WATER ALLOCATION STUDY OF UPPER AWASH VALLEY FOR EXISTING AND FUTURE DEMANDS

(From Koka Reservoir to Metehara Area)

BY

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HYDRAULICS ENGINEERNING

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I

CERTIFICATION

I, the undersigned, certify that I read and hereby recommend for acceptance by Addis Ababa University a dissertation entitled "**Water Allocation study of Upper Awash valley For Existing and Future Demands**" in partial fulfillment of the requirement for the degree of Master of Science in Hydraulics Engineering.

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II

DECLARATION AND COPY RIGHT

I, **Berhanu Azazh Tumebo**, declare that this thesis is my own original work that has not been presented and will not be presented by me to any other University for similar or any other degree award.

Signature

III

ACKNOWLEDGEMENT

My foremost praise goes to my heavenly Father who is the real source of my life's joy, peace, relief and achievements in this bad realm, next of the free unaccountable gifts and acts that are accomplished by his son Jesus.

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IV

ABSTRACT

Unlike most other river basins in Ethiopia, the water resources of the Awash River have been highly developed and utilized over the last five decades. A number of major irrigation projects are currently being built, designed and planned and it is very essential to estimate the availability of water.

This research aims on water allocation of the existing and planned water demands in the upper awash valley. It evaluates the availability of water resources in expansions and developments of additional water abstracting schemes. The thesis compiles recent studies in the basin and meteorological, hydrological and demand data for each irrigation schemes were considered for the analysis.

Water Evaluation and Planning System (WEAP) model is used for the study for water allocation of the river water based on the existing water requirement and user priority setting situation. The model is operated by using the monthly based data in both the demand side and supply sides.

The water resources availability assessment and the allocations are performed for two scenarios;

Scenario I: The present (2007/2008) water use rate

This scenario holds the overall existing upper Awash valley and down stream irrigations which are currently utilizing the Koka

release. The overall irrigable area in this scenario is around 56,500 ha.

Scenario II: The present water use rate plus various schemes under construction

In this scenario the analysis is done by combining the current water use rate with ongoing irrigation schemes by taking the current account year of 2010.The total irrigable area under this scenario is 95,156 ha.

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According to the results of scenario I, if the irrigation level goes at present rate 92.7% of the demand will met the requirement for upper valley irrigation groups Wonji area and Nura Era complexes (UV1 and UV2) average annually up to 2038 by setting the same priority. After the year 2028 the demand coverage will be reduced to 84 % for these farms. The upper valley irrigations group 3 (UV3) get the coverage of 81% as per to the current abstraction annually. The lowest coverage will be observed in down stream farms (middle and lower valley farms) i.e. 57% from 2008-2028 mean annually. In the current scenario about 75 % the required water is delivered sufficiently and 25% is deficit annually for the stated years to the cumulative demands.

According to the results of the future scenario by differing the priority of allocation for each sets of demand site, the annual average requirement met for UV1, UV2, and UV3 will be 97%, 72% and 63% respectively from the years 2010-2028.The implementing demand sites namely Fentale, Metehara expansion and Wonji expansions get annual average coverage of 65%, 71% and 53% respectively; but after the year 2028 these sites get the coverage of only 59%, 63% and 40%

respectively. The total coverage for all demand sites will be reduced to only 55% at 2028.

For each the demand site from months July to December the coverage is full with nil unmet demand; but from months January to June the significant amount of irrigation deficit is observed in all sites except for urban water supplies. The period from February to June is the time with intensive irrigation in most sites with low flow of river, so that deficit is observed. Peak mean unmet is observed at June (213.4 MMC). The demand site with peak unmet demand is the DSIrr (middle and lower valley farms) with 85.6 MMC at June.

In the last part of this study the detail results of water allocation and water availability analysis are discussed widely.

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ABBREVATIONS

a.s.l	above sea level
CWR	Crop water Requirement
DSM	Demand side management
EEPC	Ethiopian Electric Power Corporation
ESC	Estate sugar corporation
EVDSA	Ethiopian valleys Development studies Authority
FAO	Food and agriculture organization of the United Nations
GDP	Gross Developmental product
GIR	Gross Irrigation Requirement
GIS	Geographical Information Systems
HDC	Horticultural Development Authority
ha	Hectare
IFAD	International Fund for Agriculture
Km^2	Kilo meter square
MMC	Million Cubic meters
M^3	Cubic meter
M^3/sc	Cubic meter per second
MoWR	Ministry of water resource
MW	Mega Watt
NIR	Net Irrigation Requirement
OIDA	Oromiya Irrigation development authority
OWWDSE	Oromiya water works Design and Supervision Enterprise
PET	Potential evapotranspiration
RRC	Relief and Rehabilitation Commission
UV1	Upper valley irrigation Groups1
UV2	Upper valley irrigation Groups 2
UV3	Upper valley irrigation Groups 3
WEAP	Water Evaluation and Planning
WRDA	Water resources development Authority

WR	Water requirement
WWDSE	Water works Design and Supervision Enterprise

CHAPTER 1
INTRODUCTION AND BACK GROUND

1.1. Introduction

Ethiopia, the country with 12 river basins, is considered as ‘the water tower’ in north east Africa. Most of the rivers in these basins cross the national boundary. According to various studies the total available water (mean annual flow) is estimated at 122 billion cubic meters and the ground water potential is about 2.6 billion cubic meters while the potentially irrigable land in the country has been estimated at 3.7 million hectares. Although Ethiopia’s water resource is enormous, very little of it has been developed for agriculture, hydropower, industry, water supply and other purposes. Of the total flow only about 1.5% is utilized for power production and 2% for irrigation. (Dessalegn Rahmato, 1999)

Ethiopia has not utilized its water resources adequately and wisely. The country lags behind many African countries in irrigation schemes development and safe water supply. Less than 6 percent of the country’s potential irrigable land is now under irrigation. In contrast, according to FAO data (1987), the three countries in sub-Saharan Africa with the largest irrigation are Sudan (2.2 million ha), Madagascar (1.0 million ha), and Nigeria (0.9 million ha).

The country is with great geographical diversity with high and rugged mountains, flat topped plateaus, deep gorges, river valleys and plains. Most of the rivers are situated and flow in unsuitable conditions for diversions and through uncultivable land. The technological and economical status of the country does not allow combating with geographical constraints that are observed in many river basins. That is why most rivers and other water sources are not under a full utilization level. The distribution of irrigation schemes in the country is quite skewed.

Unlike other rivers of the country, Awash river is actively and potentially utilizing river for various levels of irrigation developments. The potential of irrigable land inside the basin, geographical suitable for ease diversion of river, accessible condition along the river basin are some of the factors that make the river more utilizable than others. The basin holds numerous water users in governmental and private levels. Since there are ongoing large scale irrigation projects, more than 50% implementation tasks for MoWR are on Awash river basin.

The Awash basin is the most developed area with more than 60% of the potential irrigable area has been developed. In the Upper Awash valley the sugar corporation (ESC) intensively utilizes most its developed land. The horticulture development corporation (HDC) farms in the upper valley suffer some shortfalls in developed land use and efficient water utilization, apparently constrained by shortage of labor, machinery and some times water. The ESC at Wonji-Shewa and Metehara are the dominant state farms pre-existed and holds the major portion of irrigable land.

Moreover many new private and integrated irrigation farms are emerging with significant water abstraction from Awash river. These active irrigation developments are mainly occurring in the Upper Awash valley where population density is high and crop productivity is good. There are also unaccounted small traditional farms in the river banks of upper Awash valley. Since these traditional farms could not use scientifically measured amount of water it is difficult to estimate the amount of water that is abstracted by them. There are a number of small scale irrigation farms that have used water in modern manner but there are problems of operation and management. Some of the irrigation schemes also are not functional due to the problem of scheduling and lack of awareness.

An increasing developmental interest of Awash river basin will consequence to near future water shortage in the existing demands. This opinion is supported by the hydrologic variability of the river flow due to climatic variations and the increasing sedimentation rate of Koka reservoir. Still now the water availability of the basin depends on Koka reservoir capacity. But after the accomplishment of Kesem and Tendaho dams the middle and lower Awash valleys can get a considerable relief of water availability. According to previous water availability studies (Booker Tate and WWDSE) of Upper Awash sub-basin the water released from Koka reservoir can not sustain the existing and future irrigation demands via current water management.

Water allocation studies are viable for basins with multiple water demands and scarce water resource conditions to meet the existing demands. Upper Awash valley sub basin holds a multiple irrigation water users relatively in the country.

For the particular sub river basin the water allocation studies can assess the following major issues.

- Examine the water availability from Koka release for existing and future irrigation demands.
- Evaluates the amount of water that is required for the proposed and existing demands by the current water use methods.
- Prioritizing and scheduling the available water for upstream and down stream water users.
- Recommending on the current water utilization systems and future water sustainability measures.

The WEAP (Water Evaluation and Planning) model is used as the basic tool to undertake the study. The study is operated at monthly time steps. The study is based on available documentary sources and recently studied reports, most of which are provided from MoWR, WWDSE, and OIDA.

1.2. Statement of the problem

Ethiopia is one of the few countries in Africa with abundant water resources but still frequently hit by recurrent drought and famine associated with health and other extended social crises. Since majority of the country's rivers are transboundary in nature besides inability to utilize the water, they transport fertile soil abroad leaving the country. So the utilization of these rivers is limited to develop minor small scale irrigation projects for small groups of farmers and few state farms in the country. They also couldn't be used as domestic water supply sources. On the other hand Awash river and rift valley lakes, which are non trans boundary water resources in the country contributes a significant percentage of utilization for various irrigation developments unlike other river basins. There is a wide implementation of irrigation and other projects in the Awash river basin especially in the Upper valley which is additionally known by population density and suitable irrigation potential land.

There are some physical problems in the basin, such as flooding and sedimentation of Koka reservoir. These cause the decrease in storage capacity of the reservoir dynamically. The useful storage of the Koka Reservoir is estimated to be reducing at a rate of 17 Mm^3 (Booker Tate study) per year and the possibility of high sedimentation rates is a major concern for the down stream situations. So there is an expectation that the water released from Koka reservoir may not meet fully the demands of the basin in the near future. On the other hand there are some small and large scale irrigation projects are currently planned, designed and on the implementations. The unbalance between demand and supply may lead water users' conflict in the sub basin.

The need to see previously developed proposals with advanced and recent models will facilitate formulation of other alternatives and optimal water resources allocation for various demands. On other hand such allocation techniques used to minimize the water crises and the conflict among users by predicting future scenarios. The out put of such study contributes as the guide line in the sub-basin to well water management.

The model selected for the study is water evaluation and planning system (WEAP) that evaluates a full range of water development management options and takes account of multiple and competing uses of water system.

1.3 Objectives of the study.

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- ✓ Το εϖαλυατε τηε αϖαιλαβιλιτψ οφ ωατερ ρεσουρχεσ συππλιεδ φρομ Κ οκα
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σ ιν τηε συβ βασιν.

- ✓ Το αλλοχατε τηε δελιϖερεδ ωατερ συππλψ φορ διφφερεντ εξιστινγ δεμ ανδ σεχτορσ ανδ πλαννεδ προφεχτσ.

1.4 .Materials and methods

The materials used in this study include master plan documents performed so far by HALLCROW, other study documents prepared by local and foreign professionals, Oromia irrigation development Authority design documents for small scale irrigation projects and the basin description Arc View GIS maps layer obtained from Ministry of Water Resources.WEAP model has been utilized to perform an allocation and the Model user Guide is used as a guide line to operate the model.

The methodology adopted in the study follows literature review, data collection, organization and analysis of data based as per to the requirement of WEAP model. The overall approach of the study will be discussed on data analysis and results discussion parts.

WEAP simulation is carried out on monthly time step for the available data. The scenarios of future performance are projected up to the year 2038 for 30 years. Before running the model, it needs a relevant data to fulfill the purpose of the study. In this case some of the required data (Ground water data, Water quality data, Economic data and etc) are not included in this study due to unavailability of adequate data.

1.5. Descriptions of the whole basin

1.5.1. General

The Awash river basin with a total area of 110,000 km^2 drains the northern part of the rift valley in Ethiopia. It has no outlet to the oceans, the terminal point being Lake Abe on the border with Djibouti. The basin is almost entirely within the boundaries of Ethiopia, the portion within Djibouti being negligible. The river rises at an elevation of about 3 000 m in the central highlands, West of Addis

Ababa and flows north-east wards along the Rift Valley. The main river length is about 1 200 km.

The basin is bordered on its western side by the Abbay river (Blue Nile) basin, to the south west by the Omo-gibe and rift valley lakes river basins and to the south east by the Wabi-Shebele river basin. The basin lies between longitude 7°52′12″N and 12°08′24″N and latitude 37°56′24″E and 43°17′2″E.

The basin is the most extensively developed and heavily exploited in Ethiopia. In 1989 irrigation development amounted to a total of 69 000 ha, a substantial proportion of the total in the country. Currently the only water storage is Koka reservoir which has been studied in detail by Booker Tate in 2003.

The basin is also the most intensively studied in the country. The most comprehensive study of the basin is the Master Plan for the Development of Surface Water Resources in the Awash Basin, carried out by Halcrow (1989).

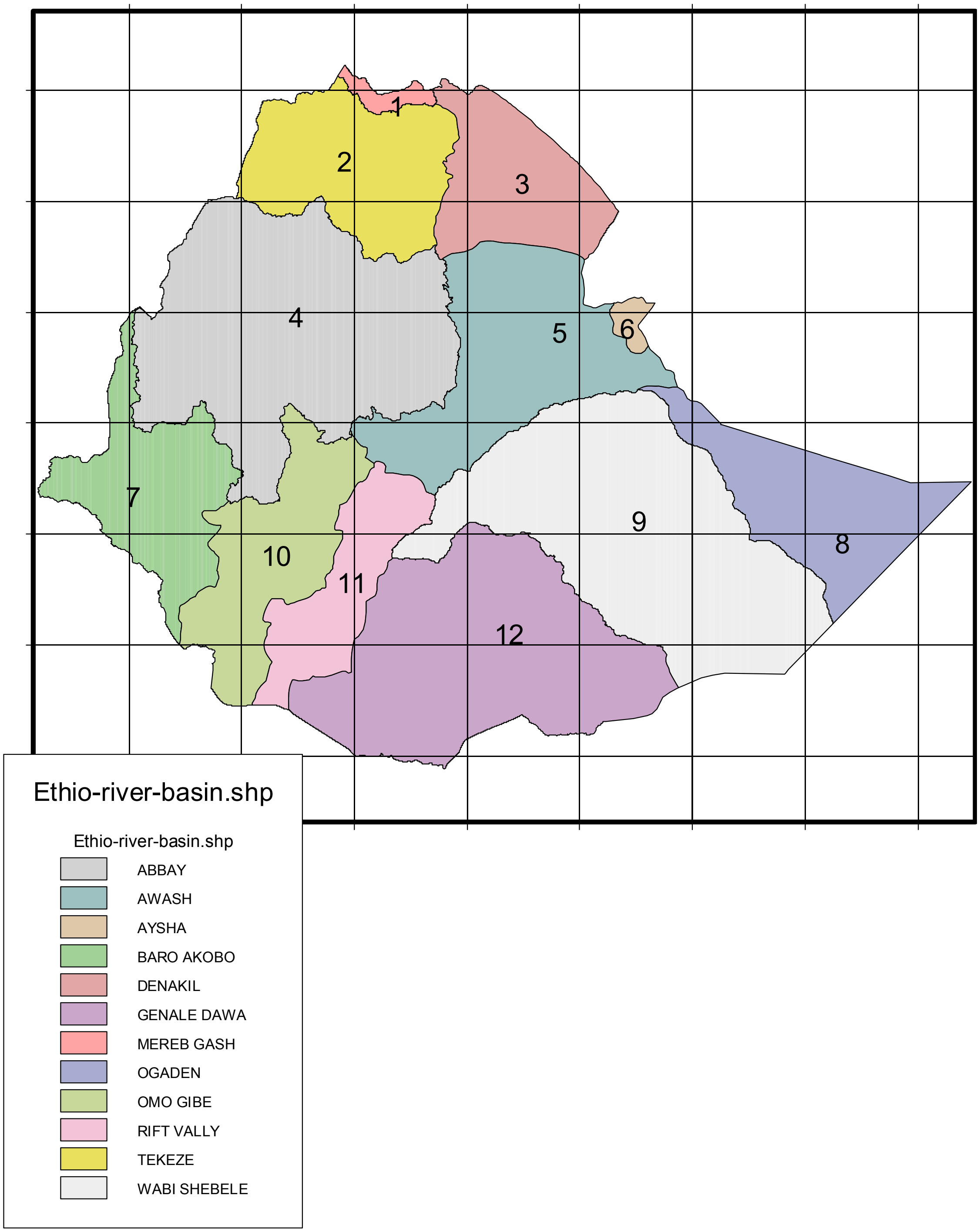


Figure 1.1: Location Map of Awash River basin with respect to other basins
(Source: Arch view GIS Shape files of basins from MOWR)

The water flows from the source first in the Becho Plains and is joined by a number of tributaries before entering the Koka Reservoir. Water released from Koka descends into the Rift Valley and gradually turns northwards, flowing at a much reduced gradient along the base of the western highlands. The Awash is fed by several major tributaries from these highlands. The flow of the Awash gradually increases reaching maximum at the start of the Gedebassa Swamp. On exiting the Swamp/Lake Yardi, the river channel is greatly reduced but the discharge is increased by contributions from large western highland catchments. After receiving contributions from the Mile and Logia Rivers, the Awash turns abruptly eastwards and terminates in a series of lakes. The total length of the Awash River is approximately 1 250km.

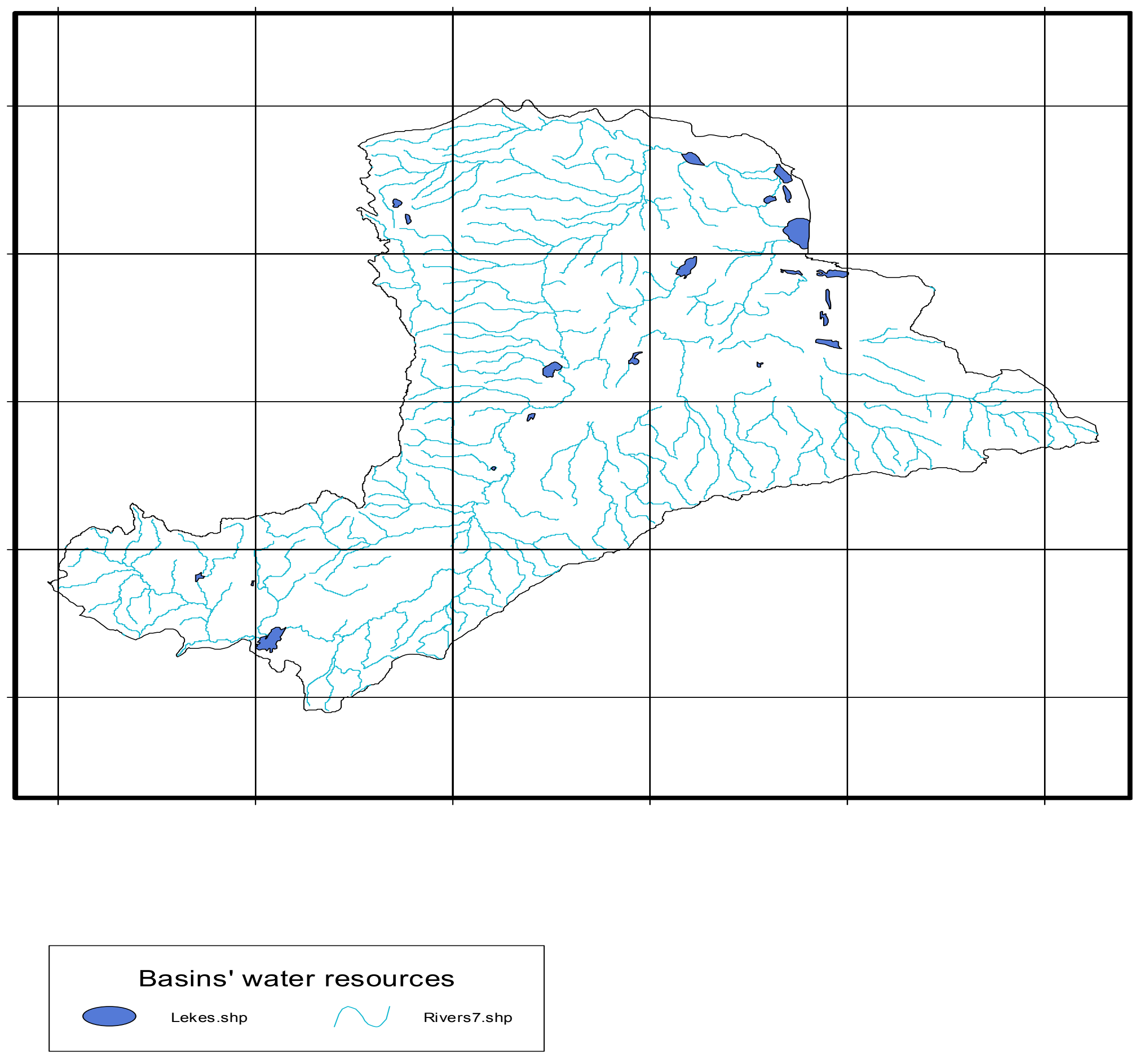


Figure 1.2 View of Awash River Basin
(Source: Arch view GIS Shape files of basins from MOWR)

1.5.2. Physiographic units of the basin

The Awash River Basin has been divided into 7 physiographic units. They are briefly described in terms of their physiographic and hydrological characteristics as follows :(Awash River basin surface water master Plan, HALLCROW 1989)

- ✓ **The Upland basin**.

  The head water of the Awash River is formed in the Upland Basin, which has eroded head ward into the Ethiopian Plateau west of Addis Ababa. This area features steep headwater streams that receive in excess of 800mm per annum of rainfall and drain into the structural basin of the Becho Plains. In much of the highland area at the western extreme of the basin, rainfall is in excess of 1200mm and rises to as high as 1750mm in a few places. From the outlet of the Becho Plains flows drain towards the Koka Dam which marks the limit of the Uplands basin.

- ✓ **The Upper Awash Valley**

  The area of the basin is in Koka reservoir and Awash station which lies
  es

- ✓ **Middle** Awash valley

  The area of the basin is in between Awash station and the Mille river. The altitude varies from 1000 m to 500 m a.s.l and the annual rain fall variation is from about 600 mm to 200 mm.They can be divided as Melka warer (Awash to Hertale), Gawane (Hertale to Gedabassa outlet) and Mile (from Gedabassa outlet to Mile confluence).In the area cotton, and sugar cane would be very appropriate with potentially higher productions.

- ✓ **Lower Awash Valleys**.

  These are the deltaic alluvial plains in Tendaho, Asayita and Dit Bahir areas as well as the terminal lake environs. The are lies between 500m and 250 m altitude with the mean annual rain fall of less than 200mm.The are can be subdivided in to the Delta and the Terminal lakes. The area is known by its high temperature, consistently over 40 ^{0}c for several months, severely limit cropping potential.

- ✓ The **Western Highlands**

  They comprise the left bank tributaries from Kesem River to Logiya River. All of these tributaries rise in high rainfall areas along the watershed with the Abbay River Basin, although the proportion of their catchments lying in the high rainfall zones generally decreases in the downstream direction. As a result the Mile and Logya rivers, the most downstream of the western highland tributaries are much more ephemeral in nature than for example the Kesem River, despite their very large catchments areas.

- ✓ The **Lower Plains**

  This are comprises downstream of Logiya, where the Awash River meanders and terminates at Lake Abe. Almost no runoff is generated in this area where rainfall is low.

- ✓ The **Eastern catchments**

  This area accounts for about 40% of the total area of the Awash Basin. Areas of relatively high precipitation (there are some small areas which receive between 800mm and 1000mm per annum) are very far away from the Awash mainstream and generated runoffs disappear in the lowland plains without contributing to the Awash river flows.

1.5.3 Climate

General

The climate of the Awash Basin is influenced by the Inter-Tropical Convergence Zone (ICTZ), a zone of low pressure that marks the convergence of dry tropical easterlies and moist equatorial westerliness. As this zone migrates northwards across the basin is causes the small or spring rains in March and at its northernmost position (attained in June/July) it results in the heavy summer rains. Its subsequent movement southwards during August, September and October restores drier weather which prevails until the following spring.

Temperature

Not surprisingly given the difference in altitudes, the temperature varies considerably within the basin. The mean annual temperature in Addis Ababa is 16.7°C compared to nearly 30°C at Dupti. There is a strong relationship between temperature and altitude as summarized in Table 1.1 which shows means temperatures in the growing season related to altitude.

Table 1.1: Temperature and Altitude in the Awash River Basin

Mean Temperature (°C)	Altitude (m)	Mean Temperature (°C)	Altitude (m)
> 27.5	< 450	15 - 17	2 250 – 2 550
25 – 27.5	450 – 900	12 - 15	2 550 - 3 100
22.5 - 25	900 – 1 400	10 - 12	3 100 – 3 400
20 – 22.5	1 400 – 1 750	7.5 - 10	3 400 – 3 850
17 - 20	1 750 – 2 250	< 7.5	> 3 850

Source: Land Use Planning and Regulatory Dept; Ministry of Agriculture (1984), updated by MoWR

Relative Humidity

Relative humidity is or has been measured at 32 stations in or adjacent to the basin. There is relatively little variation over the basin with the mean annual relative humidity varying from 60.2% in Addis Ababa to 53.6% at Dubti down to a lowest of 49.7% in Dire-Dawa. Seasonal variation, as would be expected is higher in the lower rainfall areas.

Evaporation

Mean annual evaporation as estimated from measurements made from evaporation pans at a number of meteorological stations around the basin, has been shown to relate strongly to elevation. This relationship was used for calculating evaporation rates at key locations in the basin, especially as required for input to the model.

Evapo-transpiration

Evapo-transpiration was analyzed in some depth as part of the Awash Master plan study which looked at observed data from a number of sources. Potential evapotranspiration (PET) values calculated from Penman by using other meteorological parameters.

Rainfall

The rainfall regime in the Awash River Basin shows four different rainfall regimes:

- Seven rainy months between March and September, with peaks in April and August.
- Seven rainy months between March and September, generally increasing with a high in August when the rainfall coefficient reaches 3.0)
- Seven rainy months from February to April and June to September. For the intervening months the rainfall coefficient falls below 0.6 making the regime bimodal.
- Six rainy months being March and April and the June to September. In the first part the peak month has a rainfall coefficient inferior to 1.0, while in the second part it is in excess of 3.0.

It is important to understand the concept of “rainy” in this context. A “rainy” month is defined as one in with a rainfall coefficient exceeding 0.6. The rainfall coefficient is defined as the mean monthly rainfall total divided by 1/12 of the mean annual precipitation.

1.6. Description of the Particular study area

1.6.1 Sub-basins' features

The sub basin is located between the confluence of Koka dam and Awah station; with in the great African rift valley .The water availability of the whole basin depends on this sub basin due to Koak reservoir. The releases from Koka are used to generate power at the Koka hydropower station (Awash I). Wonji/Shoa sugar estate lies approximately 12 km downstream of the dam; one main pump station is used to lift water from the River Awash to supply the main irrigation area of 5 664 ha. The significant available water demand for urban supplies are Nazereth and Metehara towns with relatively low abstractions. The Nazereth water supply is abstracted by a pipeline from a point between Koka dam and Wonji/Shoa. A few kilometers downstream of the estate there is a second much smaller reservoir at Melkassa, after which power is generated at two further hydropower stations, Awash II and III. These are located just below the point where the drainage from the irrigation areas is returned to the river. The drainage water is used for several small-scale irrigation schemes to grow other crops, with the result that the return to the river from the combined irrigation systems are negligible. After passing through the Awash II and III Station, the water is then used for many other irrigation systems further downstream. The water for these systems is supplemented by flow in the downstream tributaries, although as noted above, Koka dam is currently the only point of regulation.

At 1989 irrigation level Halcrow estimated that the total irrigated area in this particular sub basin is 23,284 ha, where as at 2003/2004 the irrigation level shows small rise to 23,284ha.But the activity level may raise by 100% by the coming two/three years as per the implementing programs. Even though Halcrow in 1989 proposed that the new extended potential irrigable land of the sub basin was 10 600 ha, there are more than 30 000 ha irrigable land have been under implementation for near future use.

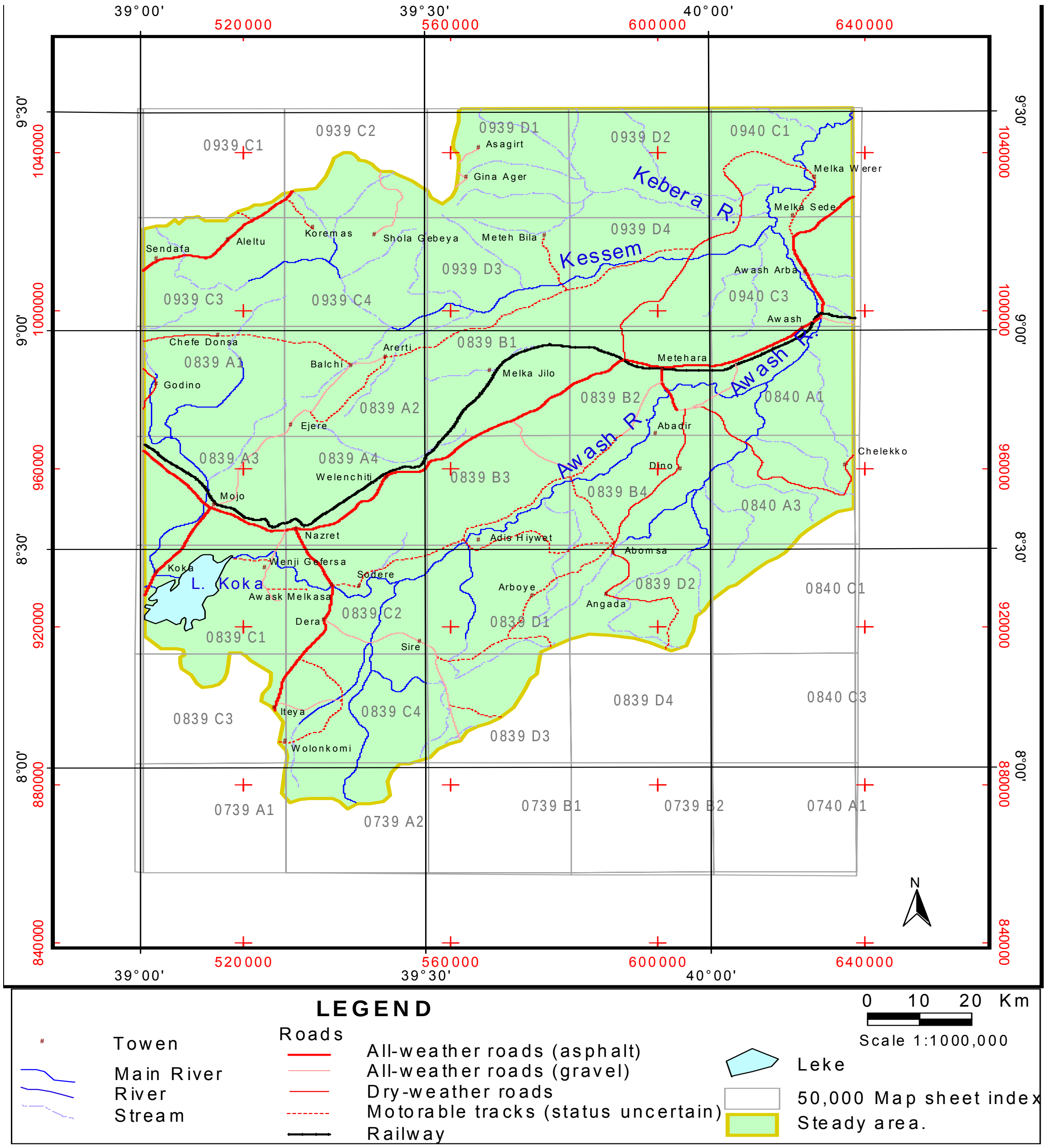


Figure: 1.3. Location Map of Upper Awash
(Source: Booker Tate study ,2003)

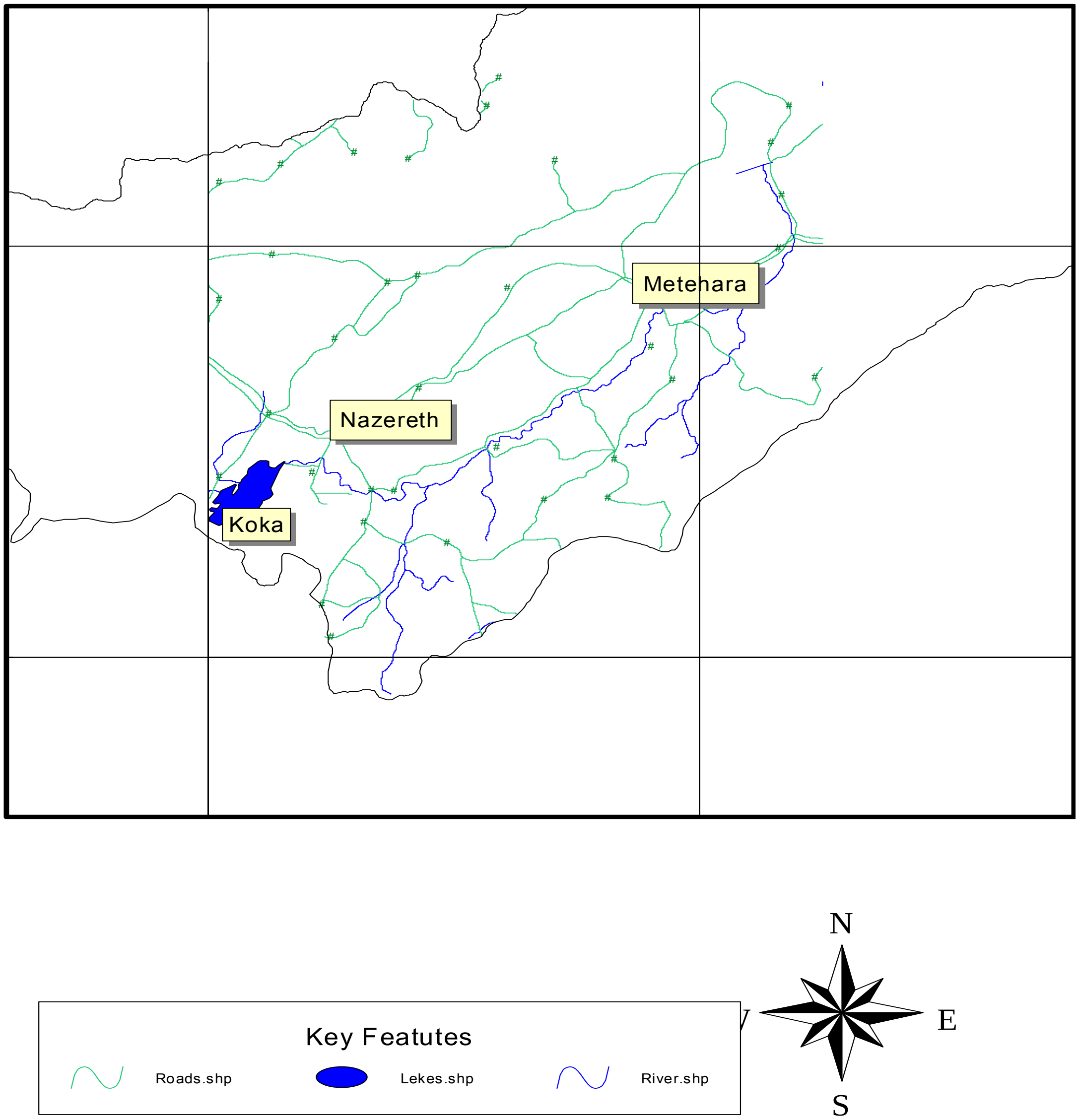


Figure 1.4 The Upper Awash Valley areas

1.6.2. Socio-economic conditions.

Before the development of irrigation in the Upper, Middle and Lower valleys population of the basin was essentially divided geographically, economically and culturally in to two main groups. These are the sedentary cultivators in high lands (Amhara and Oromo) and the transhumant pastoralists in low lands (Afar and Issas). The approximate divide between these two distinct groups lies at an elevation of 1500 m above sea level, which elevation is normally taken as the boundary of rain fed agriculture.(Halcrow 1989).

The study area is governed by sedentary cultivators in which the lively hood of the people in the area is based on income generated from agricultural activities, which includes crop production and livestock grazing. In most cases sedentary farming with limited mobility of inhabitants in search of grazing and water depends on favorable climatic conditions.

The main cereals produced in the sub-basin are wheat, teff, sorghum, maize, barley and etc next to sugar cane, fruits and vegetables. The main constraints in the crop production are lack of adequate quantity and distribution of rain fall, poor economic conditions to own oxen to plough their land, loss of extension seed inputs and low awareness to practice productive agriculture. About 10% of the agricultural practice is animal rearing. This has a great importance in their daily life conditions, in that oxen used in cultivation system, like plowing, horses and camels used for transportation and the remaining utilized as food sources.

The sugar cane extension developmental program in Wonji and Metehara areas will contribute towards alleviating poverty. The development venture will enable poor farmers to generate additional income by pooling the resources in the irrigation development endeavors. The irrigation development will also create employment opportunities for the participating farmers. The new development program, however, should be viewed with proper care that farmers should fully participate in the planning, design, and implementation phases to attain meaningful change in the well-being of the community.

On other hand an implementation of the number of small scale irrigation schemes by OIDA will contributes a substantial support in attaining of food security in the area. The lower part of sub basin is commonly known by its recurrent drought with high temperature. The ongoing integrated large scale irrigation project of Fentale can alleviate the crop production problems of the area.

Chapter 2
Background of Irrigation Developments

2.1. Irrigation Development in Ethiopia

Ethiopia having a total area 1,129,000km^2 is endowed with precious natural resources: water and irrigation land. Its geographical location and favorable climatic conditions provides the country with relatively high amount of rain fall in East Africa. The country is sub-divided in to 12 river basins draining water in to different directions and point of destinations. Preliminary studies and professionals estimate revealed that the country has an annual surface runoff close to 122 billion cubic meters of water excluding the ground water potential. Most of the major rivers are trans-boundary types transporting multitude of water and sediment to neighboring countries, HALCROW (1989).

Until recent time, the water potential of the country was not accurately known, and even today this is still a contentious area. There have been different estimates of the irrigation potential of the country, and the issue has not been satisfactorily resolved. One of the earliest estimation was made by the World Bank (1973), which suggests a figure between 1.0 and 1.5 million hectares. According to Ministry of agriculture (1986) the total irrigable land in the country measures 2.3 million hectares. The international Fund for Agricultural Development (IFAD 1987), on the other hand gives a figure of 2.8 million hectares, where as the office of the national committee for central planning's 1990 figure , which is based on WRDA's estimation ,is 2.7 million hectares. The Indian engineering firm water and power consulting services' estimates 3.5 million hectares is the highest estimate so far studied and EVDSA accepted the figure and was using in the early 1990s.(Dessalegn Rahmato;Water resources development in Ethiopia 1999).

According to the Metaferia consulting Engineers in association with Eco-consult 2002; it is difficult to access the exact potential irrigable area and actually irrigated land in Ethiopia. Some schemes have been damaged and are currently not operational, some other schemes built and managed by the producers' co-operatives but not used by the farmers, who mostly do not want to join these co-operatives, are deteriorating. The irrigation potential of Ethiopia is estimated to be between 1.8 and 3.7 million ha. The potential for medium and large scale irrigation projects was identified as 3.3 million ha. Separate studies have indicated a potential for small scale irrigation of between 165 and 400 thousand ha. A recent study gives irrigation potential on river basin basis with a total of 3.7 million ha.

BCEOM phase 2,section 2, volume 5 (1998) states in 1990 in Ethiopia as a whole a total of 161,000ha irrigated agriculture were developed, of which 64,000ha in small scale schemes and 97,000 ha in medium and large schemes. Approximately 38,000ha were under implementation.

According to HALCROW (1989) the gross irrigation potential of the country is shown in the table 2.1 below.

Table 2.1: Gross irrigation potential of the main basins of the country

No	Basin name	Gross irrigable Area (ha)	Utilization ha
1	Blue Nile	760,000	30,000
2	Baro-Akobo	600,000	-
3	Wabishebele	355,000	-
4	Genale-Dawa	300,000	8,850
5	Omo-Gibe	248,000	-
6	Northern rivers	200,000	-
7	Awash River	206,000	69,900
8	Rift valley lakes	47,600	-
	Total	2,716,600	

Source: HALCROW Awash master plan volume 2 (1989) (-) no data

At present about 4.6 percent of the potentially irrigable land is developed. Most of the development has been in Awash valley which is the most accessible and suitable basin for irrigation development.

Table 2.2 Irrigation potential and developed size of river basins

River basin	Potential irrigable land ha	Area under irrigation ha	Percent utilized
Awash	204,400	69,900	34.2
Wabishebele	204,000	20,290	9.9
Genale-Dawa	435,300	80	0.02
Rift valley lakes	122,300	12,270	10.0
Omo-Ghibe	450,120	27,310	6.1
Baro-Akobo	748,500	310	0.05
Abbay (Blue Nile)	977,915	21,010	2.1
Tekeze	312,700	1,800	0.6
Mereb-Gash	37,560	8,000	21..3
Afar (Denakil)	3,000	-	0.0
Total	3,495,795	161,010	4.6

Source: Based on Tesfaye Gizew and Kemal Zekarias (1989)

But according to FAO, Irrigation in Africa in figures, AQUASTAT survey 2005 the total area under irrigation currently in Ethiopia is increased to 289,530 ha.

Table: 2.3. Salient features of irrigation development of Ethiopia.

Features	Figures
Potential for irrigation	2,700,000 ha
Total area under irrigation	289,530 ha
Percent of cultivated area by irrigation	2.5%
Annual increase rate of irrigation	6.2%
Cropping intensity	142 %
Main irrigated crops	Vegetables
Area of vegetables	107,126 ha
Percent of total irrigated crops	26

Source: Irrigation in Africa in figures, FAO water report 29 (2005)

Αχχορδινγ το τηε χυρρεντ πλανσ οφ ΜοΩΡ , τηε γοϖερνμεντ οφ Ετηιοπια ηασ χο
μμιττεδ ιτσελφ το δεϖελοπ 430,000 ηεχταρεσ οφ λανδ ιν τηε χομινγ φιϖε ψεαρσ.
Ωιτη ιτσ οων φινανχιαλ ρεσουρχε τηε γοϖερνμεντ βυιλτ Κεσεμ δαμ, ωηιχη χαν χ
ονσερϖε 550 μιλλιον χυ.μ. ωατερ. Τηε Κεσεμ προφεχτ ιν τηε Αφαρ Ρεγιοναλ Στατ
ε ισ βελιεϖεδ το
δεϖελοπ 20,000 ηεχταρεσ οφ λανδ. Τηε γοϖερνμεντ ηασ αλσο χονστρυχτεδ α δα
μ οφ Τενδαηο ιν τηε Αφαρ ρεγιον. Τηε δαμ χαν ηολδ 1.8 βιλλιον χυ.μ. οφ ωατερ α
νδ ιτ
χαν ιρριγατε 60,000 ηεχταρεσ φορ τηε Τενδαηο Συγαρ φαχτορψ ωηιχη ισ υνδ
ερ
χονστρυχτιον.Τηισ προφεχτ αλσο ινχλυδεσ τηε ιρριγατιον οφ 23,000 ηεχταρεσ ο
φ λανδ φορ τηε λοχαλ χομμυνιτιεσ (ΜοΩΡ 2007).

Τηερε ισ αλσο αν ιρριγατιον προφεχτ ωηιχη ισ υνδερ χονστρυχτιον ιν τηε Αμ
ηαρα
Ρεγιοναλ Στατε ον Κογα Ριϖερ. Τηε προφεχτ ωιλλ δεϖελοπ 7,200 ηεχταρεσ οφ λα
νδ.
Τηε φεδεραλ γοϖερνμεντ ισ αλσο χονστρυχτινγ α δαμ ιν τηε Σομαλι Ρεγιοναλ Στ
ατε νεαρ Γοδε τοων. Τηισ προφεχτ ωιλλ δεϖελοπ 2,220 ηεχταρεσ οφ λανδ. 12 ιρ
ριγατιον προφεχτσ αρε ιν τηε πιπελινε ανδ 233,912 ηεχταρεσ οφ λανδ χαν βε δεϖ
ελοπεδ υνδερ τηεσε προφεχτσ.

2.2. Ιρριγατιον πολιχψ ανδ Δεϖελοπμεντ οβφεχτιϖεσ ιν Ετηιοπια

2.2.1. Ιρριγατιον Πολιχψ οφ Ετηιοπια

Τηε ιρριγατιον πολιχιεσ οφ οφ Ετηιοπια χαν βε συμμαρισεδ ασ φολλοωσ.

- Ενσυρινγ ιρριγατιον δεϖελοπμεντ βψ εξχυτιον ωιτη τηε φραμεωορκ οφ τηε σοχιο–εχονομιχ δεϖελοπμεντ πλανσ οφ τηε χουντρψ.
- Remarking a reasonable percentage of the GDP for development of irrigated agriculture.
- Effective irrigation development with in the framework of water resources development.
- Promoting irrigation development through socio-economic goal-achieving strategies and participatory approaches.
- Enhancing participation of Regional and Federal Governments in the development of large scale irrigation schemes.
- Ensuring the sustainability of suitable water quality for irrigation.
- Establishing water allocation and priority setting criteria.
- Providing drainage facilities for irrigation schemes.
- Promoting decentralization and use based management of irrigation systems.
- Developing prioritized lists of schemes based on food requirements, needs of the national economy, raw materials and other needs.
- Supporting and enhancing traditional irrigation schemes.

2.2.2. Objectives for irrigation developments.

The broad goals and specific objectives of the policies formulated by the government of Ethiopia are summarized as below.

- Developing and enhancing small-scale irrigated agriculture and grazing land for food self-sufficiency at the house hold level.
- Development and enhancement of small-, medium-, and large-scale irrigated agriculture for food security and food self-sufficiency at national level, including export earning and to satisfy the need of local agro-industrial demands.
- Promotion of irrigation study, planning and implementation of irrigated farms; studies to be conducted to design stage level for implementation by the private sectors and/ or the government.
- Promotion of water use efficiency, control of wastage, protection of irrigation structures and drainage systems.

2.3. An overview of Awash river basin and its development.

2.3.1. General

Awash River basin, with a total area of 115,543.7 km^2 has approximately 4527.1 Mm^3/annum water resources. It is one of the most developed and highly utilized river basins with respect to other basins of the country. Irrigation development is by far the main consumer of water than other demands in the basin. Hydroelectric power is also generated from Koka Dam.

The basin is divided in to about 75 small sub-catchments which contribute a significant amount of flow to the river.

2.3.2. Overview of water resources availability

According to MOWR, 2005 scenario the total run off generated from Awash river is 4527.1Mm^3/annum. A large amount of this is lost to seepage, evaporation and evapo-transpiration from open water surfaces and wetlands. It is interesting to look in a bit more detail at where the runoff is generated and where it is lost.

The tributaries upstream of Koka Dam as well as those flowing directly into the Koka Lake contribute a total of 1650.9 Mm^3/annum. The biggest single contributor of runoff is the Akaki River. Seepage and evaporation losses from the Koka Reservoir account for over 400 Mm^3/annum of this and the MAR reduces to 1248.3 Mm^3/annum immediately downstream of the Dam.

Between Koka Dam and the Amibara Irrigation scheme off take (a few kilometres upstream of the confluence with the Kesem River) 593.9 Mm^3/annum of runoff are added to the flow in the Awash River, almost all coming from the Arba I, Keleta and Arba II Rivers on the right bank.

Between the Amibara off take and the Lake Yardi outflow, an additional 1122.2 Mm^3/annum enters the river from the western highlands, the largest contributions coming from the Kesem and Najeso Rivers. All of this is effectively lost to evaporation and evapo-transpiration from the Gedebassa Swamp/Lake Yardi system.

Downstream of Lake Yardi some major tributaries add 1076.7 Mm^3/annum before the Awash River reaches the Tendaho Dam site. Downstream of the Tendaho Dam site the only additional runoff is provided by the Logiya River, adding 84.2 Mm^3/annum.
Approximately 1264.4 Mm^3/annum are lost to seepage, evaporation and evapo-transpiration.

There are six existing and under construction reservoirs in the basin for urban water supply, hydropower and irrigation developments. The storage reservoirs that have been modeled in the simulation model are listed in the table below.

Table: 2.5 Significant modeled storage Reservoirs of Awash river basin

Dam / Reservoir	River	Location (UTM)		Storage Capacity (Mm^3)*	Use	Status
		East	North			
Dire	Dire	493 107	1 011 061	25.0	Urban water supply	Operational
Legedadi	Legedadi	495 816	1 001 861	43.8	Urban water supply	Operational
Gefersa	Gefersa	460 664	1 001 861	6.23	Urban water supply	Operational
Koka	Awash	517 166	935 966	1 071	Regulation/hydropower	Operational
Kesem	Kesem	597 239	1 011 545	500	Irrigation/regulation	Under construction
Tendaho	Awash	713 297	1 292 777	1 860	Irrigation	Under construction

* Note: Storage capacity at Maximum operating level (Full supply level)
Source: MOWR (2005) hydrology department

2.3.3 **Water demands of the basin**

Irrigation Demand

As already stated, irrigation demand is by far the largest of all the demands from the Awash River and these demands are set to increase in both the short and medium term. During the investigations for this study a number of sources were consulted in order to get as complete a list as possible of all the irrigation demands. These investigations were complicated by the fact that there is no one centralized source of information on existing or proposed irrigation schemes. In total there are about 96 irrigation schemes or off takes were identified in the whole basin. Most of these are small scale irrigation schemes that are implemented to attain the food security of rural peasants particularly in Awash valleys. It should be noted that where possible the larger schemes were broken down into components to allow for the maximum flexibility in modeling.

Urban and Industrial demands

There are currently four urban and industrial consumers taking water from Awash River: namely Addis Ababa, Nazereth, Awash town and Metehara. Addis Ababa is supplied from three reservoirs (Dire, Legadadi and Gefersa) in the Awash Basin plus a number of other sources. The Nazereth scheme is relatively new and forecasted growth in demand has been incorporated into the model. The Metehara scheme is also new and while demand levels are so small compared with irrigation demand.

Power Generation

Power is generated at the Koka Dam (Awash I) and at the Awash Melkassa schemes (Awash II and III) downstream. The latter two are effectively run off river schemes since the headwater ponds are heavily silted. There are plans for a further scheme (Awash IV) immediately downstream of Awash III. Although this has not been the case in the past power generation is now to be considered to be secondary to irrigation in the Awash River and this fact has been taken into consideration in the model. It is anticipated that new schemes in other basins will gradually take over the majority of the electricity demand currently supplied by the Awash River.

2.4. Over all view of Upper Awash Valley

2.4.1 General

Upper Awash Valley is one of the hydrological zones in the basin with high demand level irrigation and Hydropower due to its suitable natural resources (land, water and accessible conditions).The section of catchment is lying between Koka reservoir and Awash station. The elevation of the riverine area ranges from 1500m and 1000 m. The mean annual rainfall generally lies between 600mm and 800 mm.The areas was traditionally livestock grazing area with limited rain fed cultivation before some years ago. But now days the peasants are aware of the benefit of irrigated crop production by using Awash river in traditional irrigation and by governmental support of small irrigation schemes implementation. The total area of the sub-catchments is 7,100 km^2 with a potential irrigable land of 37,300 ha (according Halcrow 1989) and more than 24,000 ha land is irrigated still now from the only water source of Awash river. But current feasibility studies shows that the potential irrigable land more than the above figure.

The regional location of the study area lies with in administration region of Oromia. Part of East Shewa zone and some districts of Arsi zone are found in this sub basin. The Booker Tate (2003) study considers the Uplands of Awash and Upper Awash valley as Upper Awash basin unlike with Halcrow.

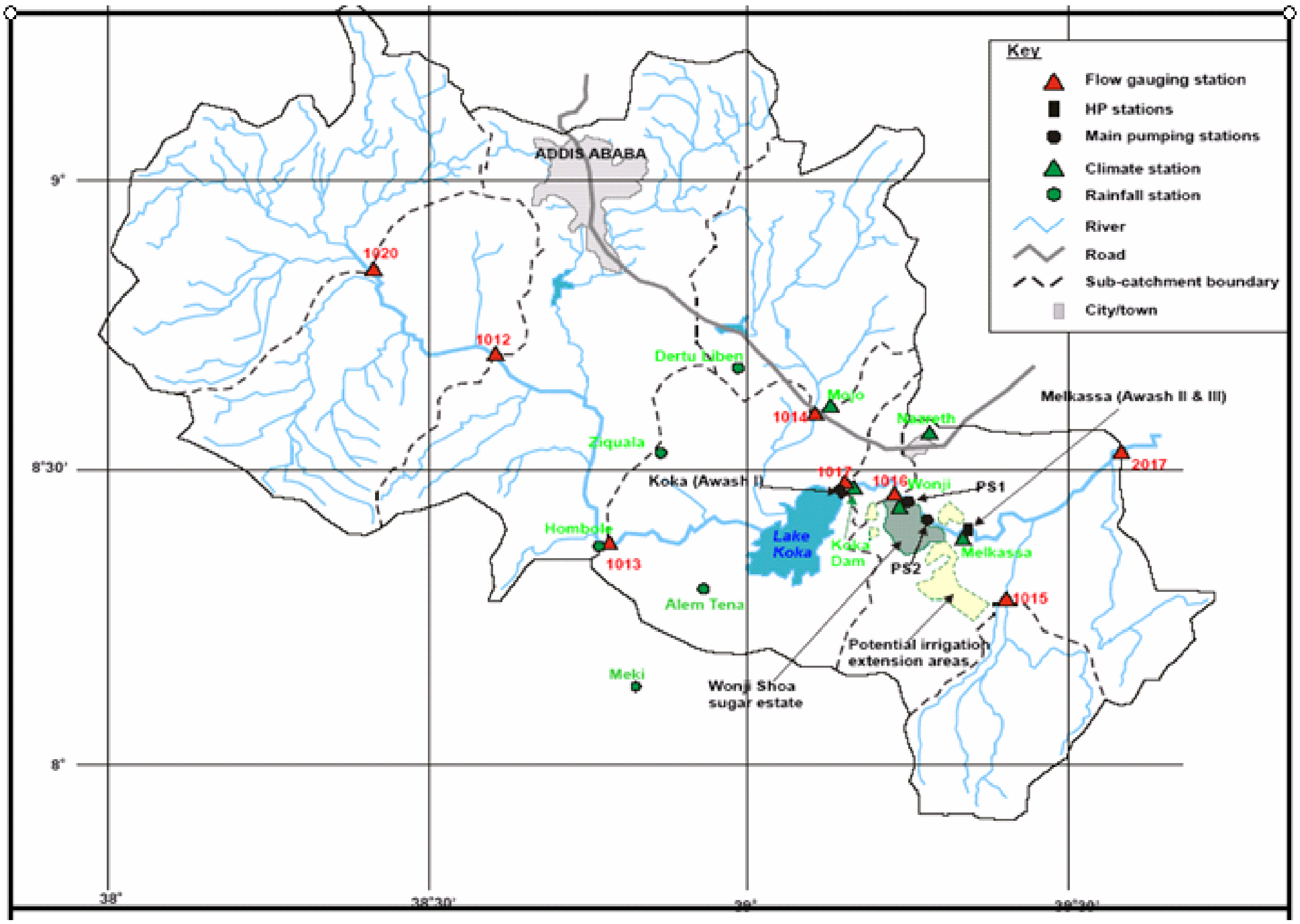


Figure 2.1.Some features of the uplands and Upper awash Valley

2.4.2. Water availability.

The availability of water between Koka Dam and the confluence with Kesem River depends to a large extent on the amount of water available and the management of Koka reservoir. Even though basically the Dam was constructed for hydropower regulation, all the downstream water consuming demands are getting water from the regulated reservoir. At the initial period of construction the reservoir capacity of the Dam was 1650 Mm^3. According the bathymetric survey conducted in 1998 the capacity of Koka reservoir has been reduced from 1660 Mm^3 in 1959 to 1186Mm^3.

Sedimentation is one of the critical issues in Koka reservoir that reduces the reservoir capacity at certain rate per annum. The subsequent surveys indicated that the following rates of sedimentation in Koka reservoir.

Table: 2.6 sedimentation rates of Koka reservoir

Year	Year interval	Average annual rate of Sedimentation(Mm^3)
1969-1973	4	33.9
1973-1981	9	23.3
1981-1989	7	25

Source: HALCROW: Awash Master plan document

Koka Dam was constructed to regulate water for hydropower production. Its height is 42m and the area of water body covers about 255 km^2. It has the mean depth of 9m, a maximum length of 20 km and a maximum width of 15 km.The height of dam sight above sea level is 1590m.

The operation of reservoirs is decided according to pre-defined operating rules for each reservoir. Such operating rules are an approximation of reality and divide the reservoirs into water level–related zones. The water lying above the full supply level is taken to be in the Flood Control Zone and cannot be stored. In the next zone, the Conservation Zone, water is used as required to meet demand. In the next zone down, the Buffer Zone, some restrictions are applied so that the water is not used too quickly. Below the "dead storage level" in the Inactive Zone it is not possible to use the water other than to satisfy evaporation and seepage losses from the reservoir.

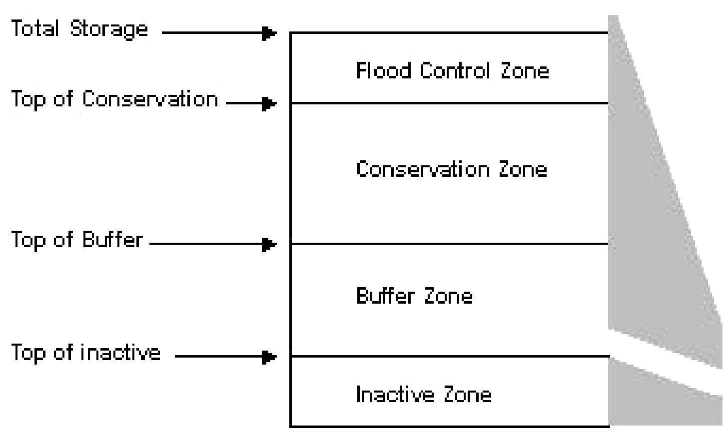


Figure 2.2: Zoning of reservoir Storage

CHAPTER 3
Literature Review

3.1. Some of the models used in water Allocation

3.1.1. HEC Model

The Hydrologic modeling system is designed to simulate the precipitation-run off processes of water shed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology and small urban or natural water shed runoff. It is also used in water allocation studies in the basins with high water demands.

Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, for forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, flood plain regulation and system operation.

3.1.2. WEAP model

The Water Evaluation and Planning System (WEAP) aims to incorporate these values into a practical tool for water resources planning. WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation--water use patterns, equipment efficiencies, re-use, prices and allocation--on an equal footing with the supply side--stream flow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies.

WEAP is comprehensive, straightforward and easy-to-use, and attempts to assist rather than substitute for the skilled planner. As a database, WEAP provides a system for maintaining water demand and supply information. As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. As a policy analysis tool, WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

3.2. Some of the pre-studies of the sub basin.

1. Halcrow 1989: Awash basin master plan

Most of the current comprehensive studies on the Awash River basin depend on modeling results of Halcrow (1989).They consider following broad levels of irrigation development scenarios.

i. Sustaining the then irrigated areas of 68 800 ha (Upper valley 23 300 ha, Middle valley 19900 ha and lower valley 25600ha.)
ii. Expanding irrigation up to 40 years by setting the following scenarios:
   - Scenario I: Koka raised by three meters and Kesem constructed.
   - Scenario II: Koka raised by three meters and Tendaho and Kesem constructed.
iii. Long term expansion beyond the level determined by the economic viability, to determine the potential limit of expansion in irrigation.

According to Halcrow 1989 the major source of irrigation water for various demands in basin is the release from Koka reservoir. The live storage required at Koka to sustain 68800 ha is 850 MMC power generations being priority (or 660 MMC irrigation is being priority) will be reached in 2008 assuming annual sedimentation rate of 25 Mm^3/year.

2. Ministry of water resources (2005)

According to the 2005 investigation of MoWR the annual irrigation area is increased to 50000 ha which is 23% lower than the 1989 development. Major reduction in irrigation area has been observed in the last 16 years (1990-2005) in the lower and middle valley particularly in the cotton fields. From this preliminary analysis one can infer that expansion of the existing land by about 16000 ha for cotton or about 8000 ha for sugar cane will bring back to the 1989 development level. Based on Halcrow prediction the development of 68800 ha could be sustained up to the year 1998 with out additional storage.

In both cases the raising of Koka dam by 3m which adds about 615 MMC of live storage is considered. The construction of Kesem and Tendaho dams are included in this scenario. They indicated that a maximum development expansion in the lower valley with Tendaho dam constructed is 36 900 ha, adding with the 1989 existing irrigation reach 62500 ha.

Table 3.1: Existing and potential net irrigation areas (ha) as proposed by Halcrow (1989) with respect to MoWR (2005):

	Exiting 1989 (Halcrow)	Existing 2005 MoWR	Expansion proposed Halcrow 1989	Expansion proposed MoWR 2005	Total Halcrow 1989	Total MoWR 2005
Upper valley	23284	23504	10625	17903	33910	41407
Middle Valley	21896	14591	36320	20000	58216	34591
Lower Valley	25600	11600	36900	48000	62500	59600
Total	70780	49695	83846	85903	154626	135598

Source: Feasibility study of Wonji/Showa expansion WWDSA 2005

The above table shows that the 2005 MoWR expansion proposed is more extensive in the upper and lower valleys as compared to the Halcrow proposal. The total expansion of the 2005 proposal 85903 ha is approaching the potential Halcrow expansion of 83846 ha.

The Halcrow expansion pre-supposes the raising of the Koka dam along with construction of Tendaho and Kessem dams, where as the MoWR expansion is based on the construction of the Tendaho and Kessem dams both in 2008.The other major difference between their proposal is that Halcrow used the initial live storage of the Tendaho dam as 720 MMC, where as presently the initial live storage is 1673 MMC.

Irrigation group	Existing schemes	1989 Irrigation Halcrow ha	Irrigation 2003/2004	Halcrow 1989 proposed	Irrigable area (ha)	WoMR 2005 Proposed expansion	Irrigable area (ha)
UV1	-MelkaHidi -Wonji-shoa -Wonji out growers	89 5,925 987	1510 5928 765	Wonji-Shoa extension	3914	Bofa Dodota Welenchiti	3462 2241 9000
UV2	-Melka woba -Degaga -Tibila -Golgota -Merti Jeju -Nura Era	200 279 757 567 1,944 3,576	5083	-Nur Era Rehabilitation -Nura Era Extension	6556 4772		
UV3	Metehara/Abadir	8,960	10,218	-Abadir extension -Metehara Extension -Arba	630 310 1000	-Metehara	3200
	UV total	23,284	23,504		10626		17,903
MV1	-Awra Melka -Yalo	1,285 630	1,285 630	Kesem	8900	Kesem	20000
MV2	-Melka sadi	4,212	2223	Angele Bollhamo	11000		

	Amibara/Melka werere IAR Melka werer Amibara/RRC Agele pump sch Angele irrigated Far Balhamo/SF Heledebe RRC	3,815 1390 300 1973 3296 424 2000 17410	2117 3242 1008 8590	Dijilu	1700		
MV3	Gewane/Maro Entahodeta RRC Gelila Dura RRC	2171 130 270		Maro Gala Maro Gala extension	8000 6720		
	MV Total	21,896	14,591		36320		20000
LV1	Mile (SF) Mile RRC Logia RRC	940 500 160 1600	1600				
LV2	Dudti (SF) Dudti (RRC)	5600 1845		Lower valley rehabilitation	15939	Tendaho Dam	48000

	Dit Bahri SF Tanga Kuma SF Dit Bahri RRC	3506 4038 950 15939	6000	Lower valley expansion	18450		
LV3	Awssa Assaita Sembeleta Garni SF Sembeleta sahele Berga (RRC) Bokaytu (RRC) Kerebula (RRC) Karadura RRC Algana (RRC) Wonse (RRC) LV Total	2651 765 1736 560 580 514 370 465 25600	4000 11600	Lower valley rehabilitation Lower valley expansion	8061 18450 36900		48000
	Basin Total	70780	49,695		83846		85903

Table 3.2: Halcrow (1989) and MoWR (2005) irrigation expansion program

Source: WWDSE; Feasibility study of Welenchiti Bofa report (2006)

3. Awash River modeling by WWDSA

The model is based on the 41 years of flow series (1963-2003) by using HEC-5 software and defining four scenarios.

- **Scenario I.** The 2005 withdrawal rate in the basin.
- **Scenario II**: The 2005 withdrawal rate plus Tendaho project 48000/60000 ha are operational.
- **Scenario III**: scenario II plus Wonji expansion by 5703 ha and Metehara expansion by 3200 ha and Kesem dam added with 20,000 ha.
- **Scenario IV**: Scenario III plus Welenchiti additional 9000 ha sugar cane expansion.

Irrigation schemes are amalgamated in to four principal groups for the simulation model .These are : Upper valley UV, Middle valley MV, lower valley upstream of Tendaho dam and lower valley downstream Tendaho dam. The schematic below in figure 2.3 shows that the HEC model structure of the sub basin.

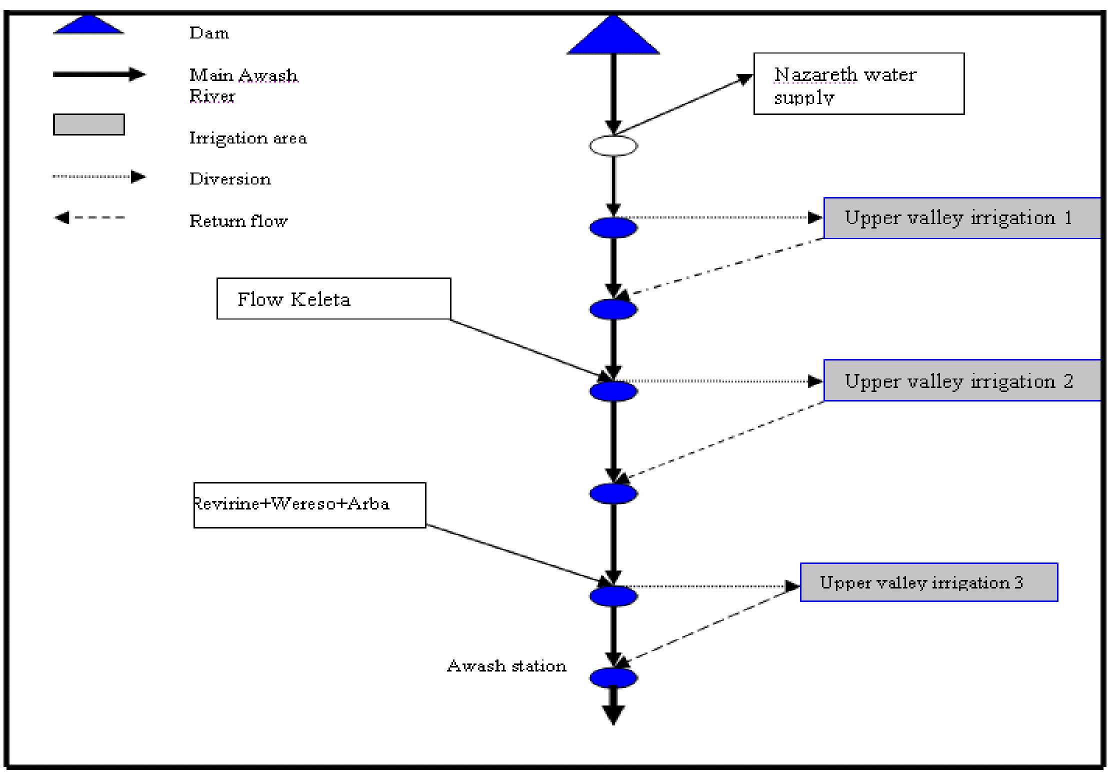


Fig 3.1 Schematic of HEC-5 Model network For Upper Awash Valley (By WWDSE 2006)

4. Booker Tate and MCE Studies

Booker Tate & MCE (2003) Study on their Wonji/Shoa sugar factory expansion studies, have Reviewed and Updated the Feasibility study on Irrigation and Agricultural land Extension covered the following topics.

(i). River inflow in to Koka Reservoir

They estimated monthly inflow in to Koka dam (Mm^3) for the period 1963-2002 using the Halcrow (1989) regression model which is based on the measured flow of Awash river at Hombole (Mm^3) and river at Mojo (Mm^3). The equation is

$$Q_{Koka} = 1.065Q_{Hombole} + 1.180Q_{Mojo}$$

(ii) Evaporation estimate from Koka reservoir

They used the Penman method for estimating evaporation from the reservoir. Wonji, Nazereth and Koka stations are used for estimating average monthly temperature, humidity, sunshine hours and wind for use in their model. The Nazereth wind speed data are found to be on high side they used the Ziway data which they indicated is more reliable than Nazereth wind speed data.

Table 3.3: Booker Tate & MCE (2003) Estimate of Koka Reservoir Evaporation (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wonji area	167.6	165.8	197.3	185.8	196.3	187.1	168.8	166.5	162.2	177.0	166.7	162.5	2104
Nazereth	177.6	168.9	193.8	191.5	213.8	203.5	169.3	172.2	170.0	183.7	177.1	177.3	2199
Koka Dam	160.7	156.4	186	180.3	191.0	181.3	160.6	162.9	162.3	174	162.4	156.6	2035
Koka reservoir	168.6	163.7	192.4	185.9	200.4	190.6	166.2	167.2	164.8	178.2	168.7	165.5	2112

Source; Booker Tate Final report (2003)

(iii).Power generation

Some of the basic information about the power plants that are located in study area are summarized in Table 2.9.There are three main Hydropower plants to generate the total power capacity of 107.2 MW. These data refer to the systems as originally constructed, that is, not accounting for changes over time. They are namely Kaka (Awash I) that is generated from Koka reservoir; where as Awash II and Awash III are run off river hydropower plants.

Table3.4: Basic reservoir and Power plant data

	Koka(Awash I)	Awash II	Awash III
Year Commissioned	1960	1966	1968
Reservoir storage capacity (Mm^3) Total Live	 1850 1680	 2.6 2.24	 0.07 0
Surface area (km^2) for operating Level Maximum Minimum	 1590.7 1580.7	 1535.5 1534.5	 1471.8 1470.8
Regulated flow (m^3/s)	42.3	39.9	39.9
Net head (m)	29.5-39.5	59.4-60.4	60.5-61.5
Number of turbines	3	2	2
Production capability (GWH) Installed Firm	 110 80	 182 135	 185 135
Power capacity Installed Firm	 43.2 34.5	 32 32	 32 32

Source: Booker Tate Final report (2003)

(iv).Koka reservoir capacity and sedimentation

There are four separate sources of information were found on the capacity and sedimentation of Koka reservoir. These are as follows;

a).**Original design data supplied by the EEPC**.

The original design data of Koka reservoir states that the total storage capacity at the maximum operating level of 1 590.7 m is 1 850 Mm^3 and the live capacity is 1 680 Mm^3 (giving a dead storage of 170 Mm^3).

b) .**Tate & Lyle (1984)**.

The Tate and Lyle (1984) study states that the sediment inflow to Koka reservoir is 27 Mm3 per year, but no source or justification is given for this figure. A graph in the Tate & Lyle report shows that the reservoir capacity declining from approximately 1 660 Mm3 in 1969 to 1 330 Mm3 in the 1981 survey, with predicted declines to about 1 070 Mm3 in 1992 and 820 Mm3 in 2002. These values assume the above sedimentation rate of 27 Mm3/yr (approximately) to make the predictions. The capacity of the reservoir at construction is stated as 2 000 Mm3, but it is not clear to what level this relates.

c) **Awash Basin Master Plan – Halcrow (1989)**

The Halcrow stated that the negligible sedimentation to Koka reservoir from 1960 to 1969.It is not explained in the original source, and the survey errors may make this observation unreliable. Since this is the case it is unclear why the average annual rates have been calculated only from 1969. They conclude that the data cannot be accepted as reliable, and another survey was proposed to remedy the situation. However, the results from the new survey were not available at the time of the report, and a preliminary value of 25 Mm3/y was proposed.

d) **Partial report provided by the EEPC**.

This gives the results of a new survey carried out in 1999. This is the only source that gives the surface area against water elevation as well as the storage capacities against elevation. There results are tabulated in table 2.11 and figure 2.3 below. These rate is reasonable than the other studies and taken as input for this study.

Table 3:5 Estimates ok Koka reservoir capacity and sedimentation rates as per to EEPR (1999)

Year of survey	Reservoir capacity (Mm^3)	Change in capacity (Mm^3)	Cumulative change in capacity (Mm^3)	average annual rates of change since 1960 (Mm^3/year)
1960	1850	-	-	-
1969	1662	188	188	20.9
1973	1526	136	324	24.9
1981	1333	193	517	24.6
1988	1192	141	658	23.5
1999	1188	4	662	17

Note: Capacities are determined at maximum operating level of 1 590.7

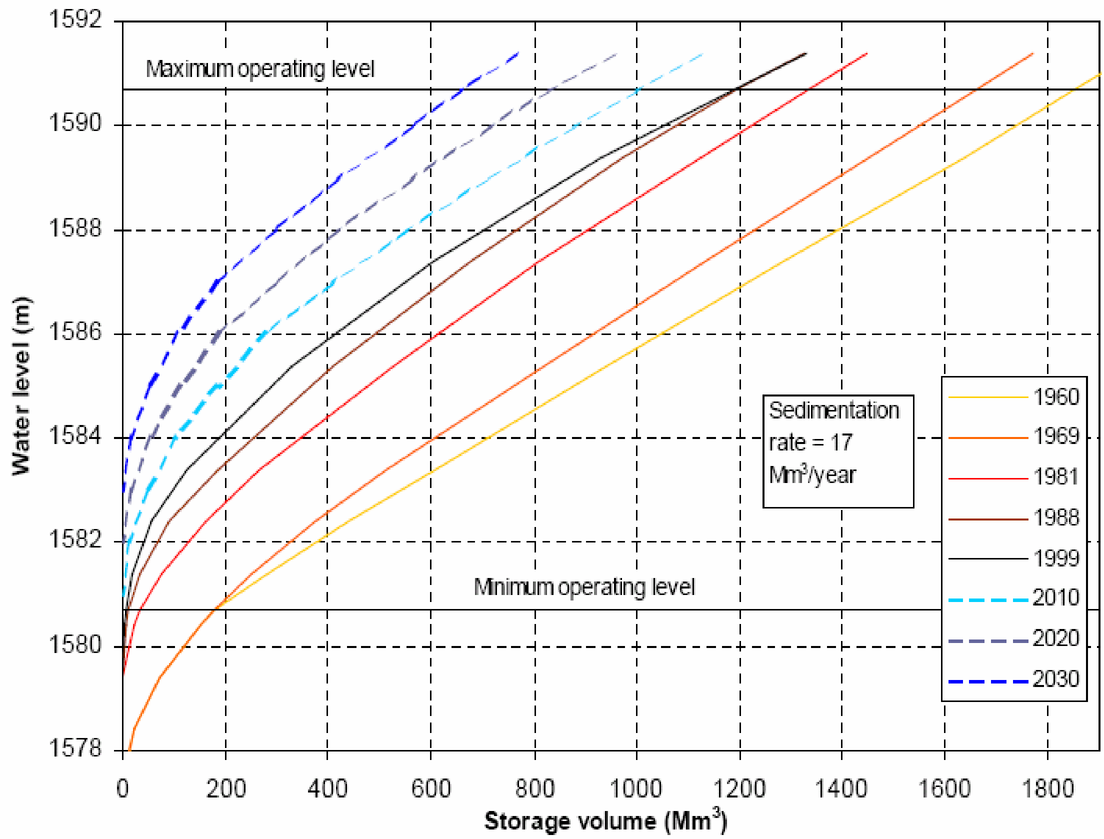


Figure: 3.2; Koka reservoir capacity –elevation curve (EEPC 1999)

Chapter 4

Data sources and Availability

4.1. General

ΩΕΑΠ μοδελ χονταινσ α διστινχτ σετ οφ ινφορματιον, δατα ανδ ασσυμπτιο νσ αβουτ αλλ τηε σψστεμσ ωηιχη λινκσ δεμανδσ ωιτη συππλιεσ. Σεϖεραλ διφφερεντ στυδψ αρεασ ασ δεφινεδ ιν ΩΕΑΠ χουλδ αχτυαλλψ βε υσεδ το ρεπρεσεντ τηε σαμε γεογραπηιχ αρεα ορ ωατερ σηεδ, εαχη υνδερ αλτερνατιϖε χονφιγυρατιονσ ορ διφ φερεντ σετσ οφ δεμανδ δατα ορ οπερατινγ ασσυμπτιονσ.Ιν τηισ ωαψ,στυδψ αρεα σ χαν βε τηουγητ οφ ασ ρεπρεσεντινγ σεπαρατε δαταβασεσ ωηερε διφφερεντ σετ σ οφ ωατερ συππλψ ανδ δεμανδ δατα αρε στορεδ, μαναγεδ ανδ αναλψζεδ.

Ωατερ αλλοχατιον μοδελσ νεεδσ ϖαριουσ δατα οφ ωατερ ρεσουρχεσ ανδ δεμανδσ φ ορ τηε χυρρεντ σψστεμ ανδ φυτυρε δεϖελοπμεντσ. Τηε ωατερ σψστεμσ τηατ αρε χυρρεντλψ ε ξιστ ωιλλ βε χαλιβρατεδ φρομ εξιστινγ ηιστοριχαλ δατα. Βασεδ ον χυρρεντ αχχουντσ σχεναρι οσ αρε βυιλτ το εξπρεσσ τηε φυτυρε χονδιτιονσ.

Ιν τηισ στυδψ τηε μοδελ υσεσ α μοντηλψ τιμε στεπ φορ βοτη ινπυτσ (ινφλοωσ) ανδ ουτπυτ (ουτφλοωσ). Ινφλοω το τηε σψστεμ χορρεσπονδσ το τηε ρυνοφφ φρομ Αωαση ριϖερ φρομ τηε ρελεασε οφ Κοκα ρεσερϖοιρ ανδ ηιστοριχαλ φλοω ρεχορδσ ε ξιστσ ατ διφφερεντ γαυγινγ στατιονσ ιν τηε συβ βασιν. Τηερε αρε νο σιγνιφιχαντ ρυν οφφ χοντριβυτιονσ φρομ τριβυταριεσ εξπεχτ τηε Κελετα ανδ Αρβα ινφλοωσ.

Τηε μαιν ουτ φλοω φρομ τηε σψστεμ ισ τηε ωατερ δεμανδ φορ ιρριγατιον υσερσ . Τηε αμουντ οφ ιρριγατιον ωατερ τηατ ισ αβστραχτεδ ιν εαχη αχτιϖιτψ λεϖελ οφ τηε σψστεμ ιν μοντηλψ βασισ ισ τηε φιναλ δατα το ρυν τηε μοδελ. Τηε χλιμα τιχ δατα φρομ τηε χορρεσπονδινγ μετεορολογιχαλ στατιονσ το ρεφερενχε εϖαπο− τρανσπιρατιον χαλχυλατιον αρε οργανιζεδ. Τηε ιρριγατιον ωατερ ρεθυιρεμεντ φορ εαχη αχτιϖιτψ λεϖελ δεπενδσ ον τηε ρεφερενχε εϖαπο−τρανσπιρατιον τηατ ισ χαλχυλα τεδ φρομ εαχη μετεορολογιχαλ σιτε, τηε χροππινγ παττερν, τηε χροπ χοεφφιχιεντ ανδ τηε αμουντ οφ ηεχταρεσ οφ λανδ αχτυαλλψ ιρριγαβλε.

Σινχε τηερε ισ νο ηιγη χονσυμπτιον οφ ωατερ φορ υρβαν ωατερ συππλψ ιν τηε συβ β ασιν, τηισ παρτ ισ λεσσ χονσιδερεδ ιν τηε στυδψ.Τηε ονλψ Υρβαν δεμανδσ ωιτη σι γνιφιχατ ωατερ χονσυμπτιονσ αρε τηε Ναζερετη ανδ Μετεηαρα ωατερ συππλιεσ, ωηιχη α ρε ινχλυδεδ ιν τηε στυδψ. Τηε μοντηλψ ωατερ δεμανδ δατα αρε εντερεδ ιν τηε μοδελ. Other data in each demand sites includes the efficiency for the system, return flows and losses are considered in this study.

4.2. Sources of Data

Ιτ ισ ασσυμεδ τηατ ωιτη ρεσπεχτ το οτηερ βασινσ,Αωαση ριϖερ βασιν ηασ βεττερ δατα αϖαιλαβιλιτψ. Α νυμβερ οφ σμαλλ ανδ λαργε στυδιεσ ηαϖε βεεν υνδε ρτακεν φορ τηε σακε οφ ωατερ υτιλιζατιον φορ ϖαριουσ ιρριγατιον δεμανδ σ. Τηε δατα φορ τηισ στυδψ ισ βασεδ ον εξιστινγ στυδψ δοχυμεντατιονσ οφ τηε βασιν ανδ σμαλλ ρεπορτσ φορ σομε δεσιγνεδ σχηεμεσ.

Τηε βαχκ γρουνδ οφ τηισ στυδψ ισ βασεδ ον τηε μαστερ πλανσ οφ Αωαση συ ρφαχε ωατερ (Ηαλχροω 1989) ωηιχη ηαδ βεεν οβταινεδ φρομ ΜοΩΡ.Σινχε τηε δατα ον τηε Μαστερ πλαν αρε πρεπαρεδ βεφορε 17 ψεαρσ,ιτ χουλδ νοτ ηελπ φυ λλψ φορ τηισ στυδψ.Μορε−οϖερ τηε μοδελ νεεδσ τηε υπδατεδ δατα το δεϖελοπ φυτυρε σχενα ριοσ σο τηατ χυρρεντ δατα φορ τηε βασιν ισ εσσεντιαλ.Τηε ρεθυιρεδ δατα φορ τηε εξιστινγ ιρριγατιον δεμανδσ ατ 1989 λεϖελ αρε οβταινεδ φρομ Ηαλχροω.

Τηε στρεαμ φλοω δατα φορ τηε σψστεμ ισ οβταινεδ φρομ ΜοΩΡ, φρομ τηε δεπαρτμεντ οφ Ηψδρολογψ;τηε ρεχεντ στυδψ ηελδ ον ωατερ ρεσουρχεσ αϖαιλ αβιλιτψ ον τηε Αωαση ριϖερ βασιν.Τηε χομπιλεδ στρεαμ φλοω δατα φρομ 1962 το 2004φορ μοστ γαυγεδ στατιονσ αρε χομπιλεδ ιν μοντηλψ βασισ. Τηε δατα οφ Κοκα ρεσερϖοιρ ρελεασε, χαπαχιτψ ανδ σεδιμεντατιον ρατε αρε ωελλ στυδιεδ βψ Βοοκερ Τατε ιν 2003.Τηεψ αλσο στυδιεδ τηε εξπανσιον οφ Ωονφι αρεα φο ρ φαρτηερ ιρριγατιον δεϖελοπμεντσ ιν Ωονφι αρεα.
Τηε Ωελενχηιτι ανδ Βοφα ιρριγατιον σχηεμεσ βασεδ ον Βοοκερ ανδ Τατε στυδ ιεσ αρε ον γοινγ βψ ΩΩΔΣΕ. Αλλ τηε νεχεσσαρψ δατα ον τηε υππερ παρτσ ο φ τηε

στυδψ αρεα αρε οβταινεδ φρομ ΩΩΔΣΕ.

Α νυμβερ οφ σμαλλ σχαλε ιρριγατιον δοχυμεντσ τηατ αρε δεσιγνεδ, ιμπλεμεντ εδ ανδ υνδερ χονστρυχτιον βψ ΟΙΔΑ ηαϖε βεεν οβταινεδ φρομ ΟΙΔΑ χεντραλ βρανχη Τηε χυμυλατιϖε αμουντ οφ ωατερ τηατ ηασ βεεν εξτραχτεδ φορ αλλ α μαλγαματεδ
αχτιϖιτψ λεϖελσ ισ οργανιζεδ φρομ τηεσε δοχυμεντσ. Τηερε αρε αλσο τηε προ ποσεδ σμαλλ σχαλε ιρριγατιον σχηεμεσ φορ φυτυρε σχεναριο βψ ΟΙΔΑ. Τη ε φεασιβιλιτψ στυδιεσ οφ τηεσε δοχυμεντσ αρε υσεδ το ασσεσσ τηε ωατερ δ εμανδ φορ εαχη δεμανδ νοδε ιν χροπ ωατερ ρεθυιρεμεντ χαλχυλατιονσ. Ο νε οφ τηε λαργεστ προποσεδ ιρριγατιον σχηεμε ισ τηε Φενεταλε ιντεγρατεδ ι ρριγατιον δεϖελοπμεντ
ωηιχη ηαϖε βεεν δεσιγνεδ βψ ΟΩΩΔΣΕ, ανδ οωνεδ βψ Μετεηαρα συγαρ χανε φαχτορψ ανδ ΟΙΔΑ. Ιτ ισ ονε οφ τηε λαργεστ φυτυρε σχεναριο το δεϖε λοπ
αβουτ 18 000 ηα οφ ωηιχη παρτ οφ τηε δεϖελοπμεντ ωιλλ σερϖε το Μετεη αρα
συγαρ χανε φαχτορψ ανδ τηε ρεμαινινγ μαφορ προπορτιον ωιλλ χονχερν τη ε
πεασαντσ οφ Φενταλε διστριχτ .Τηε νεχεσσαρψ δατα φορ τηισ προφεχτ ισ οβ ταινεδ
φρομ ΟΙΔΑ μαιν βρανχη.

4.3. The available data for the study

4.3.1. Crop Water Requirement

Χροπ ωατερ ρεθυιρεμεντ (ΧΩΡ) ισ δεφινεδ ασ τηε δεπτη οφ ωατερ νεεδεδ το μεετ τηε ωατερ λοσσ τηρουγη εϖαπορατιον οφ δισεασε φρεε χροπ γροωινγ ιν λαργε φιελδσ υνδερ νον−ρεστριχτινγ σοιλ χονδιτιονσ ινχλυδινγ σοιλ ωατερ ανδ φε ρτιλιτψ ανδ
αχηιεϖινγ φυλλ ροδυχτιον υνδερ τηε γιϖεν γροωινγ ενϖιρονμεντ (ΦΑΟ,1977).Τ ηε στιματιον οφ χροπωατερ ρεθυιρεμεντ υνδερλιεσ εφφεχτιϖε πλαννινγ φορ χ ροπ προδυχτιον ατ φαρμ λεϖελ.Ωατερ ρεθυιρεμεντ (ΩΡ) ισ τηε συμ οφ ωατερ απλιεδ φρομ σοιλ προφιλεσ(Σ), ραιν φαλλ ανδ ιρριγατιον ρεθυιρεμεντσ.

ΩΡ= Ρ+ ΝΙΡ +Σ

Τηε ιρριγατιον ρεθυιρεμεντ ισ τηερεφορε τηε διφφερενχε βετωεεν τοταλ χροπ ωα τερ
ρεθυιρεμεντ ανδ εφφεχτιϖε ραινφαλλ ανδ ωατερ φρομ σοιλ προφιλε.

ΝΙΡ=ΩΡ−(Ρ+Σ)

Εστιματιον οφ χροπ ωατερ ρεθυιρεμεντ ισ τηε βασιχ πρερεθυισιτε το γετ τηε μο ντηλψ
αβστραχτεδ ωατερ ιν εαχη δεμανδ σιτε.Τηε εστιματιον ισ δονε βψ υσινγ αναλ ψτιχ μετηοδσ βασεδ ον αϖαιλαβλε χλιματολογιχαλλψ δατα .Τηε μοστ ωιδελψ υ σεδ μετηοδ το χομπυτε χροπ ωατερ ρεθυιρεμεντ ισ Πενμαν−Μοντειτη.Ιτ υσεδ τη ε χλιματολογιχαλλψ φαχτορσ συχη ασ ραινφαλλ, τεμπερατυρε, ρελατιϖε ηυμιδ ιτψ,ωινδ ϖελοχιτψ ανδ συνσηινε ηουρ ωηιχη εσσεντιαλλψ οϖερ τηε ρατε οφ ε ϖαπο− τρανσπιρατιον.

$$ET_o=\Omega * P_\nu + (1-\omega) * \phi(\upsilon) * (E_\alpha \,\square\, E_\delta)$$

Ωηερε: ΕΤο =Ρεφερενχε χροπ εϖαπο−τρανσπιρατιον ιν μμ/δαψ
Ω =Τεμπερατυρε ρελατεδ ωειγηινγ φαχτορ
$P_{\nu=}$ Νετ ραδιατιον ιν εθυιϖαλεντ εϖαπορατιον ιν μμ/δαψ
φ (υ)=Ωινδ−ρελατεδ φυνχτιον
$E_\alpha \,\square\, E_\delta$=διφφερενχε βετωεεν τηε σατυρατιον ϖαπορ πρεσσυρε ατ με αν αιρ τεμπερατυρε ανδ τηε μεαν αχτυαλ ϖαπορ πρεσσυρ ε οφ
τηε αιρ, βοτη ιν μβαρ.

Χαλχυλατιον προχεδυρεσ

Τηε χαλχυλατιον οφ ρεφερενχε εϖαπο−τρανσπιρατιον (ΕΤο) ισ βασεδ ον ΦΑΟ Π ενμαν−Μοντειτη μετηοδ (ΦΑΟ1998). Ινπυτ δατα ινχλυδεσ μοντηλψ βασεδ τεμ περατυρε (μαξιμυμ ανδ μινιμυμ), ηυμιδιτψ, συνσηινε ανδ ωινδ σπεεδ. Χροπ ωατε ρ ρεθυιρεμεντ (ΕΤχροπ)οϖερ τηε γροωινγ σεασον αρε δετερμινεδ φρομ ΕΤο ανδ ε στιματεσ οφ χροπ εϖαπορατιον ρατεσ, εξπρεσσεδ ασ χροπ χοεφφιχιεντσ (Κχ) βα σεδ ον ωελλ
εσταβλισηεδ προχεδυρεσ (ΦΑΟ,1977).

$$E_{\tau\chi}= K_\chi * ET_o$$

ΧΡΟΠΩΑΤ ισ α χομπυτερ προγραμ φορ ιρριγατιον πλαννινγ ανδ μαναγεμεν τ δεϖελοπεδ βψ τηε Λανδ ανδ Ωατερ Δεϖελοπμεντ Διϖισιον οφ (ΦΑΟ,1998). Ιτ σ
βασιχ φυνχτιον ινχλυδε τηε χαλχυλατιον οφ ρεφερενχε εϖαποτρανσπιρατιο ν , Χροπ ωατερ ρεθυιρεμεντ χαλχυλατιον,ανδ πλαννινγ χροπσ ανδ σχηεμε ιρριγ ατιον. Τηε εστιματιον οφ χροπ ωατερ ρεθυιρεμεντ νεεδσ τηε αναλψσισ οφ χλι ματιχ δατα ανδ
αγρονομιχ πραχτιχεσ οφ τηε προφεχτ αρεα. (Τηε εστιματεδ ποτεντιαλ εϖαποτρ ανσπι ρατιον δατα φορ ιμπορταντ σιτεσ οφ τηε στυδψ αρε σηοων ον Αννεξ Β)

Irrigation demand estimation procedures

Αλλ τηε σατεδ ιρριγατιον σχηεμεσ ηαϖε διστινχτ παραμετερσ συχη ασ χροπ τψπεσ, χλιματιχ χονδιτιονσ, χροππινγ παττερνσ ανδ τηε αρεα οφ ιρριγατιον.Σο τηε φολλοωινγ παραμετερσ σηουλδ βε φολλοωεδ το εστιματε τηε τοταλ ιρριγατιον ωατερ δεμαν δ ιν εαχη σπεχιφιχ προφεχτ σιτε.

4.3.2 Present Irrigation demands

Ιν τηισ στυδψ τηε εξιστινγ ιρριγατιον δεμανδσ οφ τηε υππερ αωαση ϖαλλε ψ αρε στατεδ ασ; υππερ ϖαλλεψ ιρριγατιον γρουπσ 1(Υς1), Υππερ ϖαλλεψ ιρριγατι ονσ 2 (Υς2), Υππερ ϖαλλεψ ιρριγατιονσ 3 (Υς3) ,τηε χυμυλατιϖε τοταλ εξιστινγ Ο Ι∆Α σμαλλ σχαλε ιρριγατιον (ΟΙ∆Α 1) ανδ τηε χυμυλατεδ συμ τηε εξιστινγ μιδδ λε ανδ λοωερ Αωαση ϖαλλεψ φαρμσ (∆ΣΙ).

Ταβλε 4.1: Ιρριγατιον δεμανδ σιτεσ ωιτη τηειρ χομμανδ αρεα φορ ΩΕΑΠ εϖαλυα τιον

No	Site name	Node name	Operating status	Command area (ha)
1	Wonji and out growers	UV1	Existing	7054
2	Nura Hera complexes	UV2	Existing	8753
3	Metehara/Abadir	UV3	Existing	12896
4	Wonji area expansion	WAE	Future	17338
5	OIDA small scale irrigations	OIDA1	Existing	1607
6	OIDA small scale irrigation	OIDA2	Future	609
7	Fentale integrated irrigation	Fent	Future	18130
8	Metehara expansion	METexp	Future	3200
9	Down stream irrigations	DSI	Existing	26191
Total				**95155**

Τηε αβοϖε ταβλε ινδιχατεσ τηε τοταλ χυρρεντ ανδ φυτυρε ιρριγατιον αρεασ τηα τ διρεχτλψ
δεπενδ ον Κοκα ρεσερϖοιρ ρελεασε. Τηερε αρε σο μανψ μινι υναχχουντεδ ωατε ρ
υσερσ ανδ τραδιτιοναλ φαρμ λεϖελσ τηατ αρε αβστραχτινγ ωατερ φρομ Αωαση Ριϖερ.
Τηε δοωνστρεαμ ιρριγατιον φαρμσ φορ τηειρ χυρρεντ δεϖελοπμεντ ηαϖε α λσο
υτιλιζεδ τηε ωατερ τηατ ισ ρελεασεδ φρομ Κοκα ρεσερϖοιρ. Τηε χυμυλατιϖε μεαν μοντηλψ ωατερ αβστραχτιον φορ μιδδλε ανδ λοωερ ϖαλλεψσ ωιλλ βε μεργ εδ ασ ονε δεμανδ νοδε ιν τηισ στυδψ. Τηε φυτυρε ιμπλεμεντατιονσ φορ δοωνστρε αμ ωατερ υσερσ αρε νοτ χονσιδερεδ ιν τηισ αναλψσισ.

1. Upper Awash irrigations 1(UV1)

Τηε υππερ Αωαση ϖαλλεψ ιρριγατιονσ1 (Υς1) ινχλυδεσ τηε Ωονφι στατε συγαρ χανε
φαρμ ανδ τηε ουτ γροωερσ συρρουνδινγ Ωονφι αρεα.Ωονφι στατε φαρμ ισ χονστ ρυχτεδ ιν τηε εαρλψ 1960σ.Ιτ χομπρισεσ α τοταλ οφ 5905 ηα νετ ιρριγαβλε λανδ , ιν ωηιχη
ωατερ ισ συππλιεδ βψ χοντινυουσ ελεχτριχαλ πυμπινγ φρομ τηε Αωαση ιν το σε ττλινγ βασιν ατ τηε ηεαδ οφ τηε μαιν χαναλ. Ιρριγατιον ισ δονε ον 25 ηα βλοχκ ροτατιον
δυρινγ 12 ηουρσ οφ δαψ τιμε. Νιγητ στοραγε ρεσερϖοιρσ χοϖερ α συρφαχε αρεα οφ
60 ηα. Ιρριγατιον ισ δονε βψ φυρροω ϖαρψινγ ιν λενγτη φρομ 32 μ το 64 μ δεπενδι νγον σοιλσ ωηιχη αρε ϖερψ μιξεδ ρανγινγ φρομ φινε τεξτυρεδ χλαψσ το σανδψ χλαψσ.
Αχχορδινγλψ ιρριγατιον ροτατιον ρανγεσ φρομ 15 το 35 δαψσ, δεπενδινγ ον τηε σοιλσ ον αϖεραγε ροτατιον οφ 20 το 27 δαψσ.Ωατερ αβστραχτιονσ αρε μεασυρε δ ον α δαιλψ βασισ βψ ΕΣΧ φρομ πυμπινγ ηουρσ ανδ σταφφ γαυγεσ αρε αλσο ινσ ταλλεδ ατ τηε ηεαδοφ μαιν χαναλ.
Ιρριγατιον ισ νοτ πραχτιχεδ δυρινγ τηε ωετ μοντησ οφ ϑυλψ, Αυγστ ανδ Σεπτεμβ ερ.
Περφορμανχεσ αρε ρεπορτεδ το βε σατισφαχτορψ ανδ τηε οϖεραλλ ωατερ εφφιχι ενχψ οφ
τηε στατε ισ ρεχορδεδ το τηε ρανγεσ φρομ 50% το 60%. Τηε σεχονδ γρουπσ ο φ
ιρριγατιον ωατερ υσερσ ιν Υς1 φορ τηε προδυχτιον οφ συγαρ χανε αρε τηε ουτ γρ οωερσσυρρουνδινγ Ωονφι αρεα. Τηεψ οων τηε τοταλ νετ αρεα οφ 1149 ηα.Τηε ου τ γροωερσ αρε πεασαντ ασσοχιατιονσ ρυν βψ α χηαιρμαν, χομμιττεε ανδ μεμβε ρσ.Τηε μεανμοντηλψ ωατερ αβστραχτιον τηεσε φαρμσ ισ εστιματεδ ιν χομβιν

ατιον ωιτη Ωονφι στατε φαρμ.Ταβλε 3.2, σηοωσ τηε οϖεραλλ ιρριγατιον σιτεσ ε νχλοσεδ ιν Υς1 ωιτη τηειρ χηαραχτεριστιχσ.

Table 4.2   Υς1 ιρριγατιον σιτεσ

Φαρμ	Οωνερσηιπ	Αχτιϖε ιν α ψεαρ	Φαρμ λοχατιον*		Νετ ηα	Οφφ τακε λοχατιον		Ρετυρν φλοω λοχατιον	
			Εαστινγ	*Νορτηινγ*		*Εαστινγ*	*Νορτηινγ*	*Εαστινγ*	*Νορτηινγ*
Ωονφι_Στατε	Στατε Φαρμ	2007	527395	929822	5905	525542	934726	538165	928025
ΩΟ_Κοριφτυ	Ουτ γροωερσ	2007	524438	936867	143	523465	936615	525367	937285
ΩΟ_Βοκυ	Ουτ γροωερσ	2007	527494	934261	195	529012	934015	533421	928923
ΩΟ_Αδυλλαλα	Ουτ γροωερσ	2007	530338	933361	240	529079	933975	533421	928923
ΩΟ_Ωακε Μεα	Ουτ γροωερσ	2007	532058	931510	311	531076	932381	533421	928923
ΩΟ_ΩακεΤιο	Ουτ γροωερσ	2007	532832	929717	144	531558	929995	533421	928923
Βισηολα	Ουτ γροωερσ	2007	533864	927283	70	533314	928883	538165	928025
ΩΟ_Ηαργιτι	Ουτ γροωερσ	2007	532515	926754	46	534239	928441	538165	928025
				Τοταλ	7054				

Source; Water resources and flood hydrology of Awash basin (MoWR 2005)

2. Upper Awash irrigations 2 (UV2)

Τηε Νυρα Ερα χομπλεξ (Υς2) ισ λοχατεδ ιν τηε μιδδλε παρτ οφ υππερ Αωαση ϖα λλεψ. Ιτ χομπρισεσ ϖαριουσ ΗΔΧ φαρμσ ον βοτη τηε λεφτ ανδ ριγητ βανκσ οφ Α ωαση ριϖερ.

Τηε χυρρεντ τοταλ ιρριγαβλε αρεα ισ ασσυμεδ το βε 8753 ηα.Ωατερ υσε σψστεμ οφ τηε φαρμσ ισ ϖερψ ποορ. Τηε οϖεραλλ εφφιχιενχψ   οφ τηε σψστεμ ισ 30% .Μαι νλψ τηε φαρμ ισ στατε οωνεδ το προδυχε φρυιτσ,ϖεγετατιονσ, τοβαχχο, χοττονπ αστυρε, χρεαλσ ανδ πυλσεσ. Τηε φολλοωινγ ταβλε σηοωσ τηατ τηε ιρριγατιον σ ιτεσ οφ Υς2.

Table; 4.3   UV2 irrigation sites

Farm	Ownership	Active in a year	Farm location*		Net ha	Off take location*		Return flow location*	
			Easting	*Northing*		*Easting*	*Northing*	*Easting*	*Northing*
Tibila	State Farm	2007	565068	935497	650	562611	941750	564194	942218
Addis Hiywot	State Farm	2007	563219	941256	100	562650	941890	563371	942598
Degaga	State Farm	2007	546167	932458	180	545534	931205	546572	931028
Merti_Jeju_ Achamo	State Farm	2007	573295	946596	632	571718	945539	585904	955891
Merti_Jeju_ State	State Farm	2007	581909	953670	1245	574331	948085	585904	955891
Nura_Era _State	State Farm	2007	588711	963673	2712	571664	947093	597432	968651

Nura_Era_ Privates	Private	2007	581484	957576	3334	571664	947093	597432	968651
				Total	8853				

Source; Water resources and flood hydrology of Awash basin (MoWR 2005)

3. Upper valley irrigations3 (UV3)

Τηε Υς3 δεμανδ νοδε χομπρισεσ Μετεηαρα ανδ Αβαδιρ συγαρχανε πλαντατιονσ. Τηε Μετεηαρα συγαρ χανε φαχτορψ ωασ εσταβλισηεδ ατ 1975 βψ Ετηιο–Ηολα νδ βιλατεραλ αγρεεμεντ. Αωαση Ριϖερ ισ τηε ονλψ σουρχε οφ ωατερ το βε αβστραχτ εδ φορ ιρριγατιον οφ Μετεηαρα συγαρχανε εστατε φαρμσ. Αχχορδινγ το τηε 2005 ασσεσσ μεντ οφ ΜοΩΡ τηε τοταλ αρεα χοϖερεδ βψ τηε χανε ιν Υς1 φαρμσ ισ 12896ηα.

Table; 4.4: **UV3 irrigation sites**

Farm	Ownership	Active in a year	Farm location*		Net ha	Off take location*		Return flow location*	
			Easting	*Northing*		*Easting*	*Northing*	*Easting*	*Northing*
Metahara_ Abadir	State Farm	2007	594282	972594	3889	596711	966618	598053	974622
Metahara_ Metehara	State Farm	2007	604596	976321	8118	602709	980263	609966	980482
Metahara_ North_Farm	State Farm	2007	606177	981365	889	597342	968373	610310	978222
				Total	12896				

Source; Water resources and flood hydrology of Awash basin (MoWR 2005)

4. Small scale irrigations of OIDA (OIDA1)

Ονε οφ τηε στρατεγιεσ τηατ ηαϖε πλαννεδ βψ τηε γοϖερνμεντ οφ Ετηιοπια τ ο ινχρεασε φοοδ σεχυριτψ οφ τηε ρυραλ πεασαντσ ισ τηε δεϖελοπμεντ οφ σμα λλ σχαλε ιρριγατιον πραχτιχεσ. Δεπενδινγ ον τηισ στρατεγψ τηε Ορομια ρεγιο ναλ ιρριγατιον αυτηοριτψ ηασ τριεδ το εξερχισε ιρριγατιον τεχηνολογψ σο τηατ ηουσε η ολδ φοοδ σεχυριτψ χαν βε ατταινεδ τηρουγη δεϖελοπμεντ οφ ωατερ φορ πυρπ οσε οφ ιρριγατεδ αγριχυλτυρε.

Τηε ΟΙΔΑ ηασ ιμπλεμεντεδ μορε τηαν 12 σμαλλ σχαλε ιρριγατιον σχηεμεσ βψ

αβστραχτινγ συβσταντιαλ αμουντ οφ ωατερ φρομ Αωαση ριϖερ βψ διϖερτι νγ ατ διφφερεντ λοχατιονσ.Μοστ οφ στατεδ ιρριγατιον φαρμσ αρε λοχατεδ ιν μιδδλ ε παρτ οφΥππερ Αωαση ϖαλλεψ ανδ Φενταλε διστριχτσ.

Table; 4.5: **Details of small scale irrigation owned by OIDA in the Upper Awash valley**

Farm	Owner	Active in		Net ha		

						location*		location*	
	ship	a year	*Easting*	*Northing*		*Easting*	*Northing*	*Easting*	*Northing*
Melka_Oba_1	OIDA	2007	542038	926928	60	541262	926557	542318	926244
Qobo Malmele	OIDA	2007	541496	926193	30	541262	926557	542318	926244
Betu_Degaga	OIDA	2007	545244	932040	100	545143	930994	546071	930893
Doni_WV	OIDA	2007	561457	940408	400	560951	939868	562435	941337
Doni_Care	OIDA	2007	561997	940881	200	560715	939666	562435	941337
Lugo	OIDA	2007	591809	961144	57	591505	960570	592382	961346
Sara	OIDA	2007	594661	964227	120	593951	963489	596448	966340
Weba	OIDA	2007	595755	965269	160	593951	963489	596448	966340
Gara_Dima	OIDA	None	580064	953928	300	578702	952984	581393	955657
Sogido_1	OIDA	2007	594244	964566	70	593951	963489	596448	966340
Sogido_2	OIDA	2007	595182	965452	70	593951	963489	596448	966340
Melka_Oba_2	OIDA	2007	542088	927271	40	540679	926526	542818	926559
				Total	1607				

Source; Water resources and flood hydrology of Awash basin (MoWR 2005)

Τηε χροπσ ανδ χροππινγ παττερνσ τηατ ηαϖε βεεν πραχτιχεδ ιν μοστ οφ τηε φαρ μσ
αρε σιμιλαρ. Τηε μαιν χροπσ τηατ αρε προδυχεδ ιν τηε ιρριγατιον φαρμσ αρ ε
ϖεγεταβλεσ (Τοματο,ονιον,πεππερ,χαββαγε),Χερεαλσ (μαιζε,σοργηυμ,τεφφ,) ανδ πυλσεσ (Η.βεαν).Τηε ωατερ αβστραχτιον φορ ιρριγατιον ρεθυιρεμεντ φορ τηε αβ οϖε
φαρμσ μεργεδ βψ τακινγ ιν το αχχουντ τηε οπτιμαλ χροππινγ παττερν ανδ συμμι νγ υπ τηε τοταλ μοντηλψ ωατερ αβστραχτιον οφ εαχη σμαλλ ιρριγατιον φαρμ ασ συιταβλε φορ ΩΕΑΠ.

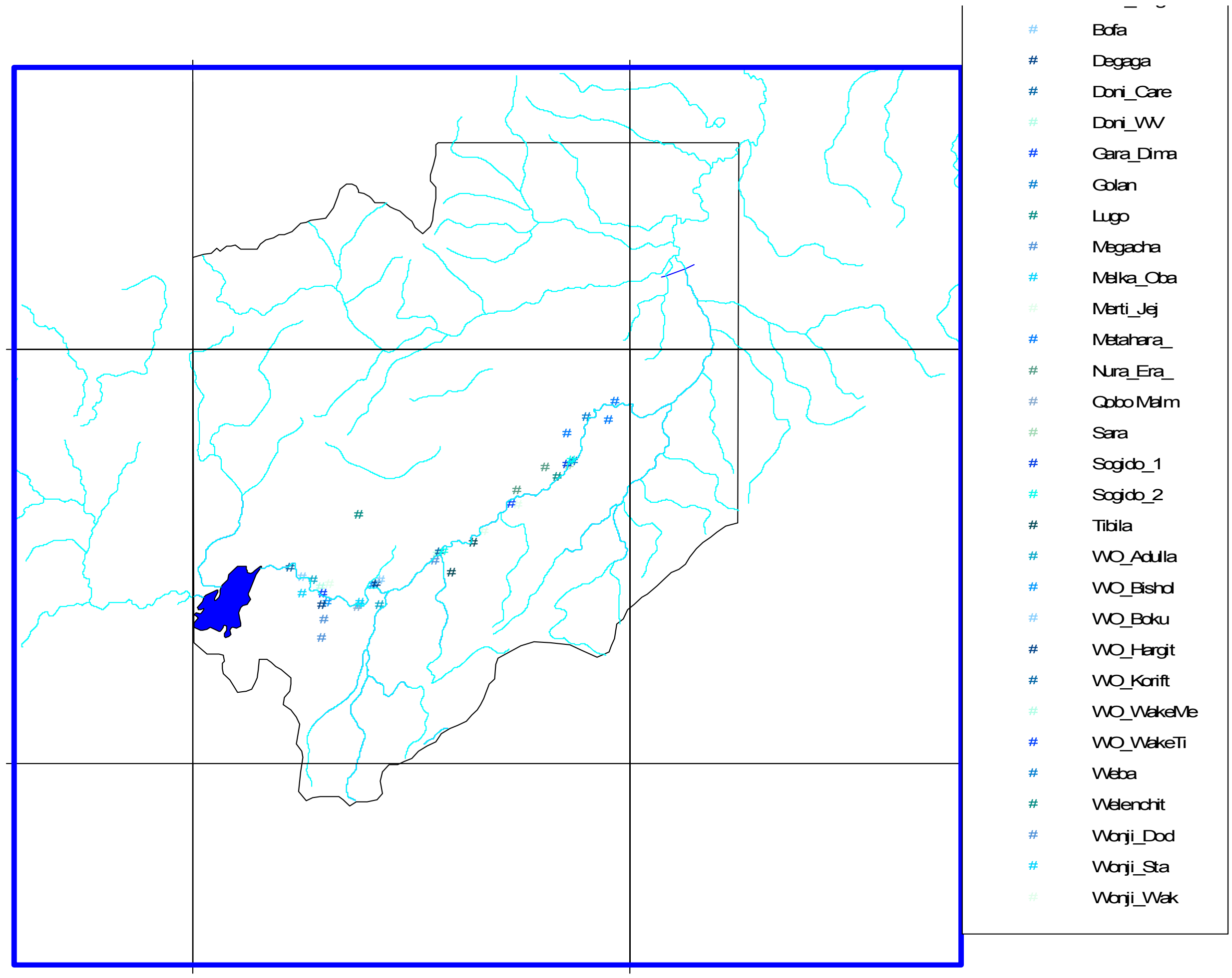


Figure 3.1. Lactation points of some irrigation nodes owned by OIDA in the sub-basin

4.3.3. Irrigation schemes in project stage

Υππερ Αωαση συβ βασιν, ωιτη ιτσ ποτεντιαλ λανδ το βε ιρριγατεδ ανδ συιταβλε χονδιτιον φορ ιρριγατιον ισ υτιλιζινγ ποτεντιαλλψ Αωαση Ριϖερ φορ τηε πρε σεντ ανδ φυτυρεδεϖελοπμεντ σχεναριοσ. Νεαρλψ εθυαλ σιζε οφ χυρρεντ ιρρ ιγατεδ αγριχυλτυρε,νεω προφεχτσ ηαϖε βεεν πλαννεδ ανδ υνδερ χονστρυχτιον φορ νεαρ φυτυρε δεϖελοπμεντ ιν τηε συβ βασιν.Ον τηε οτηερ ηανδ τηερε ισ α συ βσταντιαλ ρατε οφ αννυαλ δεχρεασε οφ Κοκα ρεσερϖοιρ χαπαχιτψ δυε το σεϖερ σεδιμεντατιον οφ τηε υπλανδσ.

Τηε φολλοωινγ αρε τηε μαφορ ιδεντιφιεδ σχεναριοσ ιν τηε παρτιχυλαρ συβ βασιν.

Φυτυρε Ιρριγατιον Δεμανδσ

Α νυμβερ οφ μεδιυμ ανδ σμαλλ σχαλε ιρριγατιον αρε εξπεχτεδ το βε οπερατιοναλ ιν 2010. Σομε οφ τηεσε ωασ σχεναριοσ οφ 2007 ανδ λαγγεδ βψ διφφερεντ ινχονϖενιενχεσ.Τηε 2010 Σχεναριο ινχλυδεσ τηε φολλοωινγ χηανγεσ φρομ τηε 2007 ρεφερενχε σιτυατιον

Νεω ιρριγατιον σχηεμεσ ον λινε ασ συμμαρισεδ ιν τηε φολλοωινγ λιστ

1. **Ωονφι αρεα ιρριγατιον εξπανσιονσ**
   - Ωονφι Δοδοτα νορτη (2 241 ηα οφ συγαρ)
   - Ωονφι Δοδοτα σουτη (1500 ηα φορ συγαρ)
   - Ωονφι Ωακε Τιο Εξπανσιον (512 ηα οφ συγαρ)
   - Ωελενχηιτι–Βοφα (12 462 ηα οφ συγαρ)

Ταβλε; 4.6: Σχηεμεσ οφ Ωονφι αρεα ιρριγατιον εξπανσιον

Φαρμ	Οωνερσηιπ	Αχτιωε ιν α ψεαρ	Φαρμ λοχατιον*		Νετ ηα	Οφφ τακε λοχατιον		Ρετυρν φλοω λοχατιον	
			Εαστινγ	*Νορτηινγ*		*Εαστινγ*	*Νορτηινγ*	*Εαστινγ*	*Νορτηινγ*
Ωονφι Δοδοτα_Ν	Ουτγροωερσ	**2010**	533000	923000	2241	534071	928600	538165	928025
Ωονφι Δοδοτα_Σ	Ουτγροωερσ	**2010**	532500	918000	1500	534071	928600	538165	928025
Ωονφι ΩακεΤιο	Ουτγροωερσ	**2010**	534332	932274	512	533199	929106	536919	928646
Ωελενχηιτι	Ουτγροωερσ	**2010**	541873	950715	9000	536892	928618	563042	969686
Βοφα	Ουτγροωερσ	**2010**	547323	933359	3462	540188	926374	554828	932924
				Τοταλ	**16715**				

Σουρχε;ΩΩΔΣΕ 2006:Ωονφι Σηεωα συγαρ χανε πλαντατιον εξπανσιον (Ωελενχηιτι Βοφα ιρριγατιον προφεχτ δεσιγν ρεπορτ)

2. **ΟΙΔΑ σμαλλ σχαλε σμαλλ ιρριγατιον σχηεμεσ**:
   - Γολαν (50 ηα οφ χοττον/μιξεδ χροπσ)
   - Βαταλε Κιιλτυ (330 ηα οφ χοττον/μιξεδ χροπσ
   - Μεγαχηα (125 ηα οφ χοττον/μιξεδ χροπσ)
   - Αλαγ Δορε (104 ηα οφ χοττον)

Table:4.7 New proposed small irrigations by OIDA

Year	Scenario	Diversion		Area (ha)	Off take		Return	
		East	North		East	North	East	North
Golan	**2009**	599190	977241	50	598867	976362	600509	977577
Batale_Kiiltu	**2009**	546867	926850	330	545961	924290	548066	928746
Megacha	**2009**	561063	938764	125	560235	939049	562369	940872
Alag_Dore	**2009**	570600	943324	104	569106	942920	570730	945564

Total	609

Τηε ιρριγατιον ωατερ ρεθυιρεμεντσ φορ τηεσε σμαλλ σχαλε προφεχτσ αρε εστιμ ατεδ ιν αμαλγαματεδ μαννερ βψ υσινγ Νυρα Ηερα Μετεορολογιχαλ δατα. Τηε τα βυλατεδ
αμαλγαματεδ ιρριγατιον ωατερ αβστραχτιον (ΜΜΧ) ισ Σηοων ιν Αννεξ Χ

Φενταλε Ιντεγρατεδ Ιρριγατιον Προφεχτ

Φενταλε λαργε σχαλε ιντεγρατεδ ιρριγατιον, τηε προφεχτ ον χονστρυχτιον ισ τη ε ονε
χονσιδερεδ ασ 2009 σχεναριο. Τηε προφεχτ αρεα ισ λοχατεδ ιν Εαστ Σηεωα ζονε ,
ανδ νεαρ Μετεηαρα τοων. Ιτ ισ λοχατεδ ατ $8^0$37□Ν, $39^0$43϶Ε ανδ αλτιτυδε ϖαρψιν γ
φρομ 1180μ α. σ. λ. το 950μ α.σ.λ.Τηε προφεχτ ισ προποσεδ το ιρριγατε τηε χομμανδ αρεα οφ 18130 ηα ωιτη εξπεχτεδ βενεφιχιαρψ ηουσε ηολδσ οφ 1420 ανδ Μετεηαρα συγαρ φαχτορψ.

Τηε μαιν οβφεχτιϖε οφ τηε σχημε ισ το ταχκλε φοοδ σεχυριτψ προβλεμσ οφ τηε
πεασαντσ ανδ το συππλψ χανε συγαρ φορ Μετεηαρα συγαρ φαχτορψ.Ουτ οφ 18 ,130 ηα ποτεντιαλ λανδ 13,355 ηα ισ φουνδ το ποτεντιαλλψ συιταβλε φορ χροπ σ ανδ 4,775 ηα αρε συιταβλε φορ φοραγε.

Ταβλε:4.8 Συμμαρψ οφ συιταβλε λανδ αλλοχατιον φορ ιρριγατεδ χροπσ ιν Φενταλε

No	Suitable land	Allocated area (ha)	Remark
1	Suitable land for field crops	6717	Southern block
2	New proposed area by OIDA	3940	For sugar cane and field crops
3	Potential land to produce sugar cane	2700	For sugar cane

4	Suitable for forage	4713	Alfalfa
	Total	18130	

Source: OIDA Fentale Report 2005

The following table shows the main crops proposed to be developed with their command area allocation and expected yield.

Table: 4.9 Irrigation farm allocations for various crops

NO	Types of crops	Total area	Yield /hectare
1	Sugar cane	2700	1600
2	Maize	2575	15
3	sorghum	2575	13
4	Teff	659	5
5	Onion	1961	145
6	Potato	800	140
7	Pepper	601	7
8	Cabbage	614	160
9	Tomato	567	220
10	Haricot bean	958	8
11	Orange	390	150
12	Forages/Alfalfa	4775	-
	Total	18 130	

Source: (OIDA Fentale Report 2005)

Nura Hera and Metehara meteorological stations are considered to be the most reliable Class I stations from which meteorological information relevant to the project area can be derived. The data from these stations is proposed to be used for the catchment's study as well as for estimation of meteorological variables at the irrigation command area. The necessary adjustment for the differences in elevation will be made in transferring the data for estimating the values of reference crop evapo-transpiration (ET_o) specific to Fentale project command area.(The monthly irrigation water abstractions for Fentale is shown in Annex C)

4.3.4. Urban water Supply

Τηε σιγνιφιχαντ τοωνσ τηατ υτιλιζε ωατερ φρομ Αωαση Ριϖερ ιν τηε υππερ Αωα σηα αρε Ναζερετη ανδ Μετεηαρα τοωνσ.

Nazereth Water supply:

Σταρτινγ φρομ Οχτοβερ 2002 Ναζερετη τοων ηαϖε υτιλιζεδ Αωαση ριϖερ ασ τηε τηειρ ονλψ ωατερ σουρχε. Τηε ραω ωατερ φορ τηισ σχημε ισ λοχατεδ ατ αβουτ 3κμ δοων στρεαμ οφ Κοκα δαμ ανδ ατ αβουτ 15 κμ διστανχε φρομ τηε χεντερ οφ τηε τοων

Ταβλε: 3.10. Ποπυλατιον προφεχτιον οφ Ναζερετη τοων

Ψεαρ	1980	1985	1995	2005	2010
Λοω σχεναριο	68,000	86,000	134,000	199,000	242,000
Ηιγη σχεναριο	69,000	92,000	157,000	256,900	327,000
Μεδιυμ σχεναριο	68,000	89,500	145,000	226,500	282,200

Σουρχε: δραφτ ρεπορτ οφ Ναζερετη ωατερ συππλψ 1983

Αχχορδινγ τηε ωατερ συππλψ δεσιγν ρεπορτ οφ Αδαμα τοων τηερε ισ νο ελαβορα τεδ δατα αϖαιλαβλε φορ μαφορ ωατερ χονσυμερσ. Ουτ οφ τηε δατα χολλεχτεδ φρομ ωατερ συππλψ σερϖιχε οφφιχε φορ εαχη κεβελε τηε χονσυμερσ ωηο υσε μορε τηαν 30μ^{3} το 15 μ^{3} ωατερ περ μοντη ωερε ιδεντιφιεδ.Τηε ωατερ δεμανδ ισ χατεγοριζεδ ασ δομεστιχ ανδ νον δομεστιχ, ωηερε νον δομεστιχ δεμανδσ ινχλυδε πυβλιχ ανδ ινδυστριαλ δεμανδσ.

Ταβλε: 3.11 Εστιματεδ ωατερ προφεχτιονσ οφ Ναζερετη τοων

Ηοριζον	Δομεστιχ (μ^{3}/δαψ)	Νον δομεστιχ(μ^{3}/δαψ)	Τοταλ(μ^{3}/δαψ)
2000	4001	1480	5481
2005	5815	2442	8257
2015	12201	5490	17691
2025	24653	8628	33281

Σουρχε: Ωαστε ωατερ στυδψ οφ Αδαμα τοων 2003

Νοτε: – τηε σψστεμ τακεσ 20% φορ λεακαγε ανδ λοσσεσ
–Τηε αϖεραγε αννυαλ γροωτη ρατε οφ ποπυλατιον ισ 3.2%
–Τηε μοντηλψ δεμανδ δατα ιν α ωαψ συιταβλε φορ ΩΕΑΠ μοδελ α ρε σηοων ιν Αννεξ Χ

Metehara Water supply;

Τηε δομεστιχ ανδ νον δομεστιχ ωατερ δεμανδσ φορ Μετεηαρα τοων ωιτη ποπυλατιον προφεχτιονσ αρε σηοων βελοω.

Ταβλε: 4.12. Αγγρεγατε ωατερ δεμανδ προφεχτιον φορ Μετεηαρα τοων

Ψεαρ	1994	1999	2007	2017
Ποπυλατιον	4000	20,000	34,100	60,000
Δομεστιχ δεμανδ (μ^{3}/δαψ)	364	558	1538	3780
Νον–δομεστιχ δεμανδ (μ^{3}/δαψ)	203	323	606	1106
Αγγρεγατε αϖεραγε ωατερ δεμανδ(μ^{3}/δαψ)	567	881	2144	4886
Αννυαλ γροωτη ρατε (%)	8.5	7.4	6.9	5.8

Σουρχε; Μετεηαρα τοων ωατερ συππλψ δεσιγν ρεπορτ

Τηε δεταιλεδ δατα οφ Μετεηαρα τοων ωατερ συππλψ ωηιχη αρε προϖιδεδ φορ τηε ΩΕΑ μοδελ αρε σηοων ιν Αννεξ Χ.

4.3.5. Στρεαμ φλοω Δατα

Τηε στρεαμ φλοω δατα οφ χερταιν ηιστοριχαλ περιοδ αρε ρεθυιρεδ σπεχιφιχαλλ ψ ιν ορδερ το σετ υπ ανδ ρυν τηε αλλοχατιον μοδελ. Τηεσε αρε δεριϖεδ φρομ ρυνοφφ δατα μεασυρεδ ατ σελεχτεδ γαυγεδ στατιονσ ιν τηε συβ βασιν. Στρεαμ φλοω ηασ βεεν γαυγεδ ατ μανψ λοχατιονσ ον τηε Αωαση Ριϖερ οϖερ τηε ψεαρσ. Φορ μανψ οφ τηεσε σιτεσ, δατα ωερε χολλεχτεδ φορ ονλψ σηορτ περιοδσ οφ τιμε ανδ φορ μ ανψ ιτ ωασ νοτ ποσσιβλε το εσταβλιση αν αδεθυατε ρατινγ χυρϖε. Τηε δατα φορ αλλ οφ τηε στατιονσ ωερε προϖιδεδ φρομ τηε Ηψδρολογψ Δεπαρτμεντ οφ Μ οΩΡ ανδ χαρεφυλλψαναλψζεδ ανδ ασσεσσεδ.Αμονγ τηε οϖεραλλ γαυγινγ στα τιονσ οφ τηε Αωαση ριϖερ βασιν φορ τηισ στυδψ φεω οφ τηε αϖαιλαβλε στατι ονσ οφ υππερ Αωαση ϖαλλεψ αρε σελεχτεδ ανδ λιστεδ ιν τηε φολλοωινγ ταβλε 3.13.

Ταβλε 4.13: Ηψδρολογιχαλ Γαυγινγ Στατιονσ οφ τηε στυδψ αρεα ιντο χονσιδερατιον

Στατιον ναμε □	Λατιτυδε νορτη	Λονγιτυδε εαστ	□ Περιοδ οφ δατα	Χατχημεντ αρεα(Κμ^{2})
Αωαση ≅ Ηομβολε	8^{0}23э	38^{0}47э	1962–2000	7656
Μοφο ≅ Μοφο ϖιλλαγε	8^{0}36э	39^{0}24э	1962–2000	1264
Αωαση βελοω Κοκα	8^{0}28э	39^{0}14э	1970–2000	11219
αωαση ≅ Ωονϕι	8^{0}27э	39^{0}14э	1969–2000	11690
Κελετα ≅ Σιρε	8^{0}17э	39^{0}24э	1966–1999	747
Αωαση≅ Νυρα Ηερα	8^{0}32э	39^{0}35э	1975–1997	14173
Αωαση ≅ Μετεηαρα	8^{0}15э	39^{0}51э	1962–2000	16416

Σουρχε: ΜοΩΡ ηψδρολογψ δεπαρτμεντ (Ωατερ ρεσουρχεσ–φλοοδ ηψδρολογψ στ υδψ
2005)

Μοστ στατιονσ□ ηιστοριχαλ δατα αρε αρρανγεδ ιν μεαν μοντηλψ ρυνοφφ βασ ισ φορ τηε περιοδ φρομ ϑανυαρψ 1962 το Δεχεμβερ 2004 βψ ΜοΩΡ ηψδρολογψ δεπαρτμεντ εξχεπτ σομε οφ τηε μισσινγ δατα. Ωηερε δατα αρε νοτ αϖαιλαβλε φορ τηε εντιρε
ρεχορδ περιοδ ρεφερενχε ηασ βεεν μαδε το στατιονσφορ ωηιχη τηε αππροπριατ ε
περιοδσ οφ ρεχορδ αρε αϖαιλαβλε ανδ τηε γαπσ ηαϖε βεεν φιλλεδ βψ μακινγ ρεφερενχε το τηε ρελατιϖε ρυνοφφ ποτεντιαλ οφ τηε χατχηεμεντσ βεινγ χομπαρεδ.

Τηε ρεχορδσ ασ υσεδ το γενερατε τηε ινπυτ φιλεσ φορ τηε ΩΕΑΠ μοδελ αρε ινχλ υδεδ ιν Αννεξ Α

4.3.6. Ρεσερϖοιρ Πηψσιχαλ ανδ οπερατινγ Δατα

Τηε οπερατιον προχεδυρεσ οφ Κοκα δαμ ωασ προϖιδεδ βψ ΕΕΠΧ. Τηε δαμ ισ

οπερατεδ πριμαριλψ φορ ποωερ προδυχτιον; τηατ ισ τηε λεϖελσ ανδ ρελεα σεσ αρε
χοντρολλεδ ιν ορδερ το αχηιεϖε τηε ρεθυιρεδ ποωερ προδυχτιον ατ τηε τηρεε στ ατιονσ.Οτηερ υσεσ αρε νοτ τακεν ιντο αχχουντ, ανδ νορ ισ τηερε ανψ νεεδ το οπερατε τηε ρεσερϖοιρ φορ φλοοδ χοντρολ. Ηοωεϖερ, σινχε ποωερ σψστεμσ α ρε ιντερχοννεχτεδ
αχροσσ τηε χουντρψ, τηε Αωαση στατιονσ χαννοτ βε χονσιδερεδ ιν ισολατιον. Τηε οπερατιον τακεσ αχχουντ οφ τηε οτηερ ηψδροποωερ ανδ τηερμαλ στατιο νσ ιν τηε
χουντρψ, τηε αϖαιλαβιλιτψ οφ ωατερ ανδ μαιντενανχε νεεδσ ατ αλλ σιτεσ ασ ωελλ ασ
τηε εξπεχτεδ δεμανδσ.Τηισ μεανσ τηατ τηε οπερατιον οφ Κοκα χαννοτ βε δεφινε δ βψ ανψ στανδαρδ ρυλε ωηιχη ισ γενεραλλψ φολλοωεδ εαχη ψεαρ, βυτ ιτ ισ ο περατεδ διφφερεντλψ δεπενδινγ ον α ωιδε ρανγε οφ φαχτορσ.Φορ ινστανχε,ιν α

σιτυατιον ωηερεοτηερ στατιονσ αρε προδυχινγ βελοω νορμαλ,συχη ασ ωηεν ρ εηαβιλιτατιον ωορκ ισ γοινγ ον, τηε δεμανδ φρομ Κοκα χουλδ βε ινχρεασεδ. Χ ονϖερσελψ, ωηεν οτηερ στατιονσ αρε προδυχινγ ατ ηιγη λεϖελ, α λοωερ λεϖελ οφ ποωερ γενερατιον ατ Κοκα χαν βε τολερατεδ.

Ταβλε:4.14 ςολυμε–Ελεϖατιον ρελατιον οφ Κοκα ρεσερϖοιρ

Ωατερ λεϖελ α.σ.λ □	ωατερ λεϖελ φορμ δατυμ (μ)	στοραγε ϖολυμε οφ Κοκα ατ 2007 (Μμ⊥3)
1591.4	111	1209
1590.7	110.3	1069
1589.4	109	811
1587.4	107	486
1585.4	105	213
1583.4	103	6
1582.4	102	0
1581.4	101	0

Source: Derived for 2007 from (Booker Tate study 2003)

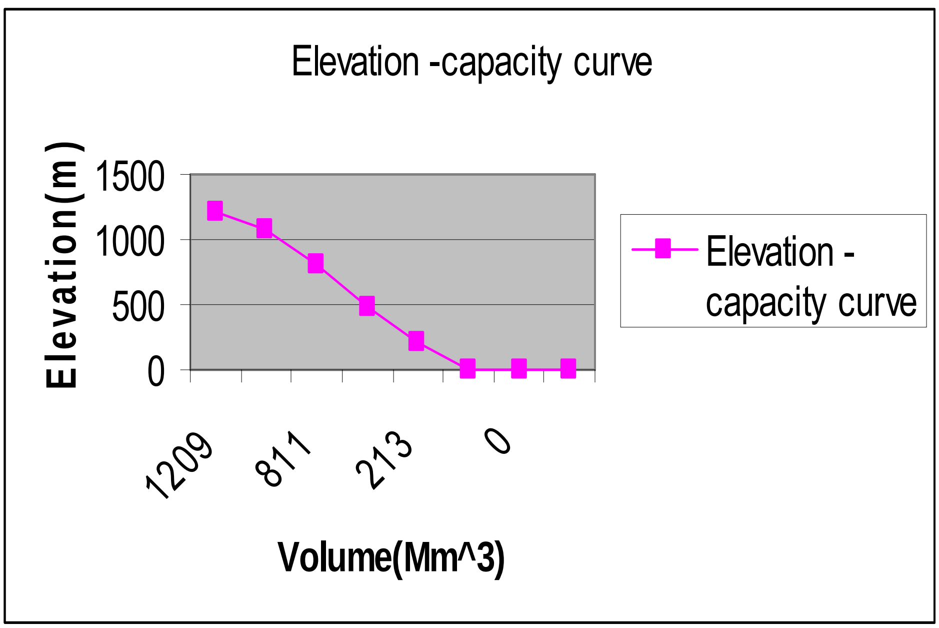


Figure 4.2 Volume elevation Curve of Koka reservoir

Table 4.15 Salient features of Koa reservoir

Description	Site Datum	Ethiopian datum

	(m)	m a.s.l
Dam crest	112.8	1593.2
Maximum Flood retention	111.8	1592.2
Normal operating level	110.3	1590.7
Spillway Gate invert level	104.6	1585.0
General silt level Upstream of Dam	100.3	1580.7
Power station water Intake Invert level	95	1575.4
Bottom Outlet Invert Level	89.1	1569.5
Minimum foundation level at dam	71	1551.4

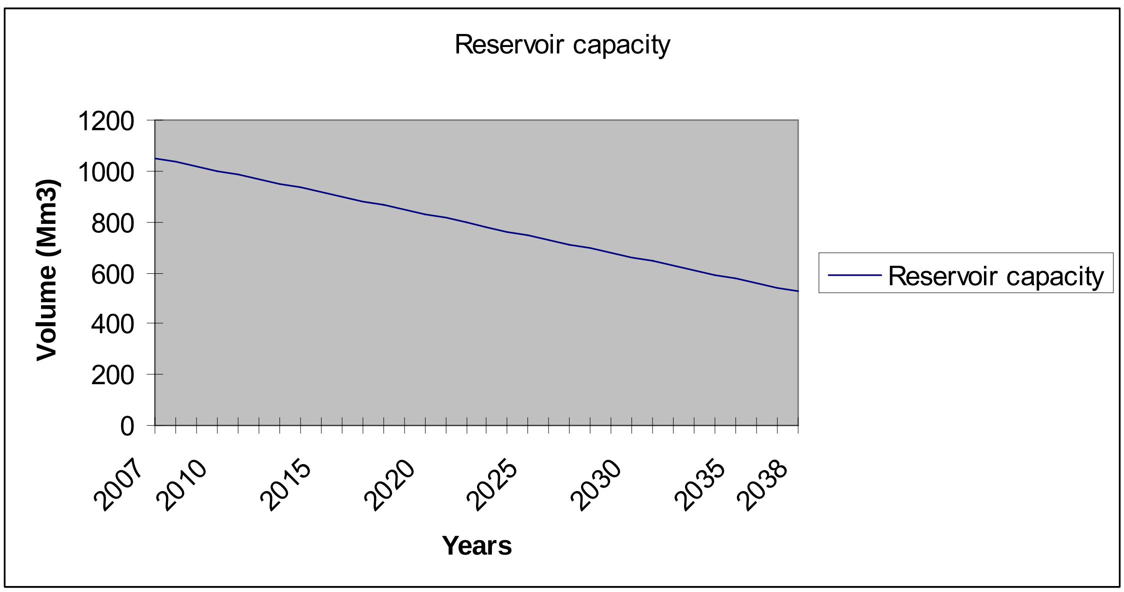
Source: Derived from Booker Tate 2003

Τηε τοταλ ωατερ αβστραχτιον φρομ Κοκα ρεσερϖοιρ φορ τηε χυρρεντ ιρριγατιο
ν λεϖελ ωασεστιματεδ ασ 823 Μμ⊥3 αννυαλλψ. Ωηεν Τενδαηο Δαμ ισ οπερατιο
ναλ τηε τοταλ
Κοκα ρελεασε φορ σατισφψινγ τηε δοωνστρεαμ δεμανδ βεχομεσ 518 μμ⊥3 (τηατ ι
σ ρεδυχινγ τηε πρεσεντ λοωερ ϖαλλεψ δεμανδ οφ 140Μμ⊥3).Τηε πρεσεντ (2007)
λιϖε στοραγε οφ Κοκα ρεσερϖοιρ ατ φυλλ ρεσερϖοιρ λεϖελ οφ 1590.7 μ ισ αβου
τ 1069Μμ⊥3
ωιτη τηε αννυαλ σεδιμεντατιον ρατε οφ 17Μμ⊥3.
Αχχορδινγ το τηε Βοοκερ στυδψ οφ Κοκα ρεσερϖοιρ ωατερ βαλανχε μαδε οϖερ
τηε περιοδ1962–2003 μεαν αννυαλ σεεπαγε λοσσ ισ τακεν ασ μεαν ινφλοω ιν το
κοκα
1588Μμ⊥3 μινυσ Ουτ φλοω 1332 Μμ⊥3 μινυσ Νετ εϖαπορατιον λοσσ 177Μμ⊥3
ωηιχη ισ εθυαλ το 79Μμ⊥3.

Table 4.16: The expected Koka reservoir capacity of future years

Ψεαρσ □	Εξπεχτεδ ϖολυμε Κοκα ρεσερϖοιρ Μμ⊥3
2007	1052
2008	1035
2009	1018
2010	1001
2011	984
2012	967
2013	950
2014	933

2015	916
2016	899
2017	882
2018	865
2019	848
2020	831
2021	814
2022	797
2023	780
2024	763
2025	746
2026	729
2027	712
2028	695
2038	525



Φιγυρε 4.3 Ρεδυχτιον ρατε οφ Κοκα ρεσερϖοιρ χαπαχιτψ

Τηερε ισ γενεραλλψ πατχηψ ινφορματιον αϖαιλαβλε ον χαπαχιτψ ανδ συρφαχε αρεα οφ
Κοκα ρεσερϖοιρ τηρουγη τηε ψεαρσ. Τηισ στυδψ ηασ αδοπτεδ τηε κοκα ρεσερϖ οιρ δατα τηατ ισ εστιματεδ βψ ΕΕΠΧ ιν 1999 ωηιχη ωασ υπδατεδ ανδ ρεινφορχεδ βψ Βοοκερ
Τατε ιν 2003.

Chapter 5

The model Application and Data Analysis

5.1. **WEAP model and its Analysis**

Τηε σοφτ ωαρε σελεχτεδ φορ τηε αναλψσισ οφ τηισ στυδψ ισ τηε ωατερ εϖ αλυατιον ανδ πλαννινγ σψστεμ (ΩΕΑΠ).Ιτ ισ α μιχροχομπυτερ τοολ υσεδ φ ορ ιντεγρατεδωατερ ρεσουρχεσ πλαννινγ.Ιτ οπερατεσ ον βασιχ πρινχιπλεσ οφ ωατερ βαλανχεαππλιχατιον φορ ιρριγατεδ αγριχυλτυραλ χατχημεντσ ανδ χομπλεξ τρανσβουνδαρψ ριϖερ σψστεμ. Τηε σελεχτιον οφ ΩΕΑΠ φορ τηισ παρτιχυλαρ στυδψ ισ δυε το ιτσ αβιλιτψ το χομπυτε ιρριγατιον ωατερ ανδ οτηερ δεμανδσ βασεδ ον αϖαιλαβλε δατα. Ιτ ισ α ρεχεντ μοδελ τη ατ ποσσεσσεσ α νυμβερ οφ ϖερσατιλιτψ ανδ αδϖανταγεσ.ΩΕΑΠ ισ τηε μαφορ αναλψτιχ τοολ ιν οργανιζινγ δατα, προφε χτινγ ωατερ δεμανδ ανδ συππλψ, ανδ εϖαλυατινγ αλτερνατιϖε ωατερ δεϖε λοπμεντ στρατεγιεσ.

ΩΕΑΠ ισ χομπρεηενσιϖε, στραιγητφορωαρδ ανδ εασψ−το−υσε, ανδ αττεμπτ σ το ασσιστ ρατηερ τηαν συβστιτυτε φορ τηε σκιλλεδ πλαννερ. Ασ α δαταβασε, ΩΕΑΠ

προϖιδεσ α σψστεμ φορ μαινταινινγ ωατερ δεμανδ ανδ συππλψ ινφορματιον . Ασ
α φορεχαστινγ τοολ,ΩΕΑΠ σιμυλατεσ ωατερ δεμανδ, συππλψ,φλοωσ,ανδ στ οραγε
Ασ α πολιχψ αναλψσισ τοολ,ΩΕΑΠ εϖαλυατεσ α φυλλ ρανγε οφ ωατερ δεϖε λοπμετ
ανδ μαναγεμεντ οπτιονσ ανδ τακεσ αχχουντ οφ μυλτιπλε ανδ χομπετινγ υσε
οφ ωατερ σψστεμσ.

ΩΕΑΠ αππλιχατιονσ γενεραλλψ ινχλυδε σεϖεραλ στεπσ. Τηε στυδψ δεφι νιτιον σετσ υπ τηε τιμε φραμε, σπατιαλ βουνδαρψ, σψστεμ χομπονεντσ ανδ
χονφιγυρατιον οφ τηε προβλεμ. Τηε Χυρρεντ Αχχουντσ προϖιδε α σναπση οτ οφ αχτυαλ ωατερ δεμανδ,ρεσουρχεσ ανδ συππλιεσ φορ τηε σψστεμ. Αλτ ερνατιϖε
σετσ οφ φυτυρε ασσυμπτιονσ αρε βασεδ ον πολιχιεσ , χοστσ, τεχηνολογι χαλ
δεϖελοπμεντ ανδ οτηερ φαχτορσ τηατ αφφεχτ δεμανδ, πολλυτιον, συππλψ α νδ
ηψδρολογψ. Σχεναριοσ αρε χονστρυχτεδ χονσιστινγ οφ αλτερνατιϖε σετσ οφ
ασσυμπτιονσ ορ πολιχιεσ. Φιναλλψ, τηε σχεναριοσ αρε εϖαλυατεδ ωιτη ρ εγαρδ το
ωατερ συφφιχιενχψ, χοστσ ανδ βενεφιτσ,χομπατιβιλιτψ ωιτη ενϖιρονμεν ταλ
ταργετσ, ανδ σενσιτιϖιτψ το υνχερταιντψ ιν κεψ ϖαριαβλεσ·

ΩΕΑΠ χαν αδδρεσσ α ωιδε ρανγε οφ ισσυεσ λικε σεχτοραλ δεμανδ αναλψσ ισ,
ωατερ χονσερϖατιον, ωατερ ριγητσ ανδ αλλοχατιον πριοριτιεσ, γρουνδ ωατε ρ ανδ
στρεαμ φλοω σιμυλατιον, ρεσερϖοιρ οπερατιον, ηψδροποωερ γενερατιον, πο λλυτιον τραχκινγ, εχοσψστεμ ρεθυιρεμεντσ, ϖυλνεραβιλιτψ ασσεσσμεντσ α νδ βενεφιτ

αναλψσισ.ΩΕΑΠ ισ στρυχτυρεδ ανδ οργανιζεδ ιν το φιϖε σεπαρατε βυτ ιντεγ
ρατεδ χορε προγραμσ; τηε σετυπ, Δεμανδ, Διστριβυτιον, Συππλψ ανδ εϖαλ
υατιον
προγραμσ.
Τηε σετυπ προγραμ εσταβλισηεσ τηε προγραμ υνδερ στυδψ, δεφινινγ τηε στ
υδψ αρεα, τιμε ηοριζον, σψστεμ πηψσιχαλ χομπονεντσ ανδ τηειρ σπατι
αλ ανδ
τεμποραλ ρελατιον σηιπσ. Τηε δεμανδ προγραμ υσεσ δεμογραπηιχ , σοχιο
–
εχονομιχ ανδ υνιτ ωατερ ρεθυιρεμεντ ινφορματιον το γενερατε τηε χυρρεν
τ
ανδ φυτυρε ωατερ δεμανδ αχχουντσ φορ εαχη δεφινεδ δεμανδ σιτεσ.
Προφεχτεδ ωατερ δεμανδσ αρε πασσεδ το τηε συππλψ προγραμ φορ ωατ
ερ
βαλανχε αναλψσισ.Τηε διστριβυτιον προγραμ δεσχριβεσ τηε μοντηλψ δεμ
ανδ
ϖαριατιονσ,διστριβυτιον εφφιχιενχψ ιν εαχη δεφινεδ δεμανδ σιτε. Τηε συπ
πλψ
προγραμ σιμυλατεσ τηε σπατιαλ ανδ τεμποραλ ωατερ αλλοχατιονσ βετω
εεν
συππλψ σουρχεσ ανδ δεμανδ σιτεσ.Τηε εϖαλυατιον προγραμ εϖαλυατεσ α
νδ
χομπαρεσ διφφερεντ πολιχψ σχεναριοσ ιν τερμσ οφ δεμανδ μαναγεμεντ,
τρανσμισσιον εφφιχιενχψ, ιμπροϖεμεντ, θυαντιτψ ανδ θυαλιτψ οφ τηε συπ
πλιεδ ωατερ, ανδ τηε ενϖιρονμενταλ ανδ εχονομιχ ιμπαχτσ.

ΩΕΑΠ χονσιστ οφ φιϖε μαιν ϖιεωσ: σχηεματιχ, Δατα, Ρεσυλτσ, Οϖερϖιεω α
νδ
Νοτεσ.Τηε σχηεματιχ ϖιεω ινδιχατεσ τηε χονφιγυρατιον οφ ουρ σψστεμ ινχλ
υδινγοβφεχτσ λικε νοδεσ, ριϖερσ, ρεσερϖοιρσ ανδ διφφερεντ λινκσ. Τηε δατ
α ϖιεω αλλοωσ χρεατινγ ϖαριαβλεσ ανδ ρελατιονσηιπσ, εντερινγ ασσυμπτι
ονσ ανδ προφεχτιονσ υσινγ ματηεματιχαλ εξπρεσσιονσ. Τηε ρεσυλτ ϖιεω αλ
λοωσ δεταιλεδ ανδ φλεξιβλε δισπλαψ οφ αλλ μοδελ ουτπυτσ ιν χηαρτσ ανδ τ
αβλεσ. Τηε οϖερϖιεω ηιγηλιγητσ κεψ ινδιχατορσ οφ τηε σψστεμ φορ θυιχκ ςι

εωινγ. Φιναλλψ τηε νοτε ϖιεω προϖιδεσ α μεανσ το δοχυμεντ ασσυμπτιονσ οτηερ μεμορανδυμ.

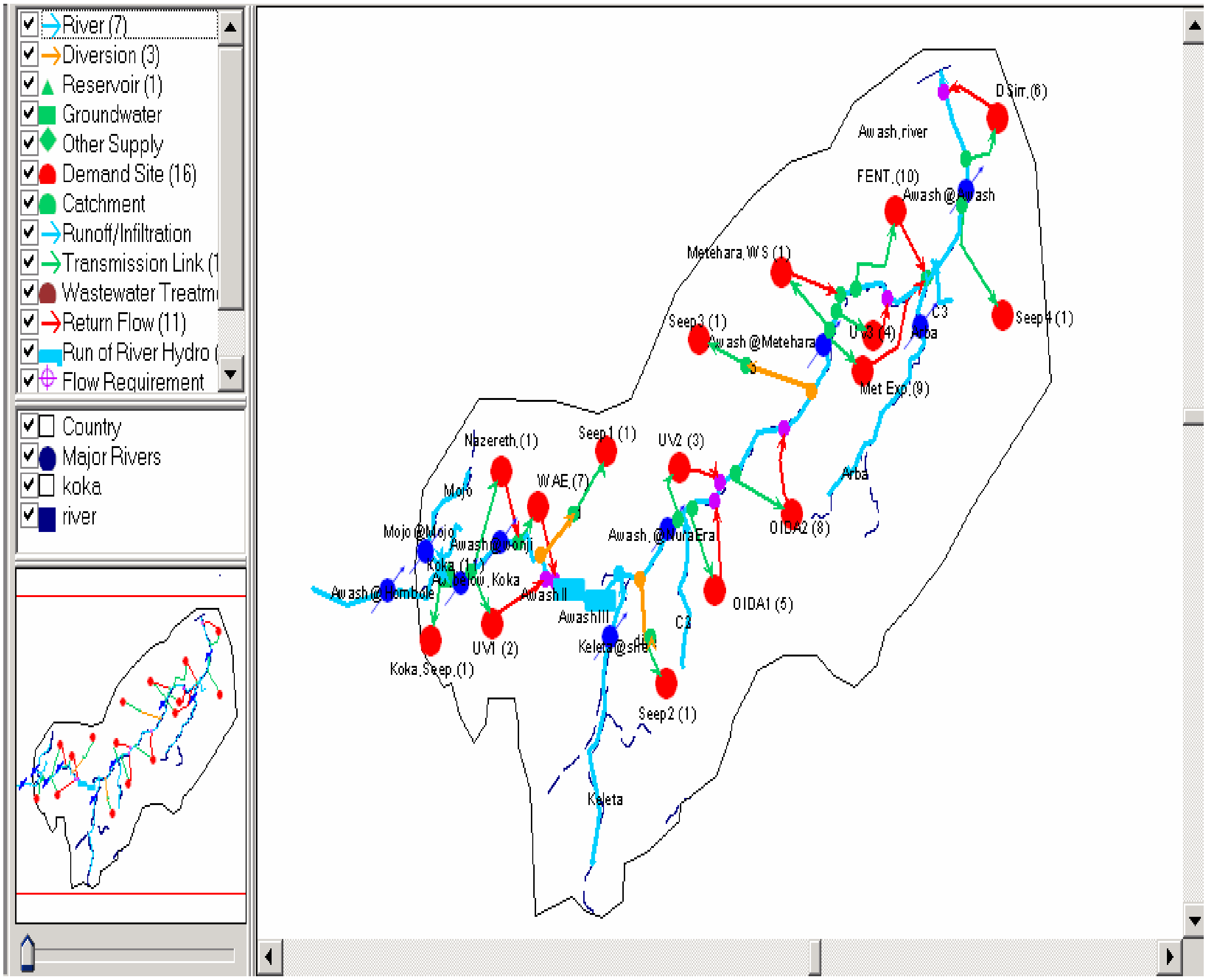


Figure 5-1 Schematic of the study area with respect to Future scenario

5.2. Definitions of some terms used in the study

1. Schematic:

It is the starting point for all activities in WEAP and the spatial lay out which visualize the physical features of water supply and demand system. It contains nodes that represent physical components such as a demand site waste water treatment plants, ground water aquifer, reservoir or special

λοχατιον αλονγ α ριϖερ. Νοδεσ αρε λινκεδ βψ λινεσ τηατ ρεπρεσεντ τηε νατ υραλ
ορ μαν−μαδε ωατερ χονδυιτσ συχη ασ ριϖερ χηαννελσ, χαναλσ ανδ πιπελιν εσ.
Τηεσε λινεσ ινχλυδε ριϖερσ,διϖερσιονσ ανδ τρανσμισσιον λινκσ ανδ ρετυρν φλοω
λινκσ.Τηε σχηεματιχ οφ τηισ στυδψ ισ σηοων αβοϖε ιν φιγυρε 5.1.

2. Δεμανδ σιτε:

Ιτ ισ τηε σετ οφ ωατερ υσερσ τηατ σηαρε α πηψσιχαλ διστριβυτιον σψστ εμ, τηατ
αρε αλλ ιν δεφινεδ ρεγιον ορ τηατ σηαρε αν ιμπορταντ ωιτηδραωαλ συππλ ψ ποιντ.Ιν ουρ στυδψ τηερε αρε 16 δεμανδ νοδεσ ινχλυδινγ σεεπαγε λοσσε σ ασ ονε δεμανδ νοδε ιν φυτυρε σχανριο ανδ 12 δεμανδ νοδεσ ιν χυρρεντ σχεναριο. Μανψ σμαλλ δεμανδ σιτεσ ωιτη σιμιλαρ χηαραχτεριστιχσ αρ ε λυμπεδ τογετηερασ ονε νοδε φορ σιμπλιχιτψ το μαναγε τηε στυδψ ανδ ωιτη τηε φλεξιβιλιτψ
συππορτ οφ τηε μοδελ. Τηερε αρε μορε τηαν 15 σμαλλ σχαλε ΟΙΔΑ ιρριγατι ον
σιτεσ ωηιχη αρε αμαλγαματεδ ασ α νοδε ΟΙΔΑ1.Φουρ υνδερ ιμπλεμεντεδ
ΟΙΔΑ σμαλλ σχαλε ιρριγατιον σιτεσ φορ φυτυρε σχεναριο αρε λυμπεδ ασ ΟΙΔΑ2
νοδε.

3. Current account

Ιτ ισ τηε βασε ψεαρ φορ τηε μοδελ ανδ τηε σψστεμ ινφορματιον (ε.γ. δεμαν δ δατα, συππλψ δατα). Ιτ ισ τηε σταρτινγ ψεαρ φορ αλλ σχεναριοσ το βε βυιλτ ανδ ρεφλεχτσ τηε οβσερϖεδ οπερατιον οφ τηε σψστεμ ασ δατα σψσ τεμ.Τηε χυρρεντ αχχουντ ψεαρ τακεν φορ τηισ στυδψ ισ 2008 φορ σχενα ριο Ι ανδ 2010 φορ
σχεναριο ΙΙ.

4. Σχεναριοσ:

Σχεναριοσ αρε σελφ□χονσιστεντ στορψ λινεσ οφ ηοω α φυτυρε σψστεμ μιγητ εϖολϖε οϖερ τιμε ιν α παρτιχυλαρ σοχιοεχονομιχ σεττινγ ανδ υνδερ α
παρτιχυλαρ σετ οφ πολιχψ ανδ τεχηνολογψ χονδιτιονσ.Αλλ σχεναριοσ σ ταρτ φρομ α χομμον ψεαρ (χυρρεντ αχχουντ δατα) ανδ εξπλορε ποσσιβλε χηανγεσ το τηε σψστεμ ιν τηε φυτυρε ψεαρσ αφτερ α χυρρεντ αχχουντ ψεαρσ.

5. Reference scenario

Ιτ χαρριεσ φορωαρδ τηε χυρρεντ αχχουντ δατα ιν το τηε προφεχτ ψεαρ περιοδ
σπεχιφιεδ ανδ σερϖεσ ασ α ποιντ οφ χομπαρισον φορ οτηερ σχεναριο σ ιν ωηιχη οτηερ χηανγεσ μαψ βε μαδε το τηε σψστεμ δατα. Τηε ρεφερε νχε
σχεναριο περιοδ σελεχτεδ φορ τηισ στυδψ ρανγεσ φρομ 2008 το 2038. Τηι σ
εναβλεσ το σεε τηε χονδιτιονσ οφ τηε σιμυλατιονσ φορ τηε χομινγ 30 ψεα ρσ.

6. Annual actively level:

Ιτ ισ τηε αμουντ οφ ωατερ ρεθυιρεδ αννυαλλψ φορ εαχη δεμανδ σιζε τηε αρε
οφ λανδ βεινγ ιρριγατεδ αννυαλλψ.Τηε αρεα οφ ιρριγαβλε λανδ σπεχιφιε δ ιν
εαχη ιρριγατιον δεμανδ σιτε ανδ τηε ποπυλατιον σιζε το χονσυμε τηε υρβ ανωατερ (Ναζερετη ανδ Μετεηαρα) αρε χονσιδερεδ ασ αννυαλλψ αχτι ϖελψ
λεϖελσ ιν τηισ αναλψσισ

7. Annual water use rate:

Τηε αϖεραγε ωατερ χονσυμπτιον περ υνιτ οφ αχτιϖιτψ λεϖελ ινδιχατι νγ τηε νετ ϖολυμε οφ ωατερ ρεθυιρεδ φορ εαχη ηεχταρε οφ λανδ αννυα λλψ. Τηε
αννυαλ ωατερ υσε ρατε ισ εστιματεδ ιν μ^3/ηα φορ ιρριγατιον δεμανδσ α νδ μ^3/περσον φορ υρβαν ωατερ συππλψ.

8. Monthly variation:

Τηε ϖαριατιον οφ ωατερ δεμανδ φρομ μοντη το μοντη εξπρεσσεδ ασ περχενταγε οφ αννυαλ ωατερ υσεδ ιν εαχη μοντη. Φρομ τηε προποσεδ ιρριγατιον σχηεδυλε εαχη μοντη ηασ ιτσ οων ιρριγατιον ρεθυιρεμεντ τ ηατ
αγγρεγατε το φορμ τηε αννυαλ δεμανδ.Τηε ωατερ δεμανδ οφ εαχη μοντη ισ εξπρεσσεδ ασ α περχενταγε οφ τηε αννυαλ δεμανδ ωασ υσεδ ιν τηε αναλψσισ.

9. Return flow:

Ιτ ισ τηε παρτ ωατερ τηατ ισ νοτ χονσυμεδ ατ α δεμανδ σιτε ανδ χαν βε

διρεχτεδ το ονε ορ μορε δεμανδ σιτεσ, ωαστε ωατερ τρεατμεντ πλαντσ, συρφαχε ορ γρουνδ ωατερ νοδεσ. Ρετυρν φλοωσ αρε σπεχιφιεδ ασ α περχενταγε οφ ουτφλοωσ.Τηε ρετυρν φλοωσ φορ αλλ δεμανδ νοδε αρε σπ εχιφιεδ ιν Αννεξ Χ οφ τηισ στυδψ.

10. Transmission link:

Τηεσε αρε λινεσ τηατ χαρρψ ωατερ φρομ λοχαλ ανδ ριϖερ συππλιε σ το δεμανδ σιτεσ, συβφεχτ το λοσσεσ ανδ πηψσιχαλ χαπαχιτψ, χοντραχτυ αλ ανδ οτηερ χονστραιντσ. Ιτ ισ αλσο ρεθυιρεδ το βρινγ ωατερ το σατ ισφψ ιρριγατιον ρεθυιρεμεντσ ιν χατχημεντσ τηατ ηαϖε βεεν ινδιχατεδ το ηαϖε ιρριγα τιον.

11. Demand priority;

ΩΕΑΠ αλλοχατεσ ωατερ αχχορδινγ το τηε δεμανδ πριοριτψ ασσοχιατ εδ ωιτη εαχη δεμανδ σιτε. Τηε σιτε ωιτη ηιγηεστ πριοριτψ (λοωερ νυμβερ) γετ ωατερ φιρστ, φολλοωεδ βψ σιτεσ ωιτη λοωερ πριοριτιεσ (ηιγη νυμβε ρ) ασ αϖαιλαβιλιτψ αλλοωσ.

12. Reservoir Physical data:

- **Στοραγε χαπαχιτψ**:ισ τηε τοταλ χαπαχιτψ οφ τηε ρεσερϖοιρ, τηε ηιγηεστ ϖαλυε προϖιδεδ ασ τηε μαξιμυμ ϖολυμε–ελεϖατιον χυ ρϖε ωασ υσεδ. Τηισ μαψ ηασ α δραω βαχκ φρομ εχονομιχ ανδ ωατερ στοραγε περσπεχτιϖεσ ανδ νεεδσ φυρτηερ οπτιμιζατιον το δετερ μινε τηε οπτιμαλ στοραγε σιζε.
- **Ινιτιαλ στοραγε**: ιτ ισ τηε αμουντ οφ ωατερ στορεδ ιν τηε ρεσερϖ οιρ ατ τηε βεγιννινγ οφ τηε φιρστ μοντη οφ τηε χυρρεντ αχχουν τ ψεαρ σιμυλατιον.
- **ςολυμε ελεϖατιον χυρϖε**: ιτ ισ τηε ρελατιονσηιπ βετωεεν ρεσερϖ οιρ ϖολυμε (Μμ^3) ανδ ελεϖατιον (μ).
- **Νετ εϖαπορατιον**: ιτ ισ εξπρεσσεδ ιν μοντηλψ βασισ το ρεπρεσεν τ τηε διφφερενχε βετωεεν εϖαπορατιον ανδ πρεχιπιτατιον ον τηε ρεσερϖοιρ συρφαχε.

5.3. Data organization for WEAP model

5.3.1. Demand side requirements

ΩΕΑΠ μοδελ ρεθυιρεσ τηε σιμπλιφιεδ ανδ σοπηιστιχατεδ δατα φρομ βοτη δεμαν
δ
ανδ συππλψ σιδεσ. Ιν τηισ στυδψ τηερε αρε α τοταλ οφ 9 σιμπλιφιεδ ιρριγατιον δεμανδ νοδεσ ανδ 2 υρβαν ωατερ συππλψ δατα ρεθυιρεμεντσ τηατ αρε αμαλγαμ ατεδ φρομ
τωο ανδ μορε σμαλλ δεμανδ σιτεσ ασ περ το γεογραπηιχαλ αππροαχη ανδ οτη ερ
σιμιλαρ παραμετερσ αμονγ τηεμ. Τηε δεμανδ νοδεσ ωιτη μορε ωατερ αβστραχτιονσ αρε ιρριγατιον δεμανδσ.

Σομε οφ τηε δατα συχη ασ ωατερ θυαλιτψ δεμανδ μαναγεμεντ ανδ εχονομιχ αναλψσισ ρεθυιρεδ ιν ΩΕΑΠ μοδελ αρε νοτ χονχερνεδ ιν τηισ στυδψ, σο τηατ τηε
δατα ισ νοτ οργανιζεδ φορ συχη παραμετερσ. Τηε παραμετερσ υσεδ ιν ουρ χασε σ αρε τηε αχτιϖιτψ λεϖελ οφ εαχη δεμανδ σιτε, αννυαλ ωατερ υσε ανδ μοντηλψ ϖαριατιονσ, χονσυμπτιον ανδ λοσσεσ ανδ ρετυρν φλοωσ αφτερ χονσυμπτιονσ φ ρομ δεμανδ σιδεσ.
Τηε αχτιϖιτψ λεϖελσ φορ ιρριγατιον δεμανδ σιτεσ αρε τηε νετ ηεχταρεσ οφ λανδ υνδερ
ιρριγατιον, σπεχιφιεδ φορ εαχη νοδε.Μοντηλψ ωατερ δεμανδ (Μμ^3) ισ εστιματεδ φρομ τηε χροπ ωατερ ρεθυιρεμεντ δατα σηοων ιν Αννεξ Β ανδ Χ.

Ωατερ Δεμανδ φορ ιρριγατιον (μ^3) =ΝΙΡ (μμ)∗Ιρριγατεδ αρεα (ηα) ∗10

ΝΙΡ= νετ ιρριγατιον ρεθυιρεμεντ

Τοταλ ωατερ αβστραχτιον (μ^3) = ΓΙΡ (μμ) ∗ Ιρριγαβλε αρεα ∗10

ΓΙΡ= ΝΙΡ/η

ΓΙΡ = Γροσσ ιρριγατιον ρεθυιρεμεντ

η= Οϖερ αλλ εφφιχιενχψ

Μοντηλψ ϖαριατιον ισ τηε ρατιο οφ ωατερ τηατ ισ αβστραχτεδ ιν σπεχιφιχ μοντ η το τηε
αννυαλ αβστραχτιον. Τηε συμ οφ τοταλ μοντηλψ ϖαριατιονσ ισ εθυαλ το 1.Τηε ρετυρν
φλοω φορ αλλ οφ τηε δεμανδ σιτεσ ισ ασσυμεδ το βε 10% το 20% οφ τηε τοταλ αβστραχτεδ ωατερ. Χονσυμπτιον ισ αλσο ασσυμεδ ωιτη ρεσπεχτ το ρετυρν φλοω σ.

Χονσυμπτιον (%) = 100%−Ρετυρν φλοω (%)

Αμονγ τηε ελεϖεν δεμανδ νοδεσ σεϖεν αρε αχτιϖε το χυρρεντ ψεαρ. Τηε χυρρεντ

ιρριγατιον αβστραχτιονσ φρομ δεμανδ σιδε αρε ασσυμεδ το βε χονσταντ φορ τηε

ρεφερενχε σχεναριοσ. Τηε ωατερ δεμανδ οφ υρβαν ωατερ συππλψ σιτεσ ωιλλ βε ινχρεασεδ ωιτη τηειρ ποπυλατιον γροωτη ρατε.Φορ αλλ οφ τηε δεμανδ νοδεσ τηε σιμπλιφιεδ δατα ασ ΩΕΑΠ ρεθυιρεμεντ ισ σηοων ιν Αννεξ Χ.

5.3.2. Supply and Resources data

Τηε συππλψ ανδ ρεσουρχεσ δατα ινχλυδεσ τηε ριϖερ νοδε συχη ρεσερϖοιρσ, ρυνοφφ ριϖερ ηψδροποωερ ανδ στρεαμ φλοω γαυγεσ.Κοκα ρεσερϖοιρ ισ τηε ονλψ ωατερ
ρεγυλατιον ιν τηε στυδψ αρεα ανδ αλλ τηε σαλιεντ δατα ρεθυιρεδ φορ ΩΕΑΠ αρε
οργανιζεδ ιν Αννεξ Χ.
Τηερε αρε τωο ρυν οφφ ριϖερ ηψδροποωερ σχημεσ (Αωαση ΙΙ ανδ Αωαση ΙΙΙ) βε λοω Ωονφι στατε φαρμ ατ Μελκασα. Τηε σιλεντ δατα ρεθυιρεδ φορ τηε μοδελ ισ δεριϖεδ
φρομ Τηε Βοοκερ Τατε (2003) στυδψ ρεπορτ .

Αφτερ τηε ρελεασε οφ Κοκα δαμ τηερε αρε σιξ γαυγεδ στατιονσ ιν τηε στυδψ αρε α.
Τηε ηιστοριχαλ δατα οφ 43 ψεαρσ οβταινεδ φρομ ΜοΩΡ ισ υτιλιζεδ φορ τηισ στυ δψ.
Τηε ραω δατα ισ σηοων ιν τηε ταβλεσ οφ Αννεξ Α.ΩΕΑΠ νεεδσ τηε μοντηλψ ινπ υτ οφ δατα τηατ αρε οργανιζεδ ιν ιν χηρονολογιχαλ ορδρερ.

5.3.3. Scenarios of the study area.

Τηε ιρριγατιον δεμανδσ τηατ ηασ δεπενδεδ ον τηε ωατερ συππλψ ρελεασεδ φρομ τηε Κοκα ρεσερϖοιρ χαν βε χατεγοριζεδ υνδερ τηε φολλοωινγ μαιν σχεναριοσ φορ τηε σακε τηισ στυδψ.

Σχεναριο Ι :

Τηε πρεσεντ (2007/2008) Ωατερ αβστραχτιονσ ρατε οφ τηε βασιν

Κοκα δαμ ισ τηε ονλψ ωατερ σουρχε οφ αλλ τηε χυρρεντ ιρριγατιον δεϖελοπ μεντσ οφ Αωαση ριϖερ βασιν. Αχχορδινγ το ΩΩΔΣΕ (2005) Αωαση ριϖερ μ οδελινγ
ρεπορτ αλλ τηε ιρριγατιον σχημεσ εξχεπτ Ωονφι αρεασ (Υς1) , ωιλλ φαχ ε α

σεϖερ ωατερ σηορταγε αφτερ 2038.Ηαλχροω (1989) προποσεδ τηε ραισινγ οφ Κοκα βψ τηρεε μετερσ ανδ ΚΒΡ (2003) ηασ συγγεστσ οπτιονσ οφ μιτιγα τινγ

σεδιμεντατιον προβλεμσ. Τηεψ αλσο ρεχομμενδεδ τηε χονστρυχτιον οφ εαρτ η

δαμ φυστ βετωεεν τηε εξιστινγ δαμ οφ Κοκα ανδ τηε ηψδροποωερ.

Τηε τοταλ ιρριγατεδ αρεα χυρρεντλψ βψ αβστραχτινγ ωατερ φρομ Κοκα ρελε ασε ισ

αβουτ 56 500 ηα.Νεαρλψ ηαλφ οφ τηε ιρριγατιον αρεα ισ λοχατεδ ιν τηε υππ ερ

Αωαση ϖαλλεψ.

Ταβλε 5.1. Τηε ιρριγατιον αβστραχτιονσ ανδ Φαρμ σιζε υνδερ σχεναριο Ι

Δεμανδ Φαρμσ	Δεμανδ Νοδε Ναμε	Ιρριγαβλε αρεα
Ωονφι σατε φαρμ ανδ Ουτ γροωερσ	Υς1	7054
Νυρα Ερα χομπλεξεσ	Υς2	8753
Μετεηαρα Αβαδιρ στατε φαρμσ	Υς3	12896
Σμαλλ σχαλε σχηεμεσ οφ Υππερ Αωαση ςαλλεψ	ΟΙΔΑ1	1607
Λοωερ ανδ Μιδδλε ςαλλεψ Φαρμσ	ΔΣΙρρ	26191
	Τοταλ	**56 501**

Σχεναριο 2 :

Τηε χυρρεντ ιρριγατιον αβστραχτιονσ πλυσ Μοδερατε ιρριγατιον εξπανσιονσ ιν τηε υππερ ϖαλλεψ ανδ Φενταλε Προφεχτ

Ιν τηισ σχεναριο ιν αδδιτιον το τηε εξιστινγ ιρριγατιον λεϖελ τηερε συβσταν τιαλ

χοϖεραγε ιρριγατιον ιμπλεμεντατιονσ ανδ εξπανσιονσ χονσιδερεδ. Εϖεν τηου γη τηε φυτυρε δεϖελοπμεντσ οφ λοωερ Αωαση ϖαλλεψ ιρριγατιονσ αρε νοτ μα ινλψ δεπενδεδ ον Κοκα ρελεασε,ηιγη εξπανσιονσ ιρριγατιον δεϖελοπμεντσ αρε γοι νγ ον Υππερ Αωαση ϖαλλεψ.Τηε σχηεμεσ υνδερ τηισ σχεναριο αρε προποσεδ το βε φυνχτιοναλ ατ 2010.
Νεαρ Μετεηαρα στατε φαρμ,τηε Φενταλε ιντεγρατεδ ιρριγατιον προφεχτ ισ χυ ρρεντλψ υνδερ χονστρυχτιον. Τηε τοταλ ιρριγατεδ αρεα υνδερ τηισ προφεχτ ισ 18 130 ηα ανδ ιτ ισ προποσεδ το βε οπερατιοναλ ατ 2010.Αφτερ 2011 τηε τοταλ ιρριγατιο ν σιζε τηατ δεπενδσ ον Κοκα ρελεασε χουλδ βε 95155ηα.ηεσε σηοω τηατ ωιτη ιν φιϖ ε ψεαρσ (δεσιγν & χονστρυχτιον περιοδσ) τηε ιρριγατιον σιζε οφ τηε συβ βασι ν δουβλεσ,σινχε μοστ οφ τηε σχηεμεσ ηαϖε βεεν σταρτεδ ατ 2005 ανδ αλλ ωιλλ βε φυνχτιοναλ ατ 2010.

Τηεσε ινχλυδεσ τηε Ωονφι αρεα εξπανσιονσ (Ωελενχηιτι, Βοφα, Δοδοτα), Μετεηαρα εξπανσιονσ ανδ α νυμβερ οφ σμαλλ σχαλε ιρριγατιον ιρριγατιον σ τηατ αρε ονστρυχτινγ βψ ΟΙΔΑ.

Ταβλε 5.2; Μαφορ ιρριγατιον αβστραχτιονσ ανδ τηειρ σιζε υνδερ σχεναριο ΙΙ

□ **Δεμανδ Φαρμσ**	**Δεμανδ Νοδε Ναμε**	□**Ιρριγαβλε αρεα (ηα)**
Ωονφι Αρεα	ΩΑΕ	16715
Εξπανσιονσ	□	□
Σμαλλ σχαλε ιρριγατιονσ	ΟΙΔΑ2	609
Μετεηαρα Εξπανσιον	ΜΕΤ εξ	3200
□Φενταλε Ιρριγατιον	Φεντ	18130
	Συμ	38654
Χυρρεντ Ιρριγατιονσ λεϖελ	ΣΧ Ι	56501
□ Συβ τοταλ		**95,156**

ΣΧ Ι: σχεναριο Ι

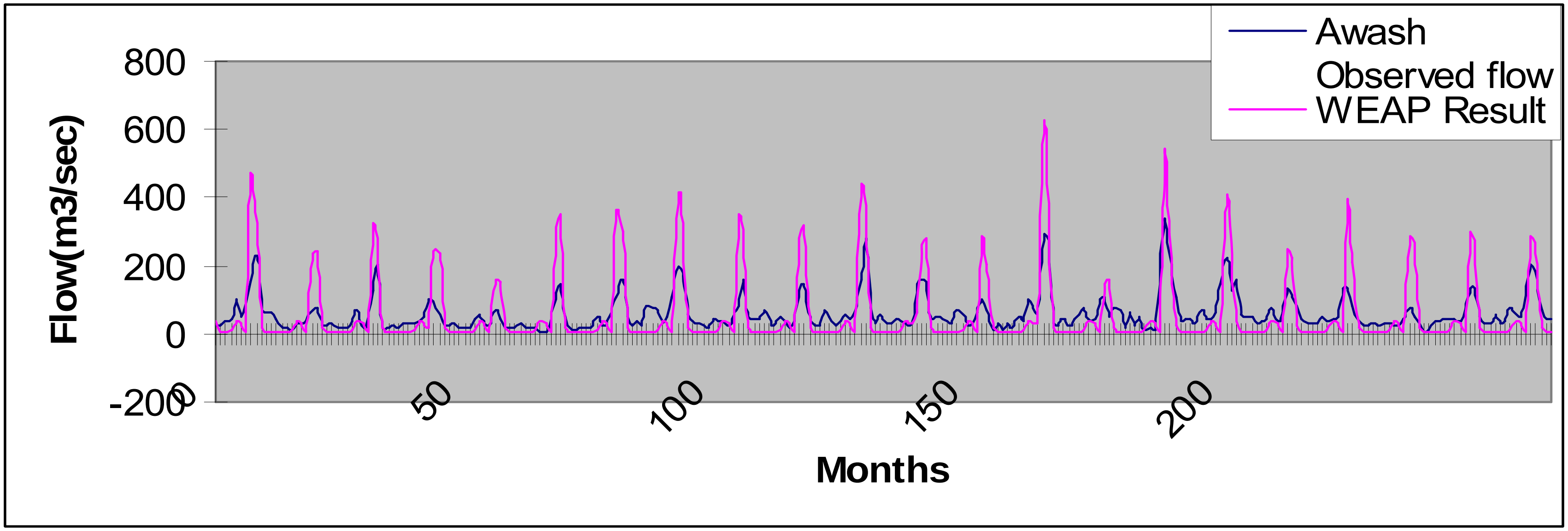
5.4. Μοδελ Χαλιβρατιον ανδ ςαλιδατιον

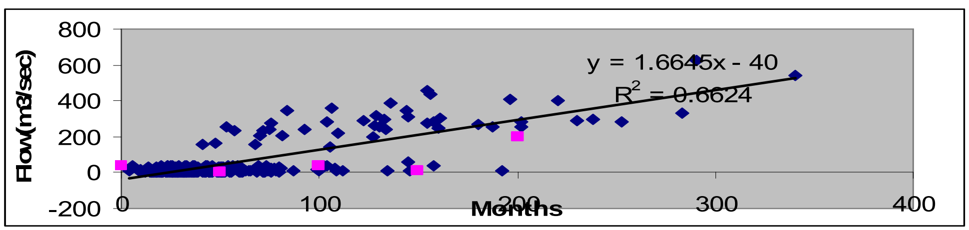
Αωαση Ριϖερ μαιν στρεαμ ισ γαυγεδ ατ α νυμβερ οφ ιμπορταντ λοχατιονσ. Ιν τη ε

Υππερ Αωαση ϖαλλεψ ασ παρτ οφ τηε στυδψ,τηερε αρε αβουτ νινε γαυγεδ στα
τιονσ. Τηεσε στατιονσ αρε διϖιδεδ ιν το α νυμβερ οφ συβ−χατχημεντσ ιν ορδερ τ
ο χαρρψ ουττηε αναλψσισ οφ ρυν οφφ χοντριβυτιονσ. Τηε συβ−χατχημεντσ ιν
χλυδε βοτη τηοσε
γαυγεδ ανδ υνγαυγεδ χατχημεντσ. Ιν γενεραλ τηε υνγαυγεδ χατχημεντσ αρε
ειτηερ σμαλλ ορ ιν αρεασ ωηερε ρυν−οφφ κνοων το βε ρελατιϖελψ λοω.

Ιν τηισ παρτιχυλαρ στυδψ σινχε τηε μοδελ ισ χαρριεδ ουτ βψ τωο ρεφερενχε σχε
ναριοσ, βοτη χαλιβρατιον ανδ ϖαλιδατιον προχεσσεσ αρε περφορμεδ ιν τηε χυρ
ρεντ σχεναριοσ. Τηε φιρστ σχεναριο δεσχριβεσ τηε σιτυατιον οφ χυρρεντ ωατε
ρ αβστραχτιον φορ 2007/ 2008 λεϖελ οφ ιρριγατιον ανδ οτηερ δεμανδσ. Ιτ αλσο ε
ϖαλυατεσ τηε αϖαιλαβιλιτψ οφ
ωατερ ρεσουρχεσ ανδ συππλιεσ ασ περ το τηε χυρρεντ ρατε αβστραχτιον ωιτ
η ουτ
αλτερινγ τηε δεμανδσ.

Τηε σεχονδ σχεναριο σηοωσ τηε χονδιτιον ωηατ μιγητ ηαππεν, ιφ αλλ τηε ονγοι
νγ ωιλλ βε οπερατεδ ανδ υτιλιζε τηε αϖαιλαβλε ωατερ ρεσουρχεσ.Βοτη οφ τηεσε
σχεναριοσ ασσυμεσ τηατ τηε εξιστινγ σιτυατιον οφ Κοκα ρεσερϖοιρ μαναγεμεν
τ ωιτη χονσταντ αννυαλ γροωτη ρατε οφ σεδιμεντατιον.Τηε στατιονσ το βε χαλι
βρατεδ ιν τηισ στυδψ ισ; φλοω μεασυρεδ ατ Αωαση ριϖερ ατ Αωαση στατιον .
Τηε χαλιβρατιον προχεσσ ισ δονε βψ υτιλιζινγ 50% οφ στρεαμ φλοω δατα (1983–
2004) ανδ ςαλιδατιον ισ δονε βψ υσινγ 30% (1992–2004) δατα. Τηε οβσερϖεδ α
νδ
σιμυλατεδ στρεαμ φλοω δατα ατ στατιον ισ αναλψσεδ φορ τηε χυρρεντ σψστεμ.





Φιγυρε 5.2. Μοντηλψ σιμυλατεδ ανδ Οβσερϖεδ Φλοω οφ Αωαση ατ αωαση (1983–2004)

Χηαπτερ 6
Results and Discussion
6.1 Γενεραλ οβσερϖατιονσ

- Τηε ρεσυλτσ ιν τηισ μοδελ αρε περφορμεδ βψ σεπαρατινγ τηε ωατερ δεμανδ χονδιτιονσ ιν το τωο σχεναριοσ.Τηε χυρρεντ ωατερ αβστραχτιον σιτεσ αρε χονσι δερεδ ασ σχεναριο Ι ανδ τηε νεω ιμπλεμεντινγ σχηεμεσ ωιτη τηειρ εστιματεδ ωατερ δεμανδσ ιν χομβινατιον οφ χυρρεντ αβστραχτιον αρε χονσιδερεδ α σ σχεναριο ΙΙ. Τηε χυρρεντ αχχουντ φορ σχεναριο Ι ανδ σχεναριο ΙΙ αρε 2008 α νδ 2010 ρεσπεχτιϖελψ. Τηε ρεφερενχε σχεναριοσ αρε χονσιδερεδ ασ 2009– 2038 ανδ 2011–2038 φορ χυρρεντ σχεναριο ανδ φυτυρε σχεναριο ρεσπεχτιϖελψ. Τηερε ισ ρελατιϖελψ νο ηιγη ρισκ οφ ωατερ δεφιχιτ αχχορδινγ το τηε αναλψσι σ οφ σχεναριο Ι χομπαρεδ το τηε σχεναριο ΙΙ.

- Ιφ τηε ωατερ αβστραχτιον χοντινυεσ ασ α χυρρεντ ρατε (ιν τηε σχεναριο Ι) τηε δελιϖερεδ ωατερ το αλλ δεμανδ σιτεσ ωιλλ δεχλινε φρομ 1,018.9 ΜΜΧ (ατ 2008) τ ο 681.3 ΜΜΧ (ατ 2038) φορ εξιστινγ ιρριγατιον φαρμσ, ωηερε ασ τηε υνμετ δεμανδ ρισεσ φρομ 56.3 ΜΜΧ (ατ 2008) το 561.1 ΜΜΧ (ατ 2038).Ιν τηισ σχεναριο μορε τηαν 50% οφ ιρριγατιον ωατερ δεφιχιτ ισ οβσερϖεδ ον δοων στρεαμ ιρριγατιονσ

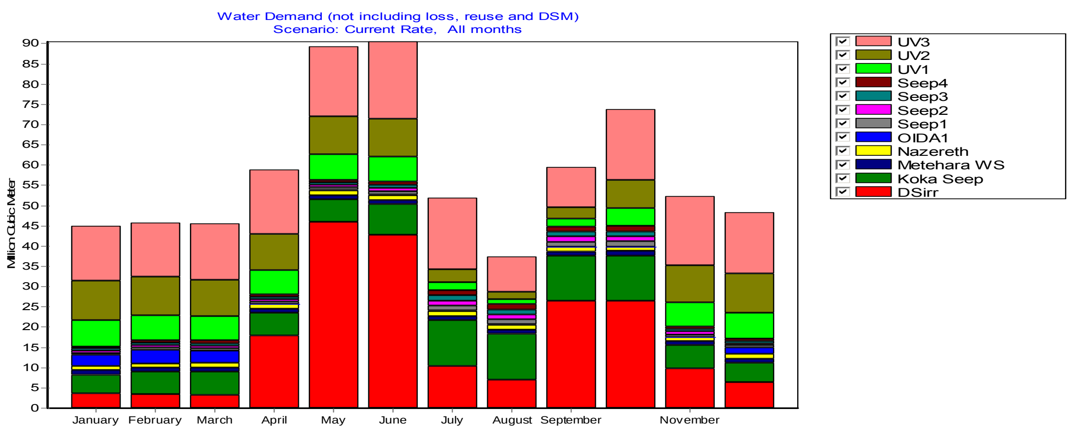
  ναμελψ ιν τηε μιδδλε ανδ λοωερ εξιστινγ ιρριγατιον φαρμσ. Φρομ τηε αναλψζεδ ρεσυλτσ, τηε συππλψ ρεθυιρεμεντ ατ 2038 ωιλλ βε υνμετ βψ 46 %.

- Ιν τηε σχεναριο ΙΙ, ωηερε τηε εξιστινγ ιρριγατιον σιζε νεαρλψ δουβλεσ ιν τηε σ υβ– βασιν, τηε χριτιχαλ ωατερ δεφιχιτ οβσερϖεδ ιν τηε ρεφερενχε σχεναριο φορ αλλ ι ρριγατιον φαρμσ. Ιν τηισ σχεναριο τηε αμουντ οφ συππλψ δελιϖερεδ ωιλλ δεχλινε φρομ 1,437 ΜΜΧ το 994.1 ΜΜΧ φρομ ψεαρσ 2010 το 2028 ρεσπεχτιϖελψ. Βυτ τηε υνμετ δεμανδ ρισεσ φρομ 345.2ΜΜΧ το 925 ΜΜΧ (φρομ 2010 το 2038).Τηε αναλψσισ σηοωσ τηατ τηε συππλψ ρεθυιρεμεντ ατ 2038 ωιλλ βε υνμετ βψ 51%.

Τηε εντιρε ωατερ ρεθυιρεμεντσ ανδ μοντηλψ σιμυλατεδ ωατερ δεμανδσ οφ βοτη σχεναριοσ αρε σηοων βελοω ιν ιν ταβλεσ 6.1 ανδ 6.2 ωιτη ρεσπεχτιϖε φιγυερσ. ωατερ αλλοχατιον πριοριτιεσ οφ εαχη δεμανδ νοδε αρε δισχυσσεδ ατ 6.4.

Table 6.1.Water Demand (not including loss, reuse and DSM) scenario I **In Mm3**

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSirr	3.5	3.4	3.2	17.9	45.9	42.9	10.4	7	26.4	26.4	9.8	6.5	203.3
Metehara WS	1	0.9	1	1	1	1	1	1	1	1	1	1	12.2
Nazereth	1.2	1	1.2	1.1	1.2	1.1	1.2	1.2	1.1	1.2	1.1	1.2	13.6
OIDA1	2.6	3.2	3.1	0	0.1	0.2	0.2	0.1	0	0	0	1.7	11.3
UV1	6.4	6.2	6	5.9	6.2	6.1	2	1.2	1.9	4.5	6	6.4	59.1
UV2	9.8	9.4	9	9	9.4	9.3	3.1	1.9	2.8	6.9	9.1	9.8	89.5
UV3	13.5	13.4	13.9	15.9	17.4	19.1	17.8	8.6	9.9	17.4	17	15	179
Sum	38	37.5	37.4	50.8	81.2	79.7	35.7	21	43.1	57.4	44	41.6	568



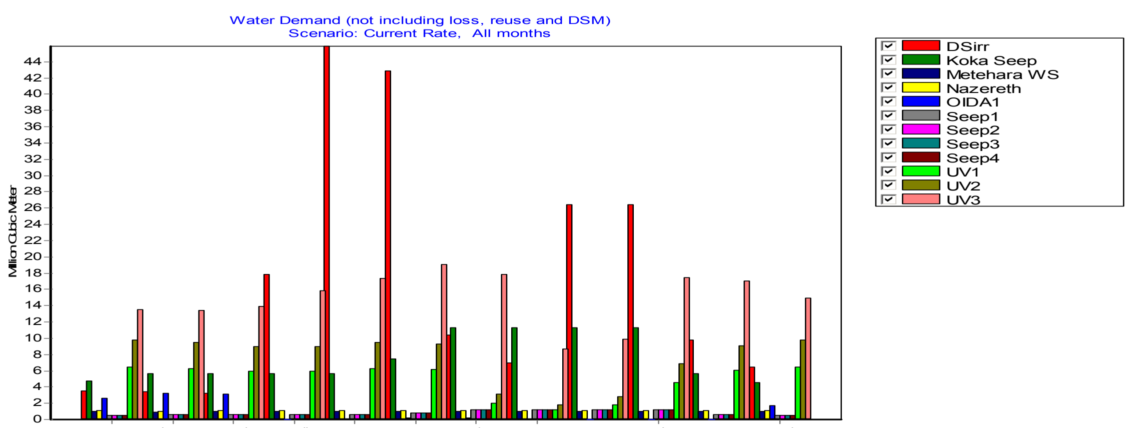


Figure.6.1 Monthly average demands (with out including losses) of Current demands

The total net amount of water required to meet the irrigation demands of all the sites up to 2028 is 568Mm^3. May and June months with maximum demand requirements than other months. The middle and lower valley irrigation sites in combination needs more water in each month.

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSirr	3.5	3.4	3.2	17.9	45.9	42.9	10.4	7	26.4	26.4	9.8	6.5	203.3
FENT	15.3	13.8	8.3	17	20.9	29.3	21.8	29.7	29.8	25.1	20	21.4	252.5
Koka Seep	4.7	5.6	5.6	5.6	5.6	7.5	11.3	11.3	11.3	11.3	5.6	4.6	89.9
Met Exp	2.5	0.4	1.3	2.4	2.2	2.9	4.1	4.8	4	2.8	2.1	1.8	31.2
Metehara Ws	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	10.4
Nazereth	1.1	1	1.1	1	1.1	1	1.1	1.1	1	1.1	1	1.1	12.6
OIDA1	2.6	3.2	3.1	0	0.1	0.2	0.2	0.1	0	0	0	1.7	11.3
Seep4	0.5	0.6	0.6	0.6	0.6	0.8	1.3	1.3	1.3	1.3	0.6	0.5	10
UV1	6.4	6.2	6	5.9	6.2	6.1	2	1.2	1.9	4.5	6	6.4	59.1
UV2	9.8	9.4	9	9	9.4	9.3	3.1	1.9	2.8	6.9	9.1	9.8	89.5
UV3	13.5	13.4	13.9	15.9	17.4	19.1	17.8	8.6	9.9	17.4	17	15	179
WAE	17.4	15	15.9	15.5	19	18.5	2.2	0.3	8.4	18.6	19	18.4	168.5
All Others	2.8	3.4	3.4	1.9	1.9	2.6	3.8	3.8	3.8	3.8	1.9	2.4	35.5
Sum	81.1	76.4	72.4	93.6	131.4	141	79.9	72	101	120	93	90.4	1,152.80

Table: 6.2. Water demand (with out losses in MMC) with respect to future scenario

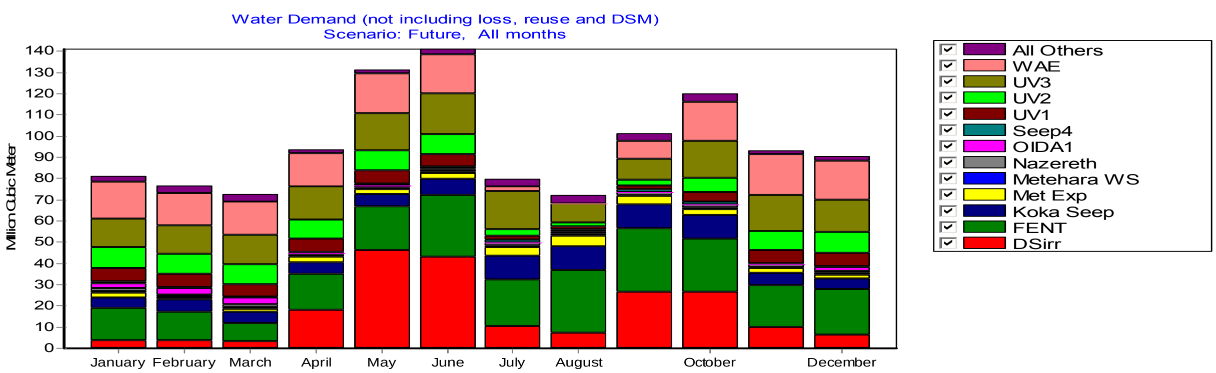


Figure 6.2 .a .Monthly average water demands of future scenario

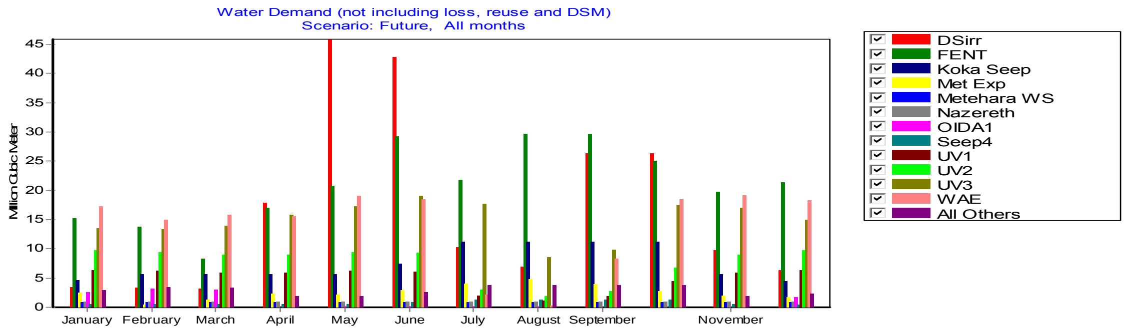


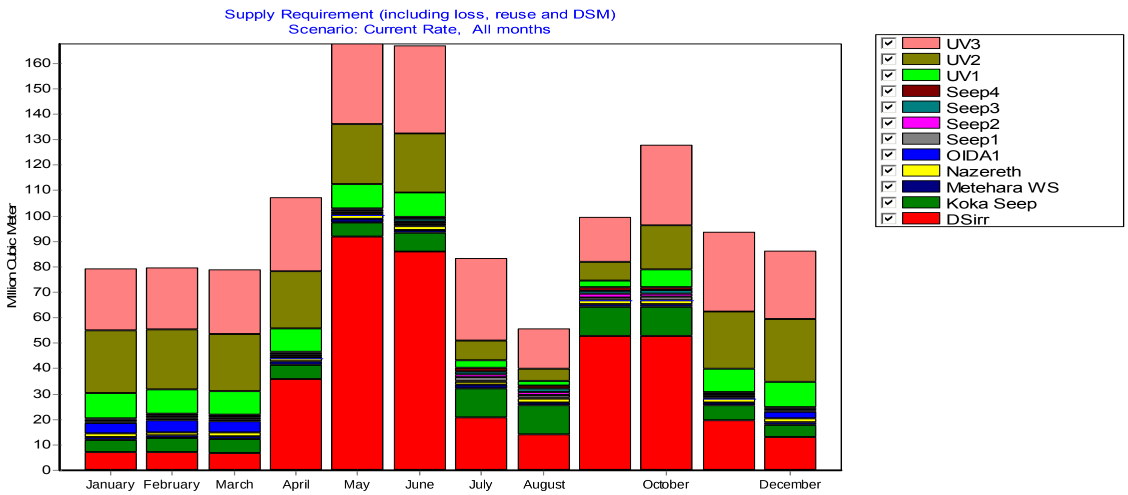
Figure 6.2.b. Monthly average demands of each site with respect to Future scenario

From the above simulated results the total water demand for future scenario in nearly twice of the current scenario. Fentale integrated irrigation project is the future demand site with maximum water demand next to down stream irrigations. The above computed water demand did not include the over losses of the particular systems.

The entire supply requirements including losses for the current and future scenarios will be described in the tables 6.3 and 6.4 with their respective figures below.

Table 6.3. Supply required including losses (MMC) in Current scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSIrr	7	6.8	6.5	35.7	92	86	20.8	14	52.8	52.8	19.7	12.9	406.6
Koka Seep	4.7	5.6	5.6	5.6	5.6	7.5	11.3	11.3	11.3	11.3	5.6	4.6	89.9
Metehara WS	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	15.3
Nazereth	1.4	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	17
OIDA1	3.8	4.6	4.4	0	0.2	0.3	0.3	0.2	0	0	0	2.5	16.2
Seep1	0.5	0.6	0.6	0.6	0.6	0.8	1.3	1.3	1.3	1.3	0.6	0.5	10
Seep2	0.5	0.6	0.6	0.6	0.6	0.8	1.3	1.3	1.3	1.3	0.6	0.5	10
Seep3	0.5	0.6	0.6	0.6	0.6	0.8	1.3	1.3	1.3	1.3	0.6	0.5	10
Seep4	0.5	0.6	0.6	0.6	0.6	0.8	1.3	1.3	1.3	1.3	0.6	0.5	10
UV1	9.9	9.6	9.2	9.1	9.6	9.4	3.1	1.9	2.9	7	9.3	9.9	91
UV2	24.4	23.6	22.6	22.6	24	23	7.7	4.6	7.1	17.2	22.7	24.4	223.8
UV3	24.5	24.4	25.3	28.9	32	35	32.4	15.7	18	31.7	31	27.2	325.5
Sum	79.2	79.6	78.8	107	168	167	83.3	55.5	99.7	127.7	93.5	86.4	1,225.20



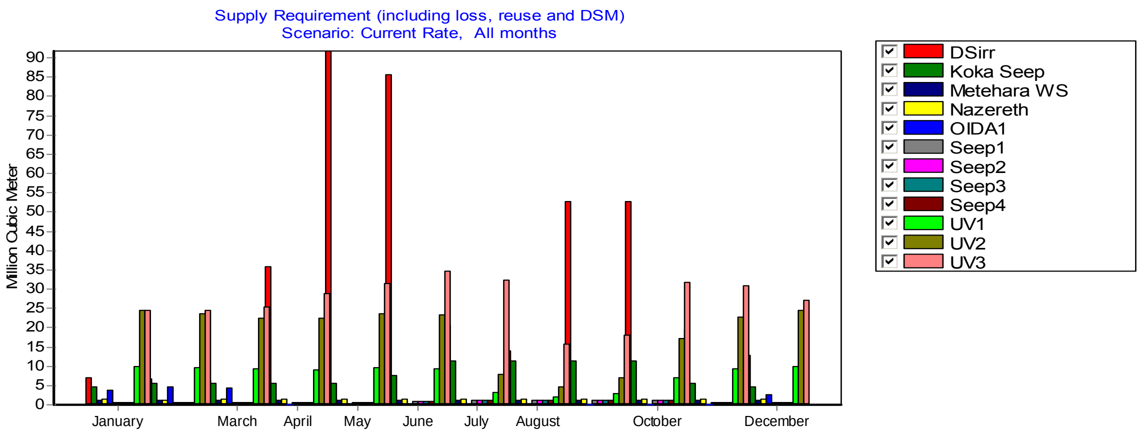


Fig: 6.3. Supply required including losses (MMC) in Current scenario

Table 6.4. Supply Requirement (including losses in MMC) for future scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DSirr	7	6.8	6.5	35.7	91.8	85.7	20.8	14	52.8	52.8	19.7	12.9
FENT	25.5	23	13.9	28.4	34.8	48.8	36.4	49.6	49.7	41.8	33.1	35.7
Met Exp	4.2	0.7	2.2	3.9	3.7	4.8	6.8	7.9	6.7	4.6	3.5	3
Metehara WS	1.1	1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Nazereth	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
OIDA1	4.4	5.4	5.1	0	0.2	0.3	0.3	0.2	0	0	0	2.9
UV1	9.9	9.6	9.2	9.1	9.6	9.4	3.1	1.9	2.9	7	9.3	9.9
UV2	24.4	23.6	22.6	22.6	23.6	23.2	7.7	4.6	7.1	17.2	22.7	24.4
UV3	24.5	24.4	25.3	28.9	31.6	34.7	32.4	15.7	18	31.7	31	27.2
WAE	23.2	20.1	21.2	20.7	25.4	24.7	2.9	0.4	11.1	24.7	25.6	24.5

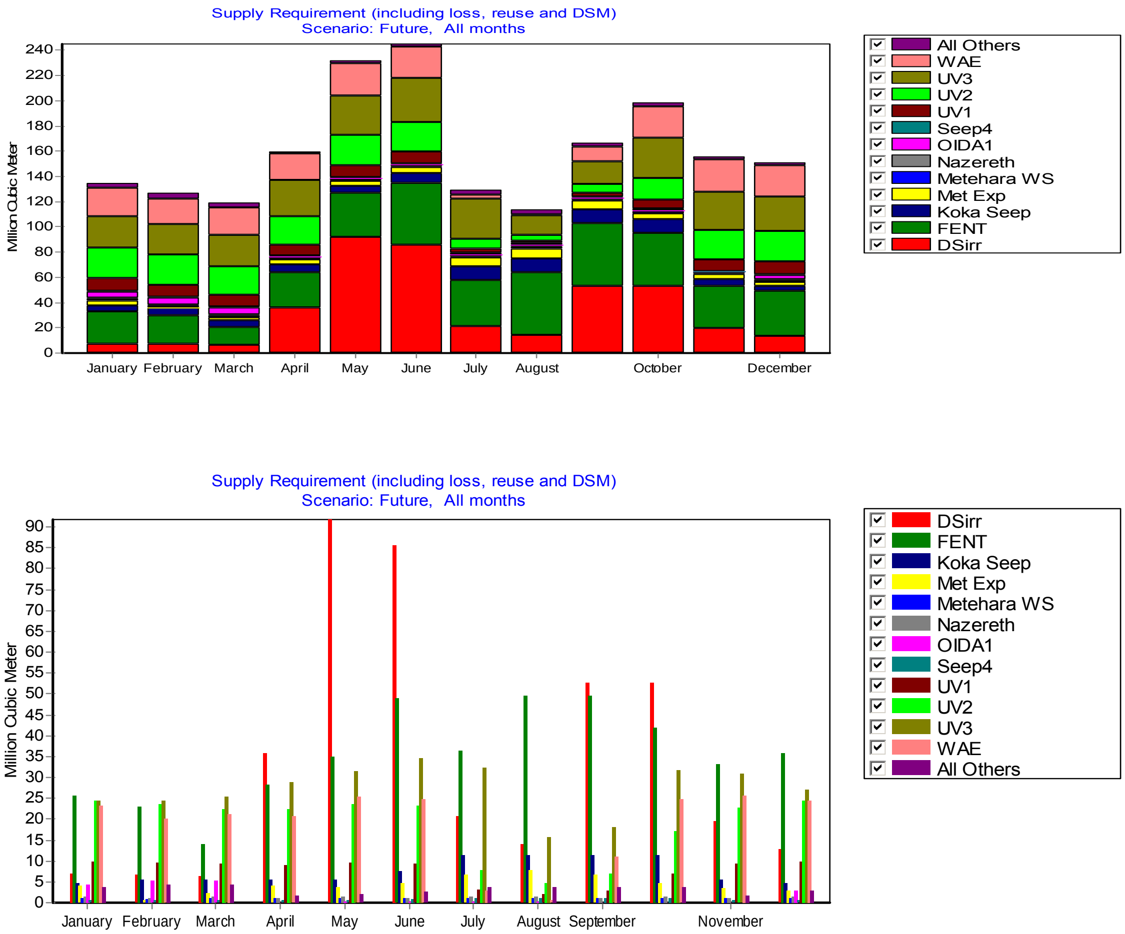


Figure 6.4 Supply Requirement for future scenario

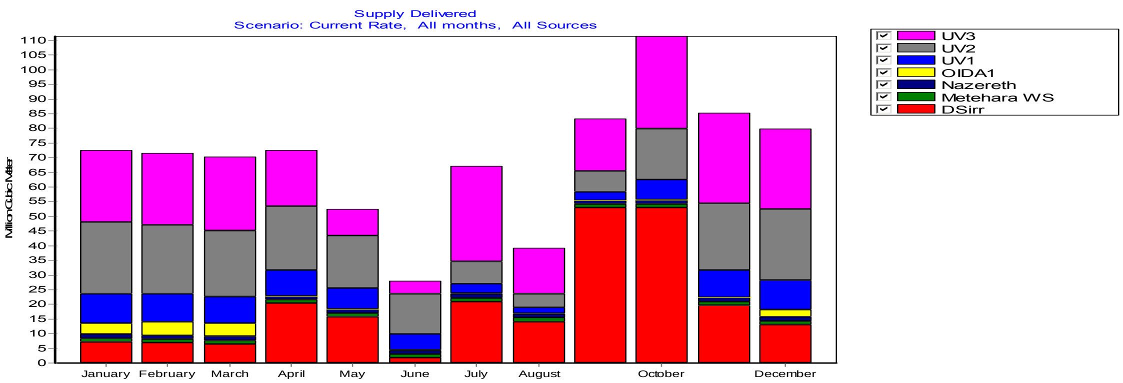
6.2. Allocation of Delivered Supplies

As stated in the previous topic there is no high risk of water shortage if the demand condition continues with the current abstraction rate. According to this analysis there is no full required supply coverage for both the current and future scenarios. The delivered amount of water is allocated for each demand site as per to the required quantity and the priority set in the model, in spite of some portion of unmet rate.

The delivered quantity of water with demand site allocations for both the current and future scenarios are described in tables 6.5 and 6.6 with there respective figures

Table 6.5 Monthly average supply delivered for each demand site in current scenario (Mm^3)

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSIrr	7	6.8	6.3	20.2	15.6	1.6	20.8	14	52.8	52.8	20	12.9	230.6
Metehara WS	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	15.3
Nazereth	1.4	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	17
OIDA1	3.8	4.6	4.4	0	0.1	0	0.3	0.2	0	0	0	2.5	15.8
UV1	9.9	9.6	9.2	8.8	7.2	5.5	3.1	1.9	2.9	7	9.3	9.9	84.3
UV2	24.4	23.6	22.6	21.7	17.7	13.6	7.7	4.6	7.1	17.2	23	24.4	207.5
UV3	24.5	24.4	25.1	19.1	9.2	4.3	32.4	15.7	18	31.7	31	27.2	262.7
Sum	72.4	71.5	70.2	72.4	52.4	27.8	67	39.2	83.4	112	85	79.8	833.1



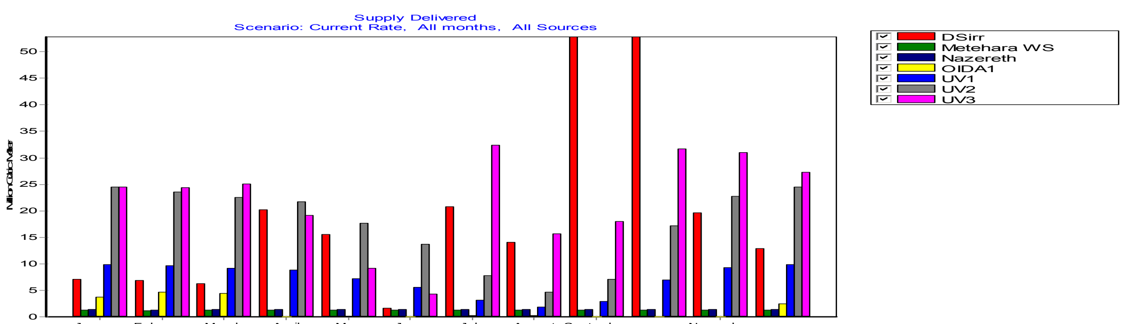


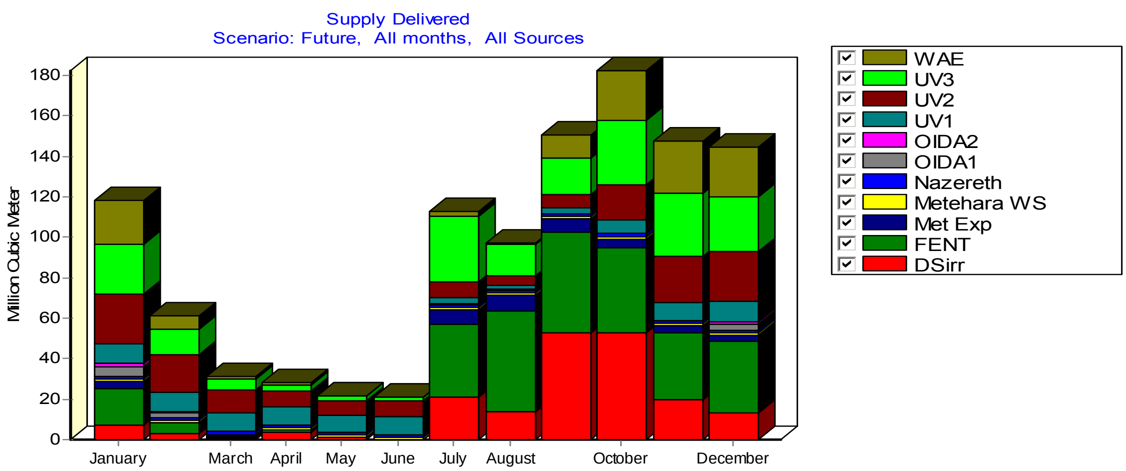
Figure 6.5 Monthly average supplies delivered for all demand sites in current scenario

From the analysis high quantity of water is delivered from months September to December with pick delivery at October, where as the less quantity of water is delivered at June.

Table 6.6 Monthly average supplies delivered for each demand site in future scenario.

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSIrr	7	2.9	0.7	3.3	1.1	0.1	20.8	14	52.8	52.8	20	12.9	188.2

FENT	18.2	5.5	0.7	1.5	0	0	36.4	49.6	49.7	41.8	33	35.7	272.2
Met Exp	3.8	0.2	0.1	0.2	0	0	6.8	7.9	6.7	4.6	3.5	3	36.8
Metehara WS	1.1	1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	13
Nazereth	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	15.7
OIDA1	4.4	2.3	0.3	0	0	0	0.3	0.2	0	0	0	2.9	10.4
OIDA2	1.9	0.8	0.1	0	0	0	0.1	0.1	0	0	0	1.4	4.5
UV1	9.9	9.6	8.9	8.5	8.2	8.8	3.1	1.9	2.9	7	9.3	9.9	88.1
UV2	24.4	18.6	11.1	7.8	7.5	7.8	7.7	4.6	7.1	17.2	23	24.4	161.1
UV3	24.5	12.4	5.5	3	2.3	1.7	32.4	15.7	18	31.7	31	27.2	205.6
WAE	21.7	6.5	1.1	1.1	0	0	2.9	0.4	11.1	24.7	26	24.5	119.7
Sum	118.3	61.1	31	27.9	21.5	20.8	113	97.1	151	182	147	145	1,115.30



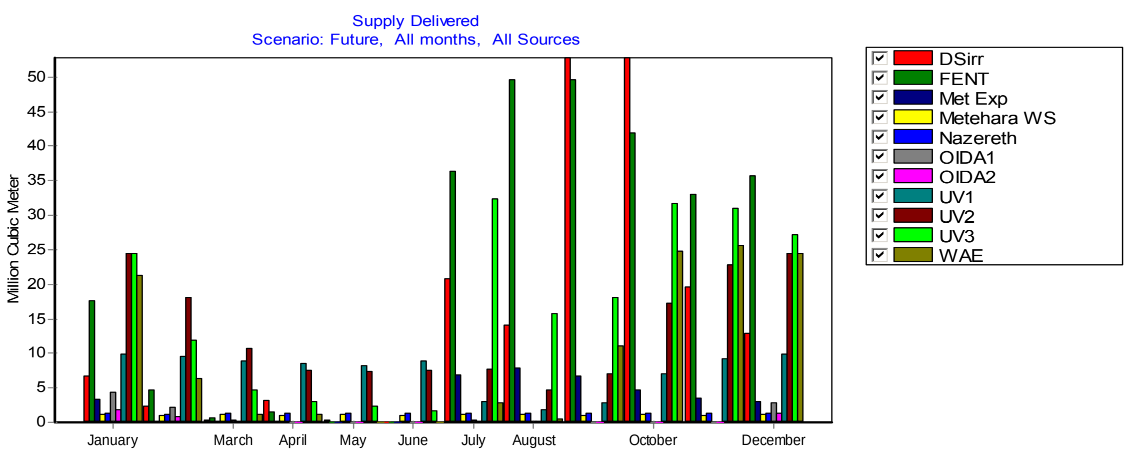


Figure 6.6 Monthly average supplies delivered at all demand site for the future scenario

In the future scenario from the analysis high quantity of water is delivered at months September to December with pick at October. The minimum amount of water is delivered at months march to June with maximum unmet demand.

6.3 Unmet Demand and supply Overages

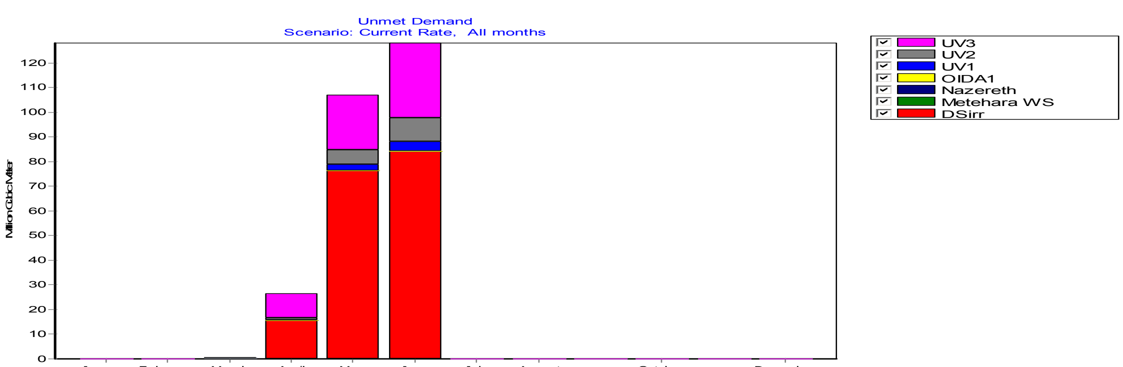
Unmet demand is the supply requirement that is not met. In other words unmet demand is the differences between supplies require and supply delivered at particular demand site and time duration. In this analysis the significant quantity of unmet demand is observed in each demand site the urban water supplies, because of their low requirement and high priority.

Among the total water requirement of the current scenario (25,728.5 MMC) 5,354.25 MMC is unmet from years 2008 to 2028 for all cumulative demands. Similarly in the future scenario analysis among the total water requirement (36,688MMC) , the unmet demand observed is 13,028.9MMC for the years 2010 to 2028.

Table 6.7 and 6.8 with their respective figures below show the average monthly unmet demands of all sites in the current and future scenarios respectively.

Table 6.7 Monthly average unmet demands for each demand site (MMC) with respect to current scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSIrr	0	0	0.2	15.5	76.2	84.1	0	0	0	0	0	0	176.1
Metehara WS	0	0	0	0	0	0	0	0	0	0	0	0	0
Nazereth	0	0	0	0	0	0	0	0	0	0	0	0	0
OIDA1	0	0	0	0	0.1	0.2	0	0	0	0	0	0	0.4
UV1	0	0	0	0.4	2.4	3.9	0	0	0	0	0	0	6.7
UV2	0	0	0	0.9	5.9	9.6	0	0	0	0	0	0	16.4
UV3	0	0	0.2	9.7	22.4	30.4	0	0	0	0	0	0	62.7
Sum	0	0	0.5	26.5	107.1	128	0	0	0	0	0	0	262.2



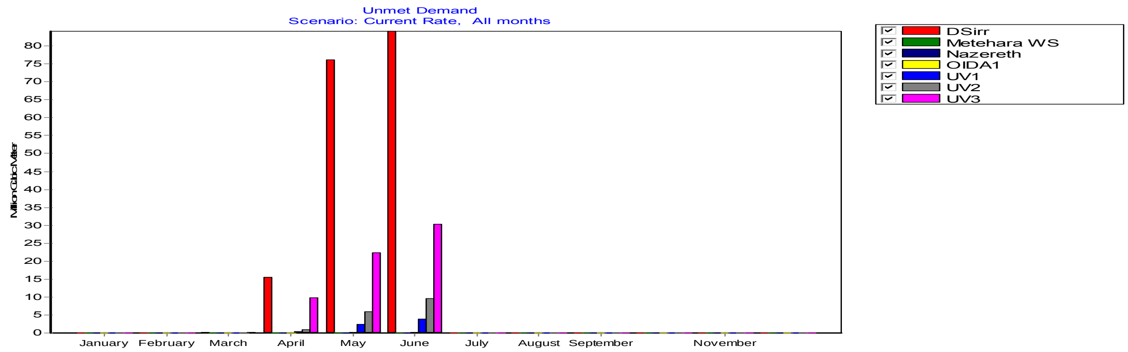
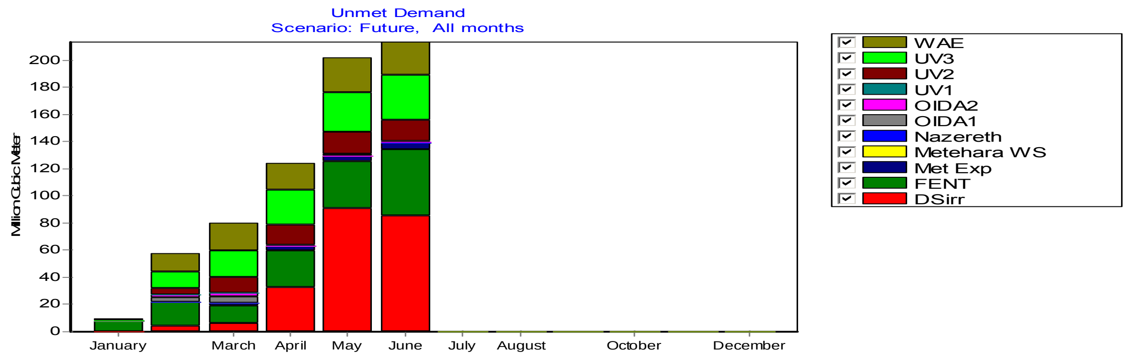


Figure 6.7: Monthly average Unmet Demands in Current Scenario

Form the analysis high unmet demand is observed in months May and June. More than 50% of the unmet demand is observed for the down stream irrigation sites at months April, May and June.

Table 6.8 Monthly average Unmet demands for each demand site with respect to Future scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
DSIrr	0	3.9	5.8	32.4	90.7	85.6	0	0	0	0	0	0	218.4
FENT	7.3	17.6	13.2	26.9	34.8	48.8	0	0	0	0	0	0	148.6
Met Exp	0.4	0.5	2.1	3.7	3.7	4.8	0	0	0	0	0	0	15.2
Metehara WS	0	0	0	0	0	0	0	0	0	0	0	0	0
Nazereth	0	0	0	0	0	0	0	0	0	0	0	0	0
OIDA1	0	3.1	4.9	0	0.2	0.3	0	0	0	0	0	0	8.5
OIDA2	0.2	1.8	2.4	0	0.1	0.1	0	0	0	0	0	0	4.6
UV1	0	0	0.3	0.6	1.4	0.6	0	0	0	0	0	0	2.9
UV2	0	5	11.4	14.7	16.1	15.5	0	0	0	0	0	0	62.7
UV3	0	12	19.9	25.8	29.3	33	0	0	0	0	0	0	119.9
WAE	1.5	13.6	20.1	19.6	25.4	24.7	0	0	0	0	0	0	104.9
Sum	9.5	57.3	80	123.8	201.8	213	0	0	0	0	0	0	685.7



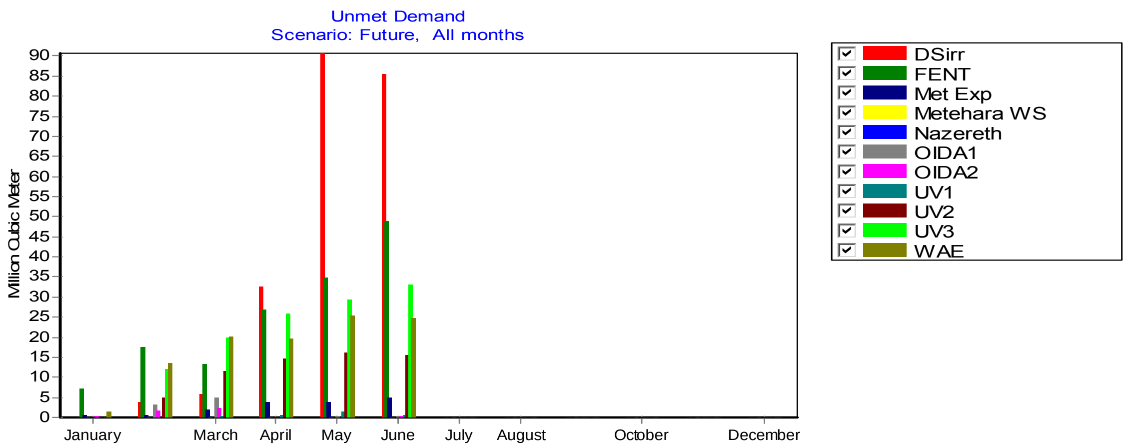


Figure 6.8 Monthly average unmet demands for each demand site with respect to Future scenario

Δεμανδ σιτε χοϖεραγε ισ τηε περχενταγε οφ ρεθυιρεμεντ τηατ ισ μετ. Ιν τηισ αναλψσ ισ τηε φυλλ χοϖεραγε ισ οβσερϖεδ φορ υρβαν ωατερ συππλιεσ (Ναζερετη ανδ μετεηαρα ωατερ συππλψ) φορ τηε εντιρε μοντησ ιν βοτη σχεναριοσ. Ιν χυρρεντ σχεναριο τηε ποορ δεμανδ σιτε χοϖεραγε ισ οβσερϖεδ φορ δοων στρεαμ ιρριγατιονσ ατ Μαψ ανδ ϑυνε.Τηεσε αρε τηε μοντησ ωιτη ηιγη δεμανδ ρεθυιρεμεντσ.Φρομ μοντησ ϑυλψ τοΦεβρυαρψ τηε χοϖεραγε ισ φυλλ φορ δεμανδ σιτεσ ιν χυρρεντ σχενα ριο.

Αχχορδινγ το τηε φυτυρε σχεναριο τηε χοϖεραγε φρομ μοντησ Φεβρυαρψ το ϑυνε ισ ρελατιϖλψ ποορ φορ αλλ τηε δεμανδ σιτεσ εξχεπτ υρβαν ωατερ συππλιεσ.Τηε αναλψ σισ
σηοωσ τηατ τηε χοϖεραγε φορ σομε δεμανδ σιτεσ ναμελψ; Φενταλε,Μετεηαρα, εξπαν σιον ανδ ωονφι αρεα εξπανσιονσ ατ μοντησ Μαψ ανδ ϑυνε αρε νιλ.Φρομ τηε μοντησ ϑυλψ το Δεχεμβερ τηε δεμανδ σιτε χοϖεραγε ισ φυλλ φορ αλλ σιτεσ.
Ταβλεσ 6.9 ανδ 6.10 σηοω τηατ τηε περχενταγε οφ δεμανδ σιτε χοϖεραγε φορ βοτη τηε χυρρεντ ανδ φυτυρε σχεναριοσ.

Table 6.9: Demand site coverage (%) for current scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DSIrr	100	100	96.7	56.6	17	1.9	100	100	100	100	100	100
Metehara WS	100	100	100	100	100	100	100	100	100	100	100	100
Nazereth	100	100	100	100	100	100	100	100	100	100	100	100
OIDA1	100	100	99.1	100	29.1	12.5	100	100	100	100	100	100
UV1	100	100	100	96.2	74.9	58.7	100	100	100	100	100	100
UV2	100	100	100	96.2	74.9	58.7	100	100	100	100	100	100
UV3	100	100	99.1	66.2	29.1	12.5	100	100	100	100	100	100

Table 6.10: Demand site coverage (%) for current scenario

Nodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DSIrr	100	43.2	10.5	9.3	1.2	0.1	100	100	100	100	100	100
FENT	71.3	23.7	5.3	5.3	0	0	100	100	100	100	100	100
Met Exp	89.5	31.6	5.3	5.3	0	0	100	100	100	100	100	100
Metehara WS	100	100	100	100	100	100	100	100	100	100	100	100
Nazereth	100	100	100	100	100	100	100	100	100	100	100	100
OIDA1	100	42.1	5.3	100	5.3	0	100	100	100	100	100	100
OIDA2	89.5	31.6	5.3	100	0	0	100	100	100	100	100	100
UV1	100	100	97.1	93.7	85.1	93.7	100	100	100	100	100	100
UV2	100	78.8	49.2	34.7	31.7	33.4	100	100	100	100	100	100
UV3	100	51	21.6	10.5	7.3	4.8	100	100	100	100	100	100
WAE	93.6	32.4	5.3	5.3	0	0	100	100	100	100	100	100

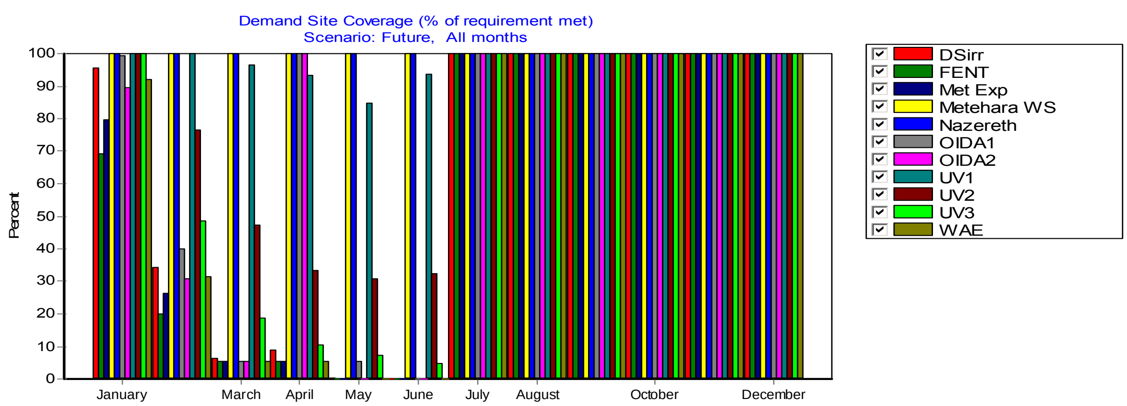


Figure 6.9. Demand site coverage for Future scenario

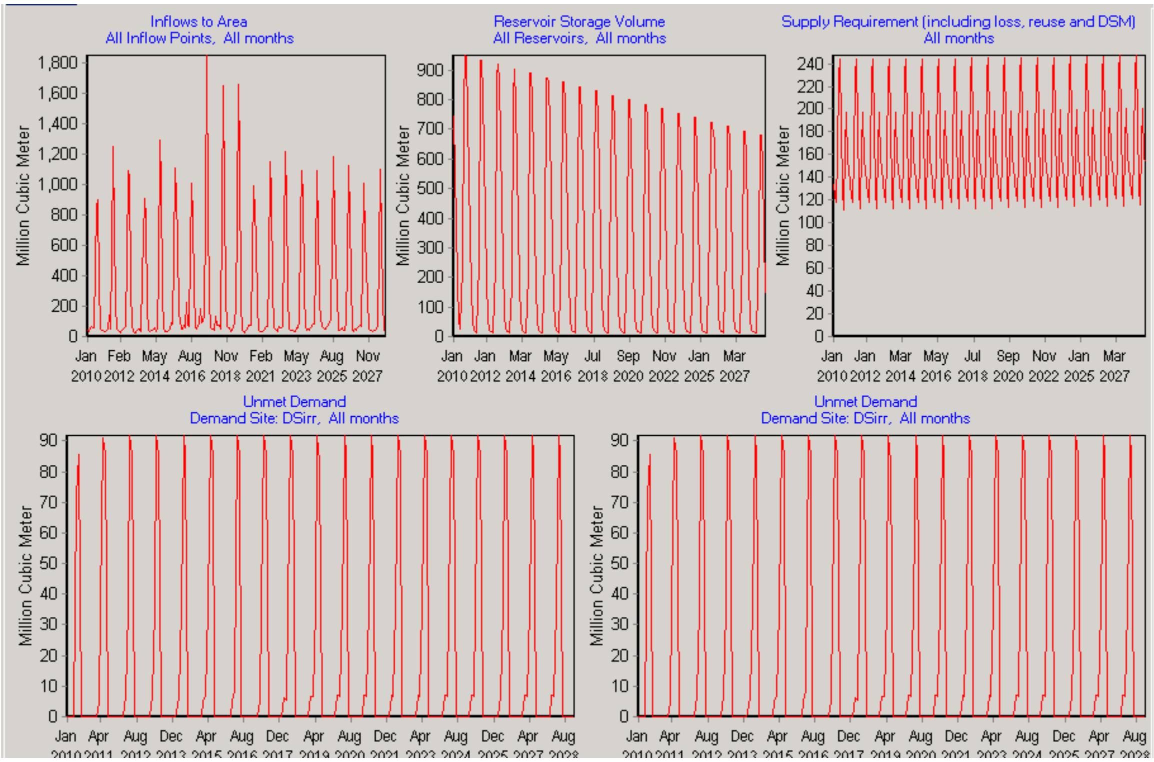


Figure 6.11 some overviews of scenario II

6.4 Water Availability Analysis

The main feature of this study is to show that the whether the delivered amount of water from Koka reservoir meets or not all the requirements of demand sites, sufficiently at all irrigation times. In spite of the variability of water requirement and priority set for each demand site by the user, the delivered and unmet amount of water is quite different for each demand nodes.

The overall requirement of water for each demand site depends up on, the size of irrigable land, water use management of the system, crops of the area and climatic factors. The above factors determine the quantity of water that is consumed in each demand site.

The second factor that determines the amount of water that is delivered for each demand site is the priority of allocation that is set by the user. In this study the demand site allocations are set in 5 priority orders for the scenario II and 4 priority orders for the current scenario. The priority is mainly set based on the following circumstances.

1. The urban water supply demands for different purposes such as domestic use, industrial uses and so on should get the first priority than the irrigation demands.

2. The close upstream irrigation sites should get similar priority and at the same time they may get prior order than the far downstream sites. This means not that all the available water is consumed by upstream sites.

3. The current (existing) demand should be prior than all the future implementing demand sites. Since the demand sites for future use should be studied and designed by assessing the water availability that supplies the intended future requirement or by putting other alternatives.

4. The reservoir site should get the last priority.

In the scenario I if the water abstraction continues in current rate, the total demand met coverage (2008-2038) will be 63%, where as the annual unmet demand coverage for the total existing demands will be 37%.For the main upper valley groups of irrigations UV1, UV2, and UV3 the total unmet coverage as per to scenario I will be 14%(UV1 and UV2) and 28% for UV3.

After the year 2038 (According to the Scenario I) the annual unmet demand coverage will increase to 41% for the cumulative demands. For UV1 and UV2 the annual unmet demand will rise to 47% after 2038 and 52% for UV3.

In the scenario II analysis (when all the ongoing irrigation demands operated) the total unmet demand (2010-2038) for all sites will be 43%.All the required water is met for urban water supplies with out any deficit. In the existing main irrigation schemes i.e. UV1, UV2, and UV3 the total annual unmet demands are 29%, 29%and 43% respectively. The highest unmet demand coverage is observed for downstream irrigations i.e. 56%.

After the 2038 the unmet demand coverage will be more than 48% for cumulative demand sites. The unmet demand site coverage for UV1,UV2 and UV3 at 2038 will be to 27%,27% and 55% respectively.

From the analysis if the current rate of irrigation continues up to 2038 by using Koka reservoir as a source the water is sufficient only for UV1,UV2,OIDA1 and urban sites (>75 dependably) and shortage is observed on others. After the commencement of on going projects all irrigation projects particularly after 2018.

Table 6.11. **Water availability analysis of 30 years from 2008-2038 With respect to Scenario I**

Nodes	***Total delivered MMC***	***Total Required MMC***	***Met Demand %***	***Unmet Demand %***
DSIrr	6,546.30	12,605.20	52	48
Metehara WS	1,093.40	1,094.50	100	0
Nazereth	781.9	782.4	100	0
OIDA1	395.8	501.3	79	21
UV1	2,416.30	2,820.00	86	14
UV2	5,946.00	6,938.80	86	14
UV3	7,268.70	10,089.70	72	28
Sum	24,448.40	38,858.20	63	37

Water availability analysis at year 2038 (As per to Scenario I)

Nodes	***Total delivered MMC***	***Total Required MMC***	***Met Demand %***	***Unmet Demand %***
DSIrr	175.3	406.6	43	57
Metehara WS	123.6	123.7	100	0
Nazereth	55.6	55.7	100	0
OIDA1	3	16.2	19	81
UV1	48.5	91	53	47
UV2	119.3	223.8	53	47
UV3	156.1	325.5	48	52
Sum	811.1	1,372.30	59	41

Table 6.12 .Water availability analysis from 2010-2038

With respect to Scenario II

Nodes	***Total supply Delivered MMC***	***Total Supply required MMC***	***Met Demand %***	***Unmet Demand %***
DSIrr	5,238.50	11,792.00	44	56
FENT	7,365.10	12,201.80	60	40
Met Exp	985.9	1,508.40	65	35
Metehara WS	860.1	860.6	100	0
Nazereth	674.1	674.5	100	0
OIDA1	232.4	547.1	42	58
UV1	1,885.00	2,638.00	71	29
UV2	4,639.50	6,491.20	71	29

UV3	5,374.50	9,438.70	57	43
WAE	2,849.00	6,513.60	44	56
Sum	30,104.10	52,665.90	57	43

Water availability analysis at Year 2038 (As per to Scenario II)

Nodes	***Total supply Delivered MMC***	***Total Supply required MMC***	***Met Demand %***	***Unmet Demand %***
DSIrr	163.5	406.6	40	60
FENT	210.6	420.8	50	50
Met Exp	29.5	52	57	43
Metehara WS	98	98	100	0
Nazereth	49.1	49.1	100	0
OIDA1	1.1	18.9	5.8	94
UV1	66.5	91	73	27
UV2	163.6	223.8	73	27
UV3	147.2	325.5	45	55
WAE	64.9	224.6	29	71
Sum	994	1910.3	52	48

Table 6.13. Average Dependability of the Demand sites at different year's interval with respect to Scenario II (%)

Sites	At 2010	from 2011-2018	From 2019-2028	From 2029-2038
DSIrr	61.3	47.8	44.2	41.6
FENT	80.1	67.9	61.3	52.6
Met Exp	83.8	72.4	65.9	58.5
Metehara WS	100	100	100	99.9
Nazereth	100	100	100	99.9
OIDA1	98.4	71.5	42.1	16.4
UV1	96	83	68.9	63.5
UV2	96	83.1	69	63.6
UV3	89.3	67.2	56.3	48.4
WAE	77.7	55.7	44.5	32.2
Sum	75.1	60.4	52.6	47.7

According to the above table at 2010 all the projects can get sufficient water (with dependability > 75%) except the down stream irrigations. For the down stream irrigations (Middle and Lower Valley farms) the deficit gap can be filled by the Kesem and Tendaho dam releases. From the years 2011 -2018 most of the farms can not get sufficient demand except the Wonji and Nura Hera farms. From the years 2019 -2038 all demand sites except urban water supplies will face sever water deficit according to the current management of Koka reservoir releases.

According to the results of HEC Model done on Awash basin by WWDSE in 2006, if the 2005 level of irrigation using Koka dam as a source continues through out the basin, the Koka release is sufficient (>75% dependability) for the current utilization of the basin up to 2028. However after 2028 except UV1 the other projects will face sever water shortage.

In the same study ,if the full expansion of the basin utilize water,Koka release is adequate only for Wonji and Tibila irrigations up to 2028.But other projects up to 2028 and after 2028 will face a sever water shortage.

According to Getenet Kebede study (2007) of optimum allocation of Koka reservoir the significant shortage will be observed after the commencement of new projects in 2010.Some irrigation projects will not get water at all nearly for seven consecutive ten days. No 100 % dependability is observed for any irrigation project after 2010.
In his study in the first scenario (2007-2016) the total of 2207.9 MMC and 220.8 MMC annual average unmet demands is observed. In second scenario (2017-2026) the total of 3906.2 MMC and annual average of 390.6 MMC unmet demand observed.

However in this study the average annual of 335 MMC unmet demand is observed in the first scenario and 784.4 MMC unmet demand is observed for second scenario.

CHAPTER 7
Summary, Conclusion and Recommendations

7.1. Summary

Τηε μαιν οβφεχτιϖε οφ τηισ ωατερ αλλοχατιον μοδελ ισ το κνοω τηε ιμπαχτ οφ τηε Υππερ ϖαλλεψ ιρριγατιον δεϖελοπμεντσ ανδ εξπανσιονσ ον τηε αϖαιλαβιλιτψ οφ ωα τερ ρεσουρχεσ οφ Αωαση βασιν.Τηε ωατερ δεμανδ οφ τηε εξιστινγ ανδ φυτυρε ιρριγατιον σ ιν τηε Υππερ Αωαση ϖαλλεψ αρε δεπενδ υπ ον τηε ρελεασε οφ Κοκα ρεσερϖοιρ ιν σπιτ ε οφ τηε δεχρεασινγ ιν στοραγε χαπαχιτψ οφ τηε ρεσερϖοιρ δυε το σεδιμεντατιον.

ΩΕΑΠ σοφτ ωαρε ισ υσεδ φορ μοδελινγ τηε ωατερ αλλοχατιον ιν τηε συβ−βασιν. Τηε μοδελ ισ δονε βασεδ ον 43 ψεαρσ φλοω δατα ιν γαυγεδ στατιονσ φρομ 1962 □ 2004 ιν α μοντηλψ−βασεσ. Φρομ τηε δεμανδ σιδε τηε ιρριγατιον ωατερ αβστραχτιον ιν εαχη δεμανδ σιτεσ αρε ανοτηερ ινπυτσ φορ τηε μοδελ.

Τηε Αωαση Ριϖερ βασιν ισ ονε οφ τηε ωελλ στυδιεδ ανδ υτιλιζεδ ριϖερ βασινσ ιν τηε χουντρψ. Τηε ριϖερ βασιν ισ διϖιδεδ ιν το 7 πηψσιογραπηιχ υνιτσ ορ συβ−βασινσ. Τ ηε στυδψ αρεα (Υππερ Αωαση ςαλλεψ) ισ ονε οφ τηε δεϖελοπεδ αρεασ βψ ϖαριουσ σμα λλ, μεδιυμ ανδ λαργε σχαλε ιρριγατιονσ. Ιρριγατιον βψ φαρ ισ τηε μαφορ ωατερ δεμανδ ανδ τηε υρβαν ωατερ συππλψ δεμανδσ αρε ινσιγνιφιχαντ.

Τηε αϖαιλαβιλιτψ οφ ωατερ ρεσουρχεσ φρομ Κοκα δαμ το τηε χονφλυενχε οφ Κεσσε μ ριϖερ ισ μαινλψ δεπενδ υπ ον τηε ρελεασε οφ Κοκα ρεσερϖοιρ. Τηε ινφλοω το Κοκα ρεσερϖοιρ ισ τηε μοδελεδ φλοωσ φρομ Μοφο Ριϖερ ανδ Αωαση φρομ Ηομβολε.Ιν τηε συβ−βασιν οφ τηε μαιν ριϖερ τηερε αρε σιξ γαυγεδ στατιονσ φρομ Ηομβολε το Αωασ η ατ Αωαση στατιον. Τηε μαφορ σιγνιφιχαντ γαυγεδ ινφλοωσ το τηε μαιν αωαση ρι ϖερ αρε Μοφο, Κελετα ανδ Αρβα ριϖερσ.

Ιν τηισ στυδψ τηε ιμπαχτσ αρε ασσεσσεδ βψ χατεγοριζινγ τηε προγραμσ ιν το τωο σχεναριοσ.

Σχεναριο Ι :Ιτ ισ μοδελεδ βψ ασσυμινγ ιφ τηε χυρρεντ (2007/2008) λεϖελ οφ ιρριγατιον χοντινυεσ υπ το 2038 ωιτη ουτ αδδιτιοναλ εξπανσιονσ.

Σχεναριο ΙΙ: Ιτ ισ μοδελεδ βψ χονσιδερινγ τηε χυρρεντ λεϖελ οφ ιρριγατιον ανδ
τηε νεω εξπανσιονσ ανδ δεϖελοπμεντσ υνδερ χονστρυχτιονσ βψ
ασσυμινγ τηε τηε χυρρεντ ψεαρ οφ 2010.

Υνδερ Σχεναριο Ι τηε οϖερ αλλ ιρριγατιον σιτεσ ιν τηε συβ−βασιν αρε αμαλγαματεδ ι
ν
το σεϖεν δεμανδ νοδεσ ωιτη τηε τοταλ αχτιϖιτψ λεϖελ οφ 56,501 ηα φορ ιρριγατιο
ν.
Αχχορδινγ το τηε ρεσυλτσ οφ τηισ στυδψ τηερε αρε σιγνιφιχαντ υνμετ δεμανδσ ορ
ιρριγατιον δεφιχιτ ιν βοτη τηε σχεναριο Ι ανδ σχεναριο ΙΙ. Ιφ τηε χυρρεντ ρατεσ οφ ιρ
ριγατιονπροχεεδ ωιτη ουτ αδδιτιοναλ εξπανσιονσ τιλλ 2038 τηε τοταλ οβσερϖεδ υνμε
τ δεμανδ
ωιλλ βε 10,383.5 Μμ^3 ανδ τηε αννυαλ αϖεραγε υνμετ δεμανδ ισ 335 Μμ^3 .Ωηερε ασ τη
ε τοταλ υνμετ δεμανδσ ωιλλ βε ινχρεασεδ ιν σχεναριο ΙΙ το 22,778.6 Μμ^3 αφτερ τηε
ιμπλεμεντατιον οφ τηε χονστρυχτινγ προφεχτσ υπ το 2038 ανδ τηε αϖεραγε αννυαλ
υνμετ δεμανδ ισ 784.4Μμ^3.

Τηε συππλψ ρεθυιρεμεντ φορ τηε χυρρεντ δεμανδ ρατε υπ το τηε στατεδ ψεαρ ισ
38,858 Μμ^3 , ωηερε ασ τηε φιγυρε ωιλλ ινχρεασε το 56,699 Μμ^3 φορ σχεναριο ΙΙ.
Τηε τοταλ συππλψ δελιϖερεδ υπ το 2038 φορ βοτη σχεναριο Ι ανδ σχεναριο ΙΙ ωιλ
λ βε 24,448 ανδ 30,184 Μμ^3 ρεσπεχτιϖελψ. Τηε αννυαλ αϖεραγε ωατερ δεμανδ ωιτη
ουτ
χονσιδερινγ λοσσεσ ισ 720 Μμ3 ανδ τηε τοταλ ωατερ δεμανδ υπ το 2038 ωιτη ουτ
ινχλυδινγ λοσσεσ ισ 22,339 Μμ^3 φορ σχεναριο Ι.

Ιν τηε σχεναριο ΙΙ τηερε αρε αδδιτιοναλ 4 ιρριγατιον σιτεσ τηατ ωιλλ σηαρε τηε αϖα
ιλαβλε
ωατερ βεσιδεσ τηε πρεσεντ ωατερ υσε ωιτη τηε τοταλ αχτιϖιτψ λεϖελ οφ 38,654 ηα.
Σο
τηε τοταλ ιρριγαβλε αρεα ιν τηε φυτυρε σχεναριο ισ 95,155ηα (χυρρεντ ιρριγατιον λε
ϖελ πλυσ χονστρυχτινγ ονχε). Τηε τοταλ ωατερ δεμανδ φορ σχεναριο ΙΙ φρομ 2010 τ
ο 2038 ισ
33,992Μμ^3 ωιτη τηε αννυαλ αϖεραγε δεμανδ οφ 1,172Μμ^3.

7.2. Χονχλυσιον

Ωηιλε μανψ σμαλλ ανδ λαργε σχαλε ιρριγατιονσ ηαϖε βεεν δεϖελοπινγ, τηερε ισ νο πλαννεδ σολυτιον ηασ βεεν σετ το ινχρεασε τηε ωατερ αϖαιλαβιλιτψ οφ τηε συβ–βα σιν.

Φρομ τηε αναλψσισ περφορμεδ ιν τηισ στυδψ τηερε ισ α σιγνιφιχαντ γαπ βετωεεν τηε

ιρριγατιον ωατερ ρεθυιρεμεντσ ανδ τηε αϖαιλαβλε ωατερ δελιϖερεδ φρομ Κοκα ρεσερϖοιρ ρελεασε φορ φυτυρε υσε.Τηε συιταβλε ποτεντιαλ οφ ιρριγαβλε λανδ ιν τηε αρεα

αλλοωσ τηε εξπανσιον ανδ δεϖελοπμεντ οφ διφφερεντ λεϖελ οφ ιρριγατιον προφεχτσ .

Ονλψ ιν τηε Υππερ Αωαση ςαλλεψ μορε τηαν 40,000ηα οφ ιρριγατιον σιζε αρε ρεαδψ το βε οπερατεδ ιν τηε ιν τηε χομινγ τωο ψεαρσ.

Τηε χυρρεντ μαναγεμεντ ανδ αϖαιλαβιλιτψ οφ ωατερ ρεσουρχεσ χουλδ νοτ μεετ τηε φυλλ ρεθυιρεμεντσ οφ τηε φυτυρε προφεχτσ χομβινεδ ωιτη τηε χυρρεντ αβστραχτιον σ. Σο τηισ

στυδψ ρεϖεαλσ τηε εξτεντ οφ τηε αππεαρινγ προβλεμ οφ ιρριγατιον ωατερ δεφιχιτ οφ τ ηε

βασιν. Ιφ ϖαριουσ ιντεγρατεδ μεασυρεσ ηαϖε νοτ βεεν αδοπτεδ το χοπε υπ τηε φαχινγ ωατερ σηορταγε προβλεμ, τηε ιμπαχτ μαψ βε εξπανδεδ φυρτηερ.

Ιν αδδιτιον οφ ασσεσσινγ τηε ωατερ αϖαιλαβιλιτψ οφ τηε συρφαχε συππλψ, σομε ρεχομμενδατιονσ ηαϖε βεεν πυτ ασ παρτ οφ τηισ στυδψ.

7.3 Ρεχομμενδατιονσ.

Ιν τηε πρεϖιουσ στυδιεσ οφ τηε βασιν τηερε ηαϖε ϖαριουσ ρεχομμενδατιονσ βεεν φορωαρδεδ ον τηε βασισ οφ ινχρεασινγ ανδ πρεσερϖινγ τηε Κοκα ρεσερϖοιρ χαπαχιτψ. Φορ ινστανχε Ηαλχροω ιν 1989 ρεχομμενδεδ ινχρεασινγ οφ κοκα ρεσερϖοιρ χαπαχιτψ βψ ραισινγ τηε δαμ ηειγητ βψ τηρεε μετερσ το εξπανδ τηε δεμανδ λεϖελ οφ οϖεραλλ βασιν. ΚΒΡ ιν 2003 ρεχομμενδεδ τηε σεδιμεντ μαναγεμεντ οφ Κοκα ρεσερϖοιρ ανδ χονστρυχτιον οφ νεω εαρτη φιλλ δαμ βετωεεν τηε ποωερηουσε ανδ τηε εξιστινγ δαμ.

Το μεετ τηε φυτυρε ωατερ ρεθυιρεμεντσ ιν τηε συβ−βασιν τηερε σηουλδ βε τωο ορ μορε ιντεγρατεδ μεασυρεσ σηουλδ βε αδαπτεδ ον τηε βασισ ωατερ ρεσουρχεσ μαναγεμεντ. Ονε ορ μορε οφ τηε φολλοωινγ ρεχομμενδατιονσ ωιλλ σολϖε τηε ρισκ οφ ωατερ δεφιχιτ οφ τηε βασιν.

1. Πραχτιχινγ εφφιχιεντ ιρριγατιον ωατερ υσεσ βψ αδοπτινγ λοω ωατερ χονσυμινγ σψστεμσ συχη ασ δριπ ιρριγατιον ιν μοστ σιτεσ οφ τηε συβ−βασιν ανδ τηε παρτιχυλαρ ωατερ υσε μαναγεμεντ σηουλδ βε πραχτιχεδ ιν Νυρα Ηερα ανδ Τιβιλα φαρμσ.
2. Χονστρυχτιον οφ ανοτηερ ρεσερϖοιρ νεαρ Νυρα Ηιρα αρεα τηατ μαψ συφφιχιεντλψ υσεδ φορ τηε υππερ ϖαλλεψ αγρο−ινδυστρψ ανδ σμαλλ σχαλε ιρριγατιονσ οφ τηε συρρουνδινγσ.
3. Χονσερϖατιον οφ φλοοδ ωατερ ιν τηε βασιν ανδ υσινγ σπατε ιρριγατιον ατ λοω φλοω ανδ ηιγη ρεθυιρεμεντ σεασονσ οφ ιρριγατιον.
4. Υτιλιζινγ τηε Βεσεκα Λακε νεαρ Μετεηαρα αρεα φορ Μετεηαρα συγαρ χανε εξπανσιονσ ανδ Φενταλε ιντεγρατεδ ιρριγατιονσ βψ μαινταινιγ ιτσ προπερ θυαλιτψ φορ ιρριγατιον.

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ΑΝΝΕΞΕΣ

- ΑΝΝΕΞΑ :Μοντηλψ Φλοω δατα ατ διφφερεντ Ριϖερ στ ατιονσ οφ τηε στυδψ αρεα

- ΑΝΝΕΞ Β: Χομπυτεδ χλιματιχ ανδ Εϖαπο−τρανσπιρατ ιον δατα ατ νεαρ βψ μετεορολογιχαλ στατιο νσ ιν τηε συβ−βασιν
- ΑΝΝΕΞ Χ :Χομπυτεδ ιρριγατιον ωατερ δεμανδσ ανδ σαλιεντ δατα φορ ΩΕΑΠ Μοδελ ιν μοντη λψ βασισ φορ δεμανδ σιτε

- ΑΝΝΕΞ Δ:Σομε Μοδελ ρεσυλτσ

ΑΝΝΕΞ Α:
Μοντηλψ Στρεαμ φλοω δατα

Ταβλε Α.1 Μοντηλψ φλοω οφ Αωαση ατ Αωαση (μ^3/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	3.15	3.39	4.89	6.5	5.73	5.71	64.72	122	139.9	49.17	7.49	6.29
1963	6.59	5.82	3.46	5.68	26.65	7.14	74.13	201	103.5	9.78	5.08	3.35
1964	1.71	3.11	5.26	6.61	10.03	8.33	69.38	145	183.5	29.34	6.12	4.26
1965	2.3	1.61	4.01	4.37	4.02	3.89	47.81	158	105.3	11.48	6.57	6.29
1966	4.51	5.76	3.91	7.08	2.32	6.69	61.76	248	162.5	16.46	4.48	3
1967	2.39	3.11	2.43	2.92	13.04	12.48	81.19	155	113	32.43	16.55	5.01
1968	5.5	9.54	7.65	34.9	9.79	9.61	99.49	177	100.1	21.66	8.17	7.92
1969	8.91	12.07	18	13.6	16.49	28.83	164.2	342	128.2	10.9	7.89	5.57
1970	6.82	5.55	24.5	7.74	4.37	6.37	183.9	321	143.7	17.36	7.38	6.57
1971	7.02	3.48	2.01	4.73	5.76	40.44	173.3	372	270.2	18.3	5.71	4.7
1972	4.99	8.76	10.4	12.8	8.62	11.05	83.35	155	55.66	7.62	2.98	2.51
1973	3.39	2.63	2.5	2.16	4.35	6.41	50.65	206	163.4	33.19	4.33	3.04
1974	2.99	2.38	6.06	7.26	5.36	8.56	112.9	205	119.7	13.53	5.78	4.33

1975	2.34	2.22	2.23	3.56	3.52	11.18	132.9	180	136.3	15.76	4.51	3.62
1976	3.39	2.99	5.17	6.1	7.17	11.02	70.14	168	82.56	8.21	6.39	4.11
1977	6.81	4.83	4.08	6.27	7.35	15.77	122.2	213	102.9	26.35	80.26	6.38
1978	5.11	5.63	7.43	4.49	5.1	19.23	91.94	201	118.7	31.9	6.44	5.59
1979	7.14	5.35	8.08	6.52	10.32	12.08	84.02	169	67.48	18.18	6.6	5.36
1980	5.11	4.99	3.8	3.08	6.65	11.51	99.21	227	86.3	12.16	4.74	4.38
1981	4.15	3.65	15.9	22.5	7.95	6.41	94.67	191	187.7	19.66	6.19	5.41
1982	4.56	4.22	3.82	5.83	5.49	6.3	49.39	174	75.97	27.12	5.96	5
1983	3.99	3.85	5.33	11.4	23.93	22.63	61.39	241	143.8	16.3	5.61	4.21
1984	3.86	2.77	2.87	2.16	4.17	25.18	123.8	142	102.5	6.89	3.17	2.86
1985	2.7	2.1	1.68	2.69	10.14	7.36	87.98	286	122.7	11.21	3.65	3.78
1986	2.08	5.7	5.79	9.95	8.2	22.53	71.51	159	101.5	8.54	3.53	3.33
1987	3.01	3.38	13	24.6	22.13	28.87	50.12	73.1	17.72	6.56	3.67	3.04
1988	3.27	5.1	3.1	4.23	3.24	9.47	52.76	255	192.5	22.13	4.87	3.92
1989	4.34	9.61	6.87	11.6	5.23	8.93	110.7	190	148.7	13.31	4.07	4.26
1990	3.53	11.86	19.2	23.8	4.94	10.97	88.73	240	115.2	17.4	3.96	3
1991	2.83	4.67	9.28	2.68	2.56	10.27	100.4	261	151.7	9.78	3.58	3.36
1992	3.5	6.1	3.44	4.35	4.23	10.78	73.87	207	141.8	16.76	4.15	3.29
1993	2.98	4.51	2.55	10.1	12.41	27.5	126.9	270	188.7	32.42	7.9	4.14
1994	2.87	2.13	2.48	4.69	4.34	10.22	75.51	161	143.1	16.86	4.95	4.93
1995	4.34	4.16	3.15	14.7	5.6	10.55	73.65	194	74.47	8.03	3.23	2.91
1996	5.53	3.89	5.99	12.3	22.08	82.97	198.4	355	129.8	13.48	5.89	4.07
1997	4.13	3.02	3.03	5.42	4.19	15.49	58.86	122	31.96	10.23	10.56	6.22
1998	5.11	3.4	11.4	8.1	11.54	25.29	140.1	374	159	42.54	8.98	5.56
1999	5.08	3.77	4.67	3.36	3.53	20.53	112.6	275	63.11	48.52	8.52	5.22
2000	4.23	3.45	2.02	3.11	5.78	12.49	64.34	182	89.79	31.39	12.31	6.16
2001	5.01	4.08	10.5	6.62	11.16	42.1	140.8	190	76.59	11.13	7.29	5.42
2002	4.2	5.12	6.42	8.64	8.32	16.55	93.74	208	122.6	18.98	8.09	4.47
2003	4.2	5.12	6.42	8.64	8.32	16.55	93.74	208	122.6	18.98	8.09	4.47
2004	4.2	5.12	6.42	8.64	8.32	16.55	93.74	208	122.6	18.98	8.09	4.47
Mean	4.28	4.744	6.54	8.53	8.475	16.34	95.46	212	121.1	19.33	7.995	4.553

Ταβλε Α.2. Μοντηλψ φλοω οφ Μοφο νεαρ Μοφο (μ^3/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	0.66	0.81	0.99	1.04	1.25	2.41	9.17	9.45	14.27	2.64	0.22	0.25
1963	0.35	0.24	0.22	0.63	0.68	1.03	21.05	31.33	2.32	0.35	0.14	0.18
1964	0.19	0.16	0.11	0.47	1.21	2.62	23.07	25.1	12.54	1.21	1.28	1.15
1965	0.41	0.5	0.62	0.65	0.78	0.58	6.32	10.66	6.24	0.04	0.5	0.03
1966	0.03	0.39	0.07	0.3	0.03	0.61	7.8	43.86	7.71	0.29	1.16	1.05
1967	1.14	1.39	1.7	1.79	2.15	4.21	11.5	34.09	13.01	0.82	2.52	0.53
1968	0.47	0.92	0.56	1.2	0.82	1.33	10.13	17.61	4.61	0.61	0.34	1.29
1969	2.16	2.81	3.86	3.77	3.2	4.68	14.44	56.66	7.5	2.52	1.62	1.78
1970	0.09	0.3	0.25	0.78	0.63	0.48	10.14	22.71	12.56	4.69	3.76	4.31
1971	4.76	3.59	4.13	4.61	6.4	9.21	16.07	49.04	8.43	2.91	0.02	0.17
1972	0.74	0.6	0.63	0.38	0.48	0.8	6.65	9.93	3.09	0.49	0.35	0.41
1973	0.54	3.07	3.86	4.02	3.56	4.66	13.31	24.52	11.89	4.32	3.96	4.31

1974	4.21	3.82	5.08	3.47	4.86	5.6	28.61	23.16	12.41	2.46	2.23	1.98
1975	3.36	2	2.03	3.4	3.64	6.7	31.87	13.68	9.68	3	2.23	2.21
1976	3.06	2.8	3.16	3.57	4.24	5.61	6.32	30.92	4.61	8.57	12.21	9.35
1977	1.03	1.26	1.55	1.63	1.96	9.08	12.59	25.95	6.22	6.1	0.45	0.05
1978	0.05	0.89	0.16	0.16	0.37	3.21	3.44	22.5	7.06	0.59	0.26	0.27
1979	2.21	3.08	3.51	4.68	2.48	0.48	4.64	9.65	1.06	0.32	0.33	0.3
1980	0.29	0.25	0.29	0.28	1.05	4.39	9.61	15.23	2.32	0.38	0.27	0.29
1981	2.74	2.45	4.72	5.13	2.99	2.96	23.83	19.87	21.61	3.13	2.5	2.38
1982	2.87	8.39	3.46	3.8	5.89	5.96	7.57	34.38	8.07	3.67	2.54	2.4
1983	0.23	0.33	1.6	0.45	1.7	2.81	5.03	28.12	9.08	0.34	0.22	0.23
1984	0.16	0.14	0.19	0.11	0.41	2.67	10.11	17.64	2.79	0.33	0.28	0.25
1985	0.21	0.14	0.14	0.29	1.32	0.33	10.68	39.96	6.75	0.31	0.33	0.38
1986	0.29	0.29	0.48	1.24	0.67	7.82	8.16	15.37	12.64	0.37	0.2	
1987	0.24	0.26	0.28	1.27	0.99	3.34	1.79	1.47	4.65	1.13	0.25	0.19
1988	0.29	0.33	0.18	0.6	0.48	1.54	8.65	21.24	11.51	1.34	0.09	0.24
1989	0.27	0.23	0.27	0.62	0.14	0.12	6.34	31.98	9.13	0.49	0.26	0.3
1990	0.25	0.93	0.6	1.28	0.22	0.37	10.43	11.31	5.96	0.37	0.21	0.29
1991	0.27	0.33	0.71	0.36	0.2	0.46	17.11	31.61	8.99	0.35	0.39	0.72
1992	0.65	0.67	0.37	0.73	0.24	1.16	3.75	16.98	14.13	0.55	0.27	0.31
1993	0.28	0.28	0.22	1.41	1.55	0.57	13.87	17.07	13.87	1.36	0.37	0.29
1994	0.22	0.16	0.21	0.21	0.25	0.87	5.79	15.44	12.4	0.47	0.34	0.34
1995	0.3	0.31	0.48	0.63	0.86	1.01	0.97	11.17	2.36	1.2	1.08	1.24
1996	1.21	1.15	5.41	1.29	8.76	24.61	44.66	71.54	8.24	0.54	0.37	0.32
1997	0.46	0.25	0.4	0.76	0.31	2.3	7.38	12.37	1.5	1.05	0.49	0.38
1998	0.39	0.57	0.72	1.22	0.53	2.38	21.56	61.56	12.69	5.55	0.5	0.47
1999	0.47	0.36	0.53	0.37	0.42	2.51	22.11	38.46	3.57	1.3	0.33	0.3
2000	0.04	0.03	0.03	0.03	0.07	0.83	7.7	11.67	1.37	0.12	0.05	0.04
2001	0.29	0.24	2.05	0.33	1.13	5.87	15.11	28.19	6.57	0.41	0.34	0.35
2002	0.36	0.28	0.39	0.32	0.36	1.46	10.13	11.74	1.83	0.35	0.29	0.38
2003	0.46	0.37	0.6	0.92	0.49	2.21	22.16	41.09	7.39	0.44	0.31	0.36
2004	0.33	0.17	0.51	1.13	0.24	2.31	8.45	15.75	4.13	0.63	0.63	0.58
Mean	0.91	1.11	1.33	1.43	1.628	3.353	12.56	25.16	7.878	1.58	1.081	1.015

Ταβλε Α.3.Μοντηλψ φλοω οφ Κελετα νεαρ Σιρε ($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	0.84	1.05	1.67	2.06	2.13	1.99	7.79	11.93	10.69	3.13	0.89	0.72
1963	0.72	0.63	0.67	1.34	4.78	1.03	7.2	20.22	5.75	1.89	1.46	1.36
1964	0.93	0.66	0.87	0.96	0.93	1.44	6.19	21.33	16.13	5.08	1.99	1.34
1965	0.53	0.66	1.05	1.29	1.33	0.48	5.36	7.15	10.99	0.13	0.78	0.03
1966	0.91	1.14	1.8	2.17	0.46	1.07	5.28	8.31	21.05	4.24	1.43	0.92
1967	0.81	0.65	0.96	1.77	2.93	1.41	8.77	17.29	21.62	18.8	6.31	1.92
1968	1.14	2.81	2.13	11.6	3.01	2.57	7.2	9.35	13.46	5.31	1.48	1.18
1969	1.37	2.91	10.1	1.95	2.59	2.7	13.61	30.68	9.15	2.16	1.06	0.75
1970	1.17	1.05	5.19	3	3.84	1.37	11.58	30.11	13.42	2.7	0.65	0.42
1971	0.35	0.36	0.37	1.42	2.52	4.9	6.84	9.34	7.25	0.66	0.23	0.11
1972	0.1	0.48	0.49	2.18	2.89	3.07	9.03	15.9	10.7	1.78	0.91	0.72

1973	0.62	0.54	0.55	0.56	2.21	1.73	5	12.43	8.92	3.26	0.66	0.52
1974	0.45	0.38	1.11	0.65	0.42	0.68	3.83	19.31	18.85	4.05	1.02	0.8
1975	0.65	0.55	0.51	1.18	1.13	2	8.32	16.9	16.71	4.91	1.6	1.18
1976	1.05	0.79	1.06	1.51	2.8	1.47	6.46	13.93	9.64	1.82	2.06	0.94
1977	1.23	1.46	1.65	2.67	2.4	2.82	8.36	13.4	6.63	11.1	4.11	1.09
1978	0.74	1.66	1.62	0.68	0.66	1.09	6	11.9	7.74	6.6	0.35	0.22
1979	0.41	0.5	0.71	0.91	2	1.6	5.77	13.95	10.12	2.88	1.07	0.85
1980	0.72	0.84	1.3	0.67	0.79	1.13	5.65	6.22	4.19	2.73	0.57	0.47
1981	0.39	0.42	3.95	7.38	0.89	0.13	4.78	17.18	37.34	4.52	2.1	1.81
1982	1.84	2.17	1.63	4.48	5.87	4.83	10.68	17.64	1.38	6.69	2	1.95
1983	1.57	1.52	3.44	3.45	14.64	7.89	14.7	19.32	21.27	5.83	1.05	0.55
1984	0.45	0.33	0.53	0.45	1.68	1.82	5.68	8.7	11.41	0.77	0.36	0.29
1985	0.24	0.23	0.27	1.02	1.35	0.55	4.88	9.05	9.69	1.72	0.86	0.68
1986	1.55	1.93	3.05	2.59	3.82	4.02	31.71	18.95	10.09	1.53	1.53	1.31
1987	0.68	0.84	5.16	5.51	8.46	8.08	6.11	9.35	10.81	5.18	3	2.81
1988	2.71	2.99	2.55	3.43	2.88	2.89	7.72	25.74	29.98	9.02	4.09	3.42
1989	3.33	3.05	3.24	5.82	6.02	5.68	22.11	35.46	28.84	10.8	4.05	2.45
1990	3.35	10.6	12	15	5.38	4.65	12.48	22.97	30.53	4.07	1.21	1.1
1991	1.04	1.08	3.02	1.56	1.39	1.64	5.96	19.04	6.25	1.86	1.12	1.14
1992	1.35	1.83	1.24	1.84	1.61	2.06	5.12	32.32	46.22	14.4	2.44	2.01
1993	2.15	2.7	1.5	3.12	5.03	1.8	10.75	25.78	15.27	4.7	1.28	0.89
1994	0.78	0.69	0.93	0.96	1.1	4.79	75.31	22.39	7.33	10.8	1.48	1.05
1995	0.97	0.91	2.89	3.46	3.53	1.9	16.72	22.07	7.28	1.18	0.62	0.69
1996	1.2	0.55	3.03	3.73	3.85	3.64	14.16	24.81	25.92	1.7	0.48	0.41
1997	0.89	0.34	0.41	0.58	0.78	1.24	11.9	9.05	5.02	3.78	4.33	2.49
1998	3.03	2.36	3.65	2.14	3.22	2.63	6.24	15.03	11.38	7.28	2.03	1.39
1999	1.34	1.15	1.91	1.22	1.55	2.16	8.06	13.33	7.19	14.1	2.06	1.38
2000	1.33	1.13	1.22	1.36	2.85	2.56	4.62	14.5	7.12	14.4	1.9	1.24
2001	0.23	0.18	0.91	0.55	3.31	4.2	8	18.05	5.55	2.33	1.32	0.81
2002	1.41	1.06	1.32	1.31	2.18	1.87	2.55	8.53	4.61	1.83	1.24	1.15
2003	1.31	1.68	1.55	5.48	1.13	3.98	6.2	10.56	7.83	1.3	0.37	1.39
2004	0.36	0.32	0.36	1.02	0.77	2.99	4.62	7.54	6.07	2.26	0.74	0.51
Mean	1.12	1.38	2.18	2.7	2.863	2.617	10.22	16.67	13.43	5.01	1.635	1.127

Ταβλε Α.4. Μοντηλψ φλοω οφ Αωαση βελοω Κοκα ($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	31	29	31.8	24.9	27.21	26.56	29.35	28.43	24.1	25.6	24.91	25.41
1963	26.5	25.7	37.1	37.6	31.61	38.11	32.48	23.67	14.1	22.8	32.22	40.06
1964	44.3	35.2	36.8	38.3	35.07	37.89	36.64	37.11	34.05	37.6	36.07	42.21
1965	42.7	40.8	37.1	32.5	33.99	50.24	37.6	33.08	37.8	33.5	31.61	40.82
1966	42.6	44.4	48.8	37	33.12	28.43	29.07	43.9	42.97	40.9	26.72	26.24
1967	25.1	29.4	27.2	26	24.2	23.74	23.11	21.95	19.52	24.1	23.1	27.55
1968	26.3	26.1	30.2	28.6	27.95	25.56	23.74	47.23	27.21	30.6	34.79	32.67
1969	29.7	30.1	34.6	33.1	33.57	32.61	31.82	114.2	102	35	29.14	31.23
1970	53.4	61.4	76.9	54.4	36.77	37.29	35.46	47.87	50.68	54.7	47.4	50.73
1971	50.4	34.3	34.8	28.8	52.59	57.76	71.42	172.4	132.2	31.8	28.47	30.7

1972	28.7	25	49	82.3	88.95	52.56	44.06	47.06	31.06	37.2	35.28	31.92
1973	31.8	25.9	20.7	21.1	21.95	22.05	25.81	25.07	56.82	34.7	26.95	25.2
1974	26.8	22.5	26.9	33.3	31.22	51.57	58.72	69.12	77.41	56.3	29.59	39.48
1975	24.9	20.3	20	15.7	13.15	12.92	12.99	48.35	64.74	37.9	16.5	11.35
1976	30	28.2	30.8	34.9	46.92	34.16	36.41	48.6	57.04	38.4	22.35	23.14
1977	22.7	22.5	27.8	26	25.25	24.57	35.11	61.21	79.56	46.4	59.25	59.07
1978	38.2	37.3	47.9	41.2	41.67	47.93	58.93	31.95	31.45	49.3	39.79	45.22
1979	49	41	28.8	27.4	29.99	28.69	21.82	38.76	50.28	41.9	34.24	37.65
1980	41.4	31.3	22.7	19.6	24.47	27.39	29.17	26.73	25.3	26.1	25.28	23.87
1981	27.6	25.2	27.9	24.1	21.61	17.84	21.62	39.74	106.9	47.4	5.76	32.79
1982	32.8	24.5	27.1	26.4	27.61	33.49	37.53	36.2	35.41	36.4	26.41	26.66
1983	27.8	24.5	28.5	27.8	27.45	31.27	45	56.94	195.2	57.9	52.97	64.1
1984	45.1	25.3	27.2	24.3	32.14	31.17	34.35	44.94	45.61	38	37.59	36.04
1985	30.1	27.5	29.1	27.2	28.96	35.05	32.74	71.36	147.3	27.2	24.41	30.45
1986	35.5	38.7	42.2	41.1	39.75	46.78	61.4	39.64	33.88	34.8	36	36.57
1987	32.3	28.7	30.7	30.1	32.32	30.82	28.24	39.4	29.95	31.4	26.19	33.01
1988	31.1	27.1	29.1	21.6	16.9	15.69	20.55	11.14	43.35	23.7	20.41	22.19
1989	26.3	24.5	26.5	24.6	30.83	43.04	42.35	56.05	141.7	64.3	42.51	43.22
1990	38.6	29	29.1	29.4	33.47	34.59	34.83	35.42	90.13	41	39.03	31.61
1991	31.8	34.3	46.4	33.1	46.95	34.39	42.28	47.26	108.9	50.9	54.58	47.56
1992	53.2	48.8	45.1	39.7	43.78	39.71	34.81	31.42	55.23	39.8	25.81	26.39
1993	28.8	27.2	28.6	27.5	31.75	48.94	40.46	128.5	236	57.9	36.97	36.65
1994	38.4	33.6	43.5	44.9	39.63	37.52	37.34	37.66	38.74	36.3	34.64	38.34
1995	41.9	31.5	33	30.9	33.58	33.53	38.62	41.8	38.51	39.7	38.5	37.62
1996	37.6	34.4	34.1	31.7	32.55	32.7	34.8	284.4	102.1	34.7	33.55	34.34
1997	37.1	42.4	54.1	61.7	70.68	62.71	49.08	54.42	39.57	39.8	35.96	30.66
1998	32.6	29.8	30.8	32.5	33	35.62	36.95	201.9	128.1	66.9	44.53	48.33
1999	49.2	47.4	56.9	54.9	58.88	69.66	76.39	198	74.97	55.8	52.16	55.6
2000	49.2	45.8	50.7	42.2	78.73	66.34	39.7	76.93	69.21	70	46.05	48.93
2001	50.7	46.4	47.4	44.6	50.13	44.63	47.06	52.52	65.66	57.9	55.14	58.38
2002	55.8	50.2	55.6	52.3	55.73	53.62	46.78	55.35	54.79	57.1	43.85	34.74
2003	36	32.5	38	33.1	38.34	27.6	38.96	46.95	87.44	46.7	43.55	46.2
2004	22.4	18.2	17.9	22.2	23.06	23.13	25.61	26.5	39.42	23.7	19.67	20.81
Mean	36.2	32.7	36	34.2	36.92	36.97	37.7	62.35	68.98	41.5	34.42	36.41

Ταβλε Α.5. Μοντηλψ φλοω οφ Αωαση ατ Ωονφι (μ^3/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	29.4	27.8	29.7	23.9	26.09	27.08	33.02	27.85	22.44	25.9	26.13	25.42
1963	25.2	24.6	34.6	36.2	30.31	38.85	36.54	23.19	13.13	23.1	33.79	40.07
1964	34	30.9	40.5	44	37.33	44.93	43.97	45.55	46.58	41.7	35.81	36.13
1965	27.8	25.3	27.2	26.6	28.85	43.3	38.66	34.07	38.21	34.8	33.97	36.68
1966	44.9	50.6	51.8	37.8	39.1	38.24	41.27	57.09	54.94	50.2	33.84	33.77
1967	29.2	32.4	35	32.8	35.73	30.6	30.92	38.75	36.08	35	33.09	39.39
1968	34.6	34.2	37	39.5	39.84	35.56	35.85	50.1	35.75	38.7	45.53	44.25
1969	27.3	30.8	33.5	32.1	38.11	36.09	34.65	155.3	142.2	45.9	36.62	35.91
1970	22.3	21.7	35.4	43.8	19.63	39.89	42.74	82.72	50.18	41.5	36.68	38.39

1971	29	34.4	38.2	28.2	54.59	58.97	75.64	64.12	41.06	36.4	39.82	32.16
1972	27	34.7	54.8	93.8	103.1	61.69	48.61	52.08	41.5	39.8	37.22	37.27
1973	31.7	26	20.6	21	27.1	31.24	36.12	32.99	62.39	43	36.35	35.08
1974	28.2	23.8	28.9	34	31.81	54.18	58.98	62.43	67.97	56.3	29.98	46.5
1975	53.2	41.1	36.4	34.2	32.13	31.62	39.98	95.06	126.5	68	37.92	37.17
1976	38.7	37	39.5	44	55.12	39.54	42.89	51.99	56.02	46.2	29.12	29.08
1977	28.8	25.9	28.6	30.5	33.51	48.23	42.28	93.68	126.4	55.5	92.77	91.1
1978	66.6	62	68.7	45.7	48.01	58.48	79.02	34.58	32.18	53.3	46.72	58.47
1979	54.2	48.9	32.7	30.8	33.5	32.48	33.76	54.29	74.46	44.3	47.5	36.7
1980	36.9	33.4	32.8	25.3	29.04	32.37	35.43	34.57	31.65	31	29.68	30.91
1981	31	30.3	32.5	32	35.59	46.7	53.85	60.57	52.64	52.9	40.65	34.12
1982	43.3	33.3	38	37.4	41.55	44.72	51.67	59.32	43.3	43.4	31.69	31.86
1983	31.5	29.2	33.1	33	34.73	40.23	62.79	79.04	81.01	65.4	56.85	66.17
1984	48.2	27.8	27.2	24.4	34.83	35.3	38.5	50.47	46.61	38.5	44.3	42.73
1985	35.4	32.6	33.9	32.2	34.6	41.26	47.56	116.9	194.2	30	26.78	32.4
1986	39.1	35.2	39.7	38.9	39.24	56.87	87.93	54.36	45.28	37.5	38.09	39.44
1987	35.5	29	33.4	32.8	39.1	33.97	41.93	55.67	42.56	35.6	33.32	34.32
1988	32.9	29.4	31.4	24.8	18.2	16.7	19.86	10.03	42.04	37.4	21.54	22.34
1989	23.2	21.8	22.9	25.2	27.1	35.97	56.78	62.12	104.3	44.6	39.74	37.76
1990	30.8	26.4	29.2	28.8	31.64	34.15	32.29	31.72	92.77	44.7	37.78	37.99
1991	29.5	32.2	43.4	34.2	42.15	29.35	45.62	46.41	122.5	53.6	56.95	46.04
1992	69.4	53.1	29.2	28.9	35.78	27.81	19.25	21.94	67.63	33.1	30.11	31.99
1993	32.7	32.1	32	32.3	34.91	44.92	43.51	66.24	70.34	68.5	37.35	36.21
1994	34.6	31.4	37.6	35	30.45	37.1	43.2	46.94	48.46	42.9	48.94	44.47
1995	39.2	31	33.4	30.1	33.96	36.64	43.31	51.17	41.06	39	37.61	32.3
1996	34.2	32.1	37.3	35.9	36.96	37.69	41.51	194.3	109.2	37.3	30.52	34.48
1997	28.3	27.4	32.3	27.5	25.73	25.31	23.81	19.22	16.04	18.1	14.24	10
1998	10.1	8.55	9.37	10.3	10.23	12.12	14.37	144.7	94.18	39	24.44	25.19
1999	25.7	19.2	30.5	29.2	37.31	35.25	39.67	95.82	49.35	34.1	29.73	32.19
2000	28.4	21.1	23.1	22.6	23.04	33.25	23.38	38.08	36.59	35.4	19.24	14.53
2001	17.6	16.8	16	13	21.71	17.74	22.72	27.71	37.94	21.8	20.5	20.19
2002	37.9	33.8	37.7	36.8	39.17	39.2	44.5	48.55	43.67	37.3	18.1	19.32
2003	18.4	19.6	18.5	19.2	19.46	23.75	35.14	42.6	80.6	44.6	37.56	46.71
2004	40.6	38.2	37.1	40.9	37.07	42.18	45.26	41.5	33.3	40.1	34.93	35.36
Mean	34.1	31.1	33.6	32.8	35.06	37.48	42.06	59.44	62.68	41.5	36.13	36.57

Ταβλε Α.6. Μοντηλψ φλοω οφ Αωαση ατ Νυρα Ηαρα ($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	34.6	74.2	53.1	28.4	30.64	30.05	45.96	72.6	57.77	58	53.76	52.57
1963	29.6	65.8	61.9	42.9	35.59	43.12	50.86	60.45	33.8	51.6	69.52	82.88
1964	39.9	82.6	72.4	52.1	43.85	49.85	61.19	118.8	119.9	93.3	73.68	74.73
1965	32.7	67.6	48.6	31.5	33.88	48.05	53.8	88.82	98.37	77.8	69.89	75.85
1966	52.7	135	92.7	44.8	45.92	42.44	57.45	148.8	141.5	112	69.62	69.84
1967	34.2	86.7	62.6	38.9	41.97	33.96	43.04	101	92.88	78.4	68.09	81.47
1968	40.6	91.5	66.2	46.8	46.79	39.46	49.9	130.6	92.05	86.6	93.67	91.52

1969	32	82.2	60	38	44.76	40.04	48.23	404.9	366.2	103	75.34	74.28
1970	26.2	57.9	63.2	51.9	23.05	44.26	59.49	215.6	129.2	92.8	75.46	79.4
1971	34.1	91.8	68.3	33.4	64.12	65.44	105.3	167.2	105.7	81.4	81.93	66.5
1972	31.7	92.7	98	111	121.1	68.45	67.66	135.8	106.8	89.1	76.58	77.08
1973	37.2	69.3	36.9	24.9	31.82	34.66	50.28	85.99	160.6	96.1	74.78	72.54
1974	33.1	63.6	51.7	40.2	37.36	60.12	82.09	162.8	175	126	61.69	96.18
1975	62.5	110	65	40.6	37.74	26.52	48.65	85.29	101.6	45.3	29.59	33.64
1976	36.2	37.1	42	45.2	50.9	34.03	42.85	62.72	57.67	34.7	18.92	21.64
1977	25	20.4	20.7	28.8	23.69	27.56	47.03	73.6	81.46	53.3	75.14	60.9
1978	43.9	50.8	51.8	45.8	39.32	45.79	67.47	60.28	52.39	55.5	39.16	51.02
1979	49.6	42.4	40.1	39.9	42.88	44.23	59.51	80.22	74.37	44	31.04	35.75
1980	38.4	31.9	34.7	29.6	24.21	28.02	41.85	40.22	32.85	34.5	22.84	21
1981	23.6	25.3	37.3	36.5	29.66	37.29	61.91	98.15	177.9	68.4	28.31	35.82
1982	35.4	35.1	28.7	26.5	35.64	40.68	54.83	79.03	56.44	52.8	25.84	27.59
1983	29.8	28.6	38.6	35.4	84.19	53.9	68.65	89.98	193.4	64.1	53.28	61.35
1984	47.6	29.2	30.3	28.5	37.59	36.75	44.55	64.26	64.37	39.6	36.67	37.97
1985	33.6	30.1	31.2	38.2	38.35	33.03	43.02	102.6	155.4	33.4	28.28	31.16
1986	45.6	40.3	42.2	40.3	42.16	55.64	85.91	60.81	51.3	40.4	36.86	39.14
1987	29.5	28.8	38.5	45.4	51.94	36.7	34.58	56.58	49.2	31.2	28.17	30.47
1988	35.8	29.7	30.6	29.4	17.42	15.71	44.67	59.5	84.69	42.8	21.98	23.05
1989	24.4	26.2	26.2	34.6	32.11	40.22	66.89	84.07	145	47.1	34.64	37.48
1990	29.5	43.7	44.4	44.5	31.62	32.02	42.16	66.16	123.1	45.7	38.62	28.35
1991	27.6	32	49.4	43.3	43.21	30.05	53.87	64.15	138.7	49.2	46.68	45.12
1992	62.4	44.7	26.3	25.6	33.74	26.16	34.67	56.12	82.66	34.7	23.35	25.85
1993	32.5	28.9	26.7	29.1	36.39	36.09	51.93	82.85	86.28	51.3	29.41	30.24
1994	33.9	27.2	32.7	31.9	25.48	39.56	77.78	73.67	61.53	38.6	41.58	46.79
1995	43.5	300	495	32.7	42.71	73.25	120.2	1609	1326	1003	923.7	925.6
1996	88.7	842	90.5	81.6	82.12	97.31	108.1	425.5	443.1	173	45.57	58.48
1997	64.3	53.2	64.1	61.9	60.42	66.02	45.45	89.01	72.3	55.7	51.32	32.61
1998	11.9	22.8	16.8	12.2	12.02	13.44	20	377.2	242.5	87.3	50.29	52.1
1999	11.9	22.8	16.8	12.2	12.02	13.44	20	377.2	242.5	87.3	50.29	52.1
2000	33.3	56.3	41.2	26.8	27.06	36.89	32.54	99.26	94.2	79.1	39.59	30.05
2001	20.7	44.8	28.6	15.4	25.5	19.68	31.62	72.23	97.66	48.7	42.19	41.76
2002	44.4	90.3	67.4	43.6	46.01	43.5	61.93	126.6	112.4	83.4	37.24	39.95
2003	21.7	52.5	33	22.8	22.86	26.35	48.91	111.1	207.5	99.8	77.27	96.6
2004	47.7	102	66.3	48.4	43.53	46.81	62.99	108.2	85.73	86.5	68.2	70.5
Mean	37.1	78.8	57.9	38.6	40.31	40.85	55.81	156.5	150.5	89.7	70.23	72.53

Ταβλε Α.7. Μοντηλψ φλοω οφ Αωαση ατ Μετεηαρα ($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	22	21.3	24.8	20.2	20.69	18.7	34.32	41.24	51.66	24.8	23.21	23.45
1963	19	21.1	33.9	46.1	53.15	36.33	41.61	74.87	57.16	38.4	31.6	38.22
1964	43.4	35.2	34	39.5	35.67	41.11	50.37	76.21	65.08	45.6	37.33	41.19
1965	43	40.6	37.2	34.4	33.02	40.52	44.7	59.53	69.68	43.4	31.44	40.42
1966	43.4	52.5	52.7	43.7	33.7	35.05	52.84	77.8	79.96	48.9	27.82	27.05
1967	25.4	31.5	25.6	30	27.3	24.86	36.75	53.8	67.59	43.8	35.04	30.26

1968	28.7	30.9	32.9	49.6	39.71	35.37	41.9	69.04	63.55	35.8	36.16	33.79
1969	29.4	34.8	50.1	35	33.52	30.7	45.82	142.3	125.5	27.2	27.8	20.57
1970	20.9	22.1	80.5	89.9	42.68	30.68	45.47	145.7	137.2	53	31.45	36.97
1971	19.7	17.4	42.6	19.2	32.44	42.95	64.64	116.6	139.6	19	16.61	17.93
1972	30.9	32.5	41.7	61	60.44	44.82	58.29	68.04	46.47	32.1	26.31	24.39
1973	25	13.1	9.78	8.04	9.35	9.23	25.72	36.92	56.47	27.4	11.93	12.34
1974	15.1	8.61	18	20.7	14.8	39.84	53.69	82.55	117.9	24.9	7.75	25.38
1975	38.3	29.5	24.9	22.3	18.66	22.63	56.35	142.3	222.1	41.9	14.24	18.37
1976	25.9	21.9	33.4	38.9	53.18	22.64	43.83	81.3	66.31	23.8	12.63	10.34
1977	21.3	19	17.5	17.8	20.59	21.56	40.02	69.64	82.31	44.9	84.14	55.48
1978	40	45.3	58.4	35.1	27.3	29.75	68.19	56.6	38.66	46.9	28	41.83
1979	50.7	38	25.6	21.1	25.34	21.15	31.18	58.12	63.17	26.8	21.87	24.03
1980	25.1	22.7	20	13.9	12.81	16.26	36.02	33.98	21.6	12.9	8.66	10.92
1981	12.1	14.5	26	32.4	16.48	20.98	50.53	89.2	133.4	72	24.98	24.75
1982	18.3	14.3	13.4	14.7	20.84	14.35	37.82	80.71	44.97	38.3	14.14	15.45
1983	13.4	13.6	17.2	16.8	50.32	30.29	52.55	78.55	155.7	59.1	40.07	50.11
1984	38.3	15.3	14.7	10.6	22.5	23.66	28.58	52.93	48.42	20.9	21.37	21.53
1985	15.1	13.4	12.9	21.8	32.63	16.83	49.43	161.6	267.2	17.1	16.39	19.68
1986	27.8	27	34.3	28.2	28.68	39.39	69.95	55.21	32.98	18.8	21.85	23.74
1987	18.9	16.3	33	27.1	19.05	12.77	10.23	35.54	22.03	6.26	5.52	5.11
1988	9.27	6.2	5.54	10.1	1.72	1.82	15.2	13.86	69.78	24.2	5.14	5.36
1989	6.54	9.47	7.73	21.8	13.2	16.37	46.67	55.03	121.5	29.1	20.13	23.57
1990	16.1	42.5	26.6	27.4	18.48	23.58	33.56	43.84	127.7	31.2	17.97	15.88
1991	13.5	19.4	32.5	26.3	26.17	15.17	37.76	60.36	142.7	37	37.71	32.56
1992	50.4	50.5	12.5	19.3	21.41	13.43	21.58	45	111.5	32.4	17.69	21.86
1993	31.9	29.2	18.5	22.7	46.51	37.27	50.16	137.7	207	63	25.79	27.38
1994	25	20.1	20.2	21	22.33	20.46	56.08	47.11	49.4	26.8	16.79	17.29
1995	14.4	19.8	39.3	22.8	16.8	29.64	61.17	71.56	49.53	16.3	15.8	15.54
1996	19.1	15.1	31.2	18.3	19.46	21.19	35.12	205	200.5	33.2	17.17	31.34
1997	26.1	17.9	26.8	30.7	22.71	22.8	44.54	50.25	17.92	17.3	11.68	7.2
1998	9.62	9.62	15.9	11.4	9.31	9.77	24.67	220.1	148.1	72.1	20.3	24.09
1999	24.3	21.6	27.3	23	27.82	38	76.2	159.5	78.76	75.9	32.84	28.03
2000	37.8	28.2	27.2	26.7	50.71	41.74	40.13	76.47	61.31	61.4	35.94	25.5
2001	28.9	27.4	27.8	23.3	52.77	25.53	37.28	65.78	66.95	26.9	28.68	31.67
2002	31.4	23.4	28.1	26	23.82	26.04	35.69	60.04	35.47	18.3	7.23	8.52
2003	12.4	10.1	12.8	15.2	9.87	12.33	35.74	71.13	80.55	28.2	18.43	35.1
2004	24.9	19.4	26	40.1	20.47	25.36	42.89	80.55	90.49	35	23.24	24.57
Mean	25.4	23.8	27.9	27.5	27.64	25.65	43.38	81.48	91.53	35.4	23.51	24.85

Ταβλε Α.8. Μοντηλψ ινφλοω φρομ Αρβα Ριϖερ($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	0.64	0.59	0.52	0.6	0.59	0.39	1.45	4.43	2.72	2.7	0.46	0.1
1963	0.55	0.36	0.21	0.39	1.32	0.2	1.34	7.51	1.46	1.63	0.76	0.2
1964	0.71	0.37	0.27	0.28	0.26	0.28	1.15	7.92	4.1	4.39	1.04	0.19
1965	0.4	0.37	0.33	0.38	0.37	0.09	1	2.65	2.79	0.11	0.41	0
1966	0.69	0.64	0.56	0.63	0.13	0.21	0.98	3.09	5.35	3.66	0.74	0.13

1967	0.62	0.36	0.3	0.52	0.81	0.28	1.63	6.42	5.5	16.2	3.29	0.28
1968	0.87	1.58	0.66	3.37	0.83	0.51	1.34	3.47	3.42	4.58	0.77	0.17
1969	1.04	1.64	3.14	0.57	0.72	0.54	2.53	11.39	2.33	1.86	0.55	0.11
1970	0.89	0.59	1.62	0.87	1.06	0.27	2.15	11.18	3.41	2.33	0.34	0.06
1971	0.27	0.2	0.11	0.41	0.7	0.97	1.27	3.47	1.84	0.57	0.12	0.02
1972	0.08	0.27	0.15	0.64	0.8	0.61	1.68	5.9	2.72	1.53	0.47	0.1
1973	0.47	0.3	0.17	0.16	0.61	0.34	0.93	4.61	2.27	2.81	0.35	0.08
1974	0.34	0.21	0.34	0.19	0.12	0.13	0.71	7.17	4.79	3.5	0.53	0.12
1975	0.49	0.31	0.16	0.34	0.31	0.4	1.55	6.27	4.25	4.24	0.83	0.17
1976	0.8	0.45	0.33	0.44	0.77	0.29	1.2	5.17	2.45	1.57	1.07	0.14
1977	0.93	0.82	0.51	0.78	0.66	0.56	1.55	4.97	1.69	9.59	2.14	0.16
1978	0.56	0.93	0.5	0.2	0.18	0.22	1.12	4.42	1.97	5.69	0.18	0.03
1979	0.31	0.28	0.22	0.26	0.55	0.32	1.07	5.18	2.57	2.48	0.56	0.12
1980	0.55	0.47	0.41	0.2	0.22	0.22	1.05	2.31	1.07	2.36	0.3	0.07
1981	0.3	0.24	1.23	2.15	0.24	0.03	0.89	6.38	9.49	3.9	1.09	0.26
1982	1.4	1.22	0.51	1.31	1.62	0.96	1.99	6.55	0.35	5.77	1.04	0.28
1983	1.19	0.85	1.07	1.01	4.05	1.56	2.73	7.17	5.41	5.03	0.55	0.08
1984	0.34	0.19	0.16	0.13	0.47	0.36	1.06	3.23	2.9	0.66	0.19	0.04
1985	0.18	0.13	0.08	0.3	0.37	0.11	0.91	3.36	2.46	1.49	0.45	0.1
1986	1.18	1.08	0.95	0.76	1.06	0.8	5.9	7.04	2.57	1.32	0.8	0.19
1987	0.52	0.47	1.6	1.61	2.34	1.6	1.14	3.47	2.75	4.47	1.56	0.41
1988	2.06	1.68	0.79	1	0.8	0.57	1.44	9.56	7.62	7.78	2.13	0.49
1989	2.53	1.72	1.01	1.7	1.66	1.13	4.11	13.16	7.33	9.3	2.11	0.35
1990	2.54	5.95	3.74	4.37	1.49	0.92	2.32	8.53	7.76	3.52	0.63	0.16
1991	0.79	0.61	0.94	0.46	0.39	0.32	1.11	7.07	1.59	1.61	0.58	0.16
1992	1.03	1.03	0.39	0.54	0.44	0.41	0.95	12	11.75	12.5	1.27	0.29
1993	0.43	1.9	0.42	1.06	2.28	0.68	0.68	2.5	3.05	3.26	0.83	0.23
1994	2.9	2.63	0.75	0.07	0.45	0.2	4.99	6.82	4.1	0.19	0.38	0.16
1995	0.04	0.03	0.74	2.46	0.35	0.1	0.31	2.74	1.08	0.04	0.01	0.01
1996	0.12	0	0.52	0.37	0.55	0.89	1	3.83	4.44	0.37	0.09	0.06
1997	0.1	0.04	0.09	0.29	0.07	0.09	2.02	4.02	0.89	1.54	4.33	0.2
1998	1.62	0.44	0.51	0.22	0.4	0.15	0.32	3.97	4.61	4.79	0.18	0.08
1999	0.08	0.02	0.21	0.09	0.05	0.1	2.51	3.49	3.87	17.3	0.37	0.11
2000	0.1	0.06	0.09	0.23	0.35	0.13	1	18.88	4.54	11.4	1.3	0.35
2001	2.29	1.84	2.78	2.29	2.62	2.33	4.5	10.18	4.55	0.47	0.26	0.3
2002	1.07	0.6	0.41	0.38	0.6	0.37	0.47	3.16	1.17	1.58	0.65	0.17
2003	1	0.95	0.48	1.6	0.31	0.79	1.15	3.92	1.99	1.12	0.19	0.2
2004	0.27	0.18	0.11	0.3	0.21	0.59	0.75	2.79	1.65	1.84	0.39	0.07
Mean	0.82	0.8	0.7	0.84	0.795	0.512	1.627	6.078	3.596	4.02	0.844	0.163

Ταβλε Α.9. Μοντηλψ φλοω οφ Αωαση Ριϖερ ατ Αωαση($μ^3$/σεχ) (Φρομ ΜΟΩΡ, Ηψδρολογψ Δεπαρτμεντ)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1962	20.4	19.5	23.4	24.9	24.04	22.81	47.99	86.54	60.93	38.1	30.52	22.62
1963	25.8	24	39.5	59.8	71.74	43.17	57.77	185.8	129.7	44.2	41.12	48.36
1964	46.1	41.7	41.7	50.8	46.12	48.68	75.51	138	93.85	60.6	37.36	48.59
1965	56	44	43	38.6	32.57	41.11	53.16	68.66	69.94	51.8	32.65	38.38

1966	41.9	62.1	56.2	59.2	41.67	40.63	63.44	96.93	97.84	46.6	25.01	28.09
1967	24.7	28.6	25	31.4	28.06	25.37	49.37	92.46	86.93	54	53.71	30.6
1968	39.9	56.3	47.2	91.8	58.94	46.87	73.75	98.34	77.4	49.8	54.71	46.11
1969	45.1	59.7	80.3	49.9	50.18	42.91	83.8	232.5	201.1	42.5	34.68	32.1
1970	33	35.1	85.7	66.2	42.79	38.45	61.45	206.3	210.3	41.4	31.24	29.35
1971	30.8	26.8	68.4	29.8	52.08	69.29	104.7	187.2	235.9	29.4	25.3	26.84
1972	33.6	37.7	50.9	84.9	93.13	62.82	76.6	92.67	60.31	35.7	26.33	31.27
1973	27.6	18.6	14.2	10.5	17.15	13.11	43.71	91.83	78.39	34.4	18.61	17.58
1974	22.3	15	28.4	31.9	21.41	54.94	76.83	99.26	133.1	37.1	11.51	30.82
1975	48	38.3	32.9	29.1	25.25	28.97	85.13	168	202.2	56.4	18.31	23.84
1976	29.7	31.4	37.4	38.9	55.01	24.82	44.66	98.99	84.64	28.3	19.42	15.94
1977	32.6	27.1	23.2	30.1	27.76	28.59	58.97	112.7	124.5	104	116.1	70.24
1978	53.3	60.7	73.3	42.4	35.79	33.94	86.58	103	65.22	66.9	30.61	51.36
1979	68.5	49.1	35.8	31.3	28.61	25.76	54.98	88.21	91.64	42	27.62	30.82
1980	34.1	28.9	27.9	21.4	14.69	17.56	48.4	54.67	38.18	28	9.85	17.81
1981	17.1	19.5	54.2	87	34.49	35.96	78.95	131.6	216.2	88	30.21	26.38
1982	28	24.7	22.8	31.2	42.07	22.61	47.29	102.9	59.58	81.4	21.83	32.94
1983	22.9	26.5	35.2	40.9	99.13	50.79	84.27	149.4	229.9	69.6	59.77	59
1984	43.8	16.9	14.9	9.35	28.28	29.33	38.93	69.43	75.08	24.1	23.32	26.69
1985	19.8	17.4	17.4	34.5	67.31	20.98	45.77	124.8	201.8	19.7	16.28	25.21
1986	19.9	30.1	30.5	32.1	35.02	50.57	95.89	89.66	57.17	26.6	23.82	26.9
1987	16.9	18.5	20	46.3	51.95	28.27	24.35	65.79	41.38	18.3	15.99	16.91
1988	26.7	21.2	17.8	19.6	5.76	6.64	43.48	118.1	144.4	51.4	13.73	13.79
1989	14.8	21.2	19.8	52.3	22.85	27.29	75.42	102.5	161.1	51.1	26.33	34.36
1990	23.6	85.2	73.3	67.2	32.02	50.1	105.4	190.1	180.6	52.8	34.1	28.54
1991	21.8	20.9	41.3	34.6	35.66	23.32	60.38	81.29	157.4	46	44.81	42.64
1992	69.8	56	25.3	51.3	35.16	17.8	35.74	123.7	144.7	37	22.8	22.86
1993	66.2	53.3	24.9	38.2	56.77	42.95	63.12	150.9	283.2	74.7	31.83	57.68
1994	30.2	30.8	44.1	36.3	31.49	33.53	140.1	154.7	154.2	39.6	52.58	44.51
1995	36.4	33.6	69.1	54.5	24.4	31.34	61.98	100.1	69.98	12.6	29.33	11.5
1996	27.5	16.7	46.7	35.4	100.1	79.57	54.1	281.1	252.7	27.4	24.61	43.12
1997	24.9	45.3	53.8	73.3	42.32	45.14	96.48	102.3	47.87	73.3	71.45	19.69
1998	58.1	27.7	49	13.3	19.8	13.41	186	329.5	238.2	104	36.89	41.39
1999	42.5	36	69.3	43.6	41.64	60.59	140.9	213.1	127.3	153	53.33	48.74
2000	47.1	34.6	35.8	40.9	70.5	38.92	58.09	129.3	109.5	78.2	42.77	29.7
2001	32.2	29.8	49.6	36.8	44.74	48.84	130	131.4	81.23	33.7	23.41	26.08
2002	31	24.3	28	29.9	24.77	26.77	44.35	73.22	53.07	27.8	4.32	9.45
2003	34.7	36.9	40	43.6	41.3	37.3	71.6	128.7	130.7	50.2	33.6	32
2004	53.1	33.2	37.4	74.4	54.35	51.58	108.5	195.7	187.8	69.2	43.74	43.21
Mean	35.4	34.1	40.8	43	42.07	36.82	72.98	131.2	129	51.2	33.15	32.65

ANNEX B

COMPUTED EVAPO-TRANSPIRATION DATA FROM METEOROLOGICAL DATA OF REPERESENTATIVE STATIONS OF THE SUB BASIN

Table B.1.Details of Major Meteorological Stations in the sub-basin

Table.B.2: Wonji are Monthly Meteorological data and Evapo-transpiration computation

Table .B. 3: **Meteorological data of Welenchiti area and Evapo-transpiration calculation**

Table .B.4: **Meteorological data of Bofa area and Evapo-transpiration calculation**

Table .B.5: **Meteorological data of Nura Hera station and Evapo-transpiration calculation**

Table B.6: **Meteorological data of Melkasa station and Evapo-transpiration calculation**

Table B.7: **Meteorological data of Metehara area and Evapo-transpiration calculation**

Table B.1.Details of Major Meteorological Stations in the sub-basin

Station Name	Latitude (N)	Longitude (E)	Altitude (m asl)	Record Period (year)
Wonji	8^0 27’	39^0 14’	1540	1962-2004
Nazereth	8^0 33’	39^0 17’	1648	1965-2004
Welenchiti	8^0 46’	39^0 24’	1456	1964-2004
Nura Hera	8^0 32’	39^0 35’	1180.0	1996-2005
Melkasa	8^0 24’	39^0 20’	1550	1977-2003
Metehara	8^0 51’	39^0 55’	950.0	1996-2005

TableB.2: Wonji Meteorological station Monthly Meteorological data and Evapo-transpiration

Months	Max.T^0 ^{0}c	MinT^0 ^{0}c	Humidity (%)	Wind (km/day)	Sun shine (hr)	Solar radiation	Reference evaporation (mm/month)	Rain fall (mm/month)	Effective rain fall
Jan	26.3	11.5	62	69	8.7	20.4	3.6	9	9
Feb.	27.3	13.1	60	60	8.9	22.0	4.0	23	22
Mar	28.9	14.8	57	60	8.7	22.9	4.3	42	39
Apr	29.0	15.3	62	52	8.8	23.1	4.4	59	53
May	30.0	15.5	60	52	8.6	22.1	4.3	47	43
Jun	29.2	16.7	60	69	8.5	21.5	4.3	78	68
Jul	26.1	16.3	74	60	7.1	19.6	3.8	192	133
Aug	25.6	16.1	74	52	6.9	19.8	3.7	192	133
Sep	26.8	15.4	73	43	7.5	20.8	3.9	97	82
Oct	27.2	12.0	63	52	8.5	21.6	4.0	48	44
Nov	26.2	11.0	62	60	9.5	21.8	3.8	9	9
Dec	25.6	10.8	63	52	8.4	19.5	3.3	8	8
Year	**27.4**	**14.0**	**64**	**57**	**8.3**	**21.3**	**1441**	**804**	**643**

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

Table B. 3: **Meteorological data of Welenchiti area and Evapo-transpiration calculation**

Months	Max Temp ^{0}c	Min Temp ^{0}c	Humidity (%)	Wind speed(km/day)	Sun shine	Mean RF (mm)	ET_o (mm/month)
Jan	26.5	12.6	52.5	117.0	8.8	19.2	4.09
Feb.	27.8	14.2	50.5	115.3	8.4	33.3	4.45
Mar	29.0	15.1	51.1	110.6	8.3	59.7	4.75
Apr	29.2	15.5	54.0	98.5	8.1	62.1	4.81
May	29.9	16.1	51.9	91.7	8.8	56.9	4.74
Jun	29.1	17.2	55.4	120.7	8.4	68.3	4.74
Jul	26.0	16.4	65.0	128.0	6.8	215.7	4.09
Aug	25.6	16.2	67.6	101.7	6.9	223.5	3.99
Sep	26.8	15.4	64.6	65.6	7.3	98.1	3.97
Oct	27.3	12.6	53.1	79.6	8.7	34.2	4.17
Nov	26.6	11.8	50.5	107.3	9.3	11.0	4.14
Dec	26.1	11.4	51.5	113.9	9.1	8.7	3.95
Average	27.5	14.6	55.6	104.2	8.2	74.225	4.32

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

Table B.4: **Meteorological data of Bofa area and Evapo-transpiration calculation**

Months	Max Temp ^0c	Min Temp ^0c	Humidity %	Wind speed(km/day	Sun shine	Mean RF (mm)	ET_o (mm/month)
Jan	30.1	13.5	47.2	117.0	8.8	10.3	4.45
Feb.	30.2	15.0	45.4	115.3	8.4	24.2	4.71
Mar	31.1	15.7	46.0	110.6	8.3	49.1	4.99
Apr	32.2	16.3	48.6	98.5	8.1	48.8	5.10
May	33.1	17.2	46.7	91.7	8.8	53.3	5.04
Jun	32.4	16.8	49.9	120.7	8.4	67.7	5.09
Jul	31.6	16.9	58.5	128.0	6.8	188.8	4.69
Aug	30.4	16.5	60.9	101.7	6.9	180.4	4.45
Sep	32.1	16.3	58.2	65.6	7.3	84.4	4.36
Oct	32.9	16.5	47.8	79.6	8.7	30.8	4.66
Nov	31.0	13.3	45.5	107.3	9.3	8.5	4.55
Dec	30.2	12.8	46.4	113.9	9.1	7.2	4.34
Average	31.4	15.6	50.1	104.2	8.2	62.79167	4.7

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

Table B.5: **Meteorological data of Nura Hera station and Evapo-transpiration calculation**

Months	Max.T^0 ^0c	MinT^0 ^0c	Humidity (%)	Wind (km/day)	Sunshine (hr)	Solar radiation $MJ/m^2/day$	Ref evaporation (mm/month)	Rain fall (mm/month)	Effective rain fall (mm)
Jan	23.1	9.6	15	147	7.9	19	3.8	24.3	8.36
Feb.	24.3	10.5	52	156	7.8	20.1	4.2	46.9	19.6
Mar	24.8	11.5	52	156	6.6	19.4	4.3	62.7	24.6
Apr	25.2	12.0	62	156	6.9	20.2	4.4	63.7	33.2
May	23.9	11.9	56	147	6.9	19.8	4.2	39.4	10
Jun	22.7	10.8	70	121	5.4	17.2	3.5	32.4	9.9
Jul	18.8	10.1	81	104	3.1	14.1	2.6	148.3	79.9
Aug	18.4	10.0	82	112	3.1	14.1	2.6	148.3	98.7
Sep	20.0	10.0	76	138	4.8	16.6	3.1	50.3	17.2
Oct	21.5	10.1	58	190	7.5	19.9	4.1	15.6	0
Nov	21.2	8.7	56	156	9.6	21.3	4.1	4.6	0
Dec	21.6	12.3	54	169	9.3	19.9	3.7	4.4	0
Mean	22.12	10.62	59.5	146	6.57	18.47	3.716667	53.40833	25.1216

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

Table B.6: **Meteorological data of Melkasa station and Evapo-transpiration calculation**

Months	Tempe ^{0}c	Humidity (%)	Wind (km/day)	Sun shine (hr)	Solar radiation $MJ/m^2/day$	Reference evapo-transpiration (mm/month)	Rain fall (mm/month)	Effective rain fall (mm)
Jan	19.8	50	269	8.9	4.2	6.26	14.5	14.1
Feb.	21.2	53	276	8.5	4.6	6.58	32.1	30.0
Mar	22.8	52	243	8.7	5.1	6.89	41.4	38.0
Apr	22.8	52	236	8.1	5.0	6.75	53.7	47.9
May	23.3	53	235	8.7	5.0	6.76	56.6	50.2
Jun	23.1	54	283	8.3	4.8	6.90	65.8	57.1
Jul	16.2	68	278	6.9	4.4	4.94	180.2	115.3
Aug	20.8	70	215	7.1	4.8	5.17	177.8	114.6
Sep	20.7	67	148	7.3	4.8	4.97	85.3	70.7
Oct	20.3	49	196	8.5	4.6	6.03	34.8	32.4
Nov	19.5	46	256	9.7	4.4	6.50	8.8	8.6
Dec	19.6	49	272	8.8	4.0	6.20	11.6	11.3
Mean	20.8	55	242	8.3	4.6	6.1625	63.55	49.18333

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

Table B.7: **Meteorological data of Metehara area and Evapo-transpiration calculation**

Months	Max.T^0 ^{0}c	MinT^0 ^{0}c	Humidity (%)	Wind (km/day)	Sun shine (hr)	Solar radiation MJ/m^2/day	Ref evaporation (mm/month)	Rain fall (mm/month)	Effective rain fall (mm)
Jan	31.3	15.8	39.2	138.2	8.8	20.6	5.0	11.97	0.0
Feb.	33.6	15.3	32.3	146.9	10.2	3.9	5.9	5.24	0.0
Mar	34.3	18.8	37.9	146.9	8.8	22.9	6.0	59	10.28
Apr	35.5	19.4	38.6	129.6	8.8	23.1	5.9	38.8	0.0
May	36.9	20.0	35.7	129.6	9.2	23.1	6.1	25.7	0.0
Jun	36.8	21.8	34.6	172.8	8.8	22.0	6.6	22.9	0.0
Jul	33.2	20.3	43.5	190.1	7.3	19.9	5.9	124	46.36
Aug	33.4	20.0	49.1	146.9	7.3	20.4	5.4	120.6	1.22
Sep	33.4	19.8	45.2	121.0	7.9	21.5	5.4	31.4	0.0
Oct	33.7	17.0	36.9	114.9	8.8	22.1	5.3	33.9	0.0
Nov	32.1	14.0	33.8	121.0	9.7	22.1	5.0	4.91	0.0
Dec	33.1	13.1	33.8	129.6	9.7	21.3	4.8	4.79	0.0
Mean	33.9	18.0	38.4	140.625	8.8	21.9	5.6	40.23	4.82

The monthly mean reference crop evapo-transpiration calculated using FAO CROPWAT 4

ANNEX C

COMPUTED IRRIGATION WATER DEMAND DATA AND SALIENT DATA FOR WEAP MODEL IN MONTHLY BASIS

Table C.1. Computed Water demand Data of Wonji Area Irrigations (UV1)

a. Salient features of UV1

Total activity level (ha)	7054
Overall efficiency (%)	60
Major crop	Sugar cane
Return flow (%)	20%
Consumption rate (%)	80%

b. Irrigation water use Wonji area Existing Irrigation

months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**annual**
GIWR (mm)	178.01	172.3	165.2	164	172	169	55.5	34.2	51.3	125.3	167	178	1632
Monthly abstraction(MMC)	12.557	12.16	11.65	11.6	12.2	12	3.92	2.41	3.62	8.84	11.8	12.6	115.1
Monthly variation (%)	10.908	10.56	10.12	10	10.6	10.4	3.4	2.09	3.14	7.679	10.2	10.9	100
Water use rate (m^3/ha)	1780.1	1723	1652	1638	1723	1695	555	342	513	1253	1666	1780	16320
Monthly losses (MMC)	5.0228	4.862	4.661	4.62	4.86	4.78	1.57	0.96	1.45	3.536	4.7	5.02	46.05
Return flow MMC)	2.5114	2.431	2.331	2.31	2.43	2.39	0.78	0.48	0.72	1.768	2.35	2.51	23.02
Monthly consumption(MMc)	10.046	9.724	9.322	9.24	9.72	9.56	3.13	1.93	2.89	7.072	9.4	10	92.1

Table C.2. Computed Water demand Data of Nura Era Complexes (UV2)

a. Salient features of UV2

Total activity level (ha)	8753
Overall efficiency (%)	40
Major crop	Fruits and vegetables
Return flow (%)	10%
Consumption rate (%)	90%

b. Water abstractions (MMC) of each Farm in (UV2)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Nura Era State	3.775	3.134	3.85	5.9	7.9	8.19	7.337	7.26	8.05	7.978	6.98	3.49	73.868
Nura Era Privates	4.64	3.85	4.73	7.268	9.72	10.	9.02	8.93	9.895	9.81	8.58	4.29	90.88
Merti Jeju Achamo	0.879	0.73	0.896	1.378	1.84	1.90	1.71	1.69	1.876	1.86	1.63	0.81	17.2
Degaga	0.42	0.515	0.492	0	0.024	0.028	0.028	0.024	0	0	0	0.28	1.81
Tibila	0.9	0.752	0.922	1.417	1.89	1.96	1.758	1.74	1.93	1.91	1.67	0.84	17.7
Merti Jeju State	1.73	1.44	1.762	2.714	3.63	3.76	3.37	3.34	3.69	3.66	3.2	1.6	33.9
UV2 total	12.35	10.42	12.62	18.69	25.	25.92	23.22	23	25.5	25.22	22.1	11.3	235.321

c. Irrigation water data used For WEAP Model

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
IWR(mm)	14.11	11.88	14.5	21.35	28.6	28.6	26.5	26.27	29	28.813	25.21	12.91	267.7
Monthly abstraction MMC	12.35	10.4	12.7	18.69	25	25	23.2	22.99	25.4	25.22	22.07	11.3	234.3
Monthly Variation (%)	5.271	4.439	5.4	7.977	10.7	10.7	9.91	9.813	10.8	10.765	9.419	4.823	100
Water use rate(m^3/ha	1411	1188	1445	2135	2856	2856	2653	2627	2902	2881.3	2521	1291	26766
Monthly losses (MMC)	7.41	6.24	7.59	11.21	15	15	13.9	13.79	15.2	15.132	13.24	6.78	140.6
Return flow MMC	1.235	1.04	1.27	1.869	2.5	2.5	2.32	2.299	2.54	2.522	2.207	1.13	23.43
Total consumption (MMC)	11.12	9.36	11.4	16.82	22.5	22.5	20.9	20.69	22.9	22.698	19.86	10.17	210.9

Table C.3. Computed Water demand Data of Metehara / Abadir area (UV3)

a. Salient Features

Total activity level (ha)	12896
Overall efficiency (%)	55
Major crop	Sugar cane
Return flow (%)	20%
Consumption rate (%)	80%

b. ***Irrigation water data of UV3 used For WEAP Model***

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
IWR(mm)	140.7	139.3	145	164.9	181	198	186	89.56	103	181.2	178	155.9	1862
Monthly abstraction MMC	18.14	17.96	18.7	21.26	23.3	25.6	23.9	11.55	13.3	23.37	22.95	20.1	240.1
Monthly variation %	7.555	7.48	7.8	8.855	9.7	10.6	9.97	4.81	5.54	9.73	9.559	8.372	100
Water use rate m^/ha	1407	1393	1452	1649	1805	1983	1856	895.6	1031	1812.2	1780	1559	18620
Monthly losses MMC	8.163	8.082	8.42	9.567	10.5	11.5	10.8	5.198	5.98	10.52	10.33	9.045	108.1
Return flow MMC	3.628	3.592	3.74	4.252	4.66	5.11	4.79	2.31	2.66	4.67	4.59	4.02	48.02
Total Consumption (MMC)	14.51	14.37	15	17.01	18.6	20.5	19.1	9.24	10.6	18.7	18.36	16.08	192.1

Table C.4. Computed Water demand Data of Small scale irrigation of OIDA Under operation (OIDA 1)

a. Salient Features

Total activity level (ha)	1607ha
Overall efficiency (%)	60
Major crops	Sugar cane
Return flow (%)	10%
Consumption rate (%)	90%

b. Water abstraction of each OIDA Farms(MMC)

Scheme Name	Irrigated Land (ha)	Abstracted Water per month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Melka Oba 1	60	0.14	0.17	0.16	0	0.01	0.009	0.009	0.008	0	0	0	0.093	0.6036
Qobo Malmele	30	0.07	0.09	0.08	0	0	0.005	0.005	0.004	0	0	0	0.046	0.3018
Melka Oba 2	40	0.094	0.11	0.11	0	0.01	0.006	0.006	0.005	0	0	0	0.062	0.4024
Batu-Degaga	100	0.234	0.29	0.27	0	0.01	0.016	0.016	0.013	0	0	0	0.155	1.006
Doni WV		0.935	1.15	1.09	0	0.05	0.063	0.063	0.053	0	0	0	0.62	4.0239
Doni Care	200	0.468	0.57	0.55	0	0.03	0.032	0.032	0.026	0	0	0	0.31	2.0119
Gara Dima	300	0.701	0.86	0.82	0	0.04	0.047	0.047	0.039	0	0	0	0.465	3.0179
Lugo	57	0.133	0.16	0.16	0	0.01	0.009	0.009	0.007	0	0	0	0.088	0.5734
Sara	120	0.281	0.34	0.33	0	0.02	0.019	0.019	0.016	0	0	0	0.186	1.2072
Weba	160	0.374	0.46	0.44	0	0.02	0.025	0.025	0.021	0	0	0	0.248	1.6096
Sogido 1	70	0.164	0.2	0.19	0	0.01	0.011	0.011	0.009	0	0	0	0.108	0.7042
Sogido 2	70	0.164	0.2	0.19	0	0.01	0.011	0.011	0.009	0	0	0	0.108	0.7042
Total OIDA 1	**1607**	**3.757**	**4.6**	**4.39**	**0**	**0.21**	**0.253**	**0.253**	**0.211**	**0**	**0**	**0**	**2.49**	**16.166**

C.Irrigation water demand data required for WEAP

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
IWR(mm)	233.8	286.2	273	0	13.1	15.7	15.7	13.13	0	0	0	154.9	1006
Monthly abstraction MMC	3.757	4.6	4.39	0	0.21	0.25	0.25	0.211	0	0	0	2.49	16.17
Monthly variation %	23.24	28.45	27.2	0	1.3	1.56	1.56	1.305	0	0	0	15.4	100
Water use rate m^/ha	2338	2862	2732	0	131	157	157	131.3	0	0	0	1549	10060
Monthly losses MMC	1.503	1.84	1.76	0	0.08	0.1	0.1	0.084	0	0	0	0.996	6.466
Return flow MMC	0.376	0.46	0.44	0	0.02	0.03	0.03	0.021	0	0	0	0.249	1.617
Consumed Water (MMC)	3.381	4.14	3.95	0	0.19	0.23	0.23	0.19	0	0	0	2.241	14.55

Table C.5. Computed Water demand Data of middle and lower valley farms (DSI)

a. ***Salient Features***

Total activity level (ha)	26191ha
Overall efficiency (%)	50
Major crops	Cotton,
Return flow (%)	10%
Consumption rate (%)	90%

b. ***Irrigation water data of Existing downstream irrigation farms of UV3***

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GIWR(mm)	22.41	21.7	21	114	292	273	66.2	44.63	168	168	62.58	41.1	1293
Monthly abstraction MMC	28.28	27.4	26	144	368	344	83.6	56.32	212	212	78.97	51.8	1632
Monthly variation %	1.733	1.68	1.6	8.8	22.6	21.1	5.12	3.451	13	13	4.839	3.18	100
Water use rate m^/ha	224.1	217	208	1139	2917	2726	662	446.3	1678	1679	625.8	411	12933
Monthly losses MMC	2.935	2.85	2.7	14.9	38.2	35.7	8.68	5.845	22	22	8.195	5.38	169.4
Return flow MMC	1.174	1.14	1.1	5.96	15.3	14.3	3.47	2.338	8.79	8.8	3.278	2.15	67.75
Consumption MMC	4.696	4.55	4.4	23.9	61.1	57.1	13.9	9.352	35.2	35.2	13.11	8.61	271

Table C.6. Computed Water demand Data of Wonji Area Expansions (WAE)

a. salient Features

Total activity level (ha)	16715ha
Overall efficiency (%)	80
Major crops	Sugar cane
Return flow (%)	10%
Consumption rate (%)	90%
Implementing time	2010

Farm	Irrigable area (ha)
Wonji Dodota	3741
Wonji WakeTio	512
Welenchiti	9000
Bofa	3462
Total	**16715**

b.Irrigation water demand data of Wonji area irrigation Expansions

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
GIWR mm	130	112.5	119	116.3	143	139	16.3	2.5	62.5	138.75	143.8	137.5	1260
Monthly abstraction(MMC)	21.73	18.8	19.8	19.43	23.8	23.2	2.72	0.418	10.4	23.192	24.03	22.98	210.6
Monthly variation (%)	10.32	8.929	9.43	9.227	11.3	11	1.29	0.198	4.96	11.012	11.41	10.91	100
Water use rate (M^3/ha)	1300	1125	1188	1163	1425	1388	163	25	625	1387.5	1438	1375	12600
Monthly losses MMC	4.346	3.761	3.97	3.886	4.76	4.64	0.54	0.084	2.09	4.6384	4.806	4.597	42.12
Return flow MMC	2.173	1.88	1.98	1.943	2.38	2.32	0.27	0.042	1.04	2.3192	2.403	2.298	21.06
Consumption (MMC)	19.56	16.92	17.9	17.49	21.4	20.9	2.44	0.376	9.4	20.873	21.63	20.68	189.5

Table C.7. Computed Water demand Data of OIDA small scale irrigations (OIDA2)

a. Salient Features

Total activity level (ha)	609ha
Overall efficiency (%)	60
Major crops	Sugar cane
Return flow (%)	10%
Consumption rate (%)	90%
Implementing time	2010

b.Irrigation water demand data of OIDA proposed small scale irrigations

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GIR mm	233.76	286.3	273	0	13.1	15.8	15.8	13.1	0	0	0	155	1006
Monthly Abstraction MMC	1.4236	1.744	1.66	0	0.08	0.1	0.1	0.08	0	0	0	0.94	6.126
Monthly variation %	23.238	28.46	27.2	0	1.31	1.57	1.57	1.31	0	0	0	15.4	100
Water use rate (m^3/ha)	2337.6	2863	2732	0	131	158	158	131	0	0	0	1550	10060
Monthly losses MMC	0.5694	0.697	0.67	0	0.03	0.04	0.04	0.03	0	0	0	0.38	2.451
Return flow MMC	0.1424	0.174	0.17	0	0.01	0.01	0.01	0.01	0	0	0	0.09	0.613
Consumption MMC	1.2813	1.569	1.5	0	0.07	0.09	0.09	0.07	0	0	0	0.85	5.514

Table C.8. Computed Water demand Data of Metehara Expansions

a. Salient Features

Total activity level (ha)	3200ha
Overall efficiency (%)	70
Major crops	Sugar cane
Return flow (%)	20%
Consumption rate (%)	80%
Implementing time	2009

b.Irrigation water demand data of Metehara expansion

parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GIR mm	78.698	12.73	42.013	73.94	69.462	89.2	127.6	149	124	86.7	65.6	55.6	974.8
Monthly abstraction MMC	2.5183	0.407	1.3444	2.366	2.2228	2.854	4.082	4.768	3.98	2.77	2.1	1.78	31.2
Monthly Variation %	8.0729	1.306	4.3098	7.585	7.1255	9.15	13.09	15.29	12.8	8.89	6.73	5.7	100
Water use rate m^3/ha	786.98	127.3	420.13	739.4	694.62	892	1276	1490	1244	867	656	556	9748
Overall Loss	0.7555	0.122	0.4033	0.71	0.6668	0.856	1.225	1.43	1.19	0.83	0.63	0.53	9.359
Return Flow MMC	0.5037	0.081	0.2689	0.473	0.4446	0.571	0.816	0.954	0.8	0.55	0.42	0.36	6.239
Consumption MMC	2.0147	0.326	1.0755	1.893	1.7782	2.283	3.266	3.815	3.18	2.22	1.68	1.42	24.96

Table C.9. Computed Water demand Data of Fentale integrated Irrigation

a. Salient Features

Total activity level (ha)	18,130ha
Overall efficiency (%)	60
Major crops	Sugar cane, cereals, vegetables, Forage
Return flow (%)	20%
Consumption rate (%)	80%
Implementing time	2010

b.Irrigation water demand data of Fentale irrigation

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
IWR(mm)	84.5	76.1	46	93.8	115	161	120	164.1	165	138.46	109.5	118.3	1393
Monthly abstraction MMC	15.32	13.8	8.4	17	20.9	29.2	21.8	29.75	29.9	25.103	19.85	21.44	252.5
Monthly variation %	6.067	5.47	3.3	6.74	8.28	11.6	8.65	11.78	11.8	9.9417	7.862	8.491	100
Water use rate m^/ha	845	761	462	938	1153	1609	1205	1641	1650	1384.6	1095	1183	13926
Monthly losses	6.128	5.52	3.4	6.8	8.36	11.7	8.74	11.9	12	10.041	7.941	8.576	101
Return flow MMC	3.064	2.76	1.7	3.4	4.18	5.83	4.37	5.95	5.98	5.0206	3.97	4.288	50.5
Consumption MMC	12.26	11	6.7	13.6	16.7	23.3	17.5	23.8	23.9	20.082	15.88	17.15	202

Table C.10. Computed Water demand Data of Towns' water supply

1. *DEMAND DATA OF NAZERETH WATER SUPPLY*

a. Salient features

Total activity level (People)	281560
Annual Growth rate %	3.2
Loss and Leakage (%)	20
Consumption rate %	80

b.Monthly Water demand data of Nazereth Town

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly water demand Mm^3	0.55	0.5	0.552	0.53	0.55	0.53	0.55	0.55	0.534	0.55	0.53	0.55	6.5
Monthly variation %	8.49	7.67	8.493	8.22	8.49	8.22	8.49	8.49	8.219	8.49	8.22	8.49	100
Consumption Mm3	0.44	0.4	0.442	0.43	0.44	0.43	0.44	0.44	0.427	0.44	0.43	0.44	5.2
Losses Mm3	0.11	0.1	0.11	0.11	0.11	0.11	0.11	0.11	0.107	0.11	0.11	0.11	1.3
Water use rate m^3/person	1.96	1.77	1.961	1.9	1.96	1.9	1.96	1.96	1.897	1.96	1.9	1.96	23.09

2. DEMAND DATA OF METEHARA WATER SUPPLY

a. Salient features

Total activity level (People)	34100
Annual Growth rate %	6
Loss and Leakage (%)	20
Consumption rate %	80

b.Monthly Water demand of Metehara Town

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly water demand Mm^3	0.2548	0.23	0.255	0.247	0.25	0.247	0.25	0.255	0.25	0.25	0.25	0.255	3
Monthly variation %	8.4932	7.671	8.493	8.219	8.49	8.219	8.49	8.493	8.22	8.49	8.22	8.493	100
Consumption Mm3	0.2038	0.184	0.204	0.197	0.2	0.197	0.2	0.204	0.2	0.2	0.2	0.204	2.4
Loss leakage Mm3	0.051	0.046	0.051	0.049	0.05	0.049	0.05	0.051	0.05	0.05	0.05	0.051	0.6
Water use rate m3/person	7.472	6.749	7.472	7.231	7.47	7.231	7.47	7.472	7.23	7.47	7.23	7.472	88

Table C:11.Monthly irrigation abstraction for major irrigation projects according to WWDSE (2006)

Scenario 1

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
UV1	12.5	12.14	11.6	11.53	12.09	11.93	3.94	2.4	3.63	8.79	11.7	12.55	115
UV2	8.83	8.6	8.22	8.17	8.56	8.45	2.79	1.7	2.57	6.23	8.29	8.88	81
UV3	18.1	17.96	18.72	21.26	23.28	25.57	23.93	11.55	13.29	23.4	22.95	20.1	240
MV1	5.58	5.69	5.44	5.4	5.66	5.59	1.85	1.13	1.7	4.12	5.48	5.88	54
MV2	0	0	0	7.36	21.33	19.84	4.67	3.18	12.74	12.2	3.29	1.47	86
MV3	0	0	0	3.14	9.09	8.84	1.99	1.36	5.43	5.12	1.4	0.63	37
LV1	0	0	0	1.92	5.56	5.17	1.22	0.86	3.32	3.13	0.86	0.38	22
LV2&3	0	0	0	12	34.76	32.33	7.62	5.19	20.76	19.6	5.36	2.4	140
Sum	45.4	44.39	43.39	70.78	120.34	117.34	48.01	27.34	63.44	82.4	59.32	52.3	775

Scenario II

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
UV1	12.5	12.14	11.6	11.53	12.09	11.93	3.94	2.4	3.63	8.79	11.7	12.55	115
UV2	8.83	8.6	8.22	8.17	8.56	8.45	2.79	1.7	2.57	6.23	8.29	8.88	81
UV3	18.1	17.96	18.72	21.26	23.28	25.57	23.93	11.55	13.29	23.4	22.95	20.1	240
MV1	5.58	5.69	5.44	5.4	5.66	5.59	1.85	1.13	1.7	4.12	5.48	5.88	54
MV2	0	0	0	7.36	21.33	19.84	4.67	3.18	12.74	12.2	3.29	1.47	86
MV3	0	0	0	3.14	9.09	8.84	1.99	1.36	5.43	5.12	1.4	0.63	37
LV1	0	0	0	1.92	5.56	5.17	1.22	0.86	3.32	3.13	0.86	0.38	22
Tendaho new	76.2	77.7	84.3	86.6	156.9	162.75	149.4	151.9	145.4	120.6	108.9	94.67	1415
Sum	121.6	122	128.3	154.3	242.44	247.76	189.8	174	188.1	183.4	162.9	144.6	2050

Scenario III

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
UV1	21.24	20.6	19.7	19.55	20.5	20.23	6.7	4.07	6.15	14.9	19.8	21.3	195
UV2	8.83	8.6	8.22	8.17	8.56	8.45	2.79	1.7	2.57	6.23	8.29	8.88	81
UV3	23.8	23.59	24.6	27.9	30.6	33.6	31.4	15.17	17.45	30.7	30.13	26.4	315
Kesem	19.9	22.8	26.2	36.8	52.3	54.3	36.6	31.9	40.1	41.1	34.2	0	396
MV2	0	0	0	7.36	21.33	19.84	4.67	3.18	12.74	12.2	3.29	1.47	86
MV3	0	0	0	3.14	9.09	8.84	1.99	1.36	5.43	5.12	1.4	0.63	37
LV1	0	0	0	1.92	5.56	5.17	1.22	0.86	3.32	3.13	0.86	0.38	22
Tendaho	76.2	77.7	84.3	86.6	156.9	162.75	149.4	151.9	145.4	121	108.9	94.67	1415
Sum	150	153.3	162.9	191.4	304.7	312.8	234.8	210.1	233.2	234	207	153.7	2548

Scenario IV

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
UV1	35	33.9	32.4	32.2	33.8	33.3	11.02	6.71	10.12	24.55	32.7	35.03	321
UV2	8.83	8.6	8.22	8.17	8.56	8.45	2.79	1.7	2.57	6.23	8.29	8.88	81
UV3	23.8	23.59	24.6	27.9	30.6	33.6	31.4	15.17	17.45	30.7	30.13	26.4	315
Kesem	19.9	22.8	26.2	36.8	52.3	54.3	36.6	31.9	40.1	41.1	34.2	0	396
MV2	0	0	0	7.36	21.33	19.84	4.67	3.18	12.74	12.2	3.29	1.47	86
MV3	0	0	0	3.14	9.09	8.84	1.99	1.36	5.43	5.12	1.4	0.63	37
LV1	0	0	0	1.92	5.56	5.17	1.22	0.86	3.32	3.13	0.86	0.38	22
Tendaho	76.2	77.7	84.3	86.6	156.9	162.75	149.4	151.9	145.4	121	108.9	94.67	1415
Sum	169.6	172.3	181.1	209.5	323.7	331.5	241	213.9	238.8	247.6	225.3	173.35	2674

ANNEX D

SOME RESULTS OF THE MODEL

Table D.1 Annual Supply Requirements for Each Demand site in future scenario

Nodes	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
DSIrr	406.6	406.6	406.6	406.6	406.6	406.6	407	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6
FENT	420.8	420.8	420.8	420.8	420.8	420.8	421	420.8	420.8	420.8	420.8	420.8	420.8	420.8	420.8	420.8	420.8
Koka Seep	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9
Met Exp	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Metehara WS	3.8	4.2	4.7	5.3	6	6.7	7.5	8.5	9.5	10.7	12	13.5	15.2	17.1	19.2	21.5	24.2
Nazereth	8.4	9	9.5	10.2	10.8	11.5	12.3	13.1	13.9	14.8	15.8	16.8	17.9	19.1	20.3	21.6	23
OIDA1	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9
Seep4	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
UV1	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91
UV2	223.8	223.8	223.8	223.8	223.8	223.8	224	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8
UV3	325.5	325.5	325.5	325.5	325.5	325.5	326	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5
WAE	224.6	224.6	224.6	224.6	224.6	224.6	225	224.6	224.6	224.6	224.6	224.6	224.6	224.6	224.6	224.6	224.6
All Others	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2

Table D.2 Annual Supply Delivered For each site in Future scenario

Nodes	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DSIrr	249.1	189.7	186.9	186.9	185.4	182	216	188.4	181.9	182.4	180	180	180	180	180
FENT	337.1	294.8	271.8	277.8	271.8	271.8	295	277.5	271.8	271.8	271.8	248.5	271.8	249.5	246.7
Met Exp	43.6	37.4	36.7	37.4	36.7	36.7	37.4	37.4	36.7	36.7	36.7	36.7	36.7	36.7	36.7
Metehara WS	3.8	4.2	4.7	5.3	6	6.7	7.5	8.5	9.5	10.7	12	13.5	15.2	17.1	19.2
Nazereth	8.4	9	9.5	10.2	10.8	11.5	12.3	13.1	13.9	14.8	15.8	16.8	17.9	19.1	20.3
OIDA1	18.6	13.2	13.2	13.2	13.2	7.8	13.2	13.2	7.8	7.8	7.8	7.8	7.8	7.8	7.8
OIDA2	8.9	6.4	3.8	6.4	3.8	3.8	6.4	6.4	3.8	3.8	3.8	3.8	3.8	3.8	3.8
UV1	91	91	91	82.6	83.5	90.7	91	91	85.6	89.9	91	78.9	88.8	81.4	91
UV2	212.6	192.4	161.1	156.5	154	162	194	209	171.5	166.7	169.6	127.1	142.8	129.7	134.9
UV3	290.8	241.7	205	205	205	203.9	253	229.3	207.7	214.2	180.6	180.6	180.6	180.6	180.6
WAE	174.5	132.6	115.6	132.6	112.5	112.5	133	132.6	112.5	112.5	112.5	112.5	112.5	112.5	112.5

Nodes	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
DSirr	157.5	216.9	219.8	219.8	221.2	224.6	191	218.2	224.7	224.2	226.6	226.6	226.6	226.6	226.6	226.6	219.8
FENT	83.7	125.9	148.9	142.9	148.9	148.9	126	143.2	148.9	148.9	148.9	172.3	148.9	171.2	174.1	174.5	125.9
Met Exp	8.5	14.6	15.3	14.6	15.3	15.3	14.6	14.6	15.3	15.3	15.3	15.3	15.3	15.3	15.3	19.5	14.6
Metehara WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nazereth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OIDA1	0.3	5.7	5.7	5.7	5.7	11	5.7	5.7	11	11	11	11	11	11	11	11	5.7
OIDA2	0.3	2.8	5.4	2.8	5.4	5.4	2.8	2.8	5.4	5.4	5.4	5.4	5.4	5.4	5.4	7.5	2.8
UV1	0	0	0	8.4	7.4	0.2	0	0	5.4	1.1	0	12.1	2.1	9.5	0	0.3	1.6
UV2	11.2	31.5	62.7	67.3	69.8	61.9	30	14.8	52.3	57.1	54.2	96.7	81	94.2	88.9	83.7	52.3
UV3	34.7	83.7	120.5	120.5	120.5	121.6	72.4	96.2	117.8	111.3	144.9	144.9	144.9	144.9	144.9	144.9	120.5
WAE	50.1	92	109	92	112.1	112.1	92	92	112.1	112.1	112.1	112.1	112.1	112.1	112.1	117.4	92
Sum	346.2	573.1	687.2	673.9	706.3	701	534	587.5	692.9	686.4	718.4	796.3	747.3	790.2	778.2	785.4	635.2

Table D.3. Annual Unmet demands for each Node in future scenario

Table D.4. Monthly average simulated stream flows at selected stations (MMC)

Stations	Jan	Febr	Mar	Apr	May	June	July	August	Sept	Oct	Nov
Awash river. Headflow	8.4	8.2	13.1	16.8	15.3	14.8	173.3	326.3	362.5	131.7	19.4
Awash river . Aw below Koka	93.8	77.7	94.4	87.7	93	90	95	136.3	130.7	99.3	82.4
Awash river . Awash@wonji	94.3	82.2	99.5	96.1	104.7	106.9	117.1	153.7	150	114.3	101
Awash river . Awash @NuraEra	100.7	172.3	154	111.2	115.5	110	152.6	323.6	283.8	199.2	158
Awash river. Keleta Inflow	11.7	11.1	14	15.2	7.8	5.3	177.1	235	325.8	214.4	14.9
Awash river. Awash@Hombole	12.7	11.9	17.7	20	22.1	32.2	263.2	558.6	325.1	54.1	26.9
Awash river. Awash@Metehara	80	68.5	93.5	88.2	83.8	77	122.9	209.6	214.5	93.2	70.1
Awash river . Awash@Awash	100.6	89.7	118	112.2	108.1	96.8	175.8	324.5	292.2	125.6	87.9
Keleta . Keleta@sire	2.1	2.4	4.8	5.3	5.6	4.7	19.5	40.8	30.4	11.7	3.9
Mojo . Mojo@Mojo	3.6	3.7	4.6	5	5.6	9.2	34.8	67.1	20.1	6	4.6

Table D.5 Annual simulated flow (MMC) in gauged stations

s	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
w	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	1,106.90	
ow	862.9	952.3	1,186.90	1,186.30	1,166.30	774.1	949.9	1,413.70	1,593.60	1,913.30	1,457.50	888.1	1,378.20	785.2	
@wonj	854.1	946.3	1,266.50	1,040.40	1,401.60	1,075.60	1,239.00	1,707.50	1,251.30	1,402.90	1,662.40	1,061.00	1,378.50	1,665.50	
@ a	1,550.60	1,648.80	2,316.10	1,908.10	2,652.80	2,001.30	2,298.30	3,599.40	2,418.80	2,536.40	2,826.90	2,032.50	2,605.10	1,792.20	
	1,716.30	998.7	999.5	953.2	990.1	1,066.10	1,033.50	1,054.80	1,042.50	965.1	1,000.20	971.2	981.3	998	
@ e	1,106.90	1,199.20	1,246.60	940.8	1,393.30	1,162.80	1,299.50	2,007.60	1,952.40	2,403.10	963.5	1,274.70	1,310.30	1,320.50	
t ra	858.8	1,296.00	1,433.70	1,361.20	1,511.60	1,135.10	1,308.20	1,586.30	1,941.90	1,446.50	1,387.60	646.2	1,131.50	1,713.20	
@	1,112.60	2,035.10	1,921.50	1,498.80	1,731.10	1,395.40	1,947.20	2,513.00	2,321.20	2,336.30	1,807.10	1,017.80	1,482.60	1,991.90	
@	118.6	125	153	78.4	128.1	220.1	160.7	209.6	197.7	90.7	127.7	97.9	136.1	147	
Mojo	113.8	156.3	183.6	72.4	168.6	198.3	106	279	161	290	65.2	216.8	259.1	222	

024	2025	2026	2027	2028
.90	1,106.90	1,106.90	1,106.90	1,106.90
.40	1,288.40	1,344.60	1,127.50	849.6
.60	1,835.00	1,719.30	1,373.50	1,006.90
.10	1,416.40	1,586.50	1,536.70	999.9
7.6	1,014.00	976.7	979.8	940.9
4.6	1,576.60	1,331.70	1,061.50	1,246.80
.80	1,300.90	1,359.10	1,069.40	617.8
.20	1,991.10	1,852.10	1,510.30	899.4

5.1	150.7	103.9	107.9	66.9
9.9	180	103.2	86.3	92.1

Table D. 6. Annual Supply required for each demand site in current scenario (MMC)

odes	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
DSirr	406.6	406.6	406.6	406.6	406.6	406.6	407	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6	406.6
Seep	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9
ehara WS	3.8	4.2	4.7	5.3	6	6.7	7.5	8.5	9.5	10.7	12	13.5	15.2	17.1	19.2	21.5	24.2	27.2	30.6
ereth	8.4	9	9.5	10.2	10.8	11.5	12.3	13.1	13.9	14.8	15.8	16.8	17.9	19.1	20.3	21.6	23	24.5	26.1
IDA1	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
eep1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
eep2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
eep3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
eep4	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
UV1	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91
UV2	223.8	223.8	223.8	223.8	223.8	223.8	224	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8	223.8
UV3	325.5	325.5	325.5	325.5	325.5	325.5	326	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5	325.5

Table D.7 Annual supply Delivered for each demand site in Current scenario (MMC)

s	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	350.3	293.4	230.6	230	229.1	229.8	321	305.8	230.7	223.5	229.1	193.4	195.1	193.4	194	193.4	229.1	193.4	193.4
ara	3.8	4.2	4.7	5.3	6	6.7	7.5	8.5	9.5	10.7	12	13.5	15.2	17.1	19.2	21.5	24.2	27.2	30.6
eth	8.4	9	9.5	10.2	10.8	11.5	12.3	13.1	13.9	14.8	15.8	16.8	17.9	19.1	20.3	21.6	23	24.5	26.1
1	16.2	15.9	15.8	15.8	15.7	15.8	15.9	16.1	15.8	15.9	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7	15.7
	91	86.9	87	85.2	86.2	87.8	91	91	86.3	87.7	86.6	79.3	79.8	80.2	81.9	83.3	88.7	82.4	74.8
	223.8	213.8	214	209.7	212.1	216	224	223.8	212.4	215.9	213.1	195.1	196.4	197.3	201.4	205	218.2	202.7	184.1
	325.5	290.8	277.9	272.5	262.7	270.6	292	314.8	278.7	290.3	259.2	230.8	251	232.8	240.5	233.5	259.2	231.8	230.4

Table D.8 Annual water demand (including losses) in current scenario (MMC)

Nodes	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
DSirr	203.3	203.3	203.3	203.3	203.3	203.3	203	203.3	203.3	203.3	203.3	203.3	203.3	203.3	203.3	203.3	203.3	203.3
Koka Seep	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9	89.9
Metehara WS	3	3.4	3.8	4.3	4.8	5.4	6	6.8	7.6	8.6	9.6	10.8	12.2	13.7	15.3	17.2	19.4	21.8
Nazereth	6.7	7.2	7.6	8.1	8.7	9.2	9.8	10.5	11.1	11.9	12.6	13.5	14.3	15.3	16.3	17.3	18.4	19.6
OIDA1	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
Seep1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Seep2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Seep3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Seep4	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
UV1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1
UV2	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5
UV3	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179

Table D.9 Annual Unmet demand in current scenario (MMC)

Nodes	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
DSirr	56.3	113.2	176	177	178	176.8	85.7	101	175.9	183	178	213.3	211.5	213.3	212.6	213.3	177.5	213.3
Metehara WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nazereth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OIDA1	0	0.3	0.3	0.4	0.4	0.4	0.2	0.1	0.3	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
UV1	0	4.1	4	5.8	4.8	3.2	0	0	4.6	3.2	4.4	11.7	11.2	10.8	9.1	7.7	2.3	8.6
UV2	0	10	9.8	14.2	11.7	7.8	0	0	11.4	7.9	10.7	28.7	27.4	26.6	22.4	18.9	5.6	21.1
UV3	0	34.7	47.5	53	62.8	54.9	33.5	10.7	46.7	35.2	66.3	94.7	74.5	92.7	85	92	66.3	93.7