, and geographically disaggregated model:

$$Q_t = \sum_{g=1}^{G} \sum_{s=1}^{S} \sum_{m=1}^{M} U_{g,s,m,t} * k_{g,s,m} \qquad \text{Equation 3}$$

Thus, unit use coefficient approaches are quite flexible for accounting for known seasonal, sectoral, and geographical differences in water use. If forecasts of units are available at this level of disaggregation, then forecasts will be capable of accounting differences in projected rates of growth among different sectors, as well as differences in the distribution of water use geographically within a given water planning area. However, this approach may be limited with one's ability to forecast future per unit uses and in some area, this may be held constant.

Regression and Econometric Models

Regression analysis seeks to derive an equation (or regression model) that can be used to estimate the unknown value of one variable (called the dependent variable) on the basis of known values of one or more other variables (called independent, or explanatory, variables) (Mansfield, 1983). The classic simple linear regression model that uses the value of a single independent variable, X, to predict the value of the dependent variable Y can be written as:

$$Y_i = \alpha + \beta X_i + \varepsilon \qquad \text{Equation 4}$$

α = An "intercept" term that estimates the value of Y when X equals 0

β = A regression parameter (or slope coefficient) that describes both the direction and degree that Y changes when X changes

ε = A random model error (or residual) term that measures the difference between the predicted value of Y, given the value of X, and the true or observed value of Y

i = An index representing dimensions such as time, individuals, geographic areas, etc.

A distinguishing feature of the regression model is the presence of the error term, ε, which is not observable nor known in advance. The presence of the error term suggests that estimating the values of α and β is equivalent to estimating the mean (or expected value) of the dependent variable. Thus, regression analysis assumes that a *statistical* relationship exists between Y and X, where the *average* value of Y is related to the value of X. For example, water use may increase, on average, with higher temperatures or higher incomes, but not all water users facing the same temperatures and earning the exact same incomes will use the same amount of water. If they did, then the relationship would be *deterministic* and there would be no need for the error term. Therefore, regression analysis recognizes that it is generally not possible with certainty to predict a single value of Y on the basis of the value of X. It is also important to note that regression models are typically estimated on the basis of samples and not the entire population of possible pairings between X and Y. Therefore, in practice, the sample estimates of model parameters, usually denoted as $\hat{\alpha}$ and $\hat{\beta}$ may deviate from their "true" values α and β. These ideas are important with respect to forecast uncertainty.

Typically, these models are fit in logarithmic space such that coefficients are interpreted as elasticity and enables one to conduct what-if scenario based on different econometric future outlooks.

Multi-variate and/or Statistical Models

Yet another class of demand forecasting models are multi-variate statistical models. These models account cross correlation in time and/or space of dependent as well as independent variables. They are useful in the sense that, by definition, enforces cross-correlation between input and outputs, if so desired. These models range from simple multi-variate regression model to those based on Artificial Neural Network or Support Vector Machines types. Usually, the type and history of data available dictates the complexity of these models as wells as their applicability.

Structure of the M&I water demand projection model

Most global water demand forecasting models include in some form the total population served, the cost of the service (price of water) and their ability to pay for the service (income or socio-economic level). Typically, ability to pay for water depends on the income level of the water user which is reflected in the per capita Gross Domestic Product (GDP) of a country. The higher the per capita GDP, the higher the per capita water use. Both municipal and industrial water consumption increases proportional to growth in per capita GDP. This is attributed to the increasing number of in-house connection (the proportion of high-income population that is supplied water inside the house) in areas with higher per capita GDP as this segment of the population could afford to live in such neighborhood. Lower per capita GDP may necessitate a yard pipe connection (where multiple residents share a single water connection in the yard), which is associated with lower per capita water use. In addition to GDP, technological advances and weather are also important factors that impact domestic and industrial water use. The importance of technological advances come through natural replacement of old fixtures with efficient household fixture found in the market. This is termed as passive efficiency measure. Long-term demand forecast that have outlooks of 20 to 50 must account for potential saving through passive efficiency and make adjustment to project water demand.

Demand forecasting models that are designed for a large area involving multiple cities and countries (such as the Nile Basin countries) are typically designed to overcome the limitation of time series data that may not be available at a single location. In such cases geographical cross-sectional models are typically used. These models have key assumptions that need to be verified through targeted data collections. Two key assumptions in developing cross-sectional models that are designed to overcome the lack of available time series data at single location are: 1) the trajectory of water use as income increases are considered similar. This allows per capita GDP to be associated with per capita water use; and 2) impact of price of water on per capita water consumption is transferable from one region to another once it is transferred in a common currency denominator such as the dollar. While several global based models assume the trajectory of water use to be similar, for example, as developing countries prosper the per capita water use may follow developed countries water use, this may not always be the case where there is significant cultural difference and the type of water use may not follow that of developed country trajectory. Transferability price impact on water use may also pose a challenge, if certain countries subsidize water in a much different way than others.

In general, water use for a region may be estimated as follow:

$$WU = WU_c * Pop \quad \text{Equation 5}$$

Where,

WU is total water use in m^3 $month^{-1}$, WU_c water use in m^3 $capita^{-1}$ $month^{-1}$, and Pop is population served.

Water use per capita is estimated as follows:

$$WU_c = \propto GDPC^{\beta 1} * Price^{\beta 2} * Tech * Seas\ Adj \quad \text{Equation 6}$$

Where GDPC is per capita GDP, *Tech* represent technology adjustment to passive water use efficiency as a result of efficiency gains by households' future efficient appliances replacement; and Seas Adj representant seasonal adjustments because of weather (rainfall and temperature).

Typically, monthly water use will follow a seasonal weather pattern, where such influence exists. α, β1, and β2 are calibration parameters relating per capita water use to independent the per capita water uses explanatory variables. The data sources and parameters are discussed in the following section.

Model Parameters

Gross Domestic Product (GDP)

Per capita income is one of the major long-term demand projection parameters that is widely used to estimate future water use of a region. Current per capita GDP for each of the Nile Basin countries was obtained from the World Bank database as a surrogate for income. The base year was set as 2016 in order to reconcile other data availability for the region.

Price

It is well documented that the price of water impacts rate of water consumption. The consultant's own research indicates that price of water and personal incomes are the two most important factors that explain the pattern of water use per capita. Price of water was collected for each of the cities from different sources: 1) Data collection from individual country by national consultants[1]: 2) publicly available utility documents; 3) The International Benchmarking Network for Water and Sanitation Utilities (IBNET) (https://tariffs.ib-net.org/); and 4) African Development Bank database (http://infrastructureafrica.opendataforafrica.org/data#source=AfDB). Source number one was given a priority. Once water prices for each of the countries and cities were collected, it was translated into a common denominator of US dollar per litter.

Weather

While municipal and industrial water demand projections are based on annual basis up to 2050, it is important to understand that seasonal demand fluctuations driven by change in weather are also considered. Typically, rainfall and temperature are the key parameters that result in monthly water use variations. Seasonally higher temperature and dry months seem to be much more correlated with higher water consumption. Having a weather parameter that allows a seasonal disaggregation is useful to combine demand and supply side systems modeling that is typically done at a monthly time scale. Inclusion of a weather factor into demand projection allows the investigation of climate variability and climate change in water use. Given the current focus of the first phase of demand projection at annual scale, monthly weather information was not included in the final model. It is recommended that future update of this models should include monthly variation of demand.

Water conservation/technology

"Natural" water conservation occurs over time because of technological advancement in water use appliances and fixtures. As old appliances and fixtures are naturally replaced, typically, per capita water use may decrease by about 0.5% to 2% annually depending on the efficiency rating of existing appliances that are in place. This type of water saving is referred to as passive efficiency as opposed to active efficiency where one would have to accelerate the rate of natural replacements through incentives or other means. Ignoring the role of passive efficiency over a long period of time such as 20 to 30 years horizon may greatly overestimate water demand and hence results in building over capacity infrastructure and unnecessary investment. In this case, passive efficacy is accounted for through a technology factor that depends on current level of efficiency as well as market penetration of different appliance and home fixtures. Technology factor can also be applied as a scenario to understand how future water demand may change as a result of technological advancements. In its simplest form a value of one would indicate no water saving because of technological advances.

Technology is captured through an index that has a value of one for the base year and decrease into the future representing future advance in technology would reduce per capita consumption as a fraction of current demand. This factor is typically represented as an exponential function of the form:

$$Tech = \exp(-\lambda * t) \qquad \text{Equation 7}$$

where λ is a parameter that represents an annual percent of decrease and t is time. Typical value of λ range from 0.5% to 2% (Voss et al., 2009). Figure 2 shows the curve of the technology factors based on an annual growth rate of 0.5% that was used in this modeling. Technology

[1] Nile Basin Initiative procured the services of individual national consultant to collect wide-range data. Data were obtained for Burundi, Ethiopia, Kenya, Rwanda, South Sudan, and Uganda. The demand forecasting team prepared an extensive set of questionnaires which can be found in Technical Note I and III.

factors were applied for only high growth scenario (see discussion on GDP growth scenario) consistent with the fact that market penetration of efficient technologies are realized typically under high GDP growth rate.

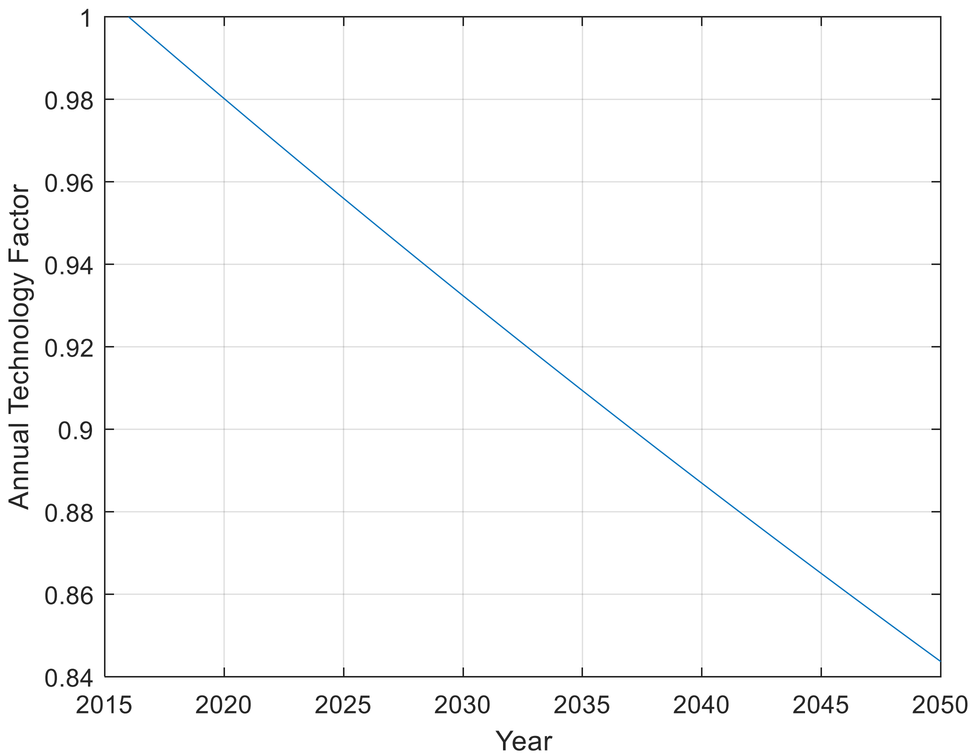

Figure 2. Technology factor based on a 0.5% annual compounded penetration factor

Baseline Model

The first step of demand projection is model fitting based on data availability for baseline year. In this case 2016 was selected as base year and water use data as well as other independent variables were collected for this year. Figure 3 shows model fit based on data from national consultants as well as literature data collected for the Nile Basin countries. In the development of this model fit several Quality Assurance/ Quality Control (QA/QC) measures were taken. Some of the challenges and how they are addressed are given below:

1) There is significant data missing for Egypt, Sudan, Tanzania, and Democratic Republic of Congo. To bridge this gap, data collected through literature reviews of a variety of documents for cities, province, and national studies were used.

2) Not all the data collected by the national consultants as wells as literature review were consistently available for 2016 base year. Some were for 2017 and other for 2018, etc. Where applicable this was corrected by aligning existing data. For example, population numbers were extrapolated forward or backward to get the 2016 number if they were not available.

3) Some of the implied per capita water use that were calculated using surveys were either too low or too high. This inconsistency is usually a result of an under/over estimation of water

production and population. Implied per capita water use of more than 200 liters per day were filtered out.

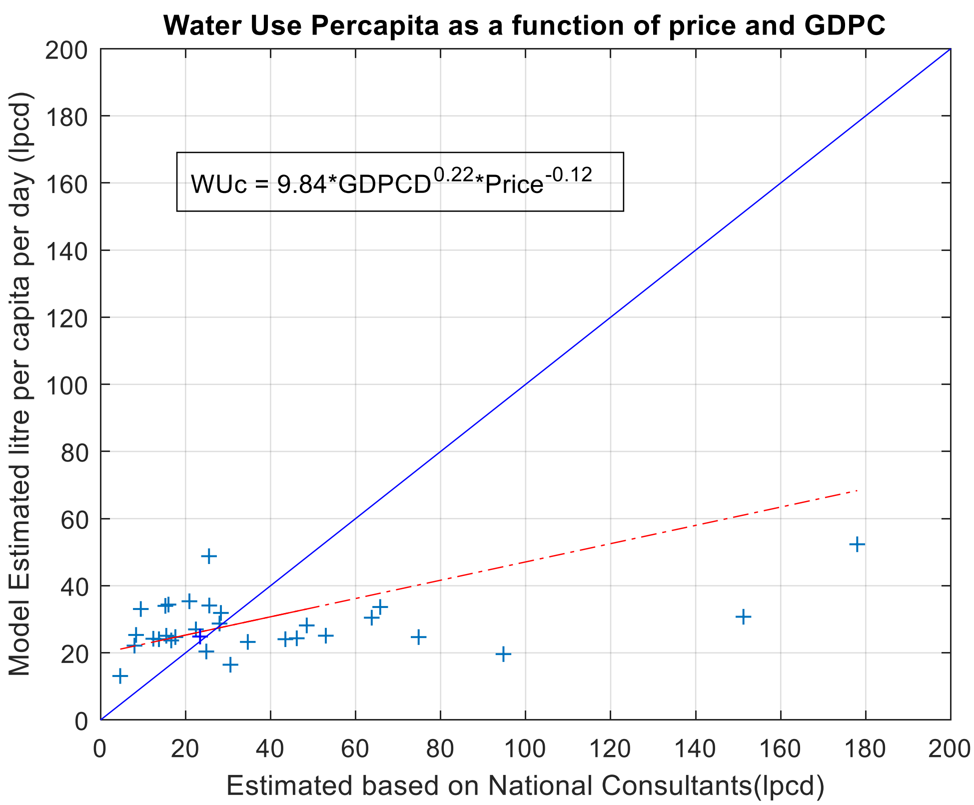

Figure 3: Estimated water use in liters per capita per day as a function of GDP per capita per day and price (US $) for a limited dataset. Blue line represents 45° line and redline represent QQ Plot[2] (quantile plots of model estimate vs. "observation").

As shown in Figure 3 GDP per capita and price of water follow expected trends. Increased GDP per capita and a lower price of water would result in higher demand. The limitation of having smaller sample size to fit the curve may impact the sensitivity of the parameters and this would need to be revisited as more data becomes available. Because of this, model output should be used as a scenario for planning purposes rather than a prediction of what would happen in the future.

Once baseline model was estimated, future percapita water use were calculated based on Gross Domestic Product (GDP) and price growth. The estimated percapita water use includes unbilled fraction[3]. Unbilled fractions, where available, were estimated based on data collected by the

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[2]QQ plot of X and Y is Quantile-Quantile plot of two variables and measures whether sample X and sample Y came from the same distribution or not

[3] Unbilled faction also known as non-revenue water is the difference between water produced at the source versus water delivered to customers that can be billed to sustain infrastructure. Non-revenue water includes bother system loss as wells as water that was not metered but available for use such as firefighting, parks, etc.

national consultant for cities within the Nile Basin countries. Where these data are not available, a minimum of 20% unbilled fraction was assumed based on literature review.

Links to the database

A database framework has been developed by the consultant to store data that potentially explain the water demand in an area. A data collection questionnaire was created to collect and populate the tables in the database framework. But not all the required data were collected by the national consultants in all the Nile Basin countries. The database framework includes linked multiple tables each of which with unique attributes to identify the geographic locations, water use sector and sub sectors, weather parameters, economical parameters, population and more. Economic variables that significantly explain water demand such as income and GDP were not readily available from the collected data. These gaps were filled by the consultant to develop a model that can best explain based on the available data. For details, please refer to Technical note I (Tassew et al., 2020).

Data Processing is one of the important components of the database to ensure data quality and functionality. The collected raw data from member countries undergone a quality check and post processing. These data are standardized and associated with specific geographic location to prevent duplication of records and to fit into the data table schema (basically the data requirements of the demand model). The processed data sets that went through quality assurance are stored in the processed database with unique identifiers to easily query model specific data sets.

The processed data is a unique record that can be queried for model development over time. For example, the screen shot of the total population of the cities in in Nile Basin countries stored in the processed database is shown below (See Table 2).

Results | Messages

	City	country	TotalCityPopulation	PopulationServedByWaterUtility
4	Kirundo	Burundi	24490	22261.41
5	Muramvya	Burundi	21311	19371.7
6	Muyinga	Burundi	17909	16279.28
7	Mwaro	Burundi	6206	5641.254
8	Ngozi	Burundi	78171	71057.44
9	Cankuzo	Burundi	5628	5115.852
10	Ruyigi	Burundi	18404	16729.24
11	Kirumba	Democratic Republic of Congo	39035	39035
12	Kituku	Democratic Republic of Congo	49788	49788
13	Oicha	Democratic Republic of Congo	55924	55924
14	Rutshuru	Democratic Republic of Congo	62016	62016

Table 2. Screen shot of the population table of the processed database

Similarly, cities of the Nile Basin countries in the processed database are stores as shown in Table 3.

CountryName	CityName	CityID	Latitude	Longitude
Burundi	Cankuzo	0101	-3.190528	29.9276487
Burundi	Gitega	0102	-3.4314103	29.9166726
Burundi	Karuzi	0103	-3.1044564	30.1537772
Burundi	Kayanza	0104	-2.9215148	29.6221876
Burundi	Kirundo	0105	-2.5851956	30.0933123
Burundi	Muramvya	0106	-3.2679789	29.6195699
Burundi	Muyinga	0107	-2.8455114	30.3337305
Burundi	Mwaro	0108	-3.5125428	29.6930408
Burundi	Ngozi	0109	-2.9084961	29.8144805
Burundi	Ruyigi	0110	-3.474205	30.237937
Democratic republic of Congo	Kirumba	201	-1.1005123	29.2758018
Democratic republic of Congo	Kituku	202	-5.9018793	29.1927879
Democratic republic of Congo	Oicha	203	0.7028069	29.5026252
Democratic republic of Congo	Rutshuru	204	-1.1850442	29.4380163

Table 3. Screen shot of the city Table from the processed database.

The demand estimates and forecasts of the Nile Basin are stored in the forecast database. Figure 4 shows the three main components of the data base to which the demand forecast model is linked to: i) raw data shown by a green box, ii) processed data shown by a yellow box (which will be completed soon after data collection is made), and iii) the results of the model outputs shown by a red box. The database will incorporate additional projected datasets of raw projected forecasts such as projected economic forecasts, population projections (orange box in Figure 4).

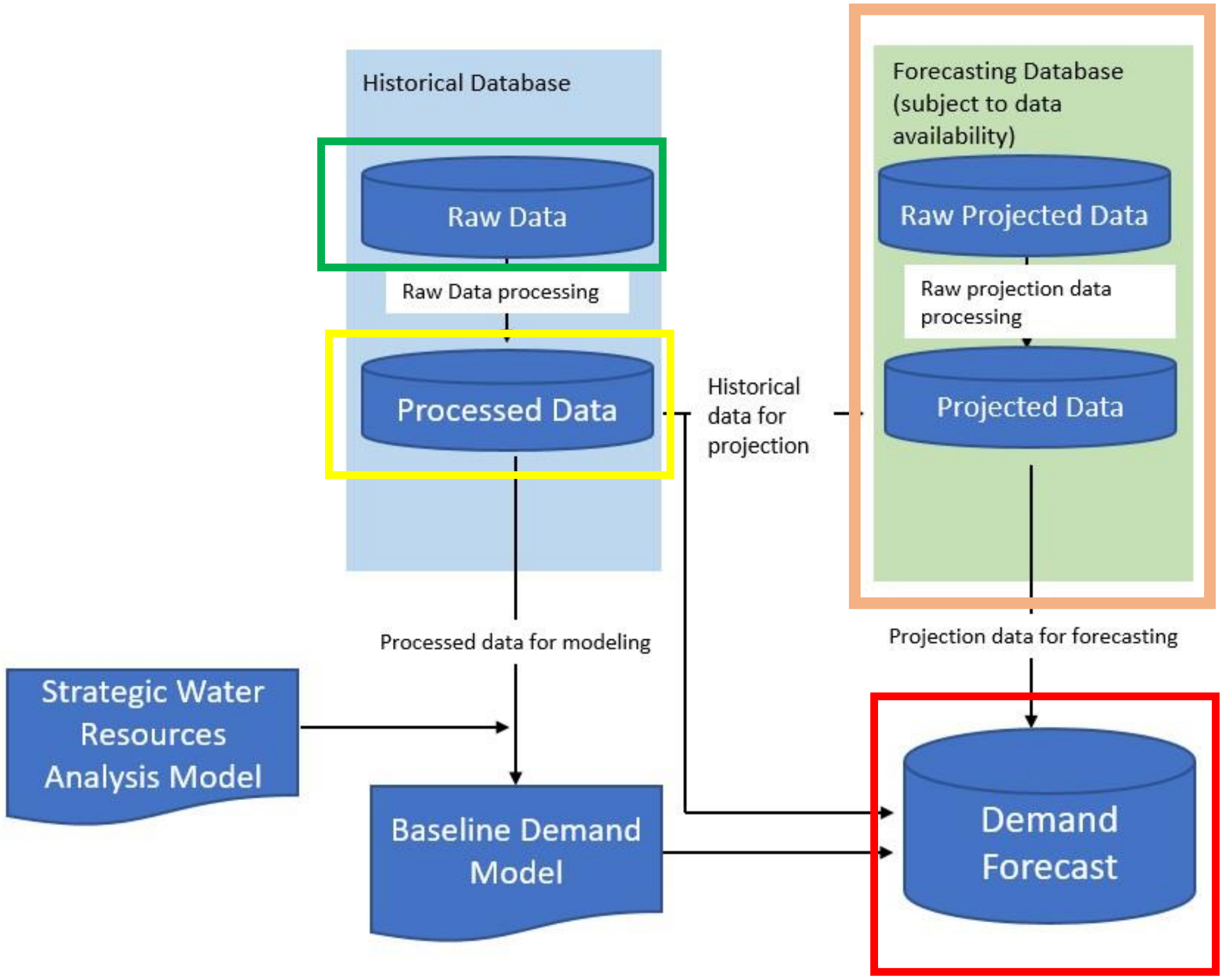

Figure 4 Database framework showing the three main components to which the forecast model is linked to.

Scenarios of demand projections

GDP scenarios

Historical GDP and their growth were collected from the World Bank database. Projecting GDP growth is one of the most difficult tasks to make as it also depends on individual countries development plan as well as external factors (e.g., economic cycles, regional growth, stability and how that impacts a given country). Table 4 shows GDP per capita and GDP growth rates in the last five-years for Nile Basin countries. As shown in Table 4 while some countries have a much faster growth rate, others do not. Even projection for developed countries is proved to be difficult. One prudent approach is to look at scenarios of expected GDP growth rate and to understand the resulting municipal and industrial water use rather than trying to project GDP. This way demand projection could also be tied to supply availability and allows a unified risk/reliability assessment.

Table 4: GDP per capita in 2016 and growth rate in the previous 5-years in each of the Nile Basin country

Country	GDP Per Capita ($/year)	5-year GDP Growth Rate (%)
Burundi	292	3.3
DRC	471	1.8
Egypt	3478	-4.3
Ethiopia	712	10.4
Kenya	1464	6.7
Rwanda	712	2.0
South Sudan	237	-19.4
Sudan	2416	9.2
Tanzania	923	3.1
Uganda	580	-0.7

In this project, different storylines (scenarios) are developed to understand what the future demand may look like for different GDP growth rates. As such a constant annual growth rate of 3%, 5%, and 10% with and without technology factor were used to estimate future water demand in order to capture a wide range of potential economic growth paths.

Price Scenarios

Along with income (reflected by GDP), price of water is the other most important factor that influences water use. In order to have a common parameter that works across the Nile Basin countries, price of water was expressed in US dollar per thousand liter. It is important to note that price of water varies widely across these countries. As shown in Table A1 in Appendix A, depending on the data source price of water varies from approximately $0.1 to $3 per thousand liters[4]. Price of water is also dependent on government subsidies that may not be consistent across the Nile Basin countries hence complicating the price signal in the water use when one uses “pooled” dataset to fit models. Projecting future price of water is challenging. Several factors impact future price of water. From an economic perspective, price of water is set through net revenue requirement of a water supply utility that include: 1) debt service obligations (such as infrastructure expenditure), 2) Renewal and Replacement (R&R) needs; 3) Capital Improvement Project (CIP) needs, 4) Operational and Maintenance (O&M) costs; and 5) Equitability (ability of low income group to afford). In addition, increases in price of water is subject to administrative and political pressures that may not be aligned with net revenue requirements. Only few utilities have a consistent rate increase as part of their long-term

[4] Three sources of data were used: 1) NBI country utilities published resources; 2) tariffs.ib-net.org; and 3) African Development Bank (AfDB) database

planning. In most cases price increases are exercised as an ad-hoc to meet a specific objective at a time.

Review of published documents in the Nile Basin countries indicates that prices are typically set in a non-regular schedule but annual amortized price increase of 0.1% to 0.5% seem to represent most practice in the region. Similar to the GDP growth projection, in this case also future scenarios of price increase of 0.05% (nominal growth reflective of heavy subsidy), 0.1%, 0.5%, and 1.0% (an aggressive scenario where revenue requirement would potentially shoulder all infrastructure improvement needs) were used to project future water demand. These price increases were assumed to be executed starting the base year.

Population scenarios

Current baseline population of one hundred nine cities identified in the project for the year 2016 was estimated based on information obtained from national consultants, country documents and/or databases. This baseline population estimation follows the following procedure:

1. Since the model is using city population as input, the population growth rate of the city is assumed to be the same as the country's population growth rate when the city's population growth rate is not available.
2. The country's population growth rate, r, is calculated as a percentage of populations in consecutive years.

$$r = \frac{P_i - P_{i-1}}{P_{i-1}} ; i = year \; and \; r = growth \; rate$$

3. A city population growth rate is determined by applying the projected population growth rates on the baseline population of a city.

The current population is shown in Appendix Table A1.

Medium and high population growth rates were selected for future scenarios. Future projections were obtained from World Bank Database that provides country projection around the world through 2100. For each of the one-hundred nine cities the 2016 baselined population was allowed to grow at the same percentage as their respective country for medium and high future scenarios. These population projections are included in a separate database (Tassew et al., 2020).

Results: Percapia projections

Figures 5 through 14 show projected percapita water use for a selected city in each of the Nile Basin countries under difference price and GDP growth scenario with and without a technology factor.

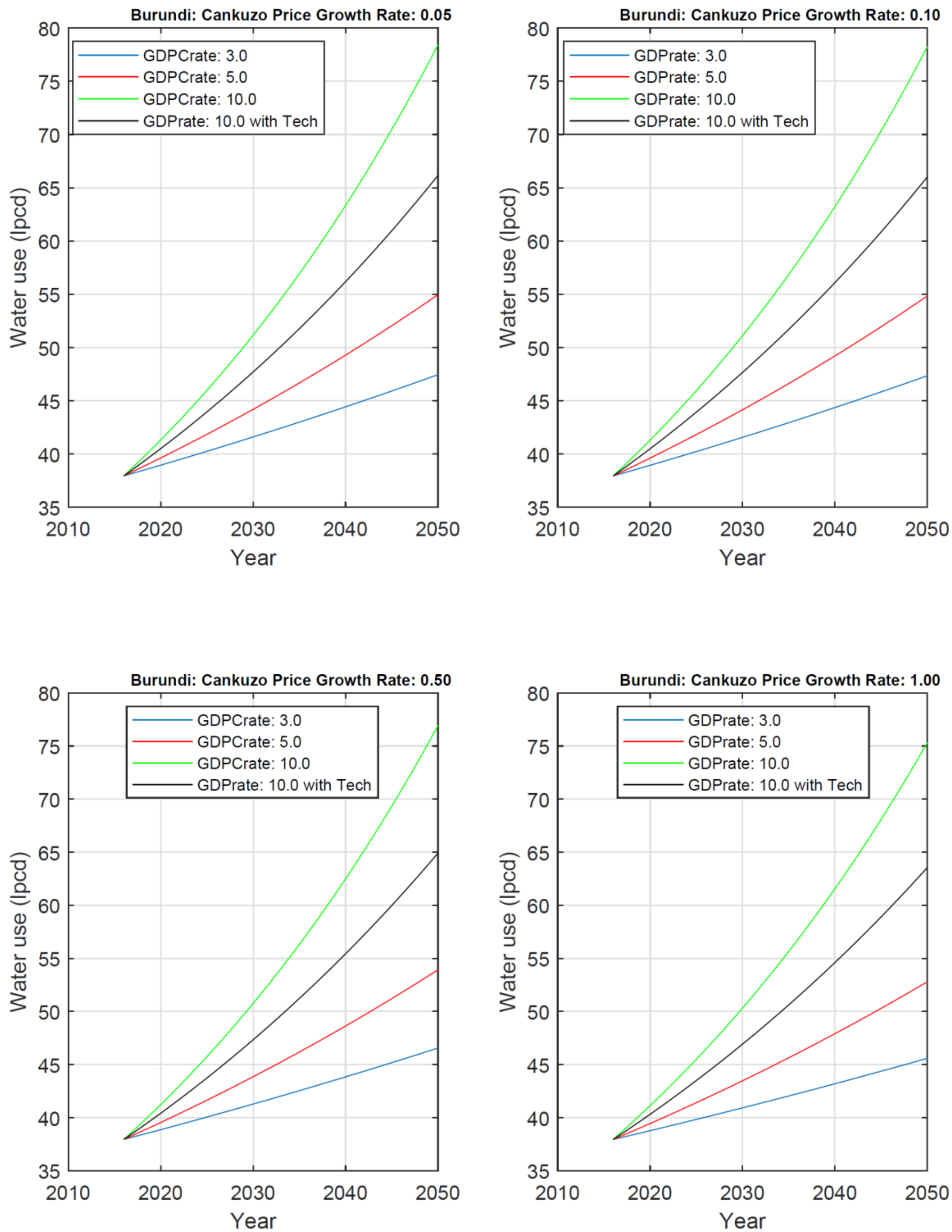

Figure 5: Projected percapita water demand for Cankuzo, Burundi under different price and GDP growth rates with and without technology factor

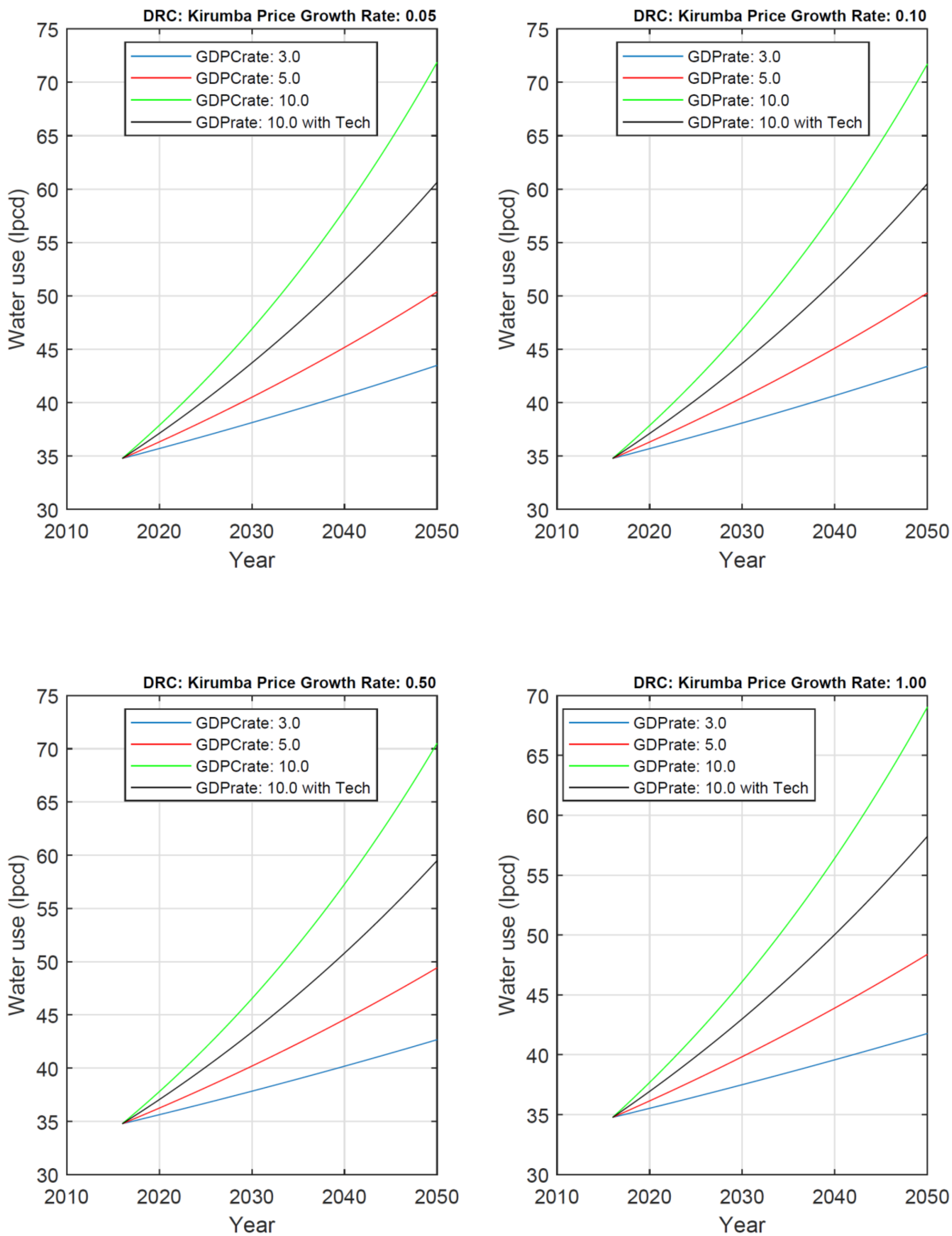

Figure 6: Projected percapita water demand for Kirumba, DRC under different price and GDP growth rates with and without technology factor.

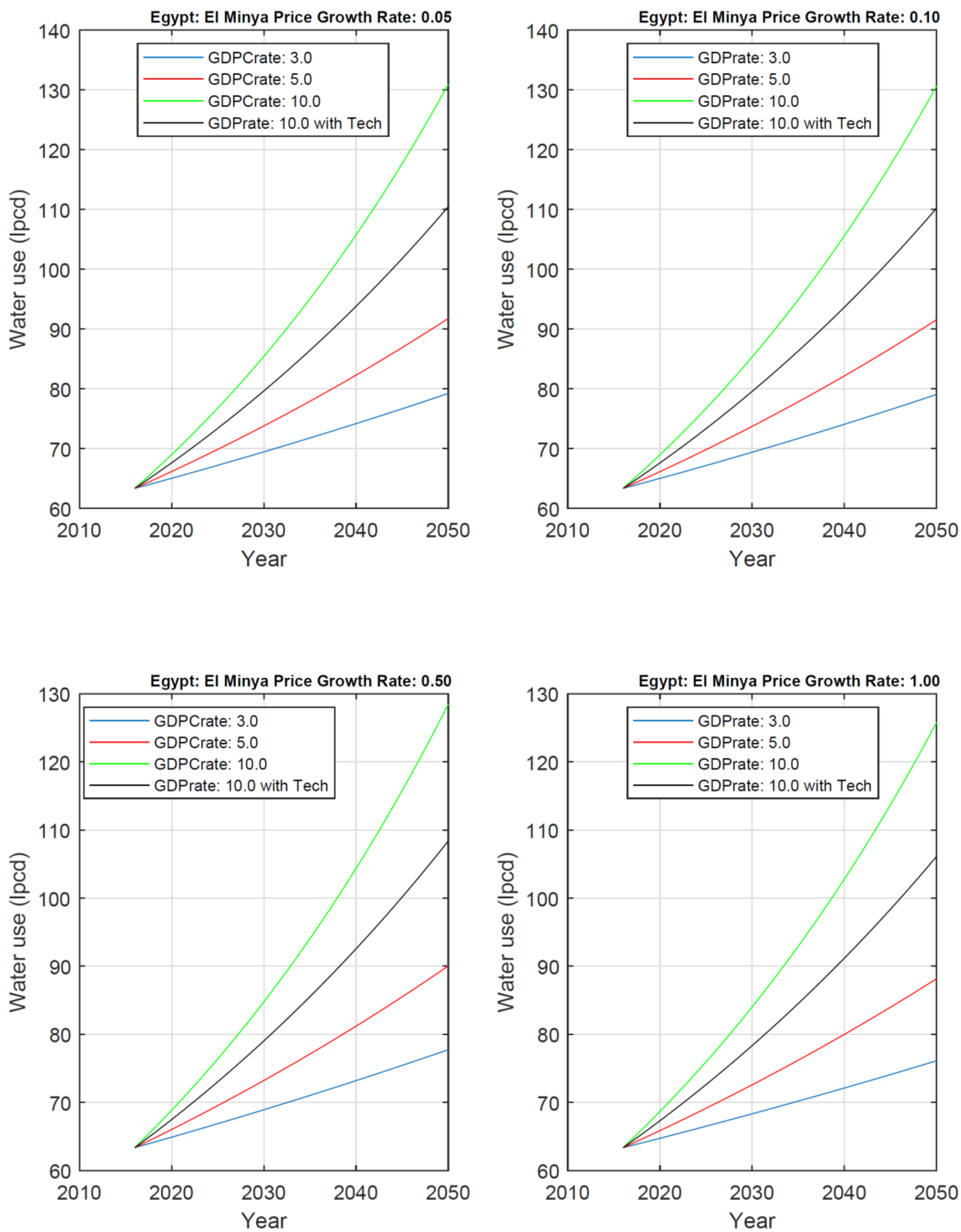

Figure 7: Projected percapita water demand for El Minya, Egypt under different price and GDP growth rates with and without technology factor.

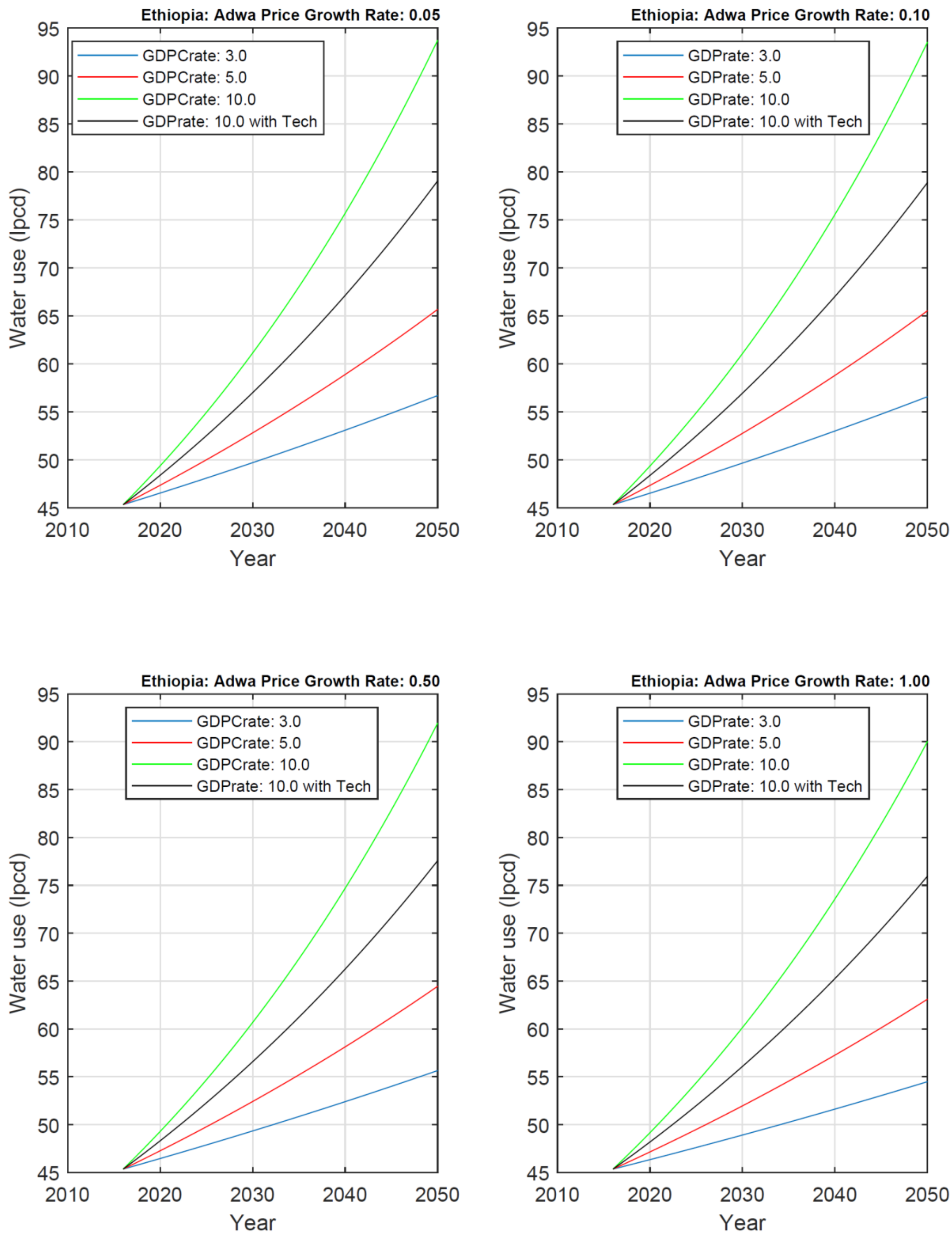

Figure 8: Projected percapita water demand for Adwa, Ethiopia under different price and GDP growth rates with and without technology factor.

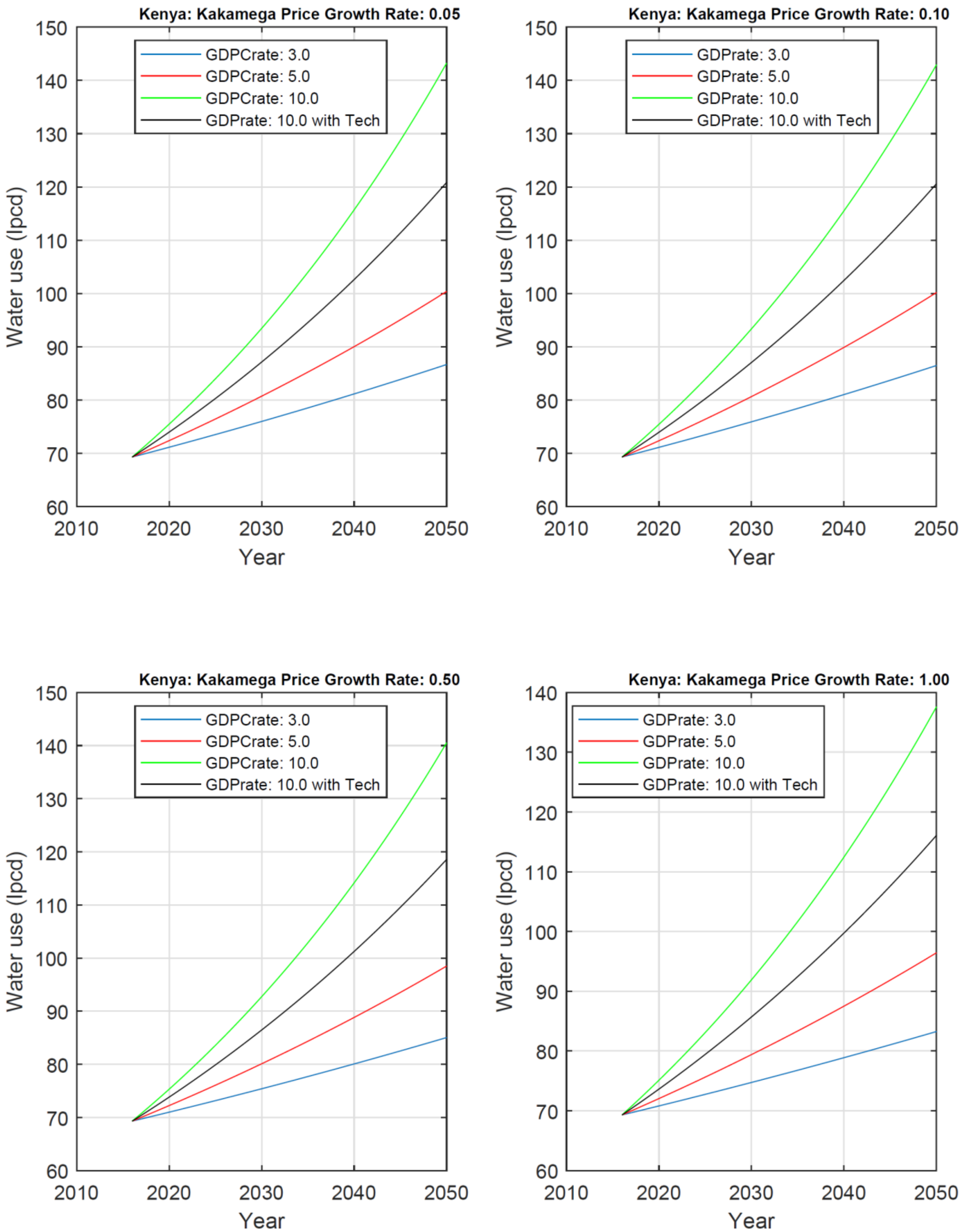

Figure 9: Projected percapita water demand for Kakamega, Kenya under different price and GDP growth rates with and without technology factor.

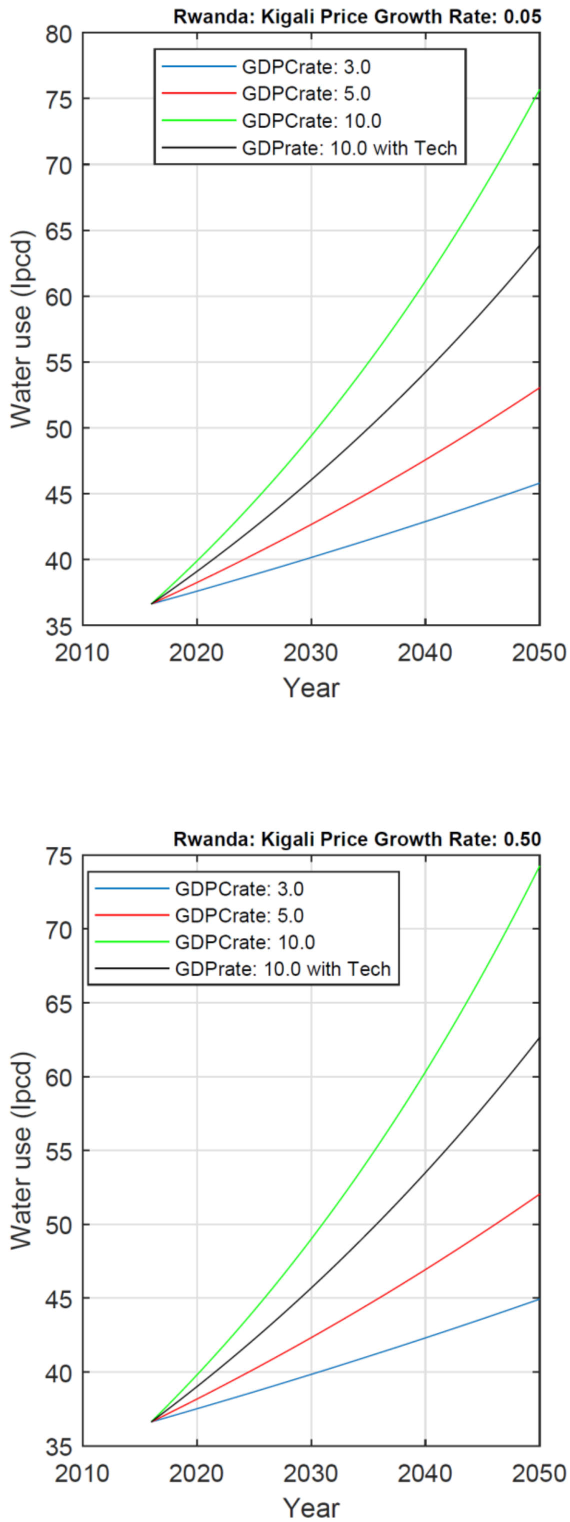

Figure 10: Projected percapita water demand for Kigali, Rwanda under different price and GDP growth rates with and without technology factor.

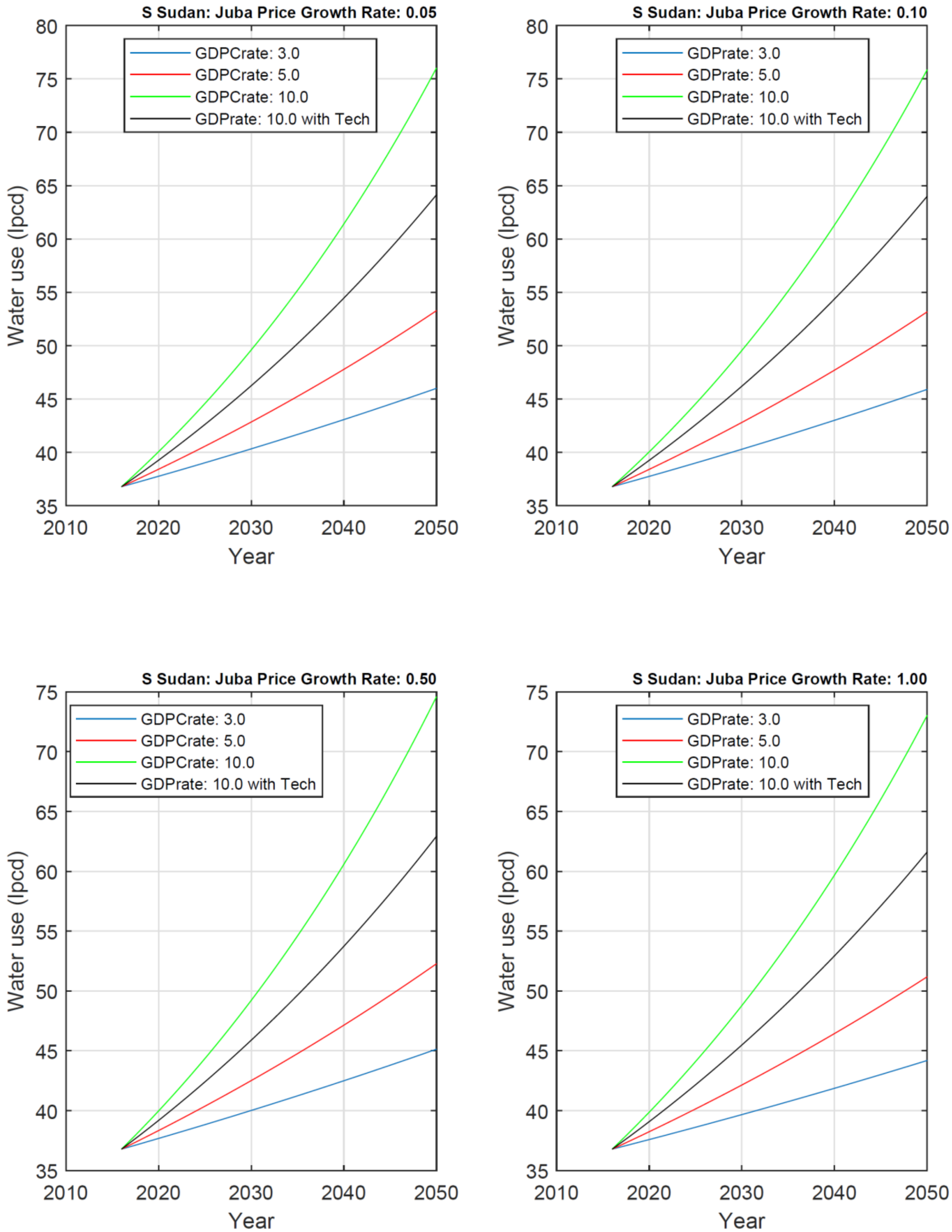

Figure 11: Projected percapita water demand for Juba, South Sudan under different price and GDP growth rates with and without technology factor.

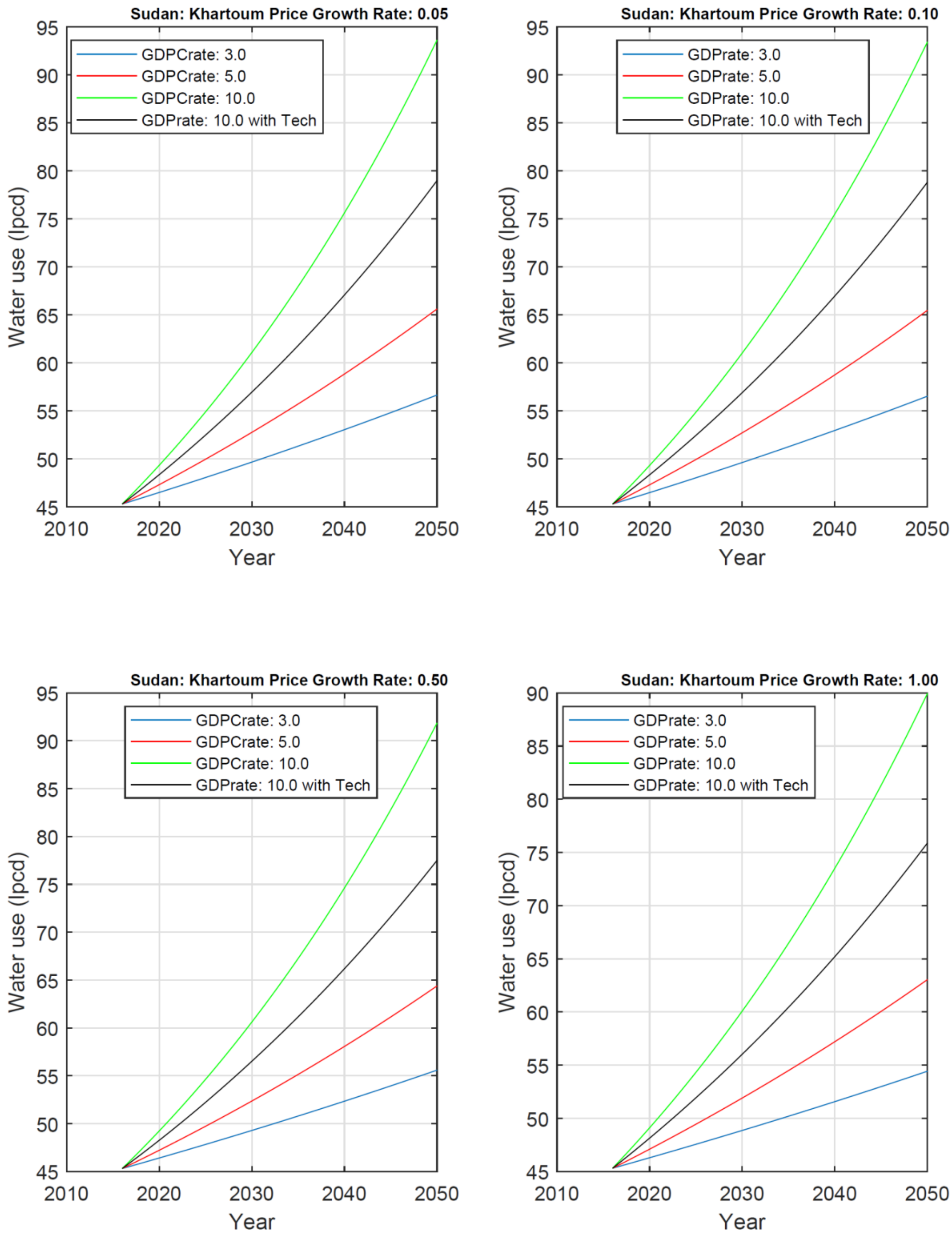

Figure 12: Projected percapita water demand for Khartoum, Sudan under different price and GDP growth rates with and without technology factor.

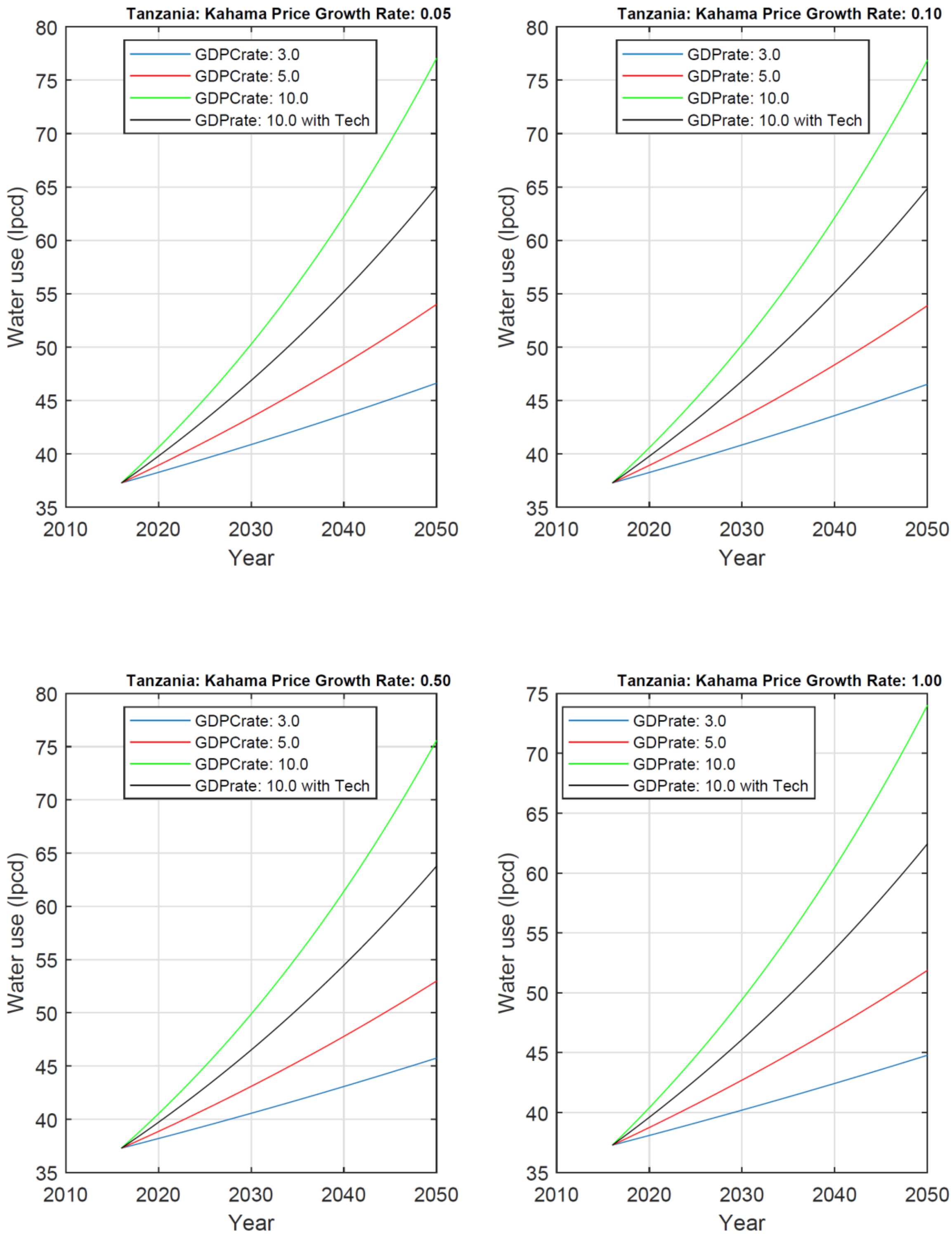

Figure 13: Projected percapita water demand for Kahama, Tanzania under different price and GDP growth rates with and without technology factor.

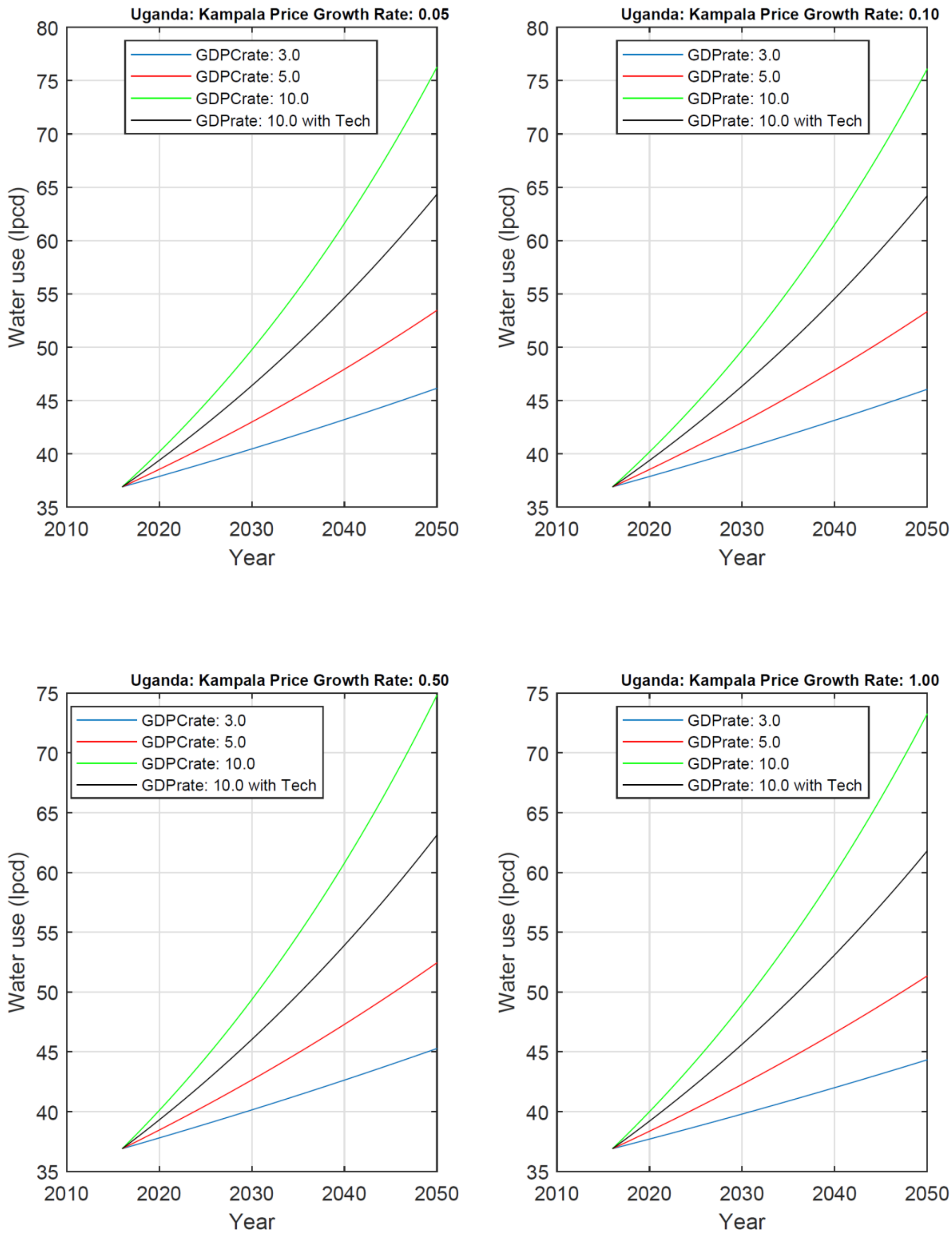

Figure 14: Projected percapita water demand for Kampala, Uganda under different price and GDP growth rates with and without technology factor.

Results: Municipal and Industrial demand projections

A total of 32 future scenarios (four price growth, four GDP growth one with technology scenario, and two population growth) were used to project potential water demand for each of the identified the Nile Basin cities.

Tables 5 through 14 show projected municipal water demand for each of the Nile Basin cities under scenarios of high population, high GDP with and without technology factor. Additional data is provided for all scenarios and for all cities through a separate supplemental document of plots in the. Industrial water demands were projected (not plotted) and those data are in provided as *.mat file in supplemental document. Because of limited data availability, industrial demand forecasts were derived as a percentage of municipal water demand. While a flexible database and code is written for use by NBI staff, currently the percentage of industrial water demand was set at 26% of municipal water demand based on literature review.

Table 5: Municipal water demand projection for selected cities in Burundi

				2050 Demand (m^3/day)	
City	**Current Population**	**Current Demand (m^3/Day)**	**2050 Population**	**High Econ**	**High Eon with Tech**
Cankuzo	5628	214	14585	1144	965
Gitega	72606	2313	188157	12390	10453
Karuzi	19185	726	49718	3889	3281
Kayanza	43595	1830	112976	9804	8271
Kirundo	24490	929	63465	4978	4200
Muramvya	21311	862	55227	4616	3895
Muyinga	17909	716	46411	3834	3234
Mwaro	6206	208	16083	1117	942
Ngozi	78171	2938	202579	15739	13279
Ruyigi	18404	730	47694	3912	3300

Table 6: Municipal water demand projection for selected cities in the DCR

				2050 Demand (m^3/day)	
City	**Current Population**	**Current Demand (m^3/Day)**	**2050 Population**	**High Econ**	**High Eon with Tech**
Kirumba	39035	1357	103815	7461	6295
Kituku	49788	1731	132413	9517	8029
Oicha	55924	1944	148732	10690	9018
Rutshuru	62016	2156	164934	11854	10001

Table 7: Municipal water demand projection for selected cities in Egypt

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	2050 Demand (m^3/day) High Eon with Tech
El Minya	5393010	341640	9551032	1250685	1055159
Qena	3104367	196658	5497840	719929	607379
Asyut	4300293	272418	7615828	997274	841365
El Giza	8468577	536474	14997867	1963934	1656902
Cairo	9359043	592884	16574884	2170441	1831125
Alexandria	5065977	320923	8971856	1174843	991174

Table 8: Municipal water demand projection for selected cities in Ethiopia

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	2050 Demand (m^3/day) High Eon with Tech
Adwa	69994	3174	142712	13376	11285
Ambo	81452	3456	166073	14565	12288
Axum	77160	3274	157322	13798	11641
Assossa	49023	2007	99954	8457	7135
Bahir Dar	281941	13142	574853	55390	46731
Debre Birhan	102047	4268	208065	17988	15176
Debre Markos	97875	4839	199558	20393	17205
Debre Tabor	86812	3631	177002	15302	12910
Gambela	78141	3244	159323	13670	11533
Gondar	324499	14505	661625	61134	51576
Mekele	373150	16062	760820	67693	57110
Metu	48667	2224	99228	9375	7909

Table 9: Municipal water demand projection for selected cities in Kenya

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Kakamega	2048266	141943	4403544	630795	532180
Bungoma	2094911	94217	4503826	418702	353244
Trans Nzoia	1235470	55564	2656123	246929	208325
Vihiga	767362	50930	1649743	226336	190951
Bomet	953024	50366	2048896	223825	188834
Nandi	1002140	43686	2154490	194143	163791
Uasin Ngishu	1243166	53798	2672669	239079	201703
Kericho	953775	40574	2050510	180311	152122
Kisumu	1261010	55104	2711031	244883	206599
Siaya	1096237	44844	2356788	199288	168132
Nyamira	758375	39368	1630422	174953	147602
Kisii	1511392	78458	3249325	348670	294160
Homabay	1258023	56714	2704610	252040	212637
Busia	990137	44925	2128685	199647	168435
Migori	1238596	60220	2662844	267619	225781

Table 10: Municipal water demand projection for selected cities in Rwanda

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Kigali	1028972	37677	2063032	156150	131738
Musanze	445263	17255	892728	71512	60332
Huye	393225	14398	788394	59673	50344
Muhanga	381932	13985	765753	57959	48898
Nyagatare	555123	28457	1112991	117938	99500
Rubavu	483349	17698	969088	73350	61883
Rusizi	479991	17576	962355	72840	61453

Table 11: Municipal water demand projection for selected cities in South Sudan

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Juba	800000	29425	1789183	136031	114764
Malakale	160765	5051	359548	23350	19699
Yei	230000	4470	514390	20666	17435
Wau	223008	5985	498753	27668	23343
Maridi	109810	2792	245588	12909	10891
Bor	215673	5282	482348	24421	20603
Renk	137000	3250	306398	15025	12676
Torit	250000	5061	559120	23399	19741
Bentiu	95000	2308	212465	10670	9002
Aweil	120460	3063	269406	14161	11947
Kuacjok	63000	1531	140898	7076	5970
Yumbio	193400	3759	432535	17377	14660
Rumbek	120650	2345	269831	10840	9146

Table 12: Municipal water demand projection for selected cities in Sudan

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Khartoum	2903935	131543	6339660	593617	500814
Kosti	255366	11568	557497	52201	44041
Sennar	147599	6686	322227	30172	25455
Gedaref	322857	14625	704838	65998	55680
Ad Damazin	1295169	58669	2827519	264756	223365
El Obeid	413617	18736	902979	84551	71333
Singa	67183	3043	146669	13733	11586
Medani	346931	15715	757395	70919	59832

Table 13: Municipal water demand projection for selected cities in Tanzania

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Kahama	40684	1517	108079	8328	7026
Musoma	151804	5659	403273	31073	26215
Bukoba	91788	3421	243839	18788	15851

Table 14: Municipal water demand projection for selected cities in Uganda

City	Current Population	Current Demand (m^3/Day)	2050 Population	2050 Demand (m^3/day) High Econ	High Eon with Tech
Kampala	2635424	97241	7157012	545869	460531
Mbarara	195322	6662	530435	37397	31551
Gulu	150306	4886	408186	27430	23141
Masaka	103227	3373	280333	18932	15972
Mubende	83769	2723	227491	15287	12897
Mbale	92857	3019	252171	16946	14296
Arua	61962	2014	168270	11308	9540
Bushenyi	41217	1406	111933	7892	6658
Busia	54798	1781	148815	10000	8437
Entebbe	70219	2287	190694	12836	10829
FortPortal	53786	1749	146066	9815	8281
Hoima	100099	3561	271839	19987	16863
Iganga	55263	1856	150078	10421	8792
Jinja	45083	1534	122432	8611	7265
Kabale	49186	1599	133574	8976	7573
Kamuli	58984	1918	160183	10764	9081
Kapchorwa	43595	1502	118391	8433	7115
Kasese	101065	3310	274462	18582	15677
Kisoro	15859	549	43068	3082	2600
Kitgum	61993	2015	168354	11313	9545
Koboko	51379	1670	139530	9376	7910
Kumi	36493	1365	99104	7664	6466
Lira	99392	3640	269919	20436	17241
Lugazi	114524	3813	311012	21405	18058

Masindi	94438	3165	256465	17765	14988
Mityana	95428	3358	259154	18851	15904
Moroto	14196	461	38552	2591	2186
Ntungamo	18719	609	50835	3416	2882
Rukungiri	35039	1211	95155	6799	5736
Soroti	49685	1615	134929	9067	7650
Tororo	42016	1366	114103	7668	6469

Discussion and Conclusion

This document (Technical Note II) presents municipal and industrial water demand projection method and results for Nile Basin cities. Accompanying two Technical Notes (I and III)[5], provide the basis for this effort. Data needed for modelling was collected through various means including individual country consultants, country development reports, literature review and publicly available databases such as that of the World Banks and African Development Bank. After extensive data Quality Assurance/Quality Control (QA/QC), available data for cities within Nile Basin countries were pooled to establish a statistical relationship that would allow demand projection into the future. These key parameters (the ability to pay for water, price of water, and technological factors) were found to be influential in estimating potential demand for water through the planning horizon of 2050.

Unified percapita as measure of future water use

Initial efforts through literature review looked at different economic groups and estimation of their current water use as well as projection of th groups' water use into the future. These grouping included: 1) in-house connection; 2) yard tap (external connection); 3) standpipe/ water kiosk; and 4) water trucks (at a community level). These approaches would have allowed the estimation of the percentage of consumers in each socio-economic group as well as percapita water use for each group. After data collection by national consultant, it became clear that data availability did not support this approach.

A useful approach that can be supported by the available data was to develop a unified percapita water use for a city (municipality, county, or province). These percapita figures used aggregate water consumption for all the socio-economic groups and tied the amount of water consumed to a GDP output of the country. In addition, price of water plays an important role influencing the amount water use. These data, where available, were collected for all the cities through national consultants. When this was not available, literature review was used to fill the gap. This allows for the development of percapita water use for each of the cities. Percapita water uses were then projected into the future through the planning period of 2050 using a GDP/price growth scenarios. Once future percapita were estimated, an adjustment was made to incorporate non-revenue water (unbilled fraction). Non-revenue water was estimated based on individual countries as a function total water production versus water delivered to customers.

Table 15 shows demand growth in Nile Basin countries under high population and GDP growth scenario with and without technology factors included. Population growth is expected to vary from country to country with Egypt showing a low growth of 77% and Uganda showing a high

5 See Technical Note I (Tassew et al., 2020) and Technical Note III (Ghebremichael et al., 2020) for additional information.

growth of 172% in Uganda and an expected mean growth of 130% across the ten countries. Under such scenario demand for water would significantly increase from a low of 266% to a high of 461% under high population and GDP scenario. Some of these increases in demand for water could be offset with introduction of high efficiency fixture and other technological advances to values that would range from 209% to 374%. While there is significant saving through technological advances, it still can not compensate for the growing water demand as it is mainly driven by population growth and increased percapita water use that comes with higher GDP (ability to pay for the service) growth. Very low current water use is expected to grow exponentially before the curve starts to flatten out.

Table 15: 2050 Demand increase (as multiplier) compared to current water use under high population and GDP growth

Country	Population Increase	Demand Increase (High Econ Growth)	Demand Increase (High Econ w/Tech)
Burundi	1.59	4.36	3.52
DRC	1.66	4.50	3.64
Egypt	0.77	2.66	2.09
Ethiopia	1.04	3.22	2.56
Kenya	1.15	3.44	2.75
Rwanda	1.01	3.14	2.50
South Sudan	1.24	3.62	2.90
Sudan	1.18	3.51	2.81
Tanzania	1.66	4.49	3.63
Uganda	1.72	4.61	3.74
Mean	1.30	3.76	3.01

Figure 15 shows range of percapita that can be expected in 2050 under different GDP and price growth scenario. The spread in the boxplot represent price differences across cities in a country. Where price differences are prevalent from city to city in a country, a range of percapita values were obtained (box plot). Where there is no price difference across cities (e.g., Egypt, DRC, etc.) a single value was obtained for a given GDP growth scenario[6].

Limitation of the current approach

One of the components of the demand projection models developed in this project is the ability to pool data across countries. This is especially useful when data are limited, and individual country-based models cannot be developed without seriously compromising its utility. This limitation was overcome by developing a methodology that is based on price, GDP, and

6 Because of data limitations, A single GDP growth for a country was linearly translated to GDP growth in a city within that country. The limitation of such approach is that not all cities will grow at the same rate as the country average. If an explicit GDP growth for a city could be estimated as a function of national GDP growth, it can be accommodated by the methodology presented here.

technological advancement across the Nile Basin countries. Such approach is also implemented successfully in other studies (Walda et al., 2016; Hejazi et al., 2013). If and when individual country level specific information are collected (see for example Tassew et al., 2020), these results need to be revised.

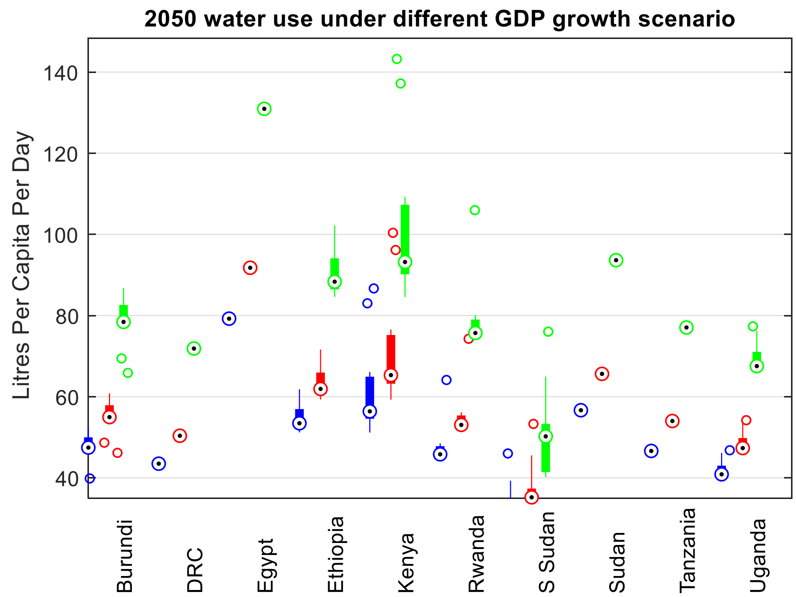

Figure 15: 2050 projected percapita water use for different GDP growth scenario. Blue (1% GDP growth), Red (5% DGP growth rate), and Green (10% GDP growth rate). Spread for country represent price differences across cities. Where a single price exist in a country there is only one dot.

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Appendix A

Table A1: Nile Basin Initiative cities municipal and industrial projections and associated population, unbilled fraction, and price of water.

City	Country Code	2016 Population	Unbilled Fraction (%)	Price ($/l)
Cankuzo	1	5628	51	0.000373
Gitega	1	72606	29	0.000427
Karuzi	1	19185	60	0.000594
Kayanza	1	43595	66	0.000348
Kirundo	1	24490	54	0.000426
Muramvya	1	21311	67	0.000502
Muyinga	1	17909	64	0.000479
Mwaro	1	6206	44	0.000690
Ngozi	1	78171	50	0.000376
Ruyigi	1	18404	65	0.000524
Kirumba	2	39035	21	0.000300
Kituku	2	49788	21	0.000300
Oicha	2	55924	21	0.000300
Rutshuru	2	62016	21	0.000300
El Minya	3	5393010	21	0.000090
Qena	3	3104367	21	0.000090
Asyut	3	4300293	21	0.000090
El Giza	3	8468577	21	0.000090
Cairo	3	9359043	21	0.000090
Alexandria	3	5065977	21	0.000090
Adwa	4	69994	30	0.000135
Ambo	4	81452	18	0.000120
Axum	4	77160	18	0.000120
Assossa	4	49023	15	0.00016
Bahir Dar	4	281941	30	0.000104
Debre Birhan	4	102047	16	0.000135
Debre Markos	4	97875	40	0.00012
Debre Tabor	4	86812	NaN	0.000135
Gambela	4	78141	NaN	0.000143
Gondar	4	324499	30	0.00015
Mekele	4	373150	24	0.000135
Metu	4	48667	34	0.00016
Kakamega	5	2048266	42	0.00003

Bungoma	5	2094911	41	0.001
Trans Nzoia	5	1235470	41	0.001
Vihiga	5	767362	36	0.00003
Bomet	5	953024	57	0.00065
Nandi	5	1002140	47	0.001791
Uasin Ngishu	5	1243166	42	0.00144
Kericho	5	953775	51	0.0027
Kisumu	5	1261010	37	0.001
Siaya	5	1096237	70	0.009531
Nyamira	5	758375	57	0.00075
Kisii	5	1511392	57	0.00075
Homabay	5	1258023	67	0.003799
Busia	5	990137	53	0.001791
Migori	5	1238596	43	0.0006
Kigali	6	1028972	15	0.00039
Musanze	6	445,263	27	0.00039
Huye	6	393,225	1	0.00039
Muhanga	6	381932	4	0.00039
Nyagatare	6	555123	68	0.00039
Rubavu	6	483349	2	0.00039
Rusizi	6	479991	NaN	0.00039
Juba	7	800000	66	0.00070
Malakale	7	160765	60	0.00184
Yei	7	230000	NaN	0.008588
Wau	7	223008	63	0.00753
Maridi	7	109810	6	0.00100
Bor	7	215673	1	0.00135
Renk	7	137000	81	0.04670
Torit	7	250000	25	0.008588
Bentiu	7	95000	50	0.008588
Aweil	7	120460	NaN	0.00100
Kuacjok	7	63000	50	0.008588
Yumbio	7	193400	NaN	0.008588
Rumbek	7	120650	NaN	0.008588
Khartoum	8	2903935	NaN	0.000640
Kosti	8	255366	NaN	0.000640
Sennar	8	147599	NaN	0.000640
Gedaref	8	322857	NaN	0.000640
Ad Damazin	8	1295169	NaN	0.000640
El Obeid	8	413617	NaN	0.000640
Singa	8	67183	NaN	0.000640
Medani	8	346931	NaN	0.000640
Kahama	9	40684	NaN	0.000540

Musoma	9	151804	NaN	0.000540
Bukoba	9	91788	NaN	0.000540
Kampala	10	2635424	36	0.00070
Mbarara	10	195322	26	0.00070
Gulu	10	150306	14	0.00070
Masaka	10	103227	21	0.00070
Mubende	10	83769	8	0.00070
Mbale	10	92857	17	0.00070
Arua	10	61962	17	0.00070
Bushenyi	10	41217	26	0.00070
Busia	10	54798	15	0.00070
Entebbe	10	70219	20	0.00070
FortPortal	10	53786	16	0.00070
Hoima	10	100099	31	0.00070
Iganga	10	55263	24	0.00070
Jinja	10	45083	26	0.00070
Kabale	10	49186	16	0.00070
Kamuli	10	58984	14	0.00070
Kapchorwa	10	43595	27	0.00070
Kasese	10	101065	21	0.00070
Kisoro	10	15859	28	0.00070
Kitgum	10	61993	13	0.00070
Koboko	10	51379	12	0.00070
Kumi	10	36493	38	0.00070
Lira	10	99392	35	0.00070
Lugazi	10	114524	23	0.00070
Masindi	10	94438	24	0.00070
Mityana	10	95428	30	0.00070
Moroto	10	14196	15	0.00070
Ntungamo	10	18719	19	0.00070
Rukungiri	10	35039	28	0.00070
Soroti	10	49685	12	0.00070
Tororo	10	42016	11	0.00070

Table A2 Demand projection data collection survey

Projection of Municipal and Industrial Water Demand for the Nile Basin

Data collection for water demand forecasting and water conservation

The purpose of this questionnaire is to gather as much data as possible to best represent the current and future water demand and supply management options in the Nile Basin countries. In addition to data collected through this questionnaire, we would like to get document or list of documents that can be accessed such as master water plans, city development plans, databases and related reports. The collected data will help develop accurate demand forecast, water conservation estimates and availability of alternative water sources. We strongly encourage you to respond to all questions. If some of the questions are not relevant, please respond "NA". The questionnaire has two parts. The first part will collect information on general water supply system and data relevant to the development of the database and forecasting model. The second part includes questions relevant to water demand and supply management measures. The questions in the first and second part are identified as DF and DM, respectively. (DF- Demand forecasting, and DM - Demand management). **Note that some inputs will require multiple columns to fill. Note the units please**.

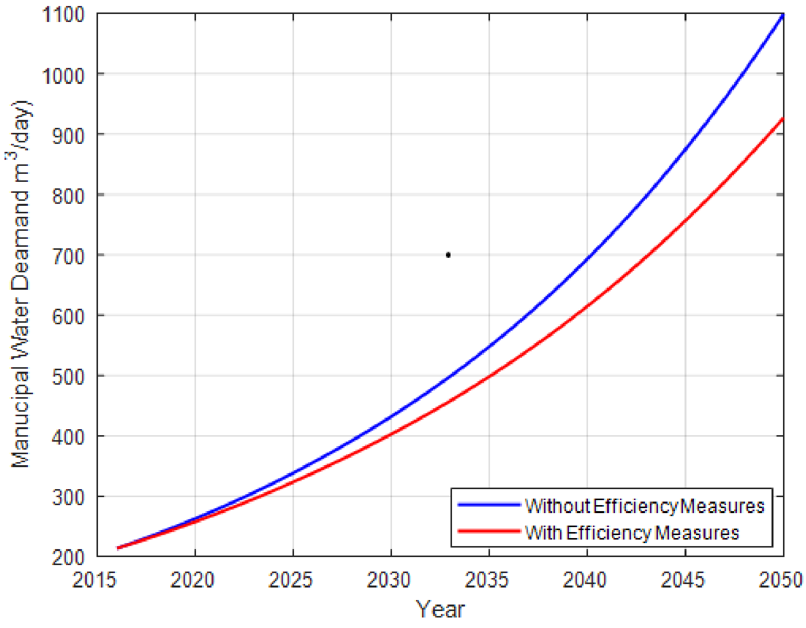
		Input
DF-1	Data Source	
	a) Country:	
	b) City/town:	
	c) Utility Name:	
	d) Website address, if any:	
	e) Type of Utility: **[1 if it applies 0 if not]**	
	i) Water	
	ii) Wastewater	
	iii) Storm Water	
	iv) Reuse	
	v) Other, please specify	
	f) Contact Information of of a person whao be reached or further information	
	i) Name of person	
	ii) Email	
	iii) Telephone	
DF-2	Population	
	a) Total population of city	
	b) Population served by water utility	
DF-3	Source of water supply **[1 if it applies 0 if not]**	
	[ ] Groundwater	
	[ ] Surface water	
	[ ] Both (Ground water and surface water)	

	[ ] Other sources of water, specify	
DF-4	Water production capacity of the water supply system a. Maximum daily water production [liters/day] b. Average daily production for most recent year[liters/day] c. Average unaccounted for water (Percentage of the daily production) d. Total water consumed by customers (liters/day)	
DF-5	Residential water use – water supply method a. In-house connection [No of connections, no of people and water use in this category] i. Number of total connections ii. Total number of people served by in-house connection iii. Total water use in this category (liters/day) b. Yard tap [No of connections, no of people in this category and water use in this category] i. Number of total connections ii. Total number of people served by yard pipe iii. Total water use in this category (liters/day) c. Stand pipe/water kiosk [No of stand pipes/kiosk, no of people and water use in this category] i. Number of total connections ii. Total number of people served by stand pipe/kiosk iii. Total water use in this category (liters/day) d. Water truck [number of people, no of trucks in month, and truck volume in use in this category] i. Number of total waters truck delivered in a month ii. Total number of people served by water trucks iii. What is the average truck volume (liters) e. Other supply method, specify [type, number of people and average water use in this category] i. What method? ii. Total number of people served by this method iii. What is the average water in this method (liters/day)	
DF-6	Water rate structure a. Type of structure Flat fee [in US $] First tier [0 up to XX liters] Second tier Third tier Fourth tier Add rows if needed more c. Is there a different billing structure for residential, commercial, industrial water users? If yes, provide billing information in liters water use for each category.	

	Flat fee [in US $]	
	First tier [0 up to XX liters]	
	Second tier	
	Third tier	
	Fourth tier	
	Add rows if needed more	
	d. When was the last time water rate prices adjusted? ?	
	i. By how much (in US $)	
	ii. How much percentage increase at the time?	
	e. What is the expectation for future rate increase? (if you know)	
	i. When?	
	ii. How much percentage?	
DF-7	Number of city population in the following socio-economic groups?	
	a. No of Low income Population	
	Income range (in US $)	
	b. No of middle income Population	
	Income range (in US $)	
	C. No of High income Population	
	Income range (in US $)	
DF-8	Number of home owners in each socio-economic group in range identified in Question 8	
	a. Low income	
	b. Middle income	
	c. High income	
DF-9	Number of renters in each socio-economic group identified in Question 8	
	a. Low income	
	b. Middle income	
	c. High income	
DF-10	Number of houses with water meters	
DF-11	Sanitation system	
	a. Number of houses connected to sewer system	
	b. Number of houses using septic tanks	
	c. Number of house using dry toilets	
DF-12	Water distribution system	
	a. Total length of water distribution system [km]	
	b. Pipe length by size category (diameter) [km, m]	
	Add rows if needed more	
DF-13	Residential water use[including single and multifamily such as condominiums]	
	a. Single family (stand alone house without sharing wall)	
	i. No of accounts	
	ii. Average water use (literss/day)	
	iii. Source of water [surface or ground water]	

	b. Multi family i. No of accounts ii. Average water use (literss/day) iii. Source of water [surface or groundwater]	
DF-14	Non-residential [such as schools, commercial buildings, hospitals, hotels, government offices, worship places. For each type provide the following information] Fill each column for the establishment a. Name b. Average water use (liters/day) c. Source of water (surface or groundwater)]	
DF-15	Industrial [such as manufacturing, mining, construction]. For each type provide the following information. Add information in each column i. Name of industry ii. Average water use (liters/day) iii. Source of water (surface or groundwater)	
DF-16	Power [hydro power and non-hydropower generation]. For each type provide the following information i. Name of power plant ii. Power plant location (Latitude and Longitude) iii. Type of plant (hydropower or non-hydropower) iv. Power production capacity v. Average water use (liters/day) vi. Source of water for non-hydro power plants (surface or groundwater, fresh or saline water)	

Municipal and industrial water projection for the Nile Basin countries



NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

MAY 2020

Technical Note III: Water Conservation Measures

Prepared for

Nile Basin Initiative

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CONTENTS

INTRODUCTION

Urban water consumption is expected to increase due to the continuing rapid growth of cities and urbanization trends that have seen substantial population relocation to urban areas. The traditional supply driven urban water management is not sustainable as it mainly focuses on expanding supply sources to meet increasing demand. Not only do such measures deplete limited available water resources, but also contribute to the soaring cost of water supply in terms of investment, operation and maintenance. It is now becoming clear that the old paradigm of planning and designing water supply systems, with little attention to demand determinants, pricing structures and financial policies, is not sustainable. Hence managing water resources efficiently and effectively have necessitated decision-making processes, institutions and technologies that emphasize efficiency of water conservation.

The need for water supply strategy that embodies effective demand management is being considered essential for sustainable water resources management. This is particularly important for the Nile Basin as the available water is projected to diminish overtime while demand is expected to grow continuously. This technical report discusses the different water supply and demand management measures that can be considered by the Nile Basin cities and how water saving estimates from water conservation measures can be incorporated into the water demand projection model. The different water demand and supply management measures that can be considered in the Nile Basin cities include: passive and active water conservation measures, water loss reduction and alternative water sources use such as rainwater harvesting, groundwater and greywater reuse. In order to account for water saving options in the water demand projection, the industrial and municipal demand forecasting model presented in Technical Note II[1] (Asefa at el., 2020) applied a technology parameter that represents the passive water conservation measures. This was applied to the high GDP growth scenario in order to assess the potential savings of demand management opportunities.

WATER DEMAND AND SUPPLY MANAGEMENT

Water saving options for water use from the Nile river can be categorized as demand side and supply side measures. The demand side options include: passive measures and active measures. The supply side options include: water loss reduction (mainly from leakage) and use of alternative water sources such as rainwater harvesting, groundwater use potential and greywater reuse. The supply side options are considered to be sources of water that will replace water abstraction from the Nile River system. These options will vary from place to place depending on precipitation amount and patterns, ground water use and greywater reuse practices and regulations. In general, the proposed water saving options will consider specific situations in each country. Short descriptions of the supply and demand management options are provided below.

[1] Accompanying Technical Note II (Asefa et al., 2020) presents a methodology that estimates future water demand through 2050 for a range of growth scenarios that also includes the impact of passive water use efficiencies.

Supply side measures:

Water loss reduction to the economic level of leakage. The amount of water saving in this case is based on the status of current water loss, utility asset management plans (maintenance or replacement schedules) and the economic level of leakage that can be achieved for the particular place. The maximum reduction of water loss can be estimated based on the point where the cost of infrastructure maintenance and/or replacement to reduce leakage is the same as the cost of water production. The water demand projection model, provided in Technical Note II (Asefa et al., 2020), includes non-revenue water estimates based on total water production vs. water delivered to customers for cities within the Nile Basin. It includes, in addition to leakage and losses, such public water uses of fire-fighting, parks, etc.

Rainwater harvesting. The options in this scenario include: rainwater harvesting from the roof or stormwater collection at a sub-catchment level. The potential rainwater that can be harvested depends on the amount of precipitation and temporal distribution of the rainy season. There is significant variation of precipitation amount received in different regions in the Nile Basin area that warrants a close assessment of its feasibility in the region. Precipitation information can be extracted from database of climate/weather patterns using the geographic coordinates (latitude and longitude) of each city that could be combined with rain capture areas to estimate potential for rainwater harvesting (Ennenbach et al., 2018). Such approach has been demonstrated to be applicable even in semi arid regions (Abdulla and Al-Shareef, 2009)

Groundwater. This option is based on the practice of groundwater use and the potential groundwater resource available in each city. Data of well yields and amount of groundwater reserve that can be tapped by each city should be taken into consideration.

Greywater reuse. This option includes the amount of greywater that can be used onsite for non-potable uses such as toilet flushing and gardening. The amount of greywater is estimated as a percentage of water supplied to customers. This would potentially apply to residents who have in-house connections of water supply and where the plumbing system is such that there is a dual pipe system that separates black water (from toilet) and the rest of the water points in the house such as showers, kitchen sinks, laundry).

Demand side measures

The two main categories for demand side management are the passive and active water conservation measures. Passive measures are relatively easier to implement and quantify the savings compared to active measures. However, if properly practiced and funded, active measures can result in much better outcomes and accelerate the natural replacement of efficient fixtures. Some examples of demand side measures with high water savings potential include: installation of water sense rated fixtures, weather-based irrigation controller systems, incentives through rebates for water saving units, grey water retrofits and rebates, high- efficiency appliances and process units, retrofits in schools, industries and large institutions. The level of water saving that can be achieved can be significantly influenced by the level of market penetration of efficient water use fixtures such as low flush toilets, water saving shower heads, appliances, and efficient systems in irrigation and industries.

Passive measures. These are driven by natural replacement of fixtures that have either reached their service life or that need to be replaced based on building codes, regulatory requirements for fixtures or lifetime of the fixture or infrastructure. This requires assessment of market penetration of water-efficient fixtures (assess the technology being imported or implemented in each country) and identification of regulations (plumbing and building codes). This also requires information on the modality of water supply (in-house connection, yard tap, etc), distribution of the socio economic groups (high and middle income) and information on age of buildings (to estimate water fixtures have reached their end of life) and size of parcels (to know if outdoor water use should be considered). These information are useful to estimate how much water can be saved if old water fixtures are replaced by water efficient ones. Some of the water savings in this scenario include replacement of toilets, cloth washers, dishwashers, shower heads, urinals, swimming pools and lawn irrigation systems.

Active measures. Active conservation measures include changes in practices and behaviors of users typically through implementation of incentives provided by utilities or governments. Active measures are designed to expedite the replacement of standard or inefficient water fixtures with more efficient ones through rebates and other incentives. This scenario includes measures for indoor and outdoor water uses. It requires information on utility and government programs in each city or country. The selection of the applicable measures (rebates/incentives) will depend on the cost of implementation to the users and the utilities/government as well as a potential deferment of new infrastructure, which might otherwise would be needed due to the growing demand for water.

The impact of both active and passive conservation measures on future water demand has been shown to be significant. For example, Figure 1 shows the water demand project in the Tampa Bay area (Florida) with and without conservation measures. Over a period of 25 years, the passive and active conservation measures would save about 17 and 25 MGD of water, respectively. This is a very significant amount considering the need to build additional infrastructure or to find additional source of water supply. In the case Nile Basin countries, such water saving would alleviate the stress on the Nile River and reduce unnecessary waste of water and financial resources..

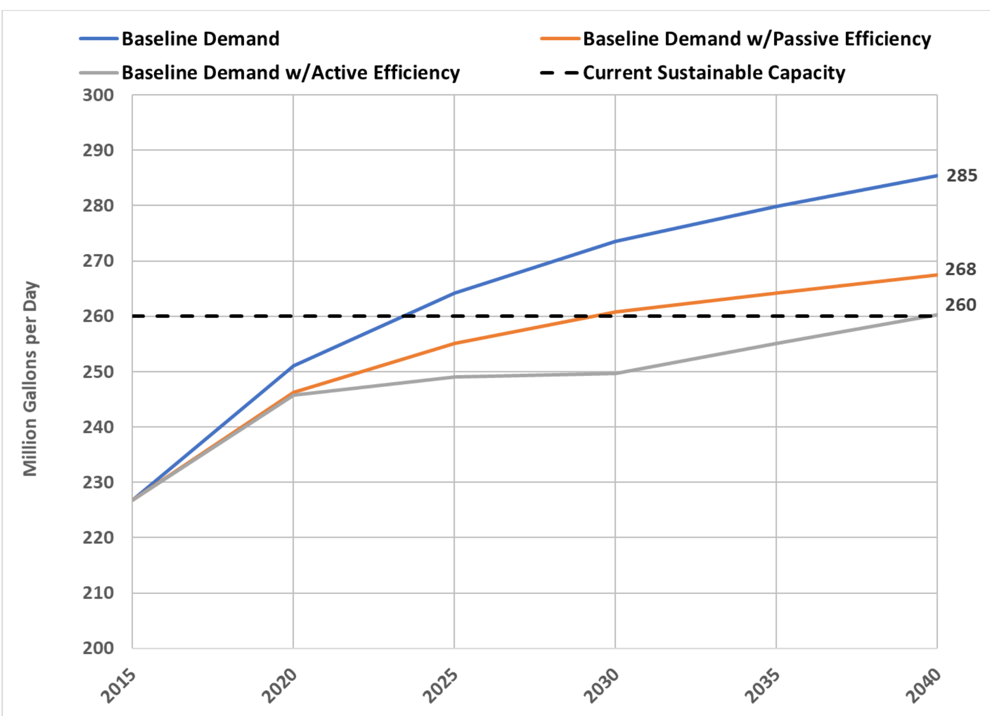


Figure 1 Water demand projection of the baseline demand with and without active and passive

conservation measures (Hazen and Sawyer, 2018).

In order to understand the level of water conservation measures it is important to assess market penetration of water saving technologies. This helps estimate potential passive and active measures that need to be considered. Savings from active and passive measures are often addressed in sequence. While passive measures are those that occur as a result of natural replacement of old fixture, active measures are facilitated by utilities and government regulations. Before the potential benefits of active water efficiency alternatives can be assessed, passive savings must be estimated. An assessment of remaining passive efficiency potential can then be used to identify, develop, screen and select technically applicable active alternatives.

WATER CONSERVATION MEASURES AND WATER DEMAND FORECASTING

Many forecasting models assume that water demand increases along with population and economic growth. In the case of economic growth, there are different theories describing the degree of coupling between economic growth and water consumption. The first theory predicts that there is a coupling between water use and economic growth. It hypothesizes that water use will increase with at least the same rate as economic growth. Under this scenario the water demand for municipal and industrial demand would be expected to exponentially increase over time.

The second theory is described by the Environmental Kuznets Curve (EKC) (UNEP, 2011). It describes the relationship between economic growth and environmental impact as an inverted U- shaped curve. Based on the Environmental Kuznet's curve (Figure 2), it is understood that initially (at low level of economic development) there is a coupling between economic growth and water use. Once a certain level of economic development is achieved (For example in the case of high GDP growth scenario), the growth of water use rate begins to slow down and ultimately decreases (decouples) with time. Decoupling indicates that economic growth (High GDP growth rate) has the potential to create favorable conditions for water demand reductions and reverse the commonly assumed continuous increase of water consumption with a growing economy. Decoupling is mainly attributed to implementation of various water supply and demand management measures that include leakage reduction, use of alternative water sources, implementation of water saving devices and non-technical measures such as pricing and policy plans coupled with education and social awareness actions. All the cities in the Nile Basin countries are at their early stage of their economic development. In general, the water demand is expected to exponentially increase over time both due to population growth and rapid economic development. At the same time the increasing market penetration of water saving facilities and awareness of water saving practices would play a role in certain parts of the society where the growth rate of water demand would be somehow controlled over time, especially for some socio economic groups such as the high income categories.

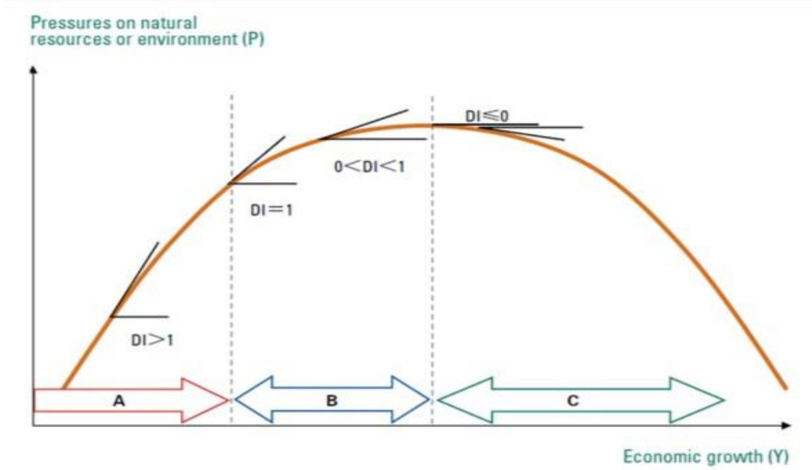


Figure 2 Environmental Kuznets Curve (EKC) (Source: UNEP 2011). In the case of water consumption, the curve indicates that as the economy grows, there is initially increased water consumption but after a certain level, advances in technology and increased awareness of resource limitations, water consumption declines over time. Such decline is attributed to water conservation measures and us of alternative water supply sources.

Too often water demand forecasting approaches underestimate or neglect the importance of water conservation and efficiency measures (Frost, 2012; Mayer, 2013). Such approaches produce inaccurate projections that may result in unnecessary and costly investments for infrastructure and management of water supply systems. For such reasons it becomes very important that water conservation and efficiency become integral part of water demand forecast. It is also important to note that with advances in technology over time, savings from water conservation will increase and hence due consideration should be made when water demand forecasts are calculated over a long-time horizon. In general, water demand forecasting that takes savings due to water conservation and efficiency would involve: 1) estimation of future total or per capita water demand based on historical water use data, 2) calculation of water saving based on conservation measures and efficiency gains, and 3) deduct the conservation savings from Step 2 as a correction factor to the water use estimate in Step 1.

Another approach where the impact of water saving practices can be incorporated into water demand projections is by taking a technology parameter as a variable in the projection model. In this case it is assumed that at innovations in technology progresses the market will make water saving fixtures and infrastructure available in the market that will be use more and more by users. The section below discusses how water conservation measures have been incorporated into the water demand projection.

WATER DEMAND PROJECTION WITH AND WITHOUT WATER CONSERVATION MEASURES

In order to understand the potential of passive and active water conservation measures in each of the Nile Basin countries and to determine the amount of water that can be saved, we included relevant question in the survey for the national consultants (See details of questions for water demand management in the Appendix A). Questions related to the passive and active measures include information on market penetration of the major water saving fixtures and appliances (toilet, shower heads, urinals and washing machines) and whether utilities or government have water conservation programs and incentive/rebate plans for efficient system installation. These were useful to determine the feasibility of passive and active water conservation measures. The survey results from national consultants is shown in Table 1. Although data was not available from all Nile Basin countries, the results (Table 1 and Appendix B) indicate that in most cases, water saving fixtures and appliances are widely available in the market. This was important for us to assume that passive measures are being implemented in new and old buildings. Hence we incorporated a technology factor in the water demand projection model that represented passive water conservation measures starting the current year all the way to 2050.

The survey results indicated that water saving incentives/rebate programs are not common and it may not be feasible to incorporate parameters for active water conservation measures in the projection model. This would be applied when the projection model gets updated in the near future. For this a relevant technology factor will be considered based on 1) the extent of initiatives taken by utilities and governments, and 2) based on the estimates of applied passive water conservation measures and the residual savings that can be achieved from demand side management.

In this project, the water demand projection model adopted an approach where a technology factor was included as one of the model parameters to represent passive water saving measures for the high GDP growth scenario. Equation 1 shows the water demand projection model where price, GDP, Technology and weather parameters are considered as key variables that will impact future water demand. For details of the model development and the assumptions, see Technical Note II (Asefa et al., 2020).

$$WU_c = \propto GDPC^{\beta 1} * Price^{\beta 2} * \boldsymbol{Tech} * Seas\ Adj \qquad \text{Equation 1}$$

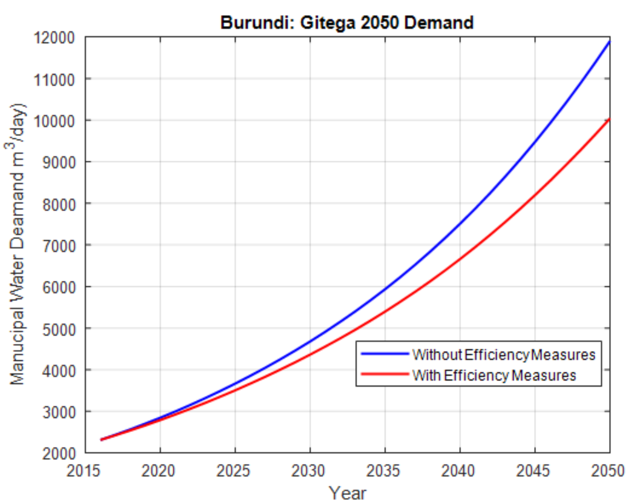
The technology parameters assumes that water conservation occurs over time because of replacement of the standard appliances and fixtures with high efficient ones. As old appliances and fixtures are naturally replaced, typically, per capita water use may decrease by about 0.5% to 2% annually depending on the efficiency rating of existing appliances that are in place. This represents the passive measures. Ignoring the role of passive efficiency over a long period of time such as 20 to 30 years horizon may greatly overestimate water demand and hence results in building over capacity infrastructure and unnecessary investment. In this case, passive efficacy is accounted for through a technology factor that depends on current level of efficiency as well as market penetration of different appliance and home fixtures.

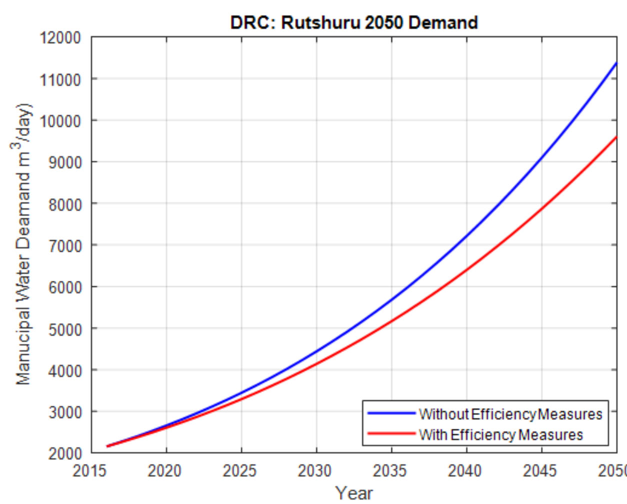
Table 1 Availability of water efficient fixture and appliances in the Nile Basin countries based on survey data from national consultants

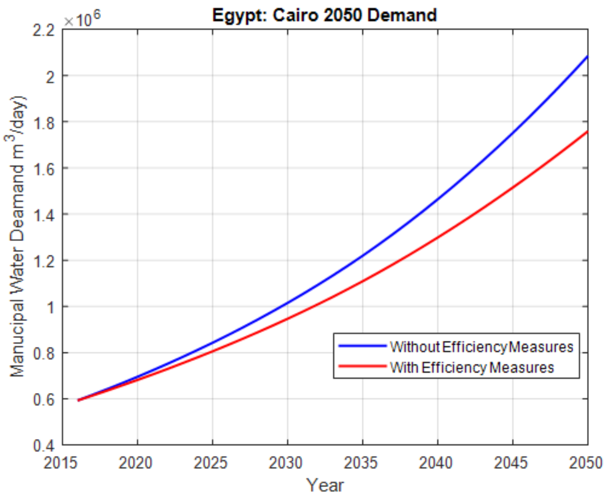
Country	Toilet, L/flush					Shower heads, L/minute					Washing machine, L/load		Urinals, L/flush				Conservation program	Rebate program
	19	13	6	5	4/dual	19	9.5	7.6	6.6	5.7	150	95	9.5	5.7	3.8	1.9		Yes=1, No= 0
Burundi			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes					Yes	Yes	Yes	No
DCR	N/A					N/A					N/A		N/A				N/A	N/A
Egypt	N/A					N/A					N/A		N/A				N/A	N/A
Ethiopia			Yes						Yes		Yes			Yes			No	No
Kenya		Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes		No	No
Rwanda				Yes	Yes				Yes	Yes	Yes	Yes			Yes	Yes	Yes	No
South Sudan		Yes								Yes		Yes				Yes	No	No
Sudan	N/A					N/A					N/A		N/A				N/A	N/A
Tanzania	N/A					N/A					N/A		N/A				N/A	N/A
Uganda	Yes	Yes	Yes	Yes						Yes		Yes		Yes	Yes		Yes	Yes

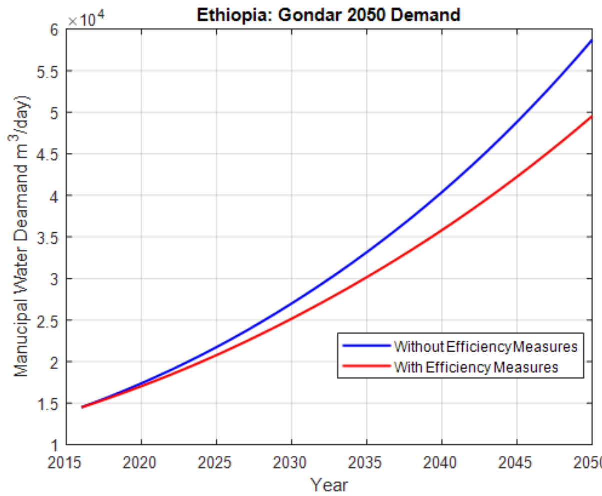
In order to understand where the cities in the Nile Basin countries stand in terms of the distribution of water saving fixtures and the use of alterative water sources, we engaged the national consultants (hired by NBI) to collect information using a survey. The survey included several questions on the type of technology currently available in the market, (such as toilets, urinals, shower heads, faucets, etc). The purpose of such information was to help understand the extent to which water saving fixtures are being used or available in the market. A template of the survey questions that was used to collect the information is attached in appendix A. Except for few countries, most of the survey results did not have data on demand management. All the collected raw data and processed data from the national consultants are documented in the database as provided in Technical Note I (Tasew et al., 2020). The few results, however, showed that high efficiency fixtures and appliances are already in the market or installed in some of the newly constructed buildings. Although there is limited data an assumption was made that efficient fixtures would be available in the market in all the countries. Moreover, as most cities in the Nile Basin are in their rapid development stage, efficient fixtures and appliances will become the norm for installation in new housing developments. Considering that most of the customers are currently using the standard fixtures (non-water saving fixtures) there is high potential for passive measures to occur as the old fixtures get replaced. This approach was used in the forecasting model, where water saving technologies will be increasingly implemented in cities and the cumulative passive measures will increases over time. It is important to note that, this is a conservative approach as active measures can also be implemented through government and utility initiatives. Considering the current economic status of utilities and governments, active measures may not be feasible for the near future. It is possible that some of the progressive utilities may implement active measures that will further reduce projected water demand.

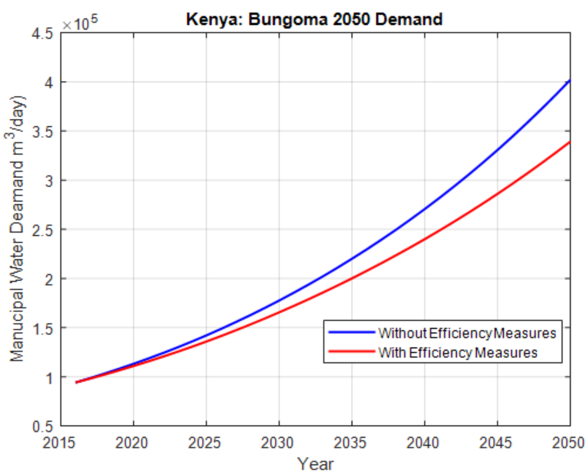
According to the model, water demand projections in all the Nile Basin cities showed that passive measures have significant reduction in water demand by 2050. Projection of selected cities with and without water conservation measures are shown in Figure 3. These figures represent extreme case scenarios of the highest GDP growth rate (10%) and highest water price growth rate (1%).

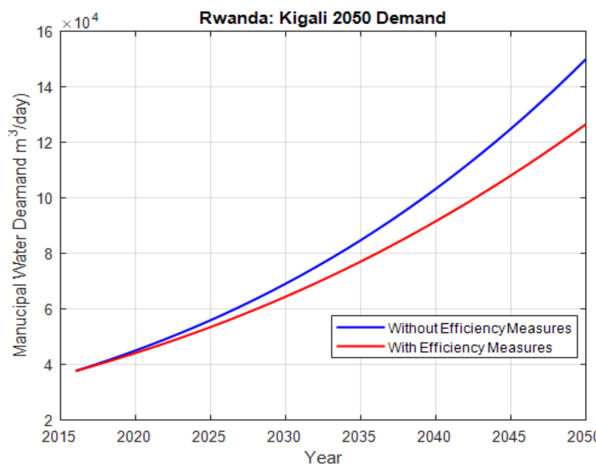


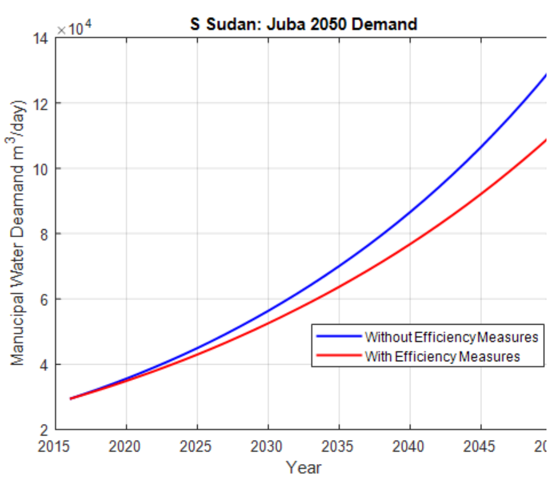



Egypt: Cairo 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
With Efficiency Measures


Ethiopia: Gondar 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
With Efficiency Measures


Kenya: Bungoma 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
With Efficiency Measures


Rwanda: Kigali 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
With Efficiency Measures


S Sudan: Juba 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
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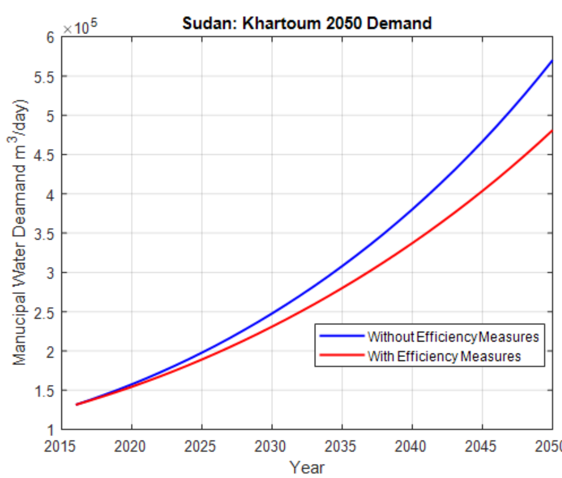
Sudan: Khartoum 2050 Demand
Manucipal Water Deamand m3/day)
Year
Without Efficiency Measures
With Efficiency Measures

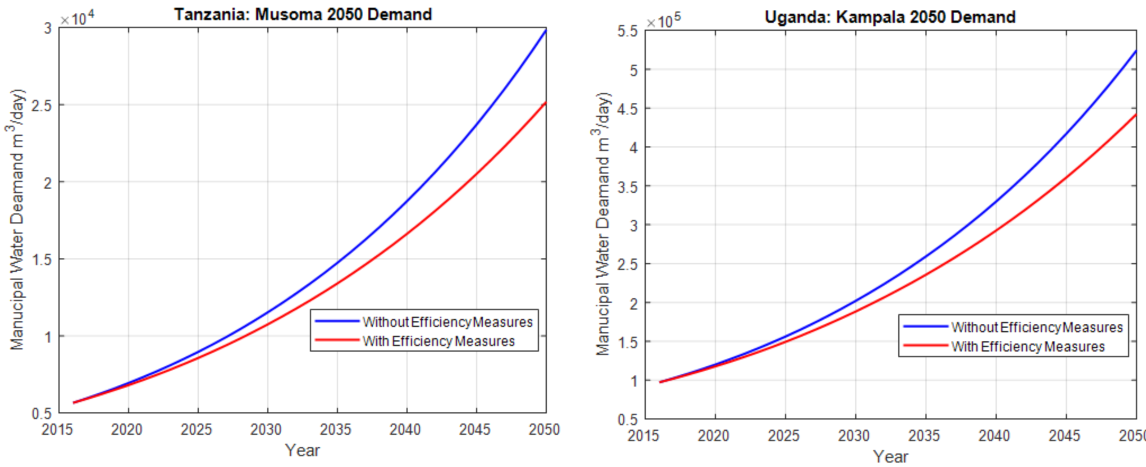

Figure 3 Water demand projection of 10 cities in the Nile Basin with and without water conservation measures.

Based on the projection for the selected cities it is clear that the total amount of water saved due to water conservation measures will achieve significant reductions in water demand from the Nile River. This is important in terms avoiding or delaying additional infrastructure requirement to meet the high water demand and to reducing the stress on the river.

For the 10 cities shown in Figure 3, the amount of water demand reduction by 2050 is presented in Table 2. The results represent the amount of water demand with and without water conservation measures and calculates the daily and annual savings based on conservation measures. The amount of water savings for the cities only from passive measures amount to 16% of the water demand. This is a significant amount that needs to be taken into consideration in future water demand assessments. Additional reductions in water demand can also be achieved through active water conservation measures if utilities/governments implements financial incentive (rebates) and other water conservation programs to expedite the installation of high efficiency fixtures and appliances. This amount can be estimated in the future when the projection model is ready for update.

Table 2 Impact of water conservation measures on the 2050 water demand projection for selected cities in the Nile basin.

City, country	Population	Water demand in, m^3/day		Water saving,	
		Without conservation measures	With conservation measures	m^3/day	m^3/year
Gitega, Burundi	14,585	12,390	10453	1,853	676,345
Rustshuru, DRC	164934	11,854	10001	339,316	123,850,340
Cairo, Egypt	16574884	2,170,441	1831125	9,558	3,488,670
Gondar, Ethiopia	661625	61,134	51576	65,458	23,892,170
Bungoma, Kenya	4503826	418,702	353244	23,450	8,559,250
Kigali, Rwanda	2,063,032	150,002	126,552	20,429	7,456,585
Juba, S. Sudan	1,789,183	130,675	110,246	89,150	32,539,750
Khartoum, Sudan	6,339,660	570,248	481,098	4,858	1,773,170
Musoma Tanzania	403273	31,073	26215	81,980	29,922,700
Kampala Uganda	7,157,012	524,380	442,400	1,853	676,345

POTENTIAL REDUCTIONS OF WATER DEMAND FROM NILE RIVER THROUGH SUPPLY SIDE MANAGEMENT

In addition to the demand side management options (passive and active conservation measures), the demand for water from the Nile River can be further reduced through the supply side management options. Although data from the national consultants was not complete, the available data shows that there is a good potential for water saving from leakage reduction and rainwater harvesting. Grey water reuse is practiced only in some countries at a very low percentage. Details of the responses to the survey questions (for cities) are provided in Appendix C and a summary at the national level is shown in Table 3. Ground water use is common in many places but is not clear the how much the potential of GW is as a fraction of the total water supply.

Table 3 Alternative water sources use in the Nile Basin countries (For details in each city see appendix C)

Country	Non-revenue water, %		Rainwater, mm		Greywater reuse practice	Ground water use
	Current	Goal	Average precipitation, mm	No of months		
Burundi	20-64	20	770-1400	9	N/A	Only few cities use GW
DCR	N/A	N/A	N/A	N/A	N/A	N/A
Egypt	N/A	N/A	N/A	N/A	N/A	N/A
Ethiopia	23-40	10	600-1988	3-6	No	Most cities use GW
Kenya	36-70	N/A	100-2000	4	Yes, for watering lawn flowers	All cities use GW
Rwanda	25-40	25	827-1320	5-12	N/A	All cities use GW
South Sudan (Only Juba)	30	25	977	7	No	Yes
Sudan	N/A	N/A	N/A	N/A	N/A	N/A
Tanzania	N/A	N/A	N/A	N/A	N/A	N/A
Uganda	10-32	N/A	802-1541	4-8	Yes, <10%	Most cities use GW

Although it may be challenging to accurately estimate the amount of water that can be saved from all the supply side management measures, the potential and applicability of the different measures in each of the Nile Basin countries can be identified based on current practices, climate conditions and advances in technology. The survey results from the national consultants shed some light into the supply side management practices (leakage, rainwater amount and temporal distribution, greywater reuse and groundwater use) and possible savings in the countries where data was provided. Qualitative information of the extent of water saving for each of the supply side management in the different Nile Basin countries is shown in Table 4. The relative potential of water savings are represented by the number of "+" signs. ("+" indicating lowest potential and "++++" indicating highest potential). The assignment of relative water saving potentials for each case has been made based on a very limited information gathered from survey results of the national consultants, reports, databases and the literature (many of which are not consistent).

The amount of precipitation and its seasonal distribution indicate that in most of the Nile Basin countries, significant amount of water can be harvested. In some places such as Burundi, DCR, and Rwanda, the extended rainy season of up to 9 months can help cities collect rainwater during large part of the year. On the other hand the potential for rainwater harvesting in Egypt and Sudan is low.

Table 4. Potential water saving options from alternative water supply options in each of the Nile Basin country

Country	Water loss reduction[2]	Rainwater harvesting[3]	Greywater reuse[4]
Burundi	++++	++++	+
DRC	+++	++++	++
Egypt	+++	+	+++
Ethiopia	+++	++	++
Kenya	++++	++	+++
Rwanda	++	+++	++
South Sudan	+++	++	+
Sudan	+++	+	+
Tanzania	+++	++	+
Uganda	+	+++	+++

[2] Savings in this category depend on current water lose levels, Repair & Replacement capital availability and the target non-revenue water set by cities.
[3] Savings potential in this category depend on specific climate/seasonal weather pattern as well as end water use that could be substituted with harvested rainwater.
[4] Savings in this category depend on current level of water supply and sewer systems coverage in each of the cities, existing practices of greywater reuse and end water uses such as toilet flushing and landscaping/gardening.

Water saving from leakage reduction is also another avenue where future water demand can be reduced. Based on the collected data and literature review, water loss in most of the cities is high (20-70%) and many have indicated to reduce the value to 20%. Uganda seems to have low water loss (10-30%, Table 3) and the potential for water saving from leakage reduction may not be significant.

Due to lack of information on the amount of groundwater use and the possible interaction between groundwater and surface water, it is not possible to indicate the potential groundwater use as an alternative water source. Knowledge of the extent of groundwater use and the type of wells (shallow and deep wells) will be useful to assess the potential of groundwater use. Based on the survey results, however, one can conclude that most of the countries have the potential to use groundwater sources to supplement water use form the Nile River.

Current industrial water use in most developing countries is characterized by linear flow system in which water is extracted, used and then disposed. Each step or process considers its water use separately and this approach results in very low water use efficiency and high water footprint. It is important that industries recognize the concept of water efficiency and productivity in order to cope with the ever-increasing water scarcity and high rate of economic developments. Industrial water uses have shown significant reduction in the past decades as a result of re-use and/or recycling within the system. Dwarka et al. (2007) estimated that by 2030, the potential for water saving in industry as a whole will reach about 26% of the water abstracted as part of the baseline scenario. Some of the major drivers for this are simple water efficiency measures as part of a larger water demand management programs.

Because of limited data availability for the Nile Basin cities, industrial demand forecasts were included as a percentage of municipal demand. The amount of municipal water demand in this report, therefore, includes industrial water demand as well.

CONCLUSION

This report presents the potential water savings that can be achieved based on current practices and trends in the various Nile Basin countries. It provides the different water demand side and water supply side management options and how they can be exploited to reduce water demand from the Nile River. Based on a survey that was carried out through the national consultants, data was collected from 6 out of the 10 Nile Basin countries. Although it was not complete, some useful information was extracted from the collected data that helped the consultant to make quantitative and qualitative estimates of water saving potentials.

Considering the demand side management practices, a technology factor was included in the demand forecasting model to account for the passive water conservation measures (passive measures represent natural replacement of standard fixtures with high efficient water use fixtures). It was found that water saving due to passive measures could be as high as 16%. This is significant amount of water and must be considered in the projection of water demand for 2050.

The savings from active measures (Water conservation measures expedited through rebates and other incentives by utilities and/or government) were not included in the forecast model due to lack of data. This is also a significant amount that should be accounted as the model gets updated in the future and more information becomes available.

Water saving potential from supply side management (that include leakage reduction, rainwater harvesting, greywater reuse and groundwater use), were represented in qualitative form due to lack of information. As more date becomes available, the amount of water saved should be estimated to reduce the stress on the Nile River. Based on the collected data, most of the countries can reduce water demand by harvesting rainwater and reducing leakage. Greywater reuse is not common but it could generate a potential saving as it gets practiced in the future. Almost all the cities in the survey indicated that they use groundwater but the amount of groundwater use is not specified, which makes it difficult to estimate the supply. In most of the cities, the rainy season extends from 3-9 months. This provides a good potential to collect rainwater either at household level or a sub catchment level to augment water supply from the Nile River. Accurate estimates of the savings from the supply side management will require additional data and this can be addressed when the projection model and database are ready for update.

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APPENDIX

Appendix A: Template for data collection survey for water supply and demand management practices.

The questions for demand management information are grouped in four categories. These categories have questions on general water conservation, water use fixtures, alternative water sources and industrial and cooling tower systems.

Category 1: General questions on water conservation measures

DM-1	What is the percentage of water sourced from surface water, ground water, salt water or other sources?
DM-2	Does the city has water conservatin policy or program? **[1 if it applies, 0 if not]** What type of water conservation measures are practiced **(indicate that apply)** i) Efficient water fixture replacements programs with rebate ii) Water conservation awareness raising programs iii) Outdoor water use reduction and efficient landscape irrigation
DM-3	If the city or utility has a rebate program, which ones are in place? [**1 if it applies, 0 if not**] i) High efficiency toilet toilets ii) Water saving shower heads iii) Efficient washing machines iv) High efficiency urinal v) Efficient cooling towers
DM-4	Does the city practice the following [**1 if it applies, 0 if not**] i) Rain water harvesting ii) Greywater reuse iii) Water loss reduction program
DM-5	If the city has water conservation program i) when was it implemented (year) ii) What is the water conservation goal for the city (percentage reduction of demand) iii) Does the utility have staff working on water conservation effort? iv) Does the utility have water audit program? v) Does the utility or municipality has annual budget for water demand management?

Category 2 - Water use fixtures

DM-6	What type of toilets are in the market. If possible, indicate **percentage of population** using the type i) 19 Liters/flush ii) 13 Liters /flush iii) 6 Liters /flush iv) 5 Liters/flush v) 4 Liters/flush (Dual flush)
	vi) Other

DM-7	What type of shower heads are in the market. If possible, indicate **percentage of population** using the type i) 18.9 Liters/min ii) 9.5 Liters/min iii) 7.6 Liters/min iv) 6.6 Liters/min v) 5.7 Liters/min
DM-8	What type of washing machines are in the market. If possible, indicate **percentage of population** using the type i) 150 Liters/load ii) 95 Liters/load
DM-9	What type of urinals are in the market. If possible, indicate **percentage of population** using the type i) 9.5 Liters/flush ii) 5.7 Liters/flush iii) 3.8 Liters/flush iv) 1.9 Liters/flush
DM-10	Based on building design, what is the number fixtures in each residential/ non-residential buildings i) Average number of toilet/showers/washing machines per residential home ii) Average number of toilets/showers/urinals per non-residential buildings
DM-11	Swimming pools Percentage of homes with pools How many public swimming pools are there in the city, also provide size of pools
DM-12	Residential buildings with yard lawn i) Percentage of buildings with lawns ii) Source of water for lawn watering
DM-13	Non-residential buildings with yard lawns. i) Percentage of buildings with lawns ii) Source of water for lawn watering
DM-14	If there are public parks provide information on i) Number of parks and size in hectares ii) How do they get their water for landscaping (municipal, wells, rain)

Category 3: Alternative water sources

DM-15	Unaccounted for water i) What is the amount of leakage in distribution system (in percent) ii) What is the target level of water loss the city plans to meet
DM-16	Rain water information i) How much is the annual rainfall in the city ii) How long is the rainy season (Number of months) iii) Average annual and monthly temperature
DM-17	Rainwater harvesting i) If rain water is harvested from roof, what is the average size of storage (barrel or reservoir) used?

	ii) If stormwater is harvested at catchment level, provide an estimate of volume collected per year?
DM-18	Grey water i) Is greywater reuse practiced? ii) What is greywater used for? iii) What percentage of the population reuse greywater? iv) What is the estimate of greywater resuse in the city (in cubic meter per year)
DM-19	Groundwater What is the percntage of population served from ground water sources?

Category 4: Industrial water use and cooling towers

DM-20	Industries i) Provide a list of major industries in the city. (Provide size in terms of production capacity) ii) What is the amount of water consumption in each industry (liters per day) iii) Type of water sources (municipal, private well, provide percentage of source) iv) Does the industry apply water conservation measures (indicate the measures) v) Does the industry reuse greywater or wastewater? vi) Does the industry collect rainwater (indicate capacity of rainwater storage)
DM-21	Cooling towers i) What is the capacity of the cooling tower? ii) Is the cooling tower single pass or closed loop system? (Indicate cycle of concentration) iii) Does the cooling tower treat the water when recycling

Appendix B Data on Availability of Efficient Water Fixtures in the Market (National consultants)

Country	Toilet, L/flush					Shower heads, L/minute					Washing maching, L/load		Urinals, L/flush				Conservation awareness program	Rebate program
	19	13	6	5	4/dual	18.9	9.5	7.6	6.6	5.7	150	95	9.5	5.7	3.8	1.9	Yes= 1, No= 0	Yes=1, No= 0
Burundi	0%	0%	10%	85%	15%	5%	0%	85%	10%	5%	0	0	0	0	90%	10%	1	0
DCR	N/A					N/A					N/A						N/A	N/A
Egypt	N/A					N/A					N/A						N/A	N/A
Ethiopia			Yes						Yes		Yes			Yes			0	0
Kenya		Yes (10L/flush)		Yes	Yes (3L/flush)	Yes	Yes	Yes	Yes	Yes	Yes (140L/load)	Yes (120 & 60 L/load)			Yes		0	0
Rwanda	NA	NA	NA	Yes But no % available	Yes But no % available	N/A	N/A	N/A	Yes But no % available	Yes But no % available	NA and no % available	Yes But no % available	NA	NA	Yes But no % available	Yes But no % available	1	0
South Sudan		Yes								Yes		Yes				Yes	0	0
Sudan																		
Tanzania																		
Uganda	Common in institutions (30-50%)	Common in residential (50-80%)	Most common (80-100%)	Less common (10-30%)	Not common (<10%)	Less common (<5% use)	Less commo n (<5% use)	Less commo n (<5% use)	Less common (<5% use)	Most common (>80% use)	Less common (<5% use)	Most common (20% use)	Rare, < 1%	Less common 20-50%	Most common 50-100%	Least common< 20%	1	1

Country	Toilet, L/flush		
	19	13	6
Burundi	0%	0%	10
DCR	N/A		
Egypt	N/A		
Ethiopia			Ye
Kenya		Yes (10L/flush)	
Rwanda	NA	NA	N
South Sudan		Yes	
Sudan			

Tanzania			
Uganda	**Common in institutions (30-50%)**	**Common in residential (50-80%)**	**Mo co (8 10**

Appendix C: Data on Alternative Water Sources (National Consultants)

Country	City	Non revenue Water		Rainwater		Greywater reuse practice	Ground water use		
		Current	Goal	Average precipitation, mm	No of months		Yes= 1, No = 0	Deep or shallow	Percentage of GW use
Burundi									
	Gitega	40%	20%	1200mm	9 months	0	1	N/A	N/A
	Karuzi	67%	20%	1100 mm	9 months	N/A	1	N/A	N/A
	Kayanza	20%	20%	1200mm	9 months	0	0	N/A	N/A
	Kirundo	20%	20%	N/A	N/A	N/A	0	N/A	N/A
	Muramvya	20%	20%	N/A	N/A	N/A	0	N/A	N/A
	Muyinga	64%	40%	770mm	9 months	N/A	0	N/A	N/A
	Mwaro	14%	0%	1400mm	9 months	N/A	0	N/A	N/A
	Ngozi	40%	N/A	1055	9 months	N/A	0	N/A	N/A
	Cankuzo	40%	N/A	1055	9 months	N/A	0	N/A	N/A
	Ruyigi	33%	20%	830	9 moth	0	0	N/A	N/A

DCR		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Egypt		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethioipa									
	Debre Birhan	NA	10%	965.25mm	4	NA	1		100% water supply source is from ground water
	Debre Markos	39.8%	NA	1388 mm	4 months from June-Septmeber	NA	1		More than 80%
	Gondar	NA	NA	1100 mm	4 months	NA	0		NA
	Debre Tabor	NA	NA	1497 mm	4 months from June to Septmber	NA	1		NA
	Metu	NA	0%	1772	6 months	NA	0		NA
	Ambo	NA	0%	912 mm	4 months from June - Septmeber	NA	0		NA
	Nekemt	NA	NA	1988mm	6 months from May to October	NA	0		NA
	Bahir Dar	NA	NA	1416 mm	6 months from May to October	NA	1		NA
	Mekele	23%	10%	618.3 mm per year	4 months	NA	1		89%
	Axum	18.5%	NA	720mm	3 months from Junly-Septmeber	NA	1		79.3%
	Adwa	NA	NA	688mm	3 months July - September	NA	1		56%
	Mizan Teferi	NA	NA	1200mm	4 months from June to Septmber	NA	1		NA
	Assosa	NA	NA	1200 mm	3 months /July,August,Septmeber	NA	1		More than 75%
	Shire	NA	NA	905 mm	4 months from June to Septmeber	NA	1		NA

	Gambella	NA	NA	600mm	3 months from July - septmeber	NA	0		0
Kenya									
Kenya	Kakamega	42	N/A	1250 - 1750	4	Yes, for flower lawn	1		
	Bungoma	41	N/A	400 - 1800	4	Yes, for flower lawn	1		
	Trans Nzoia	41	N/A	100 - 1700	4	Yes, for flower lawn	1		
	Vihiga	36	N/A	1900	4	Yes, for flower lawn	1		
	Bomet	57	N/A	100 - 1400	4	Yes, for flower lawn	1		
	Nandi	47	N/A	1200 - 2000	4	Yes, for flower lawn	1		
	Uasin Ngishu	42	N/A	624.9 - 1560.4	4	Yes, for flower lawn	1		
	Kericho	51	N/A	1400 - 2125	4	Yes, for flower lawn	1		
	Kisimu	37	N/A	725 - 1800	4	Yes, for flower lawn	1		
	Siaya	70	N/A	800 - 1600	4	Yes, for flower lawn	1		
	Nyamira	57	N/A	1200 - 2100	4	Yes, for flower lawn	1		
	Kisii	57	N/A	1500	4	Yes, for flower lawn	1		
	Homabay	67	N/A	700 - 800	4	Yes, for flower lawn	1		
	Busia	53	N/A	760 - 2000	4	Yes, for flower lawn	1		
	Migori	43	N/A	700 - 1800	4	Yes, for flower lawn	1		
Rwanda									

Rwanda	Kigali	40%	25% by 2020	1000 mm	8 months (Feb - May; and Sept - Dec.)	NA	1		
	Musanze	27%	25% by 2020	1302 mm	12 months	NA	1		
	Huye	40%	25% by 2020	1147 mm	6 months (Feb - Apr; and Nov - Jan.)	NA	1		
	Muhanga	25%	20% by 2020	1207 mm	6 months (Feb - Apr; and Nov - Jan.)	NA	1		
	Nyagatare	NA	NA	827 mm	5 months	NA	1		
	Rubavu	32%	25% by 2020	1147 mm	6 months (Feb - Apr; and Nov - Jan.)	NA	1		
	Rusizi	37%	25% by 2020	1320 mm	9 months (Sep - may)	NA	1		
South Sudan									
	Juba	30	25	977.3	7	No	1		
	Malakal	0	0	NA	NA	No	1		
	Wau	NA	NA	NA	NA	No	1		
	Meridi City	0	0	0	0	No	1		
	Bor	NA	NA	NA	NA	No	1		
	Renk	0	0	NA	NA	No	1		
	Torit	NA	NA	NA	NA	No	1		
	Bentiu	0	0	0	0	No	1		
	Aweil	NA	NA	NA	NA	No	1		
	Kuacjok	NA	NA	NA	NA	No	1		
	Yambio	0	0	0	0	No	1		
	Juba - Gombo	0	0	0	0	No	1		
Sudan									

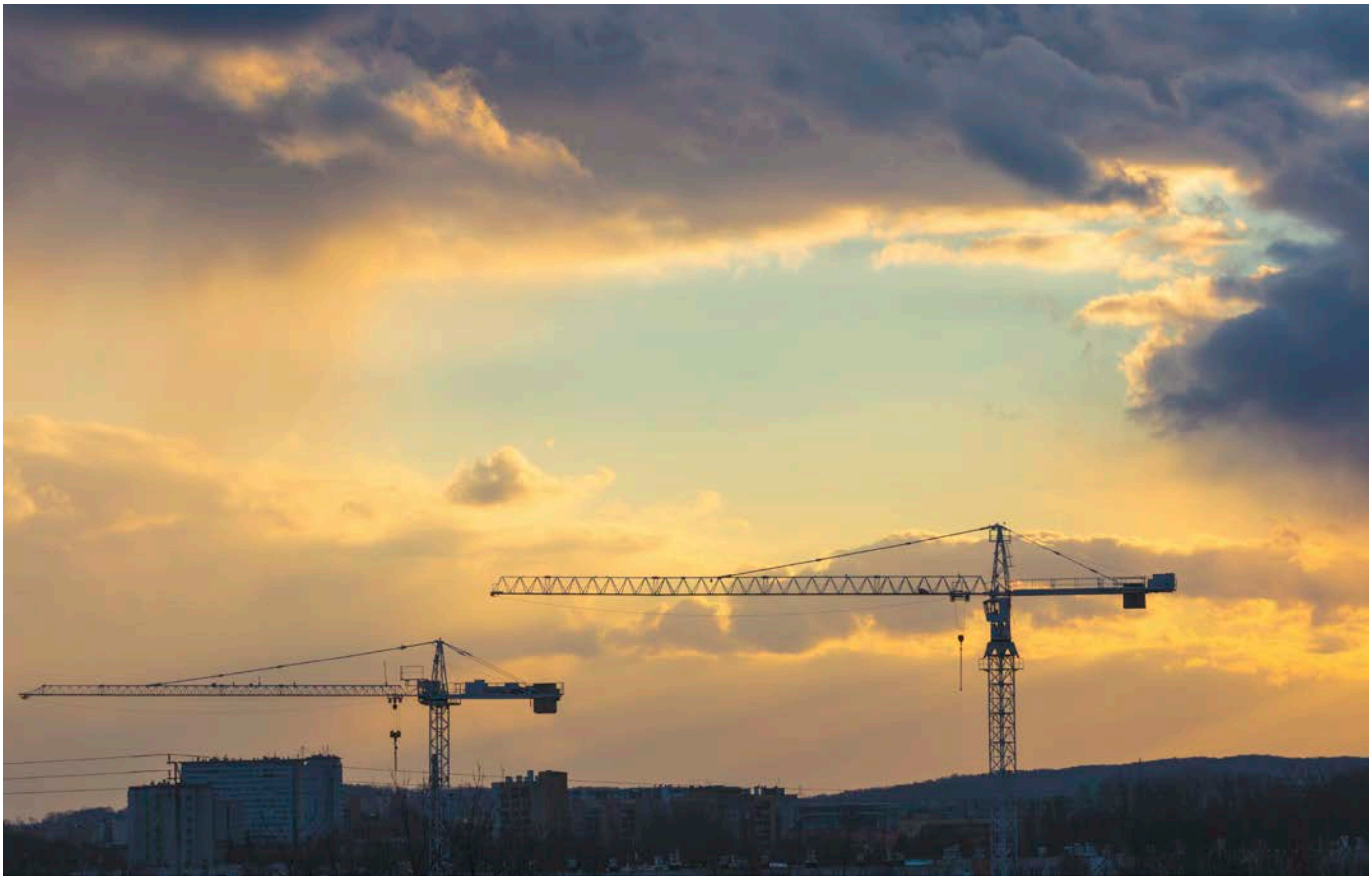
Tanzania									
Uganda									
Uganda	Arua	26%	N/A	1334	6**	Yes, <10%	1	Deep and shallow	
	Bushenyi	24%	N/A	1060	6	Yes, <10%	1	Deep and shallow	
	Busia		N/A	1431	6	Yes, <10%	1	Deep and shallow	
	Entebbe	16%	N/A	1541	6	Yes, <10%	0		
	FortPortal	17%	N/A	1369	6	Yes, <10%	1	Shallow well	
	Gulu	18%	N/A	1387	6	Yes, <10%	1	Deep well	
	Hoima	32%	N/A	1216	6	Yes, <10%	1	Deep and shallow	
	Iganga	28%	N/A	1430	6	Yes, <10%	0		
	Jinja	29%	N/A	1414	6	Yes, <10%	1	Deep and shallow	
	Kabale	11%	N/A	1239	6	Yes, <10%	0		
	Kampala	32%	N/A	1394	8	Yes, <10%	0		
	Kamuli	22%	N/A	1444	6	Yes, <10%	1	Deep and shallow	
	Kapchorwa		N/A	1159	6	Yes, <10%	1	Deep well	
	Kasese	21%	N/A	1222	6	Yes, <10%	1	Shallow well	
	Kisoro	25%	N/A	1332	6	Yes, <10%	0		

	Kitgum	10%	N/A	1202	4	Yes, <10%	1	Deep and shallow	
	Koboko		N/A	1290	6	Yes, <10%	1	Deep and shallow	
	Kumi		N/A	1293	6	Yes, <10%	1	Deep and shallow	
	Lira	29%	N/A	1351	6	Yes, <10%	1	Deep and shallow	
	Lugazi	26%	N/A	1403	6	Yes, <10%	1	Deep and shallow	
	Masaka	22%	N/A	1471	6	Yes, <10%	1	Shallow well	
	Masindi	11%	N/A	1283	6	Yes, <10%	1	Deep and shallow	
	Mbale	11%	N/A	1341	6	Yes, <10%	1	Deep and shallow	
	Mbarara	24%	N/A	1089	6	Yes, <10%	1	Deep well	
	Mityana	22%	N/A	1272	6	Yes, <10%	1	Deep and shallow	
	Moroto	14%	N/A	802	4*	Yes, <10%	1	Deep well	
	Mubende	10%	N/A	1170	6	Yes, <10%	1	Deep and shallow	
	Ntungamo	20%	N/A	1065	6	Yes, <10%	1	Deep and shallow	
	Rukungiri	29%	N/A	1068	6	Yes, <10%	1	Deep and shallow	

	Soroti	14%	N/A	1323	6	Yes, <10%	1	Deep well	
	Tororo	0.146	N/A	1456.174561	6	Yes, <10%	1	Deep well	

* one season

** Two seasons



ONE RIVER
ONE PEOPLE
ONE VISION

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