Addis Ababa University

Institute of Technology

School of Civil and Environmental Engineering

ASSESSMENT OF LONG DISTANCE WATER SUPPLY ISSUES: THE CASE OF GIMBICHU FENTALE WATER SUPPLY PROJECT

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Abstract

This project assesses the issues on long distance water supply systems with the case of Gimbichu Fentale water supply projects which is located in Oromia Region, East Shewa Zone; and which is currently serving six woredas of the zone namely Gimbichu, Ada'a, Lume, Adama, Boset and Fentale. Based on the data availed from Water supply board and Oromia Water Mineral and Energy bureau and with Hydraulic Simulation of EPANET2, it was found that there was serious issues on this long distance water supply regarding;

- High unbalance of supply (33.5 lt/sec) relative to current demand (71.95 lt/sec),
- High pressure fluctuation in the system (206.44 m at Junc J(17+325)) and negative 130.1m at Junc E(11+025),
- Significant unaccounted/loss (37%) of water in the system and the sustainability issue of the project.

It was found on the study that, supply of the source is on giving below half of the current demand of the area. On the feasibility study of the project, it was recommended that, additional boreholes should be dug to meet the demands from inception of the project. Nothing is done yet by sector office and this brings the high unbalance of supply with demand.

The issue of head loss due to friction and the issue of unaccounted water are also seen on the study. On average 37% of the water supplied is not accounted. There was significant overflow on reservoirs, collection chambers, and pressure reducing structures during wet season and serious water shortage during dry period. In addition there was a high line leakage and also there are many water meters which are not functioning.

The issue of the sustainability of the project is also assessed. Even though there was a structured water board that is on managing the system, it was found that, there is a great lack of integration among all concerned stakeholders. Nothing is done to extend the life of project beyond its design year; there is high degradation of the environment around the project site. Finally it was recommended in the project that, without properly and professionally addressing the issues raised, it is impossible to meet the goals sets of this and other long distance water supply projects already constructed or on progress in the country.

Key words: Water supply, Gimbichu Fentale project, Supply-demand, pressure, head loss, leakage, unaccounted water, sustainability

List of abbreviations

ADB	Asia Development Bank
CAD	Computer Aid Design
CARL	Current Annual Real Loss
CBO	Community Based Organization
DCI	Ductile Cast Iron
ETB	Ethiopia Birr
FBO	Faith Based Organization
GFWSP	Gimbichu Fentale Water Supply Project
GI	Galvanized Iron
HDP	High Density Polyethylene
ILI	Infrastructure Leakage Index
MASL	Meter above Sea Level
MWC	Meter Water Column
NGO	Non-Government Organization
OWMEB	Oromia Water Mineral and Energy Bureau
PVC	Polyvinyl Chloride
UARL	Unavoidable Annual Real Loss
UFW	Unaccounted For Water
UNEP	United Nation Environment Program
US	United State
USEPA	Unite State Environmental Protection Agency
WCED	World Commission on Environment and Development
WHO	World Health Organization
WP	Water Point
WSS	Water Supply and Sanitation

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1. Introduction

1.1. Background

The provision of adequate and reliable water supply in developing countries is becoming a challenge for most water utilities especially public service providers. Water demand has been increasing drastically in these countries due to many factors including population growth and agricultural industry activities. As a consequence, in many countries public service utilities have failed to provide consumers with adequate water supply and sanitation services; very often, the water has to be transported to the consumers from distance locations through water transmission pipe line. (Bernhard Lesser and Alexander Heinz, 2011)

Globally, long distance water supply is more shifting towards sophisticated piped water schemes as a result of improving standards of living and increasing aspirations of the population. Where local water sources are scare or not fit for drinking (for example, in saline belts, or in fluoride or arsenic affected areas) the most common option left is to bring in water from an outside distance sources using closed pipe systems. The cost incurred for implementing of such projects pushes the study/design to make the system to serve and address multi villages/small towns along the route.

In addition, surface water sources like rivers and reservoirs, also present a challenge. These sources are often located far away from the group of villages to serve, and involve the construction and operation of more complex installation such as head works, pumping stations, long pumping mains, water treatment plants, domestic and commercial connections, water meters and others monitoring and complex control equipment. Reservoir filling operations, distribution management and other complex operational tasks may dictate a more elaborate approach to management of such long distance water supply schemes.

Globally many researches were conducted on water supply systems. Most of the researches were independently focused on how to increase supply by reducing component wise challenges. There is a significant gap in the studies to integrally show the whole problems on specially long distance water supply systems. Therefore the aim of this research is to integrally assess the whole issues on long distance water supplies such as supply-demand situations, leakage on system and its management, effect of hydraulic pressure on main line and sustainability of the system through proper operation and management.

Water reservoirs in long distance supply systems do not only have the task to master pressure variations in the system but shall also compensate differences of water resources available and water demand, to separate supply areas from each other, to ensure suitable hydraulic conditions in very elevated points and to draw the borderline between the long distance supply system and local distribution system. For the dimensioning of water reservoirs a compromise shall be found between optimum coverage of water demand fluctuations and minimization of the dwell time of the water in the pipeline system.

Due to large pipe diameters, important water quantities may be released from long distance pipelines in case of pipe breakage and thus may lead to considerable damages. Therefore the protection devices against pipe breakage shall be arranged everywhere in the long distance supply system where otherwise increased breakage hazards would exist.

All these requirements interact in long distance water supply system and should never be considered in isolation. Therefore the design and construction, the operation and organization of a long distance water supply system require comprehensive and expertise knowledge based on practical experiences. (Mehlhom & Zweckverband Bodensee-Wasserversorgung, 2003)

1.2. Organization of the project

The entire project was organized as follows:

1. Introduction formed chapter one and it constitutes sufficient background information of the project including proper acknowledgement of the previous work on which this topic is building. It consists of but not limited to;

- Statement of the problem; which is stated in such a way that it would lead to analytical thinking on the part of the researcher with the aim of possibly concluding solutions to the stated problem. The problem statement describes the context for the study and it also identifies the general analysis approach.
- Hypothesis and research question; which are linked to the speculative proposition of the problem statement, can be inferred from the overall conceptual framework of a study, and are of critical importance to data analysis and interpretation.
- Objective of the study which is general as well as specific. The objectives of a project summarize what is to be achieved by the study and it closely related to the statement of the problem. After statement of the primary objective, a specific objective is mentioned.

2. Chapter two of this research is Literature review; which is the description of the literature relevant to this particular field or topics and it is a sound knowledge with regard to this research topic. It is therefore imperative that the researcher, at the time of the submission of the project, clearly indicates what theoretical knowledge he possesses about the prospective research.

3. Methodology constituted chapter three of the project. The methods or procedures section is really the heart of this project. It includes but not limited to, sources of data collection, Selection of the study area, data collection technique and tools of data analysis.

4. Discussions and Results from the institutions and field observation formed chapter four. This included the unbalance of demand with supply, problem of pressure in long distance closed pipe, problem of leakage and unaccounted loss and the issue of sustainability.

5. Conclusion and Recommendation was the final chapter-five. This was where the findings from all the literature, interviews and secondary data were concluded and recommended in addition to the result of the hypotheses

1.3. Statement of the problem

In a specially-commissioned survey for United Nations Environment Program (UNEP), dubbed GEO-2000, 200 leading scientists from 50 countries around the world identified a scarcity of clean water as one of the most pressing problems facing humanity. It was found out that, on average, more than 20% of the world's population lacks access to safe drinking water.

In the developing countries in particular, governments face problems of provision of social facilities, especially the supply of sufficient water of good quality at a reasonable cost to their citizens. Although the number of people with access to safe water and sanitation predominantly grew in the past decades, population growth erased any substantial gain, especially in urban areas. Between 1990 and 2000, an extra 900 million people were born in places without water and sanitation (Jan Kyrre Berg Olsen, 2011).

In Asia, urban water pollution has emerged as one of the critical forms of environmental degradation. According to the report of the Asian Development Bank (ADB), one in three Asians has no access to a safe drinking water source that operates at least part of the day within 200 meters of the home, and the situation is worst in South and South East Asia (ADB, 1997) whilst dirty water and poor sanitation also cause more than 500,000 infant deaths a year in the region, as well as a huge burden of illness and disability (WHO, 1992).

The situation is not different from that in Latin America and the Caribbean. Though the region has 13% of all the world's water supplies, water resources are distributed on a highly inequitable basis. Many people are moving to the cities and the high degree of urban population concentration means rising levels of pressure on the water resources. It is estimated that more than 130 million people do not have safe drinking water in their homes, and only 86 million are connected to adequate sanitation systems (HEA 2015).

Perhaps inevitably, the problem is most acute in Africa and West Asia. In Africa, for example, 14 countries already experience water stress or shortage. Another 11 countries may join that list in the next 25 years. The pace of population growth far exceeds the development of water resources; and governments in Africa are said to be systematically failing their people when it comes to safe water provision. At present, it is approximated that over 400 million out of over 800 million people in the continent do not have access to safe water (2006 - 2017 Stepping Stones for Africa).

Most of Africa's populations live in rural areas (around 62 percent) and yet access is lowest in the rural areas, at about 47 percent for water and 45 percent for sanitation. Low access to a safe water supply and adequate sanitation is the root cause of many diseases that affect Africa and a contributory factor to the high infant and maternal mortality rates (2016 AfDB report).

Ethiopian Water Resources Management Policy (2001) dictates that, as far as water supply for human consumption is concerned, it is to be noted that over 85% of Ethiopians' livelihood is based on farming and livestock agriculture. This has consequently resulted in subsistence level of economic life and thinly spread out settlement so that providing reliable and safe water at minimum cost becomes very difficult.

Hence over 75% of the populations living in rural Ethiopia have no access to potable water. People have to travel long distances for many hours and fetch unsafe and unreliable water from rivers and other undeveloped sources. Even in urban centers where services are apparently better in relative terms, the supply and quality of water is inadequate and unreliable compared to the demand.

Figure 1: Typical way of collecting drinking water in Lume woreda – one of the six woredas covered with Gimbichu Fentale Water supply project

Therefore to alleviate the scarcity of safe drinking water the government of Ethiopia did a number of large scale and long distance water supply projects in all regions. Among the projects implemented, Gimbichu Fentale water supply project is the one. Even though the project is implemented with better quality of material and performance, it hasacquired huge problems due to its length and passage through different ecological environments.

Among the problems, the prime is the dry up of some water points while there is a very high water pressures at other water points due to unequal pressure/head distribution in the mains. Factually, the communities along the water mains are assumed to be covered by the water supply project.But actually those who properly served by the project are very few. Therefore it needs practical research to assess the issues/factors that hinders the long distance water supply projects not to give the right services to user communities as per their design.

Figure 2: Girls waiting the release of water at one point of GFWS – Ada'a Woreda

1.4. Research Questions

The major part of our planet is now suffering from the lack of fresh water at the vicinity. To tackle the problem, the relative solution is the considering of transporting potable water from long distance to users using closed conduit system. In doing so, the major problem that faces the designers and implementers are the issue of adequately balancing demand with supply, the issue of solving sever hydraulic head loss, the issue of system leakage and the issue of sustainability.

The research questions that outlined under this topic are,

- Is the supply of the long distance water supply system meets the demand throughout the life of the project?
- What is the adverse effect of hydraulic head loss due to pipe roughness in long distance water supply?
- What is the unaccounted/leaked water in long distance water supply projects? Is Gimbichu Fentale water supply project in tolerable range?
- Is the long distance water supply sustainable in relation to its management and environmental?

1.5. Objectives

1.5.1. General objective of the research

Most often, long distanced water supply projects are designed and constructed for the community who do not have alternative water resource option at their vicinity with very high cost. Even though significantly many long distance water supply projects are implemented in our country, they do not serve the beneficiaries with optimum efficient due to problems associated with their lengths.

Thus it needs serious study, attention and management so that the long-distance water supply projects will serve as per their design, sustainably and efficiently. Accordingly, this project aims to reveal the major water supply problems/issues on the long distanced projects taking Gimbichu Fentale water supply project as a case study.

1.5.2. Specific Objective of the research

The following points are the specific objective to this research:

- To assess the current demand-supply for both domestic & non-domestic (actual demand vs supply of project) in line with design year
- To assess effect of hydraulic pressure in long distance water supplies using Hydraulic modeling tool EPANET.2

- To examine the level of leakage and unaccounted loss on long distance water supply projects – taking Gimbichu Fentale Water supply project as a case.
- To assess the sustainability of the project vs design period through environment protection and efficient operation and management.

2. Literature Review

2.1. Unbalanced water supply with demand

The provision of adequate water supply to the rapidly growing population is increasingly becoming a challenge, facing many countries worldwide. In the twentieth century, the population of the world increased from 1.6 billion at the beginning of the century to over 7 billion in the year 2010. The last decades of the twentieth century were characterized by an accelerated growth in water demand, which is rising today at a rate never experienced in any previous time of history. Human use of water has increased more than 35-fold over the past three centuries and four folds since 1940 (Easter and Hearne, 1995).

On Seventh International Water Technology Conference, Egypt 1-3 April 2003, it was briefed that, expanding urban/semi-urban areas and the growing demand for water by domestic, industrial and agriculture sectors form enormous pressure on water resources. To meet the rising demand on water, the traditional approach was based up, until recently, on expanding the supply of water from existing water resources and on the development of new water resources. As a result, the most accessible water resources have already been tapped.

Today, many developed and developing countries face growing problems of unbalanced water demand versus water supply, and suffer from degradation of water quality. While water demand continues to increase, the limited amount of fresh water resources poses a serious constraint on food security. Because of this imbalance, a search for a new water management paradigm should immediately take place. Among the techniques that recently start adopting, taking the fresh water from long distance using conduits and supplying to the water stress communities are common (HA Qdais, 2003).

Most of such long distance water supply projects are constructed to adequately meet the demands of the user communities along which the main line passes for the proposed design year.

2.1.1. Literatures reviewed on Gimbichu Fentale water supply project – case study for long distance projects

The following points are cited out while critically review Feasibility study and design document of Gimbichu Fentale Water supply project,

- The total length of the main line is 152km; that is proposed to serve six woredas of East Shewa Zone namely Gimbichu, Ada'a, Lume, Adama, Boset and Fentale.
- The design year of the project is 15years starting from 2005 to 2020GC. It predominantly designed to supply the surplus spring water from highland area of Gimbichu Woreda with using closed conduit to lowland and severely water scarcity/stressed area of Fentale Woreda.
- On study design of the project, it was mentioned that, the supply of water from two springs were not meet the design year period; and the designer recommends that another alternative source should be find to meet the demand of the design year population.

SYSTEM DESIGN CRITERIA

Design criteria define system capabilities by specifying design features and performance requirements of system components. Design criteria play important roles as factors in network solution problems. In general, design criteria provide the standard against which system performance- both observed and predicted-is compared.

The Sources of Water

The sources of water for the study area are surface springs called Mekitcho and Sire Tebela. Hence spring boxes that allow the water to flow out of the springs are needed. Besides the springs need to be fenced off to prevent dirt from washing into the area and to keep animals and people out.

Figure 3: Makecho Spring capping structure.

Ideally a water distribution system should be operated at a constant water supply rate with a consistent supply from water sources. Thus, on the day of maximum demand, it would be desirable to maintain a water supply rate equal to the maximum-day demand rate.

The flow rates of the springs have already been determined. Therefore these sources have to be analyzed whether they meet the daily water requirements of the population to be served.

The maximum-day water demand = $4.25x10^3$ m^3/d for year 2020 whereas the springs supply $2.6x10^3$ m^3/d (= $30x24x3600x10^3$ m^3/d). *Obviously the existing sources cannot meet the demand. Hence another source must be considered.*

Pipelines

Pipe segments are generally considered, if they are predicted to have any of the following conditions.

- Velocities grater then 1.8m/s

- Head losses greater than 10m/ 1 km, or
- Large-diameter pipes (400 mm or greater) having head losses greater than 1m/300m.

In fact velocities in pipe segments are acceptable up to 3m/s. In addition, none of these limits are hard and fast. The ultimate test of piping-system adequacy is the pressure at the point of delivery.

Pipelines design addresses sizing and routing. The demand condition that is most limiting for a pipe segment may be maximum storage-replenishment rate or peak-hour demand. Then the pipe size should be selected to limit velocities to 1.8m/s and head losses to less than 10m/ 1km under that demand condition.

Potentially deficient line segments may be corrected by cleaning (pigging) or lining the pipe segment to increase its hydraulic capacity, replacing or paralleling the segment, paralleling adjacent segments, providing a new pipeline to route flows around the limiting segment, or adding pipeline to loop deficient area (that is, supplying water from more than one direction). Selecting an improvement is done on a cost basis through a combination of engineering judgement and trial and error computer analysis.

The location of pipelines is determined, for most part, by availability of right-of-way and construction easements and by using common sense. When locating pipelines (especially the main line) consideration should be given to the projected growth characteristics of the service area, how far it will extend and where major demand areas are expected to be.

Furthermore the main and sub-main pipelines have been located with due emphasis on the followings points: -

- Steady gradient is maintained whenever possible.
- The length of the pipeline is kept to a minimum.
- Pipeline arrangement, which will require constant maintenance i.e. hill sides and numerous stream crossing, have been avoided or made minimum.
- Any land that is outside the control of the user community is avoided.

The rising mains (in motorized area) and gravity mains is designed for the maximum-day demand of the year 2020.The branches to PA villages is designed for peak-hour demand of the year 2020.

Storage facilities

The criteria for storage facilities must address many interrelated factors, including system storage requirements, elevated versus ground storage, and the number and location of storage facilities.

In deciding the type of reservoir (elevated or ground) construction cost and operation and maintenance costs will be considered together with other system requirements.

A number of factors shall be considered when determining the number and location of storage facilities such as size of reservoirs, location of other system components (major trunk lines and high service pumps); hydraulic elevation and zone of coverage for pressure requirements.

Equalization storage is generally less expensive to provide than increased capacities of high-service pumps and distribution piping beyond that required meeting maximum-day demand.

The capacity of reservoirs is fixed such that 30% of the total maximum-day demand is replenished. Standard reservoir sizes will be used wherever applicable. The demand or supply at a reservoir will be calculated for a given hydraulic elevation or pressure.

If supply is maintained at the constant maximum-day demand rate, the difference between the diurnal-demand curve and the maximum-day demand rate at any point in time would represent the flow into or out of the storage facilities.

Reservoir will be provided such that: -

- the area is divided into manageable pressure zones,
- large pipe sizes are avoided or minimized and
- adequate pressure in the pipeline is attained.

Pumping Station

Distribution systems may have both high service (sources) pumps and system booster pumps. Pumps must be sized to meet the full range of system demands, thus, all of the limiting demand conditions, including average-day demand, may be conditions of importance for sizing the pumps.

Typically constant speed pumps are used for service and booster pumps and system storage is used to equalize the pumping rate over the range of water demands.

Generally, service and booster pumps are provided as multiple pump installations. The pumping installation should be sized to provide maximum-day demand with any one of the pumps-preferably, the largest pump out of service. Individual pumps and combinations of pumps should be sized to maximum-day demand. In addition, the service pumps should be capable of providing maximum-day demand under peak-hour demand conditions, with the additional flow coming from storage. The main pumping stations will have a stand by capacity of 100%.

DESIGN PARAMETERS

Pressure in the pipelines

The minimum and maximum pressures in the network shall be 5m and 70m (manometric head) respectively. Hazen-Williams formula shall be used for head loss calculations.

Flow velocities

The minimum and maximum flow velocities in the network shall be 0.3 m/s and 2m/s respectively over 24 hours.

Public fountains

- The flow from a faucet shall not be less than 0.25 l/s
- A water point shall be located in a PA where the settlement density is observed to be highest.
- Consider 100% of the daily personal water requirement at a water point in a PA irrespective of fetch distance so that extension to the required travel distance can be made in the future.

System Appurtenance

Valves shall be provided wherever they are required in the network to facilitate smooth operation and maintenance of the system.

- **Air release valves: -** are located at high points so as to release air that collects in the pipe and prevent 'air locks' large bubbles of air that block the flow.
- **Washouts: -** are located at low points, at the end of pipe sections with low flows and at regular distances along the main pipeline.
- **Break pressure tanks: -**These are provided when the pipe elevation is sufficiently below the source to exceed the pressure capacity of the pipe.
- **Isolating valves: -** are located at the inlet for every tank, and at every branch and change of pipe size.

Flow measurement devices

Flow measurement devices shall be provided at all pumping stations, out let from bore-holes, reservoir out lets, and all public taps points.

SELECTION OF PIPE MATERIAL

Pipes for intakes, reservoir sites, crossing areas.

The pipes and fittings to be provides at spring protection sites, reservoir sites, gully crossings, river crossing and at pressure break tanks are generally proposed to made of DCI. At these places, the pipes are usually shorter with several fittings and connections to valves and other appurtenances. Hence, for pipes sizes not less than DN 150mm, DCI pipes are to be used while GI can be used for lower sizes.

Sub-mains & Distribution pipe

Generally the branching pipes used as sub-main or distribution pipes are proposed to be GIS pipes for sizes lower than DN 150mm. Higher sizes are either DCI or PVC or equivalent pipes depending on the actual site condition of the surveyed route.

It depends on the topography of the area, the soil nature, the pressure available and other related considerations.

Pressure consideration

Where the pipe system is known to have pressure not less than 16m manometric head, the pipe type generally proposed to be used is DCI pipes, of an equivalent pipe material. For the distribution mains only PVC pipes are proposed there pressure is lower than 16m manometric head.

Climatic Condition

In the upstream highland and mid-highland ports of the project area, the distribution mains are proposed to be PVC pipes apart from pressure requirements. In the lowland and semi-lowland part of the project area DCI and GI pipes are proposed to be used irrespective of pressure criteria & other governing factors.

Topography and Soil Cover.

In areas where the soil cover is very thin and excavation for trench is assumed to lie over massive bedrock, DCI pipes are recommended. Also where the topography is erratic with changes in slope DCI pipes are to be used in the pipeline of the system.

2.1.2. Water supply and demand implication on long distance water supply projects

Water is the most immediate and critical limiting factor to both human and environmental well-being. The reason is that water supply is, essentially, fixed. Therefore, although the real value of supplied water is currently low, changes in scenario can induce changes in water uses, and, therefore, potentially large impacts through the multiplier effect. The protection of water bodies, through stewardship, acts as a binding constraint that can result in conflicts between the affected jurisdictions (e. g., some of the states of the United States sharing a common river through inter-basin transfers). The following lists a range of issues concerning the supply and demand of water and direct effects:

WATER SUPPLY AND DEMAND ISSUES		
Issue	**Direct Effect**	**Comment**
Water conservation	Demand	Supply of water↑ ⇒ cost↓
Water supply	Supply	Cost
Water re-use	Supply	Acceptability ↓ ⇒ cost↑
Water losses	Supply	Cost↑ ⇒ infrastructure ⇒ cost↑
Sanitation	Demand	Infrastructure ⇒ cost↑
Institutional	Supply & demand	Costs↑ ⇒ trade↓⇒ revenues↓
Legal	Supply & demand	Costs ↑ ⇒ property rights ⇒ environmental equity ⇒ costs↑
Food (fisheries, livestock, crops…)	Supply	Availability↓ ⇒ cost of products↑⇒international trade↓⇒ national
Political	Supply	Costs↑ ⇒ cost of products↑⇒ international trade↓⇒ national security
Demographic	Supply & demand	Infrastructure ⇒ cost↑
Climate change		Draughts, floods, shifts in thermal energy balance ⇒Infrastructure ⇒ cost↑⇒
Agriculture	Demand	Cost↑ ⇒ cost of products↑⇒ international trade↓⇒ national security
Megacities and megalopolies	Supply & demand	Demographic ⇒ infrastructure ⇒cost↑sanitation⇒ water re-use↑⇒ costs↓
Technology	Supply &	Availability↑ ⇒ cost of products↓
Protection of vital ecosystems	Supply	Availability↓ ⇒ cost of products↑
Environment/recreation	Supply	Availability↑

Table 1: Water supply demand issues

There are also transitional issues, such as tendency to urban sprawl, the decline of agricultural land supply and many sub-issues. Fundamentally, water issues are sectoral, involve water transfers and affect both the inputs and the outputs of the national and international economies. Perhaps most important issue that affects projections – because they are long-term -- and thus the development of the impact of the issue on water availability is the potential (or actual) structural change in the sectors of the national economies (DC Petrescu, 2010).

The global water supply/demand imbalance is increasing. This is due to population growth, particularly in arid, water-short regions, contamination of water sources, and inefficient utilization of available supplies. Increasingly, futurists are predicting a world where water shortages, exacerbated by global warming, could cause increased food imports, population shifts, domestic political unrest, and geopolitical conflict. As the potential for future crisis rises each year, calls to address water supply issues are becoming more urgent, though political action to change these trends has so far been muted.

Here are a few facts about water supply and use (gleaned primarily from the World Resources Institute, the United Nations Environment Program, and the Center for Strategic and International Studies).

- Water supply is re-circulated through the atmosphere, but no “new” water is being created
- Only 3% of the earth’s total water supply is fresh water versus salt water, and the majority of fresh water is inaccessible
- 1% in surface water, such as rivers, lakes, and streams
- 29% in underground aquifers, which are being over-pumped beyond their recharge capability in many regions
- 70% in frozen glaciers
- 15-35% of agricultural water withdrawals are in excess of sustainable limits
- Water production lost due to leakage, theft, and inadequate billing practices is typically 40-50% in developing countries, and may be 10-30% in developed nations

- Industrial withdrawals are expected to rise by 55% by 2025
- Despite efforts by global governments, nearly 1.1 billion people still lack access to water supply service and 2.6 billion people lack access to sanitation, mostly in Asia and Africa
- About 5 million people die every year from water-related illness
- By 2050, untreated wastewater could contaminate one-third of global annual renewable freshwater supplies
- The world's population has tripled in the 20th century – but global water use has grown six-fold
- Another 40-50% in population growth is expected within 50 years, along with increasing urbanization and industrialization, with the fastest growth taking place in water-short areas, including the American Southwest, China, and India
- In 1995, over 400 million people lived in countries experiencing water stress or water scarcity
- By 2025, that number is expected to rise to 4 billion – over half the world's population 50% of global population growth is expected to take place in water-stressed countries
- China's demand for water is expected to increase 400% by 2030
- China's population is 21% of the world and is increasing 1%/yr, yet China only has 7% of the world's water. 400 of China's 660 main cities face water shortages one-third of rural residents drink unsafe water
- By 2020, India's demand for water is expected to exceed all current sources of supply
- 70% of irrigation and 80% of domestic water use comes from groundwater, which is rapidly being depleted. 15% of aquifers are in critical condition this is expected to grow to 60% in 25 years (Dacinia Crina Petrescu, 2012).

2.1.3. Basic demand variation for design consideration

The daily water demand in a community area will vary during the year due to seasonal climate patterns, the work situation (e.g. harvest time) and other factors, such as cultural or religious occasions. The maximum daily demand is usually estimated by adding 10-30% to the average daily demand. Thus, the peak factor for the daily water demand is 1.1-1.3.

The hourly variation in domestic water demand during the day is much greater. Generally, two peak periods can be observed: one in the morning and one late in the afternoon. The peak hour demand can be expressed as the average hourly demand multiplied by the hourly peak factor; usually, the factor is chosen in the 1.5-2.5 range. For a particular distribution area this factor depends on the size and character of the community served. The hourly peak factor tends to be high for small villages. It is usually lower for larger communities and small towns.

Where a pipe connection is designed to supply a small group of consumers, a higher value should be adopted because of the effects of instantaneous demand. A water distribution system is typically designed to cater for the maximum hourly demand.

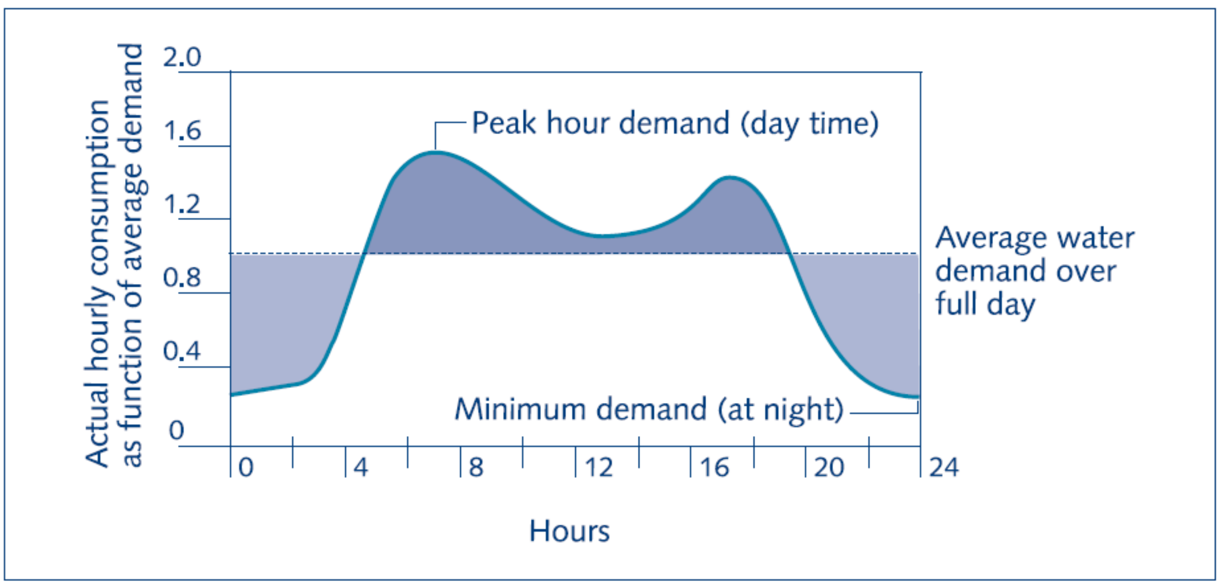


Figure 4: Water Supply demand pattern in a day

2.2. Uneven distribution of pressure in network

The big challenge in delivering water to distance users using closed water conduits is the effect of pressure drop in pipe. Because of the sheer force near the pipe wall, a boundary layer forms on the inside surface and occupies a large portion of the flow area as the distance downstream from the pipe entrance increase. At some point of this distance, the boundary layer fills the flow area. The velocity profile becomes independent of the axis in the direction of flow, and at this stage the flow is said to be fully developed. This flow phenomenon is totally governed by viscosity.

Viscosity is the amount of work needed to move one “box” of liquid against another “box” of liquid. Every liquid has its own value for this resistance to flow. The values for water are lower than for the motor oil. Another characteristic of any liquid is its attraction to a surface. It attaches itself to any surface and cannot be moved. The liquid in the “box” on the very surface of a pipe does not flow or move. It always remains stationary. The liquid in the “box” above it has to slide against it and that requires an amount of energy to overcome friction between the two “boxes”. The higher the viscosity of the liquid is; the higher the resistance to flow, therefore, the higher the friction loss.

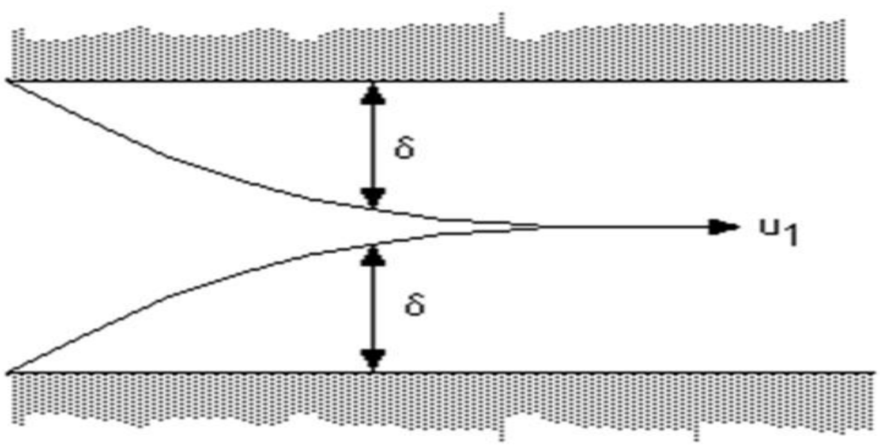


Figure 5: Flow at boundary of closed pipe

A layer is formed by this non-moving liquid and reduces the inside diameter of the pipe. This increases the velocity of the liquid passing through it. The head loss from friction is related to the velocity energy ($V^2/2g$) of the liquid squared. The liquid is not moving at the pipe wall but has a much higher velocity at the center of the pipe. The condition of the inside of a pipe also has a great effect on the head loss of the flow of liquid. The rougher it is; the thicker the layer of non-moving or slow moving liquid nears the pipe wall. This reduces the inside diameter of the pipe, increasing the velocity of the liquid. With the increase in velocity comes an increase in friction losses (2017 Pentair Ltd).

Any time a liquid flow changes direction there is resistance. Since all liquids have weight, they also have momentum. This means the liquid will always try to continue moving in the same direction. When the liquid encounters a change in direction (such as an elbow), its momentum carries the flow to the outer edge of the fitting. Because the liquid is trying to flow around the outer edge of the fitting, the effective area of the fitting is reduced. The effect is similar to attaching a smaller diameter pipe in the system. The velocity of the liquid increases and the head loss due to friction increases.

The energy lost by the liquid is converted to heat created by friction. Since the amount of liquid exiting a pipe has to equal the amount entering the pipe, the velocity must be equal. If the velocity is equal, then the velocity energy (head) must be equal. This only leaves one place for the energy to come from; pressure energy. The measured pressure entering the pipe will be higher than the measured pressure exiting the pipe.

As the roughness of the inside pipe wall increases so does the thickness of the slow or non-moving boundary layer of liquid. The resulting reduction in flow area increases the velocity of the liquid and increases the head loss due to friction. Scale deposits and corrosion both increase the roughness of the inside pipe wall. Scale buildup has the added disadvantage of reducing the inside diameter of the pipe. All of these add up to a reduction in flow area, an increase of the velocity of the liquid, and an increase in head loss due to friction.

The higher the viscosity of the liquid is, the higher the friction is from moving the liquid. More energy is required to move a high viscosity liquid than for a lower viscosity liquid. Head loss due to friction occurs all along a pipe. It will be constant for each foot of pipe at a given flow rate. Elbows, tees, valves, and other fittings are necessary to a piping system. It must be remembered that fittings disrupt the smooth flow of the liquid. When the disruption occurs, head loss due to friction occurs. At a given flow rate the losses for the fittings will be calculated using a factor that must be multiplied by a velocity head, or as the head loss equivalent to a straight length of pipe.

Because of momentum, liquid wants to travel in a straight line. If it is disturbed due to crooked pipe, the liquid will bounce off of the pipe walls and the head loss due to friction will increase. There is no accurate way to predict the effects since “crooked” can mean a lot of things.

2.2.1. Basic design considerations for pressurized pipes

Free-flow conduits are generally laid at a uniform slope that closely follows the hydraulic grade line. Examples of such conduits are canals, aqueducts, tunnels or partially filled pipes. If a pipe or tunnel is completely full, the hydraulic gradient and not the slope of the conduit will govern the flow. The hydraulic laws of closed conduit, also commonly called pressurized flows, apply in this case. Pressurized pipelines can be laid up- and downhill as needed, as long as they remain at sufficient distance below the hydraulic grade line, i.e. a certain minimum pressure is maintained in the pipe.

For community water supply purposes, pressurized pipelines are the most common means of water transmission. Whether for free flow or under pressure, water transmission conduits generally require a considerable capital investment. A careful consideration of all technical options and their costs and discussion with the community groups that will support and manage the system are therefore necessary when selecting the best solution in a particular case.

Routes always need to be checked with community members as well to make use of local knowledge and ensure cultural acceptability (N Trifunovic, 2013).

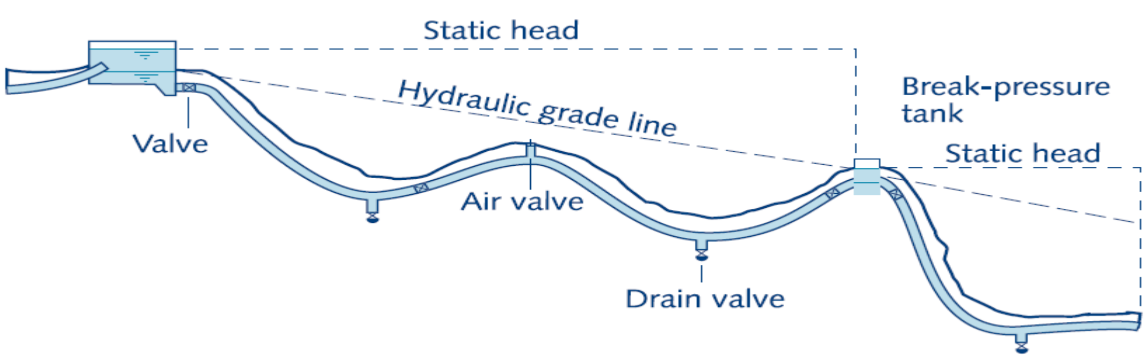


Figure 6: Water flow in closed pipe through d/f topography and effect of break pressure tank

The routing of pressurized pipelines is much less limited by the topography of the area to be traversed, than is the case of canals, aqueducts or free-flow pipelines. A pressure pipeline may run up- and downhill and there is considerable freedom in selecting the pipeline alignment. Nevertheless, such pipelines often follow the topography quite closely, being buried at a similar depth for the length of the route.

Consumer connections on transmission lines are rare, so the water pressure can be kept low, provided that the hydraulic grade line is positioned above the pipe over its entire length and for all flow rates. A minimum of a few meters water column is also required to prevent intrusion of pollution through damaged parts of the pipe or faulty joints. In fact, nowhere should the operating pressure in the pipeline be less than 4-5 mwc (meters water column).

High pressures in transmission pipes occur as a result of long distances or specific topography. During supply by gravity the maximum pressure does not occur under operating conditions. It is the static pressure when the pipeline is shut. In order to limit the maximum pressure in a pipeline and thus the cost of the pipes, the route can be divided into sections separated by a break-pressure tank. The function of such a tank is to limit the static pressure by providing an open water surface at certain places along the pipeline. The flow from the upstream section can be throttled when necessary.

2.3. Water loss and leakages

Water is an essential but limited natural resource which is indispensable for life and economic development. Water for human, commercial and industrial consumption is abstracted from natural water bodies, purified and distributed through water supply systems to users. There is renewed international awareness that water distribution systems world-wide are aging and deteriorating, while the demands on these systems, and thus on our natural water resources, are ever increasing.

Unaccounted-for-water in water distribution systems is reaching alarming levels throughout the world. Unaccounted-for-water is defined as the difference between the volumes of water entering a water distribution system and that accounted for, typically through customer water meters. Unaccounted-for-water is made up of various components including physical losses (leaks), illegitimate use, unmetered use and under-registration of water meters. Leakage makes up a large part, sometimes more than 70 % of the total unaccounted-for-water. Some unaccounted-for-water (UFW) estimates are given in Table 3.

Table 3 clearly shows the extent of unaccounted-for-water and water losses worldwide. The effect of these losses is not only severe in monetary terms, but is also severe in terms of its environmental impact.

City / Town	UFW	Annual water loss (Ml/a)	Source
Arequipa, Peru	45 %	16 770	WHO, 2001
Hanoi, Vietnam	68 %		WHO, 2001
Haiphong, Vietnam	60 %		WHO, 2001
Jerusalem, Israel	24 %	2 683	JWU, 2003
Mutare, Zimbabwe	52 %	13 104	Gumbo, 2001
Oshakati, Namibia	40 %		Government of Namibia, 2002
Johannesburg	40 %	165 000	Sapa, 2003
eThekwini (Durban)	32 %	85 000	Sapa, 2003
Tshwane (Pretoria)	24 %	29 000	Sapa, 2003
Nelson Mandela (PE)	20 %	14 000	Sapa, 2003
Cape Town	12 %	36 000	Sapa, 2003

Table 2: Some reported UFW estimates

Even though the goal of reducing unaccounted-for-water to acceptable levels remains elusive, a lot of work has been done to understand and control unaccounted-for-water, both nationally and internationally. It is now recognized that the complexities involved in this problem are much greater than initially thought and that, although a lot of progress has been made in understanding the various factors that affect unaccounted-for water, much still remains to be done. One of the major factors influencing leakage, and thus unaccounted-for water, is the pressure in the distribution system.

It was traditionally believed that leakage from water distribution systems is relatively insensitive to pressure. However, various recent field investigations have proved this assumption wrong and have shown that pressure can affect the rate of leakage from distribution systems a great deal. Pressure management has become an established water loss control strategy and is successfully applied in throughout the world.

Water produced and delivered to the distribution system is intended to be sold to the customer, not lost or siphoned from the distribution system without authorization. Not long ago, water companies sold water at a flat rate without metering. As water has become more valuable and metering technology has improved, more and more water systems meter their customers. Although all customers may be metered in a given utility, a fairly sizable portion of the water most utilities produce does not pass through customer meters.

Unmetered water includes unauthorized uses, including losses from accounting errors, malfunctioning distribution system controls, thefts, inaccurate meters, or leaks. Some unauthorized uses may be identifiable. When they are not, these unauthorized uses constitute unaccounted-for water. Some unmetered water is taken for authorized purposes, such as firefighting and flushing and blow offs for water-quality reasons. These quantities are usually fairly small. The primary cause of excessive unaccounted for water is often leaks.

There are different types of leaks, including service line leaks, and valve leaks, but in most cases, the largest portion of unaccounted-for water is lost through leaks in the mains. There are many possible causes of leaks, and often a combination of factors leads to their occurrence. The material, composition, age, and joining methods of the distribution system components can influence leak occurrence. Another related factor is the quality of the initial installation of distribution system components. Water conditions are also a factor, including temperature, aggressiveness, and pressure.

External conditions, such as stray electric current, contact with other structures, and stress from traffic vibrations, frost loads, and freezing soil around a pipe can also contribute to leaks. All water plants will benefit from a water accounting system that helps track water throughout the distribution system and identifies areas that may need attention, particularly large volumes of unaccounted-for water.

2.3.1. Benefits of minimizing water leakage

Minimizing leakage in water systems has many benefits for water customers (and their suppliers). These benefits include:

- Improved operational efficiency.
- Lowered water system operational costs.
- Reduced potential for contamination.
- Extended life of facilities.
- Reduced potential property damage and water system liability.
- Reduced water outage events.
- Improved public relations.

2.3.2. Unaccounted for water

Unaccounted-for-water includes unmeasured water put to beneficial use as well as water losses from the system. It is the difference between water produced (metered at the treatment facility) and metered use (i.e., water sales plus non-revenue producing metered water). Unaccounted-for water can be expressed in millions of gallons per day (mgd) but is usually discussed as a percentage of water production:

$$Unaccounted - for\ water(\%) = \left(\frac{Production - Metered\ use}{Production}\right) * 100\%$$

Authorized un-metered uses include firefighting, main flushing, process water for water treatment plants, landscaping of public areas, etc. Water losses include all water that is not identified as authorized metered water use or authorized un-metered use.

2.3.3. Infrastructure Leakage Index

The most commonly used leak index nowadays is Infrastructure Leakage Index –ILI (Lambert, 2003; Farley and Trow, 2003). The advantages of using ILI are that it can be consistently applied across a range of utilities and that it is a measure of what can be achieved given the condition of the infrastructure. Its key disadvantage is that it is not easily understood by non-technical readers. Additionally it does not take into account the relative costs of leakage management (and other marginal costs, like environmental costs) and it is not able to define what level of reduction is economically feasible.
It is the ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL) and it is good for operational benchmarking for real loss control.

- UARL (gallon/day)=(5.41Lm + 0.15Nc + 7.5Lp)xp, Where

- Lm = Length of water mains, miles
- Nc = Number of service connections
- Lp = Total length of private pipe, miles=Nc x average distance from curbstop to customer meter
- P = Average pressure in the system, psi

ILI is non dimensional and is recognized as the best method to represent system performance relative to system losses. An ILI closes to 1 represents a high standard of operational management. As ILI increases the quality of the operation management decreases.

2.3.4. Types of leaks

There are different types of leaks, including service line leaks, and valve leaks, but in most cases, the largest portion of unaccounted-for water is lost through leaks in supply lines. There are many possible causes of leaks, and often a combination of factors leads to their occurrence. The material, composition, age, and joining methods of the distribution system components can influence leak occurrence. Another related factor is the quality of the initial installation of distribution system components. Water conditions are also a factor, including temperature, velocity, and pressure. External conditions, such as stray electric current; contact with other structures; and stress from traffic vibrations, frost loads, and freezing soil around a pipe can also contribute to leaks.

The underground piping on either side of a water meter should be maintained. Leaks in underground plumbing can be caused by many different factors, including rusting through from age or from stray electric currents from other underground utilities that can prematurely rust metallic piping, driving over piping with heavy trucks or equipment, poor initial installation, freezing and thawing of a pipeline, leaking joints or valves, or transient high pressure events such as opening and closing valves or starting and stopping pumps quickly. Signs of underground leaks include:

- Unusually wet spots in landscaped areas and/or water pooling on the ground surface.
- An area that is green, moldy, soft, or mossy surrounded by drier conditions.
- A notable drop in water pressure/flow volume.

- A sudden problem with rusty water or dirt or air in the water supply (there are other causes for this besides a leak).
- A portion of an irrigated area is suddenly brown/dead/dying when it used to be thriving (water pressure is too low to enable distant heads to pop up properly).
- Heaving or cracking of paved areas.
- Sink holes or potholes.
- Uneven floor grade or leaning of a structure.
- Unexplained sudden increase in water use, consistently high water use, or water use that has been climbing at a fairly steady rate for several billing cycles.

If any of these conditions exist at a property, there may be a leak (EPD Guidance Document, August 2007).

2.3.5. Assessing the sustainability of the project via management of the system

Sustainability is a slightly broader idea. A water supply can be considered sustainable if all the necessary components that keep water supplies functional are in place – i.e. if the technology, management, finances, technical expertise, availability of spare parts, dependable water source, etc. are all in place. A water supply can be considered sustainable if the finances, expertise and spare parts are available and work in progress to repair the problems to the design periods. And a functioning water supply can be considered unsustainable if there are no funds available (or parts or expertise) to undertake repairs if it is ever to break down.

The World Commission on Environment and Development (WCED 1987, 8) defines sustainable development as development which 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. The concept of sustainability at first relied on environmental phenomenon, but currently, it has gone beyond the boundaries of environmental issues to include social, economic, political, and development issues (Edum-Fotwe and Price, 2009). Understanding what constitutes sustainable and unsustainable project is crucial in any project management and post-construction management system

There are five critical factors that must be considered when planning a new water supply system if long-term sustainability is to be a reasonable expectation. These factors need to be analyzed in terms of each water technology that is under consideration. The five factors are

i. Community water service requirements,
ii. Water system costs,
iii. Maintenance and management arrangements,
iv. Probable environmental impact and,
v. Expected health changes. Once probable expectations for all factors has been established for each technology under consideration, then the community can discuss what options they have and what trade-offs they are willing to make. This community analysis and decision making as to what trade-offs are most acceptable strongly increases the probability of successful long term maintenance.

Since assessing the whole factors listed above is so broader and out of scope of this paper, the researcher has only concerned with the maintenance and management factors of long distance water supply projects with leaving the other factors to other researchers. The technique used to reveal the problem on maintenance and management is using the structure questioner to the officials of GimbichuFenatle Water supply project and experts that were participated on the design and implementation of this project.

3. Materials and Methods

3.1. Introduction

To be able to achieve the stated objectives of the study, a number of relevant research instruments and methods, which included primary and secondary data collections, were employed. These were done through the use of;

- Design document review,
- Field observation,
- Formal, informal & telephone interview and
- Assessing websites.

The sources of data were Oromia Water Mine and Energy Bureau (OWMEB), Gimbichu Fentale Water supply Boards (GFWSB), beneficiary households and professionals who were participated in designing of the water supply system. Secondary data information were collected from the internet, Census reports, survey reports, journals as well as other published and unpublished documents.

3.1.1. Reviewing the design document

In doing the assessment of long distance water supply project issues, the prime document review that was conducted was the review of project documents from inception to last. When it come to the case of this research, Gimbichu Fentale water supply project, it was implemented by undergone through all design steps such as reconnaissance study, prefeasibility study, feasibility study and final project design.

During conducting this research, the researcher has collected, referred and analyzed all the documents related to this project regardless of some design documents that were wrongly cataloged at different offices and other documents that were missed because of improper handling.

Regardless of the turbulence occurred during finding of the core documents, finally the researcher had got the official design document particularly the design parameters that the designer used to fix major water supply structures such as pipe size, reservoir size, where the pressure break valves were implemented and their sizes and etc.

The initial design parameters such as water demand at each tap, size of transmission pipe lines, node elevations and size or reservoirs were reanalyzed using Epanet 2.0 water supply distribution modelling software. The demand projection put on design document was also analyzed with relation to the current demand on ground. In addition to this the hydraulic pressure in pipe system and the free head of pressure available at each tap is also analyzed.

3.1.2. Field observation

The field observation was conducted on this research after some issues on the project was analyzed and completed using secondary data collected from project line offices. The issues of long distance water supplies are addressed using these tools as follow;

- ***Demand – supply***: primary data is collected using field observation where there is excess and scarce water supply (high and low demand area) by presenting on field. By this tool, the amount of water supplied (source yield) and the demand at each water point area are observed, measured and recorded as much as possible at around similar ecological systems. The projected demand for this current time and the actual demand/supply is analyzed using water supply modelling software (Epanet 2.0).

- ***Hydraulic pressure:*** during conducting field observation, the researcher thoroughly observe the hydraulic pressure in the system. The areas where there is high pressure – where there is tape/pipe breakage due to pressure, and where there is low pressure - dried taps. The hydraulic pressure that is calculated with using modelling software and the actual pressure on ground is observed and analyzed.

- ***Leakage:***using this tool, the leakage/losses on the system are observed. Even though many leaked areas are observable, there are leakages which are not physically seen or detected specially those which are occurred at underground lied pipes and those that occur at the base of reservoirs and other structures. It is very difficult to measure the amount of leakage on the system at field level, but it is tried to estimate and compare the amount lost or leaked and the amount calculated (billed) taking the system supply and the measured/gauged amount.

- ***Sustainability:*** the level of environmental degradation at project areas, on the main line and the whole structure is observed. The level of maintenance, the level of community awareness to own project and the whole situation around the project area is observed and analyzed. Besides the management of the system (both at office (board) level and field level is also observed and analyzed compared with the available standards.

3.1.3. Interview

The interviewee incorporates officials of Gimbichu Fentale water supply members, user communities and experts who were participated in the implementation of the project. The researcher used this technique to find the problems on the management of water supply system and to assess how much the project is sustainable compared with its design year. It is how the members of the water board are capable to run this long distance water supply project and how much the local officials and user communities are supporting them on the process of running the project.

Because of all the parties or concerned bodies who are the actors to design and implement the project are not on the board, the samples interviewed are selected using purposive sampling method. Total numbers of officials that are permanently working on GFWSP are 16; out of them 7 number of officials were purposely selected for the interview. Among them three are the higher officials; Chairman of the project, Technical head of the project and Finance and Administration head. The remain are field workers and technicians (Bill collector, plumber, community organizer and Electromechanical specialist)

3.1.4. Secondary data collection from websites

Most of literatures relating to this research topic are not accessed from direct sources such as college/university library catalogs or project offices; instead most of the documents are accessed from internet/websites. For literature review and standards, journals, ebooks, teaching slides and scientific magazines that are directly or indirectly related to this research topic are collected, referred and analyzed from different websites.

3.2. Selection of the study area

The case study of this research is Gimbichu Fentale Water Supply project; which is located at Oromia Regional state, East Shoa Zone. The prime reason why this project is chosen among others is, the problems on the long distance water supply project matches with the research problems and objectives. The other point that attracts the researcher to this project is its location and accessibility to all weather asphalt road from Addis Ababa to Nazirth (Adama) and Harar; in line with,the study area is so near to the researcher living area (Addis Ababa around Burayu). Besides, as per the primary information collected, by conducting the assessment on this project, the issues on long distance water supply project can easily be revealed in the research paper.

3.3. Description of the study area

The study area (the case project location) is at East Shewa zone, Oromia Region, which is positioned at $7^{o}12'$ – $9^{o}14'$N latitude and $38^{o}57'$ – $39^{o}32'$E longitudes. There are twelve Woredas in East Shewa Zone. Adama (Naziret) is principal town. The road from Addis Ababa to Adama is all weather express asphalt road, which is 95km and the only express toll road in the country at the moment. The foremost peaks in the Zone are Yerer Mountain (3,100m) and Mt. Chukala (2,989m). The zone has gifted with copious lakes and rivers. The perennial rivers included Awash, Modjo, Dukem, Bulbula, Kesem and Bilate. The major lakes are Ziway, Shala, Abiyata, Langano and Koka.

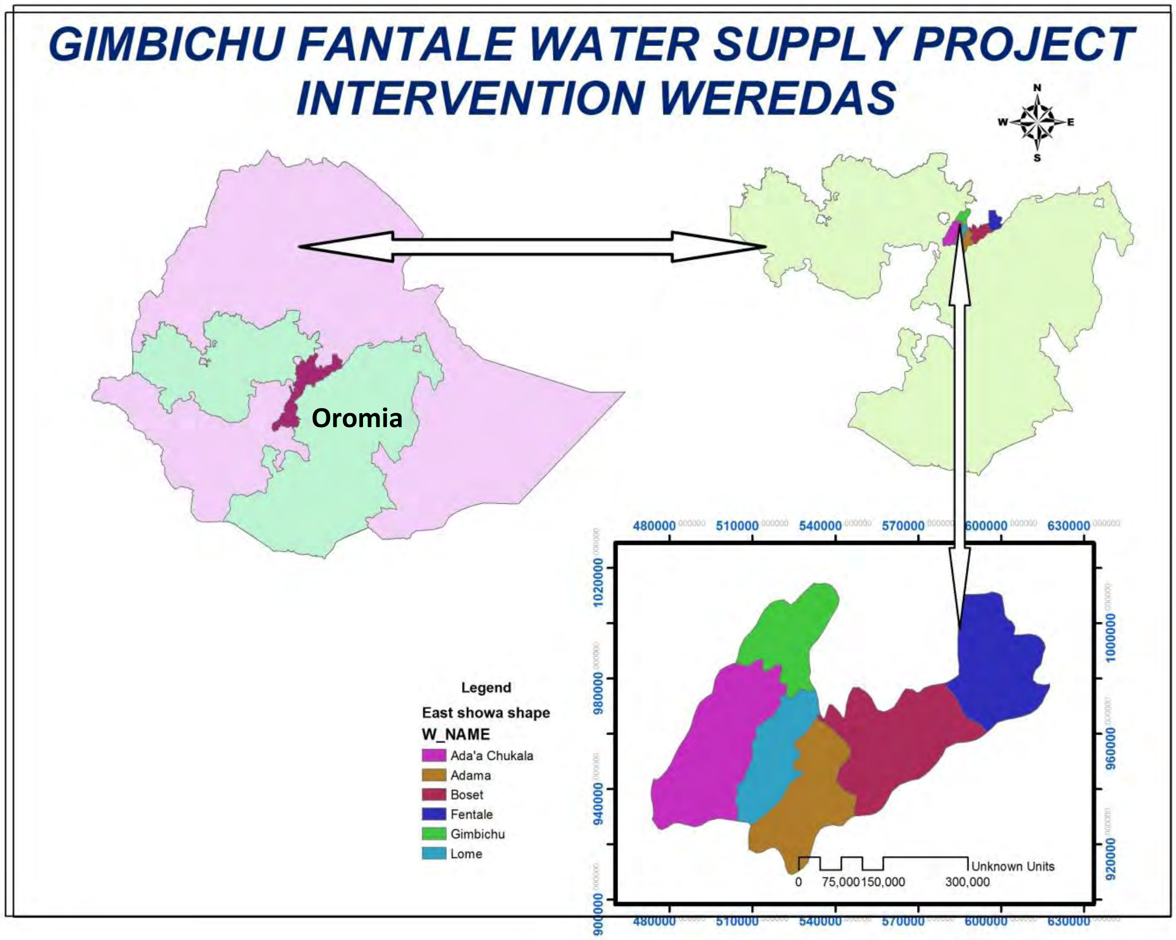


Figure 7: Study area and location of Gimbichu Fentale Water Supply Project

According to CSA Population and housing census of 2007 the total population of East Shewa is about 1,357,522 in which the urban and rural population accounted for about 25% and 75% respectively. The economically active age group (15-64) years in the zone were 52.4% of the total population. Children below age 15 years and the aged 65 years and above comprise 44.9% and 2.7% respectively. About 51.1% of the rural and 49.31% of the urban populations is females. The average family size for the zone was 4.8 (4.6 for urban and 4.9 for rural). The average population density is 127.9 persons/km^2.

The agro climatic conditions of the zone are tropical, sub-tropical and temperate. Teff, maize, wheat, Barley and sorghum from cereals, field peas, haricot bean and horse beans from pulses are fruits and vegetables are of great magnitude crop growing in the zone. The farmers of East Shewa domesticate cattle, sheep, goats, equines and camels.

Lack of potable water, soil erosion, rainfall variability, inadequate supply and towering price of agriculture inputs, lack of rural credit facility and involvedness encountered as the result of repayment of high interest rate and lack of qualified manpower in social service giving institution are the major problems of the zone. In general the zone has apposite soil for crop cultivation both rain fed and irrigated, animal rearing, fishery, trade and industrial development.

Based on the information from Oromia Water Bureau, about 45.7% of the total population of the zone was supplied with potable water. The water coverage of the zone seems high because of the number of urban center in the zone for which most of them had access to potable water. To increase the potable water coverage of the zone, Oromia Water, Mine and Energy Resource Bureau (OWMEB) planned to undertake long distance Gimbichu Fentale Water Supply feasibility study which covers the population living in the area where there is serious shortage of water source during the dry season. The project covers about 200,000 human population and 430,000 livestock population living in the parts of six adjacent districts; namely Gimbichu, Ada'a,Lume, Adama, Boset and Fentale.

3.4. Description of study project (case study)

The case study project of the research topic is Gimbichu Fentale Water supply project, which is categorized as long distance water supply based on its structural components which are tabulated below. Its main line is 152km from Chafe Donsa (Administrative town of GimbichuWoreda and supplies to lowland areas of Metahara/Fentaleworeda in East Shewa Zone). It originated from ecologically 'Woynadega' and serves the communities of 'Kola' areas. The elevation of the source is (Sire and Mekicho springs) is 2293masl and the lowest point of the project (WP55 at 150+913) is 922.3 masl.

S/N	Main features of the project	unit	Quantity
1	Pipe line (main and branched)	km	262
2	Service reservoirs	No.	9
3	Pressure break	No.	5
4	Yard connections	No.	862
5	Water point and cattle trough	No.	165
6	User community	Person	210,000
7	Livestock	No.	253,000
8	Total costs	Birr	105 Million

Table 3: Water Supply component of GFWSP

Figure 8: Layout of Gimbichu Fentale Water Supply Project

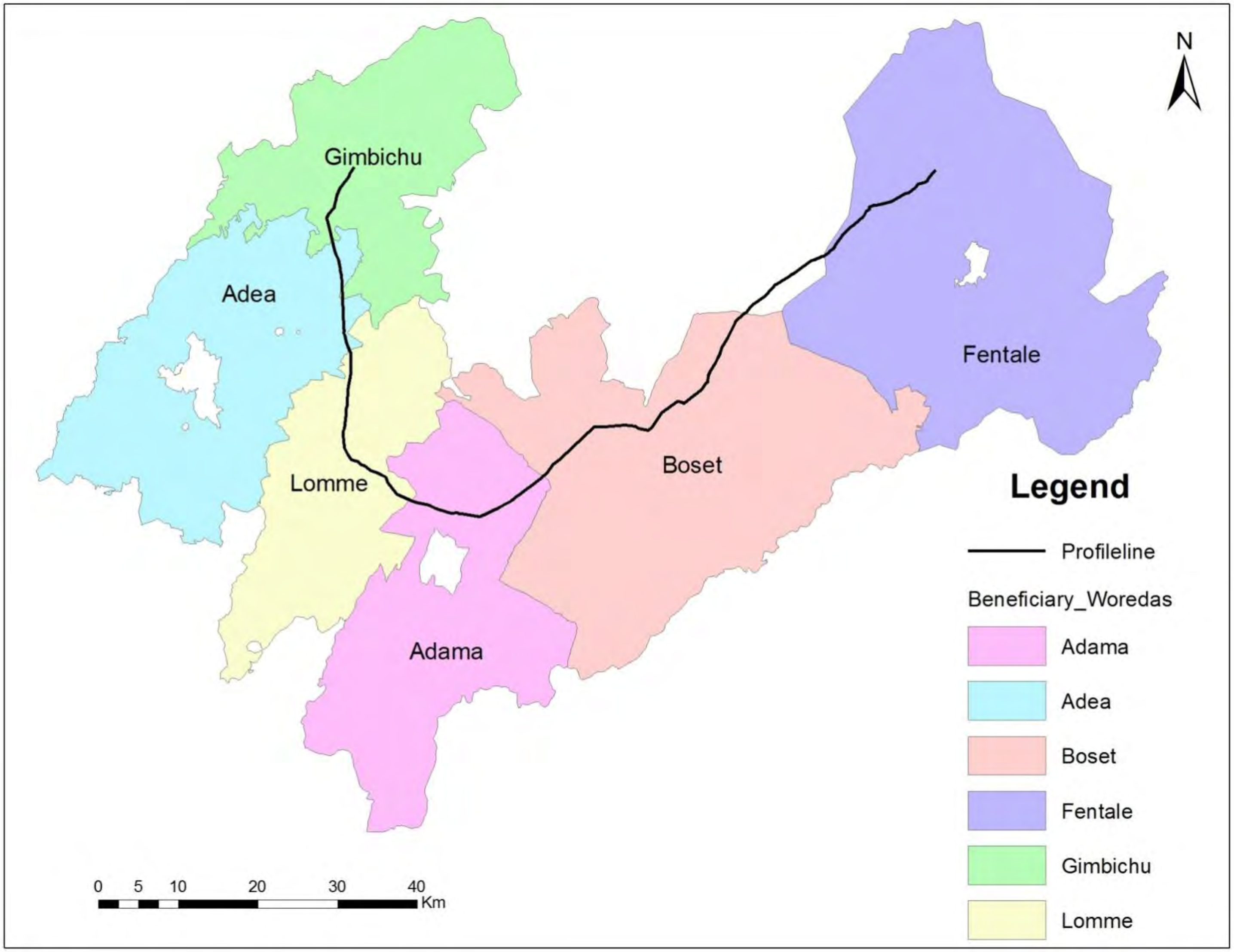


Figure 9: Mainline Layout of Gimbichu Fentale Water Supply Project in Six Woredas

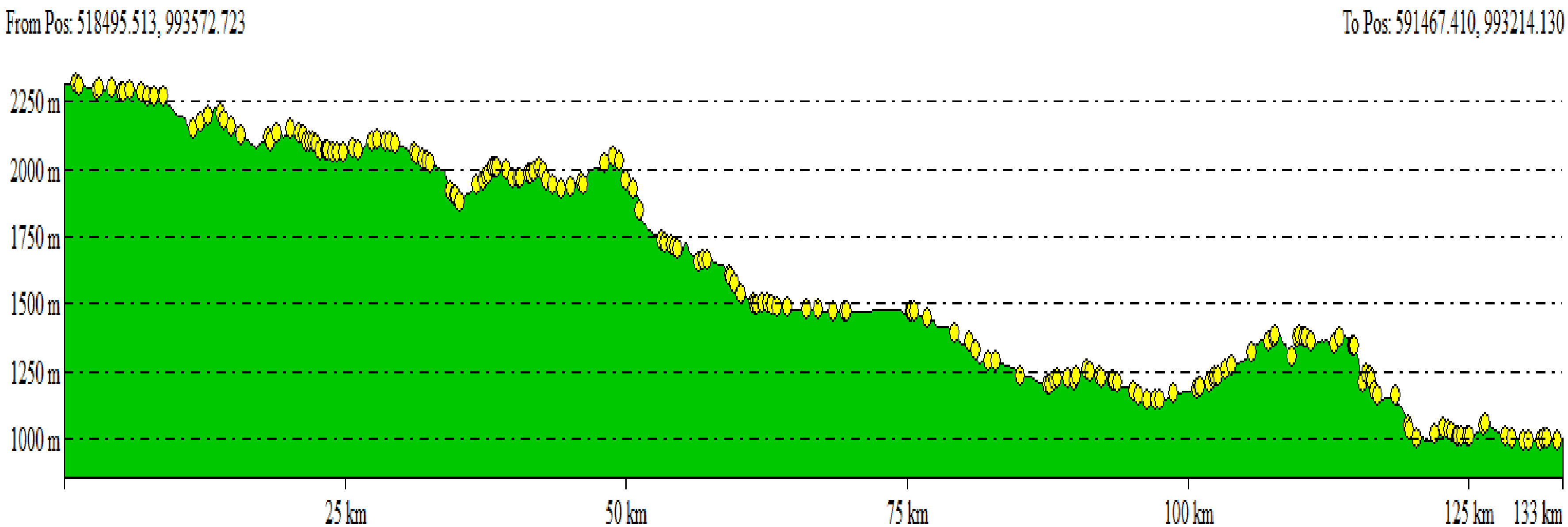


Figure 10: Vertical Cross Section of main line using Global mapper 12

Note: Coordinate Data is available for only 133km (out of 152km total main line)

4. Results and Discussions

4.1. Introduction to EPANET

The water supply distribution modelling applied to this research paper is EPANET 2.0. EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps.

In addition to chemical species, water age and source tracing can also be simulated. EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system.

These can include:

- altering source utilization within multiple source systems,
- altering pumping and tank filling/emptying schedules,
- use of satellite treatment, such as re-chlorination at storage tanks,
- Targeted pipe cleaning and replacement.

Running under Windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

4.1.1. Hydraulic Modeling Capabilities

Full-featured and accurate hydraulic modeling is a prerequisite for doing effective water quality modeling. EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

- places no limit on the size of the network that can be analyzed
- computes friction headloss using the Hazen-Williams, Darcy-Weisbach, or Chezy-Manning formulas
- Includes minor head losses for bends, fittings, etc.
- models constant or variable speed pumps
- computes pumping energy and cost
- models various types of valves including shutoff, check, pressure regulating, and flow control valves
- allows storage tanks to have any shape (i.e., diameter can vary with height)
- considers multiple demand categories at nodes, each with its own pattern of time variation
- models pressure-dependent flow issuing from emitters (sprinkler heads)
- can base system operation on both simple tank level or timer controls and on complex rule-based controls.

4.2. Modelling of Gimbichu Fentale Water supply project with EPANET 2.0

On the design document, the design demand of Gimbichu Fentale water supply project was predominantly considered rural communities and the quantity of water required for them was considered fixed. The purpose thought to be used by them is for drinking, cooking and washing; but the requirement of water for community purposes depend upon living standard and degree of culture.

On the design document of Gimbichu Fentale Water supply project, the maximum-day water demand = $4.25x10^3$ m^3/d for year 2020. On the same document it is mentioned that, the springs (supply source) average yields = $2.6x10^3 m^3$/d which is almost half of the demand. It was recommended that, since demand and supply was not matching, another source should be considered.

Currently, only five year is remained to complete the design year of this long distance water supply project. Based on the recommendation given by the designer, the researcher is assessed if there are any supply sources added to this system to alleviate the proposed demand.

The method used to assess this issue and meet the objective of the research is through interview of officials of Gimbichu Fentale Water Boards and Oromia WMEBs. In addition to this method the researcher has observed the field situation whether the supply of the project meets any demand at the project site.

Modelling parameters of Gimbichu Fentale WSP using Epanet 2.0

The hydraulic defaults that were used are;

- Flow unit: LPS (liter per second)
- Head loss formula: Hazan-William Equation
- Specific gravity of water: 1

4.2.1. Shortage of supply on Gimbichu Fentale Water supply projectt

Gimbichu Fentale water supply project is technically categorized as long distance water supply project based on the distance the main line crossed and based on the supply of the water to beneficiaries through different ecological condition from Semi wet (Woynedega) to dry (kola} regions.

The EPANET Network outlined below demonstrated the base demand of the project. The demand pattern is categorized in to four equal sections from mid night to morning and to dawn and min night again. The demand multipliers are 0.5 from mid night (12:00pm) to morning (06:00am), 1.3 from morning (06:00am) to mid-day (12:00am), 1.5 from mid-day to night (06:00pm) and 1 from night (06:00) to mid-night. The analysis is done for two days (24hr); and based on the output of the analysis; the following points are discussed under this topic.

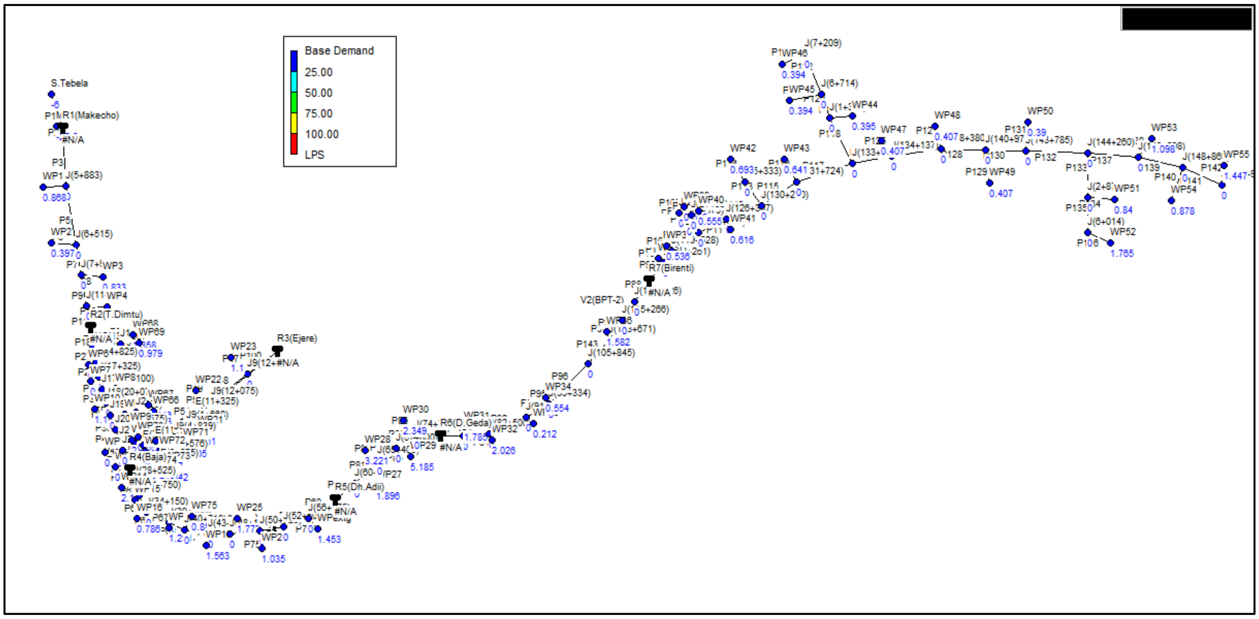


Figure 11: Demand pattern of GFWS Project

- The current demand, while summed up is 71.95lit/sec (average daily demand) and the supply (source yield) is only 33.5 lit/sec
- Therefore, the demand is much greater than the supply of the water from two springs. This is due to the increase in population, increase in awareness of using pipe water, lower cost of water collection in kind and money and the current economic activities around project. These factors bring more people to depend on this project.
- There were frequent expansions made on the project without referring the supply of source. Most of the expansions done were performed without experts' advice and design. In addition to water shortage at the sources, the issue of expansion brings significant amount of deficit on supply to the intended demands.
- Currently the OWMEB is on drilling new boreholes (six in no.) to add to the supply of project. The locations of boreholes, capital costs and partnering the stakeholders is seen as major findings under this issue.
- All the stakeholders (Government, water board, beneficiary community, FBO's, CBO's, NGO's . . .) lacks integrations in working together to alleviate the issue of supply.

Network Table - Nodes	
Base Demand	
Node ID	LPS
Junc S.Tebela	-6
Junc Makecho	-27.5
Junc J(5+883)	0
Junc WP1	0.868
Junc J(6+515)	0
Junc WP2	0.397
Junc J(7+975)	0
Junc WP3	0.833
Junc J(11+943)	0
Junc WP4	0.798
Junc J1'	0
Junc WP5	0.775
Junc J12(13+350)	0
Junc J1	0
Junc WP68	1.358
Junc WP69	0.979
Junc J(14+825)	0
Junc WP6	0.707
Junc J(17+325)	0
Junc WP7	0.866
Junc J17(18+100)	0
Junc WP8	1.039
Junc J18(20+075)	0
Junc WP10	1.148
Junc J19(20+380)	0
Junc WP11	2.722
Junc J2	0

Network Table - Nodes	
Base Demand	
Junc J24(25+325)	0
Junc (4+150)	0
Junc J7	0
Junc WP19	2.167
Junc WP70	0.553
Junc E(7+875)	0
Junc WP20	0.967
Junc E(11+025)	0
Junc J9(12+750)	0
Junc WP23	1.1
Junc J9(12+075)	0
Junc WP22	1.099
Junc E(11+325)	0
Junc J9(1+668)	0
Junc WP21	1.51
Junc J9(4+839)	0
Junc WP71	0.505
Junc J9(7+576)	0
Junc WP72	1.654
Junc E(9+575)	0
Junc WP73	0.842
Junc WP74	0.719
Junc J(28+525)	0
Junc WP14	2.1
Junc J(31+750)	0
Junc WP15	1.08
Junc J(34+150)	0
Junc WP16	0.786

Network Table - Nodes	
Base Demand	
Junc J(50+725)	0
Junc WP26	1.035
Junc J(52+500)	0
Junc J(56+175)	0
Junc WPextg	1.453
Junc J(60+700)	0
Junc WP27	1.896
Junc J(65+400)	0
Junc WP28	3.221
Junc J(67+800)	0
Junc WP29	5.185
Junc J(74+700)	0
Junc WP30	2.349
Junc J(80+150)	0
Junc WP31	1.785
Junc J(82+500)	0
Junc WP32	2.026
Junc J(91+325)	0
Junc WP33	0.212
Junc J(93+334)	0
Junc WP34	0.554
Junc J(113+671)	0
Junc WP36	1.582
Junc J(115+266)	0
Junc J(115+526)	0
Junc J(118+261)	0
Junc WP37	0.911
Junc J(119+528)	0

Network Table - Nodes	
Base Demand	
Junc WP41	0.616
Junc J(130+200)	0
Junc J(5+333)	0
Junc WP42	0.693
Junc J(131+724)	0
Junc WP43	0.641
Junc J(133+206)	0
Junc J(1+381)	0
Junc WP44	0.395
Junc J(6+714)	0
Junc WP45	0.394
Junc J(7+209)	0
Junc WP46	0.394
Junc J(134+137)	0
Junc WP47	0.407
Junc J(138+380)	0
Junc WP48	0.407
Junc J(140+972)	0
Junc WP49	0.407
Junc J(143+785)	0
Junc WP50	0.39
Junc J(144+260)	0
Junc J(2+879)	0
Junc WP51	0.84
Junc J(6+014)	0
Junc WP52	1.765
Junc J(146+598)	0
Junc WP53	1.098

Network Table - Nodes	
Base Demand	
Junc WP67	1.446
Junc WP66	0.63
Junc J20(22+575)	0
Junc WP9	0.79
Junc J21(23+375)	0
Junc WP12	0.754
Junc J22(26+550)	0
Junc WP13	0.61

Network Table - Nodes	
Base Demand	
Junc J(39+100)	0
Junc WP17	1.291
Junc J(40+713)	0
Junc WP75	0.883
Junc J(43+450)	0
Junc WP18	1.563
Junc J(48+117)	0
Junc WP25	1.772

Network Table - Nodes	
Base Demand	
Junc WP38	0.536
Junc J(122+555)	0
Junc J(0+379)	0
Junc J(2+339)	0
Junc WP39	0.555
Junc J(2+139)	0
Junc WP40	0.555
Junc J(126+307)	0

Network Table - Nodes	
Base Demand	
Junc J(148+869)	0
Junc WP54	0.878
Junc J(150+913)	0
Junc WP55	1.447
Junc J(105+845)	0

Table 4: Current Base Demand of all nodes

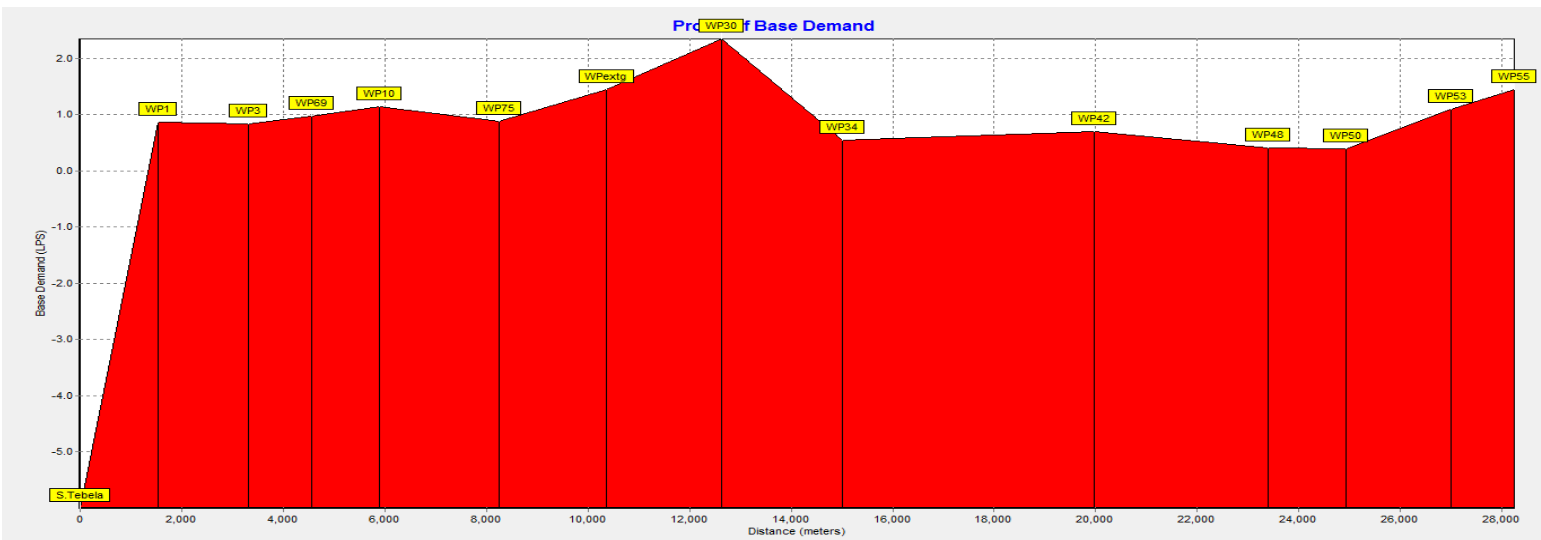


Figure 12: Profile of Current Demand for some selected sites

4.3. Uneven distribution of pressure in network

4.3.1. Friction loss effect on Gimbichu Fentale Water supply project

During field observation and based on the interview conducted with Gimbichu Fentale water supply boards, it was noted that seven water points were not functional due to the effect of hydraulic head loss in pipe and this was also verified with using EPANET 2.0 modeling software. All these water points are added on the system by expansion water supply program.

Besides there was pipe break down due to high pressure occurred particularly during rainy season. At this time most of the beneficiary community use rain water and many water points were shut down (not giving function). All the reservoirs were filled with water and the hydraulic head of the system becomes so high; and it causes pipe burst.

On the Epanet simulation for 24hrs the lowest pressure occurred in the system during the following critical times. 09 hr, 12 hr, 15hr, 17hr, 18hr, 21 hr,23 hr,

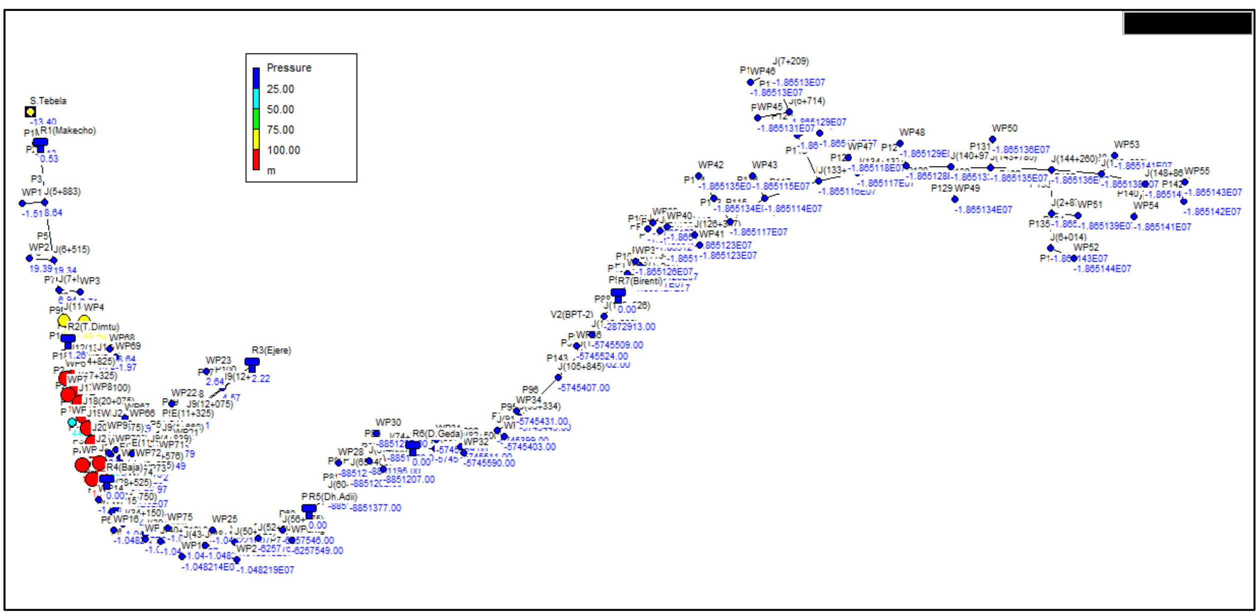


Figure 13: Node pressure of GFWS Project at Epanet Simulation of 09hr

Pipe head loss due to friction is directly proportional to pipe roughness, pipe length and kinetic energy in pipe and indirectly proportional to pipe diameter.

Network Table - Nodes	
Pressure	
Node ID	m
Junc S.Tebela	-12.94
Junc Makecho	-1.77
Junc J(5+883)	9.26
Junc WP1	2.12
Junc J(6+515)	19.99
Junc WP2	24.23
Junc J(7+975)	7.6
Junc WP3	3.75
Junc J(11+943)	83.25
Junc WP4	91
Junc J1'	19.31
Junc WP5	16.57
Junc J12(13+350)	53.19
Junc J1	24.74
Junc WP68	-19.93
Junc WP69	27.09
Junc J(14+825)	120.75
Junc WP6	119.55
Junc J(17+325)	206.44
Junc WP7	161.55
Junc J17(18+100)	205.81
Junc WP8	174.81
Junc J18(20+075)	132.46
Junc WP10	92.53

Network Table - Nodes	
Pressure	
Node ID	m
Junc WP66	30.05
Junc J20(22+575)	159.21
Junc WP9	155.68
Junc J21(23+375)	165.72
Junc WP12	190.17
Junc J22(26+550)	137.25
Junc WP13	139.35
Junc J24(25+325)	162.95
Junc (4+150)	28.68
Junc J7	27.99
Junc WP19	27.9
Junc WP70	14.1
Junc E(7+875)	-85.3
Junc WP20	-85.97
Junc E(11+025)	-130.1
Junc J9(12+750)	3.51
Junc WP23	2.4
Junc J9(12+075)	13.6
Junc WP22	11.82
Junc E(11+325)	43.99
Junc J9(1+668)	13.74
Junc WP21	26.78
Junc J9(4+839)	-14.15
Junc WP71	-10.13

Network Table - Nodes	
Pressure	
Node ID	m
Junc WP74	29.82
Junc J(28+525)	3.67
Junc WP14	6.33
Junc J(31+750)	86.76
Junc WP15	81.84
Junc J(34+150)	144.94
Junc WP16	120.46
Junc J(39+100)	88.67
Junc WP17	74.15
Junc J(40+713)	38.13
Junc WP75	3.78
Junc J(43+450)	126.62
Junc WP18	124.31
Junc J(48+117)	56.53
Junc WP25	51.27
Junc J(50+725)	58.25
Junc WP26	49.89
Junc J(52+500)	0
Junc J(56+175)	8.71
Junc WPextg	8.47
Junc J(60+700)	28.06
Junc WP27	4.95
Junc J(65+400)	130.69
Junc WP28	117.6

Network Table - Nodes	
Pressure	
Node ID	m
Junc J(80+150)	46.62
Junc WP31	50.51
Junc J(82+500)	86.45
Junc WP32	26.81
Junc J(91+325)	172.75
Junc WP33	168.31
Junc J(93+334)	120.02
Junc WP34	135.39
Junc J(113+671)	12.83
Junc WP36	-0.02
Junc J(115+266)	2.5
Junc J(115+526)	-66.75
Junc J(118+261)	10.79
Junc WP37	11.08
Junc J(119+528)	24.49
Junc WP38	30.01
Junc J(122+555)	43.35
Junc J(0+379)	44.72
Junc J(2+339)	36.33
Junc WP39	34.94
Junc J(2+139)	28.74
Junc WP40	28.11
Junc J(126+307)	75.74
Junc WP41	73.26

Network Table - Nodes	
Pressure	
Node ID	m
Junc WP43	171.8
Junc J(133+206)	161.1
Junc J(1+381)	124.72
Junc WP44	105.2
Junc J(6+714)	67.07
Junc WP45	56.47
Junc J(7+209)	68.11
Junc WP46	66.73
Junc J(134+137)	153.84
Junc WP47	146.36
Junc J(138+380)	76.98
Junc WP48	71.44
Junc J(140+972)	45.53
Junc WP49	37.98
Junc J(143+785)	46.57
Junc WP50	38.26
Junc J(144+260)	45.3
Junc J(2+879)	31.42
Junc WP51	26.9
Junc J(6+014)	2.11
Junc WP52	-3.37
Junc J(146+598)	34.38
Junc WP53	12.52
Junc J(148+869)	19.62

Network Table - Nodes	
Pressure	
Node ID	m
Junc J19(20+380)	137.69
Junc WP11	101.66
Junc J2	63.71
Junc WP67	-3.34

Network Table - Nodes	
Pressure	
Node ID	m
Junc J9(7+576)	16.26
Junc WP72	14.05
Junc E(9+575)	-7.19
Junc WP73	-3.73

Network Table - Nodes	
Pressure	
Node ID	m
Junc J(67+800)	122.35
Junc WP29	114.52
Junc J(74+700)	-30.41
Junc WP30	-74.44

Network Table - Nodes	
Pressure	
Node ID	m
Junc J(130+200)	139.37
Junc J(5+333)	33.6
Junc WP42	29.35
Junc J(131+724)	171.28

Network Table - Nodes	
Pressure	
Node ID	m
Junc WP54	15.08
Junc J(150+913)	5.35
Junc WP55	-4.79
Junc J(105+845)	123.36

Table 5: Pressure at all nodes

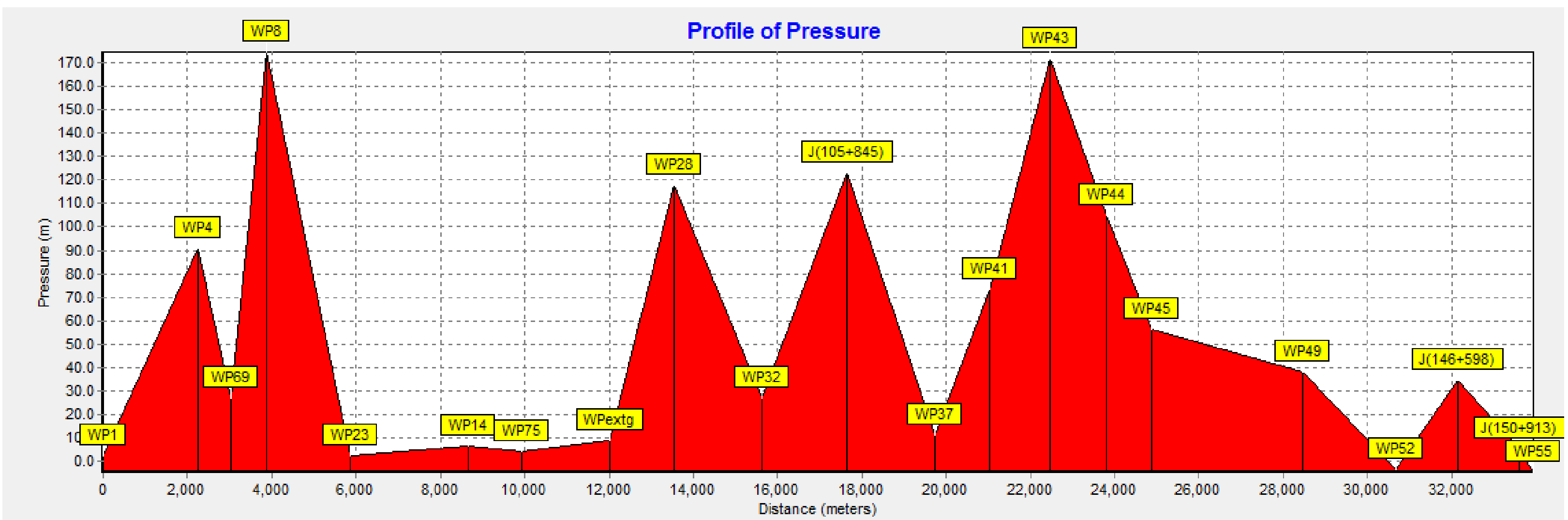


Figure 14: Pressure profile at some selected junction and water points

4.4. Water loss and leakages

4.4.1. Unaccounted water of Gimbichu Fentale Water Supply Project

Total water loss describes the difference between the amount of water produced and the amount which is billed or consumed. Leakage is one of the components of the total water lost in a network, and comprises the physical losses from pipes, joints and fittings, and also from overflowing service reservoirs.

Table 4 is the amount of water billed on Gimbichu Fentale Water supply project for one year (June 2014 – May 2015). During rainy season (July – October), there was high water loss from the system.

Month (June 2014 - May 2015)	2014/2015 metered per Woreda in m^3				Total metered water (m^3/month)
	Lume	Ejere	Ada'a and Gimbichu	Boset and Adama	
June	9,418.68	5,961.60	27,783.00	34,522.20	77,685.48
July	6,777.00	10,233.00	10,281.60	12,976.20	40,267.80
August	3,213.00	5,459.40	6,685.20	11,016.00	26,373.60
September	3,380.40	3,942.00	12,808.80	7,306.20	27,437.40
October	1,157.76	4,654.80	7,473.60	9,590.40	22,876.56
November	4,055.40	6,955.20	14,288.40	17,928.00	43,227.00
December	4,471.20	7,327.80	18,759.60	22,782.60	53,341.20
January	4,120.20	5,740.20	18,046.80	21,718.80	49,626.00
February	3,310.20	8,029.80	22,971.60	18,597.60	52,909.20
March	6,399.00	5,729.40	18,630.00	23,333.40	54,091.80
April	7,446.60	7,344.00	29,203.20	22,032.00	66,025.80
May	9,315.00	5,043.60	25,412.40	30,866.40	70,637.40

Table 6: Metered water of GFWSP (June 2014 - May 2015)

Source: Gimbichu Fentale water supply board office

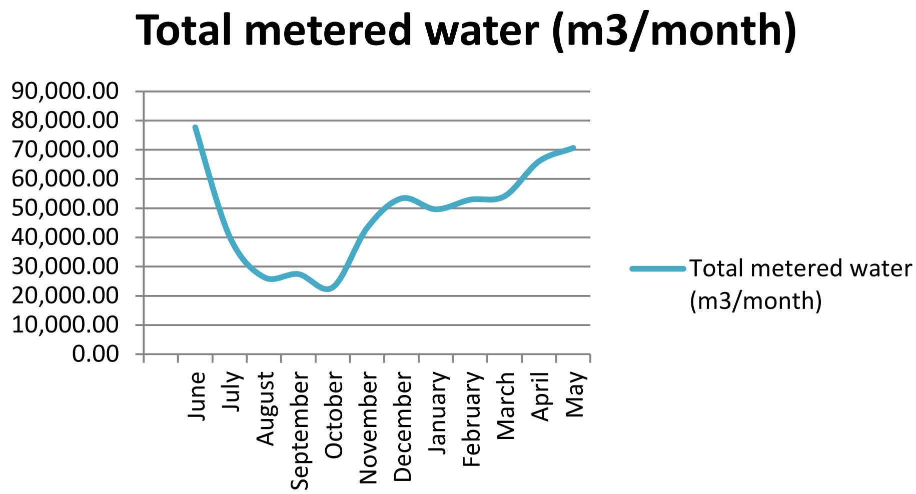


Figure 15: Graph of total water metered on GFWSP(June 2014 - May 2015)

The average annual unaccounted water of Gimbichu Fentale water supply project is 37% and the total annual water loss is 338 thousand m^3which is considered as Current Annual Real Loss (CARL).From the field observation, it was noted that, since the system is running with gravity, the concern of loss and unaccounted for water is very low.

Month (Sept. 2014 - May 2015)	Total metered water (m^3/month)	Spring Yeild (m^3/d)	No. of days in month	Spring yeild (m^3/month)	Unaccounted/loss (m^3/month)	Unaccounted/ loss (%)
June	77,685.48	2,600.00	30	78,000.00	314.52	0.40%
July	40,267.80	2,600.00	31	80,600.00	40,332.20	50.04%
August	26,373.60	2,600.00	21	54,600.00	28,226.40	51.70%
September	27,437.40	2,600.00	30	78,000.00	50,562.60	64.82%
October	22,876.56	2,600.00	31	80,600.00	57,723.44	71.62%
November	43,227.00	2,600.00	30	78,000.00	34,773.00	44.58%
December	53,341.20	2,600.00	31	80,600.00	27,258.80	33.82%
January	49,626.00	2,600.00	31	80,600.00	30,974.00	38.43%
February	52,909.20	2,600.00	28	72,800.00	19,890.80	27.32%
March	54,091.80	2,600.00	31	80,600.00	26,508.20	32.89%
April	66,025.80	2,600.00	30	78,000.00	11,974.20	15.35%
May	70,637.40	2,600.00	31	80,600.00	9,962.60	12.36%

Table 7: Unaccounted Water of GFWSP in a year

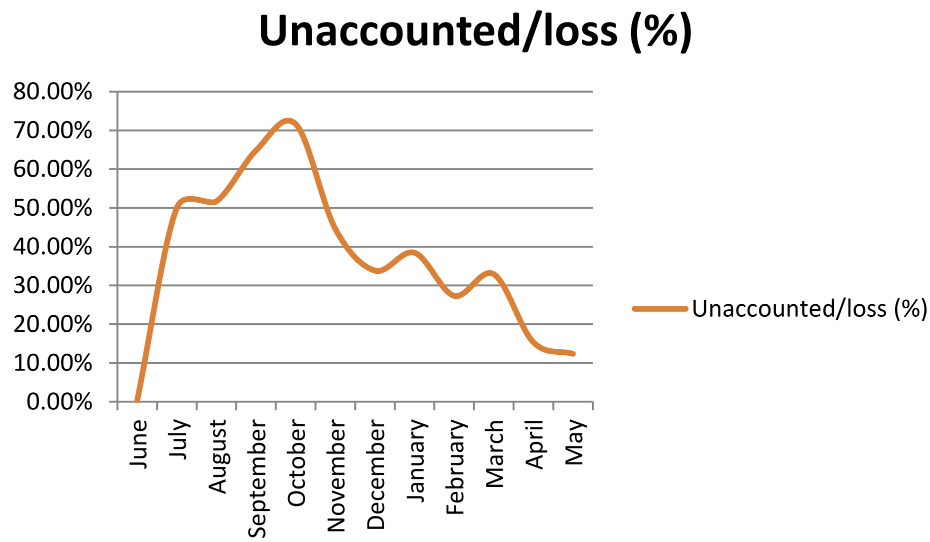


Figure 16: Graph of unaccounted for water (UFW) of GFWSP

Significant loss in the system is observed during rainy seasons from July to end of October. Since the whole system is run with gravity; during rainy season most of the community/users rely on rainwater rather than pipe water. During field visit, it was observed that during rainy season most of taps were closed especially those which are at rural KAs. This brings the over fill of reservoirs, collection chambers and pipes and make over flow high in the system which is totally unaccounted.

4.4.2. ILI of Gimbichu Fentale Water Supply Project

$$ILI = \frac{CARL}{UARL}$$

Where, CARL = Current Annual Real Loss ($338m^3$) and UARL = Unavoidable Annual Real Loss

UARL = (5.4Lm + 0.15Nc + 7.5Lp) x P; Where

- Lm = Length of water mains, miles = 94.5 miles (152km) …. Table 3
- Nc = Number of service connections = 1027 (Water point and yard connections) ….Table 3

- Lp = Total length of private pipe, miles=Nc x average distance from curbstop to customer meter = 68miles ….. Table 3
- P = Average pressure in the system, psi (35) ….. from EPANET

From the above data, UARL is calculated and it's about 41,102 gallons/day = 57 thousand m^3 of water per year. Then the ratio of CARL to UARL (ILI) is 6 which is above 1 and this one indicates quality of operation management is so poor.

4.5. Sustainability of the project

A water supply can be considered sustainable and operational if all the necessary components that keep water supplies functional are in place – i.e. if the technology, management, finances, technical expertise, availability of spare parts, dependable water source, etc. are all in place. And a functioning water supply can be considered unsustainable if there are no funds available (or parts or expertise) to undertake repairs if it is ever to break down or nonfunctional.

In addition, sustainable operation and management of any water supply system can only be achieved if appropriate organizational structures and management systems are properly put in place. That is why water supply and sewerage services in Ethiopia are tried to organize with different organizational structures. But the structures of most of the water supply services are not well studied and revised considering recent developments and needs of the community. Generally, based on the size of population, customer, and income level etc., the water supply services are categorized as large, medium and small or other similar grading. Thus, appropriate organizational structure which fits to the size of the water supply services need to be developed and implemented.

However, in developing organizational structures, various factors need to be considered. Among the factors that influence organizational structure, government policies & strategies, mission and vision/goals of the organization, and technology in use are the most important. Thus, in designing the organizational structure of the Water Supply and Sewerage Services, the Water Resources Management Policy and Strategic issues like providing reliable and sustainable service and full cost recovery ought to be considered. This means the new structure should help to enable the WSS to provide reliable and sustainable service and recover all its costs from its revenues. This helps the Water Supply and Sewerage Service to be able to perform all its functions autonomously with very limited supervision and support from the government.

Regarding the water sector management institutional setup "The Ethiopian Water Resource Management Policy" of 1999, says,

- Ensure that the management of water supply systems to be at the lowest and most efficient level of institutional set up, which provides for the full participation of users and to promote effective decision making at the lowest practical level.

- Develop coherent and streamlined institutional frameworks for the management of water supply at the Federal, Regional, Zonal, Woreda and Kebele levels and clearly define the relationships and interactions among them.

- Develop coherent and appropriate guidelines, standards, principles and norms for streamlining the intervention of NGOs loans, grants and other donations.

- Develop a framework for the sustainable and effective collaboration amongst all stakeholders including the public sector, donors, communities and the private sector at all levels as well as creates and legalize forum for the participation of all stakeholders.

- Define and implement the respective roles of the various institutions and stakeholders at all levels including Federal, Regional governments, NGOs, private sector, etc.

4.5.1. Water supply system management of GFWSP

To ensure sustainability of the utility throughout the design period, the beneficiary communities are empowered and take the responsibility of managing and administrating the water supply system. The water supply system managing body is established as per the organizational profile shown below.

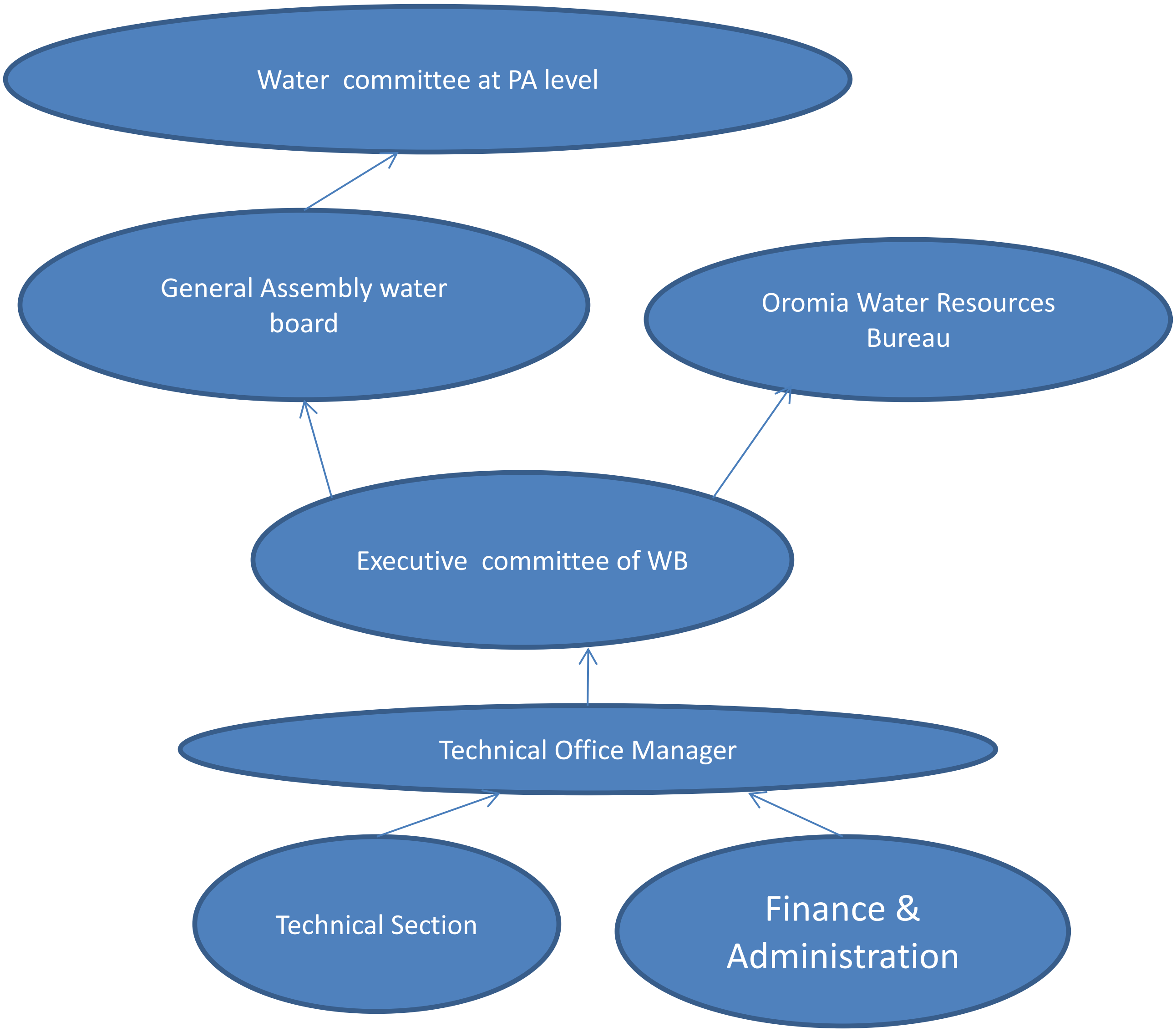


Figure 17: System Management of GFWS Project

There are 23 permanent staffs that are on managing this long water supply. The finding that was observed during site visit and during conducting interview with GFWS board members are;

- There was great lack of integration b/n all sections who is focal and responsible for managing this water supply project.
- Instead of participating experts and research institutions, everything going around this water supply is politicized with local government.

- There was serious environmental issue around this project; gullies are formed following trenches excavated and there is active agricultural farm around project site.

Figure 18: GFWS Project main line affected by gully

5. Conclusion and Recommendations

5.1. Conclusion

The spatial variation of water resource availability around the globe forms the delivery of water from one place to another either through tertian or underground water conduits. During delivering and implementing such kind of project, many issues arise. Among them are the issue of cost/quality, management, sustainability and the issue of environment takes prime stage.

To minimize the cost impeded and to reduce the environmental hazards of such kind ofprojects continues research should be done around these major issues. The issues that were seen under this research topic are the issue of demand-supply, the issue of pressure, the issue of unaccounted water and the issue of sustainability; taking Gimbichu Fentale water supply project as case study. Being implementing long distance water supply project for needy community is not solving their problem. Even there are communities where there are water points in/around their compound but who do not see any water through the taps because of many ancillary problems discussed here above.

Therefore the assessment of issues on long distance water supply project, taking Gimbichu Fentale Water supply project as case concludes the following points;

- Making sure that the current supply of source is adequate enough to meet the demand of the users; the Epanet2 analysis and field observation demonstrates that the current GFWSP do not meet the current demand of the users before its design period ends.
- Hydraulic head/pressure in pipe is so significant in long distance water supply project; and on the analysis, it is observed that, significant number of water points are not giving enough water through their tap due to low pressure while

there are water points where high pressure make difficulties on faucets and fittings.

- The unaccounted/leaked water in long distance water supply project is so abundant thatits effect (as per the analysis make in previous chapter) is clearly reduces water volume that ought to reach the beneficiaries.
- Sustainability of the project still under the question mark because of the environment issue as well as lack of focus from the concerned bodies (especially Regional and zonal government water offices) regardless of the existence of well-structured water board.

5.2. Recommendations

5.2.1. Demand – Supply

- Water demand – Supply issues are subject to uncertainty, as they are influenced by a multitude of external factors including assumptions about population growth and assumptions about domestic, industrial and commercial water use patterns, which in turn are based on assumptions about the effectiveness of water management/conservation programs.

- As it is stated under Table 4 and Figure 12 above, the demand variation of Gimbichu Fentatale WSP is almost 33 lit/sec and it is recommended to satisfy even the current demand with adding another source such as drilling borehole and omitting another extensions.

- The following factors that influence the water supply issues are recommended to be addressed, during design and beyond, especially in long distance water supply program;

    - User community capacity and behaviors (price restrictions (water tariff), income, socio-cultural factors, regulations, knowledge and awareness)
    - Demographic (population size, age and density, housing types, mixes and age, Development types, Residential lot size and occupancy rate)

- Climate change (rainfall, temperature and evaporation)
- Water efficient equipment (appliance and equipment stock and sales, structural water conservation programs)
- System design (supply source, storage infrastructure, delivery infrastructure, reticulation design, water pressure and leak detection and repair)
- Economic (Economic output, industry type, change in industrial and commercial use, price and tourism)
- Alternative source

5.2.2. Pressure and leakage

- Leakage is the major source of wasting water; and the following six factors should be addressed to reliably supply water in long distance systems

    - Material defects induced by poor design or insufficient planning at concept stage.
    - Absence of sufficient pressure break structures
    - Pipe breaks caused by poor workmanship in construction phase--laying and support of pipes.
    - Operational errors--over-pressure, water hammer valve operation, etc.
    - Corrosion due to soil and/or water chemistry effects and groundwater effects (e.g., seawater).
    - Leakage from any of the installed fittings (valves, saddles, bends, tees, hydrants, etc.)
    - Accidental or deliberate damage to hydrants and line air valves (including unauthorized tapings).

- The pressure difference of the Gimbichu Fentale WSP is above 300m (Table 5). To the minimum, it is recommended to construct 10 pressure break structures in addition to the existing 2 structures.

5.2.3. Sustainability

- A water supply system will be sustainable only if it promotes efficiencies in both the supply and the demand sides. Initiatives to meet demand for water supply will be sustainable if they prioritize measures to avoid water waste.

- On the supply side, it is fundamental to enhance operation and maintenance capabilities of water utilities, reducing non-revenue water (NRW), leakages, and energy use, as well as improving the capacity of the workforce to understand and operate the system. It is also necessary to ensure cost-recovery through a fair tariff system and "intelligent" investment planning. In addition, all alternatives to increase the water supply must be analyzed considering the entire life cycle.

- On the demand side, the adoption of water efficient technology can considerably reduce water consumption. Investments in less water intensive industrial processes and more efficient infrastructures lead to a more sustainable water supply. Concrete possibilities of economic savings, social benefits (such as the involvement of different sectors of society to reach a common objective, environmental awareness of the population, etc.) and a range of environmental gains make the adoption of water efficient technologies viable.

- Sustainable water supply involves a sequence of combined actions and not isolated strategies. It depends on the individual's willingness to save water, governmental regulations, changes in the infrastructure industry, industrial processes reformulation, land occupation, etc. The challenge is to create mechanisms of regulation, incentives and affordability to ensure the sustainability of the system.

Appendix

The interview

Assessment of Long distance water supply issues: The case of GFWSP (M.Sc Project of AAiT, Civil Engineering Department, for the stream of HYDRAULIC ENGINEERING)

For Gimbichu Fentale WS board member and Oromia Water Mine and Energy Bureau officers

1. Personal Background

1.1. Name: ____
1.2. Responsibility/Position: __________________________________
1.3. Educational Background: _________________________________
1.4. No. of year served in this project: ___________________________
1.5. Total work experience (relevant): ____________________________

2. Project description

2.1. What are the major components in the this project
- No. of water points: __________________
- No. of cattle trough:___________________
- No. or reservoir: _______________________
- No. of pressure break: ____________________
- Total length of main line: ____________________
- Total length of all network including mains: ______________
- Total project construction cost: ___________________
- Others: ______________________________

2.2. Have you referred any design document of the water supply yet? Yes/NO; if yes what type?

3. Demand - supply

3.1. In your context, is the current supply enough to meet the demand? Yes/No
3.2. If 3.1 is No; explain in detail why?
3.3. Why additional source (Bore hole drilling) as per the design not added yet??
3.4. In your opinion what should be done to alleviate the current demand??
3.5. What you propose to increase the life of the project
3.6. How much experts were on the project??
3.7. What resource do they have to manage this project??

4. Pressure

4.1. Is there any pressure problem on the system?
4.2. Where is the pressure very high frequently?
4.3. Where is pressure low very often?
4.4. How do you manage pressure fluctuation on the system?

5. Leakage

5.1. Is there any leakage on main line?
5.2. What are the causes of leakage on main water line?
5.3. Is the over flow on all structures like reservoir, WP, PBT and collection chambers monitored regularly?
5.4. What techniques are you using to regulate leakage on the system?

6. Fees

6.1. How fees are collected?
6.2. What is water tariff per m3?
6.3. Is there no complaint on water tariff?
6.4. How do you punish those who do not pay water bill willingly?

7. Operation and maintenance

7.1. How quick/fast to maintain the line breakage?
7.2. Is there shortage of any fittings/pipes for maintenance?
7.3. Are the technicians all capable to handle the breakage?
7.4. Is the logistic enough to mobilize all crew during maintenance?
7.5. Is there regular inspection on main line?

8. Quality control

8.1. Is there any quality control system on the project?
8.2. How can you achieve the quality standard?
8.3. How frequent is maintenance made on the system? Is the fittings checked before used for maintenance?

9. Others

9.1. In your opinion what are the issues on this project?
9.2. What do you recommend to alleviate the problems on this project if any?
9.3. How the local partners like NGO, CBO, and FBO are participate to run the project in junction to focal sector office?
9.4. Have you made proper documentation of all related or unrelated documents of this project?
9.5. As a case, is there any study/research conducted on this project yet?

Water fee collection form of GFWSP

Oromia Water Mine and Energy Bureau

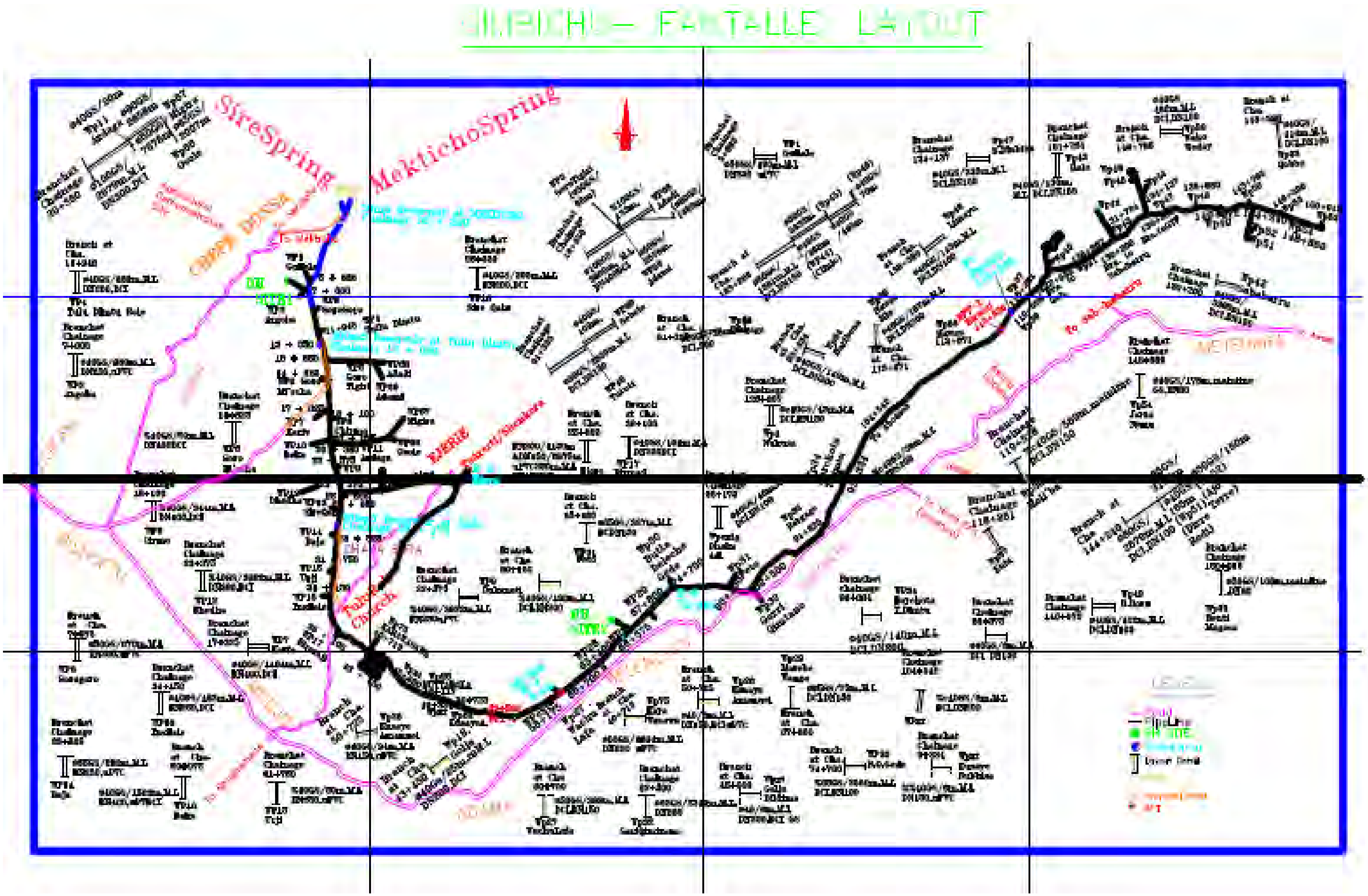
Dhabbataa Tajaajila Bishaan Dhugaatii Gimbichuu Fantaallee Galmee Analisis Sheet Kan ji'a Caamsaa 2007

Gimbichu Fental Water Supply Project - Analysis sheet of May 2015

Bosat Woreda

Lakk	Name	Kebele	Meter Size	Lakk. Ada Lakko	previous (dura)	last (amma)	Consumption (m^3)	Tarif per m^3	Consumption pay	Meter Rent	Total
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
Total											

Kan qophesee	checked by	Approved By
Maqaa ________________	Maqaa ___________________	Maqaa _____________
Mallattoo _____________	Mallattoo _________________	Mallattoo ________
Guyyaa _______________	Guyyaa _________________	Guyyaa _________


SireSpring
MektichoSpring

Free Head of GFWSP

1-AREAS WITH LOW FREE HEAD (h_{free}<5m)-Year 2020

Element	From CH	To CH	L(m)	material	D(mm)	V(m/s)	h_l(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-244	115+266	115+494	228	DCI	200	0.28	0.16	0.35	47	10	0.71	
P-169	74+800	74+950	150	DCI	200	0.51	0.31	1.14	1	10	2.09	
P-88	28+175	28+525	350	PVC	250	0.48	0.38	2.21	3	10	1.09	
P-71	7+875	9+350	1475	PVC	150	0.28	1.07	2.55	38	10	0.73	
P-245	115+494	115+526	32	DCI	200	0.28	0.02	2.72	49	10	0.71	BPT-2
P-3	2+075	3+250	1175	PVC	300	0.53	1.21	2.83	6	10	1.03	
P-81	1+668	4+839	3171	GI	80	0.74	46.09	3.38	100	10	14.54	
P-6	4+250	4+800	550	PVC	300	0.53	0.57	3.42	8	10	1.03	
P-8	5+883	WP_1	490	GI	50	0.44	4.74	4.03	15	10	9.67	G-PT
P-89	28+525	WP14	230	GI	65	0.63	3.18	4.91	8	10	13.85	BJ-PT

2-BRANCH LINES WITH HIGH FREE HEADS(h_{free}>70m)-Year 2020

Element	From CH	To CH	L(m)	material	D(mm)	V(m/s)	h_l(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-55	23+375	WP12	3922	GI	40	0.60	86.41	229.75	321	25	22.03	DH-PT
P-60	26+550	WP13	295	GI	40	0.49	4.39	207.41	222	25	14.89	SQ-PT
P-194	91+325	WP33	89	GI	25	0.43	1.84	199.51	225	25	20.69	BARG-PT
P-35	18+100	WP8	344	GI	40	0.83	13.72	193.39	209	25	39.87	C-PT
P-52	22+575	WP9	73	GI	40	0.63	1.75	189.51	196	20	24.02	DT-PT
P-32	17+325	WP7	1494	GI	40	0.69	42.53	179.42	223	25	28.47	K-PT
P-198	93+334	WP34	140	GI	40	0.44	1.74	172.25	199	20	12.46	BRTD-PT
P-286	131+724	WP-43	150	GI	40	0.51	2.45	171.10	230	25	16.32	I-PT
P-164	67+800	WP29	75	GI	65	1.56	5.53	165.47	229	25	73.70	MW-PT
P-161	65+400	WP28	327	GI	65	0.97	9.99	159.24	222	25	30.55	E-PT
P-298	134+137	WP-47	335	GI	40	0.32	2.36	145.71	211	25	7.04	BDh-PT
P-40	20+380	WP11	2679	GI	100	0.35	7.39	137.31	147	16	2.76	AR-PT
P-30	14+825	WP6	20	GI	40	0.56	0.39	132.84	134	16	19.56	GM-PT
P-122	43+450	WP18	25	GI	40	1.24	2.12	127.46	148	16	84.87	GJ-PT
P-291	0+000	1+381	1381	GI	50	0.60	23.67	124.37	209	25	17.14	
P-292	1+381	WP44	268	GI	40	0.31	1.79	121.46	208	25	6.66	DH-PT
P-99	34+150	WP16	482	GI	40	0.63	11.47	119.72	137	16	23.79	I-PT
P-38	20+075	WP10	1523	GI	40	0.91	73.04	115.10	190	20	47.96	D-PT
P-20	11+943	WP_4	326	GI	40	0.64	7.97	103.38	134	16	24.47	BTD-PT
P-41	WP_{11}	J2	2658	GI	80	0.41	13.13	99.50	122	16	4.94	
P-65	4+150	J3	20	GI	100	0.98	0.38	96.02	105	16	18.94	
P-66	J3	WP19	6	GI	65	0.65	0.09	95.93	105	16	14.67	DG-PT
P-168	74+800	WP30	2550	GI	65	0.71	43.44	94.66	209	25	17.03	BDG-PT
P-305	138+380	WP-48	145	GI	40	0.32	1.02	90.14	195	20	7.04	L-PT
P-141	56+175	WPextg	46	GI	40	1.16	3.41	85.13	200	25	74.15	DA-PT
P-67	J3	WP70	1733	GI	40	0.44	21.52	82.47	113	16	12.42	KR-PT
P-95	31+750	WP15	50	GI	40	0.86	2.14	80.72	86	10	42.83	U-PT
P-110	39+100	WP17	164	GI	40	1.03	9.77	74.00	94	10	59.59	BR-PT
P-275	126+307	WP-41	45	GI	40	0.49	0.67	72.58	111	16	14.98	S-PT

Element	From CH	To CH	L(m)	material	C	D(mm)	$Q_{p\text{-}h}$	$Q_{m\text{-}d}$	Q_d	V(m/s)	h_l(m)	El.(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-55	23+375	WP12	3922	GI	100	40	0.754		0.754	0.60	86.41	1924.38	229.75	321	25	22.03	DH-PT
P-214	101+173	101+993	820	DCI	110	200	1.582	8.884	10.466	0.33	0.79	1175.31	235.55	269	25	0.96	
P-213	101+054	101+173	119	DCI	110	200	1.582	8.884	10.466	0.33	0.11	1176.00	235.65	269	25	0.96	
P-208	97+501	98+663	1162	DCI	110	200	1.582	8.884	10.466	0.33	1.12	1177.46	236.61	267	25	0.96	
P-209	98+663	98+753	90	DCI	110	200	1.582	8.884	10.466	0.33	0.09	1179.59	234.39	265	25	0.96	
P-212	100+853	101+054	201	DCI	110	200	1.582	8.884	10.466	0.33	0.19	1182.39	229.38	262	25	0.96	
P-210	98+753	100+723	1970	DCI	110	200	1.582	8.884	10.466	0.33	1.89	1182.87	229.22	262	25	0.96	
P-216	102+338	102+452	114	DCI	110	200	1.582	8.884	10.466	0.33	0.11	1185,77	224.65	259	25	0.96	
P-207	97+160	97+501	341	DCI	110	200	1.582	8.884	10.466	0.33	0.33	1185.93	229.25	259	25	0.96	
P-211	100+723	100+853	130	DCI	110	200	1.582	8.884	10.466	0.33	0.12	1187.72	224.24	257	25	0.96	
P-215	101+993	102+338	345	DCI	110	200	1.582	8.884	10.466	0.33	0.33	1188,40	222.13	256	25	0.96	
P-217	102+452	102+639	187	DCI	110	200	1.582	8.884	10.466	0.33	0.18	1191,69	218.55	253	25	0.96	
P-204	95+719	96+387	668	DCI	110	200	1.582	8.884	10.466	0.33	0.64	1194.02	222.23	251	25	0.96	
P-219	102+684	102+723	39	DCI	110	200	1.582	8.884	10.466	0.33	0.04	1196.11	214.05	248	25	0.96	
P-322	2+879	6+014	3135	GI	100	65	1.765		1.765	0.53	31.47	900.19	22.19	248	25	10.04	
P-323	6+014	WP52	150	GI	100	50	1.765		1.765	0.90	5.39	900.19	16.80	248	25	35.93	AT-PT
P-205	96+387	96+442	55	DCI	110	200	1.582	8.884	10.466	0.33	0.05	1197.36	218.84	247	25	0.96	
P-250	116+594	118+124	1530	DCI	110	100		8.884	8.884	1.13	31.55	1148.66	193.37	247	25	20.62	
P-320	0+000	2+879	2879	GI	100	80	2.605		2.605	0.52	21.65	902.76	51.09	246	25	7.52	
P-321	2+879	WP51	165	GI	100	40	0.84		0.84	0.67	4.44	902.76	46.65	246	25	26.91	DR-PT
P-206	96+442	97+160	718	DCI	110	200	1.582	8.884	10.466	0.33	0.69	1199.12	216.39	245	25	0.96	
P-87	9+576	WP74	2654	GI	100	40	0.719		0.719	0.57	53.55	2014.10	48.81	245	25	20.18	GL-PT
P-218	102+639	102+684	45	DCI	110	200	1.582	8.884	10.466	0.33	0.04	1199,66	210.54	245	25	0.96	
P-327	148+869	WP54	178	GI	100	40	0.878		0.878	0.70	5.20	904.90	43.24	244	25	29.20	JN-PT
P-326	146+598	148+869	2271	GI	100	80	2.325		2.325	0.46	13.84	905.65	47.69	243	25	6.09	
P-324	144+240	146+598	2358	DCI	110	100	3.423		3.423	0.44	8.33	906.46	60.71	242	25	3.53	
P-203	95+681	95+719	38	DCI	110	200	1.582	8.884	10.466	0.33	0.04	1202.66	214.24	242	25	0.96	
P-167	69+100	74+800	5700	DCI	110	100	2.349	0	2.349	0.30	10.03	1444.58	170.54	241	25	1.76	DG-R6
P-325	146+598	WP53	416	GI	100	40	1.098		1.098	0.87	18.37	908.05	40.75	241	25	44.16	QO-PT
P-165	67+800	68+872	1072	DCI	110	100	2.349	0	2.349	0.30	1.89	1446.79	178.77	239	25	1.76	
P-319	143+785	144+240	455	DCI	110	100	6.028		6.028	0.77	4.58	910.78	64.72	238	25	10.06	
P-192	90+050	91+000	950	DCI	110	200	2.348	8.884	11.232	0.36	1.04	1207.67	214.00	237	25	1.10	
P-102	35+950	36+475	525	DCI	110	250	10.204	9.615	19.819	0.40	0.56	1807.33	228.28	236	25	1.06	
P-166	68+872	69+100	228	DCI	110	100	2.349	0	2.349	0.30	0.40	1450.04	175.11	236	25	1.76	
P-56	23+375	23+875	500	DCI	110	300	4.297	24.067	28.364	0.40	0.42	2010,24	229.88	235	25	0.85	
P-317	142+918	143+785	867	DCI	110	100	6.418		6.418	0.82	9.80	914,13	65.95	235	25	11.30	
P-328	148+869	150+913	2044	GI	100	80	1.447		1.447	0.29	5.18	914.69	33.47	234	25	2.53	
P-33	17+325	17+525	200	DCI	110	400	10.75	24.067	34.817	0.28	0.06	2011.89	232.28	234	25	0.31	
P-202	95+176	95+681	505	DCI	110	200	1.582	8.884	10.466	0.33	0.49	1211,19	205.74	233	25	0.96	
P-58	25+325	25+700	375	DCI	110	200	0.61	19.074	19.684	0.63	1.16	2013,91	223.82	232	25	3.09	
P-163	66+575	67+800	1225	DCI	110	150	7.534	0	7.534	0.43	2.60	1454.22	173.22	232	25	2.12	
P-191	90+025	90+050	25	DCI	110	200	2.348	8.884	11.232	0.36	0.03	1214.11	208.60	230	25	1.10	

Element	From CH	To CH	L(m)	material	C	D(mm)	Q_{p-h}	Q_{m-d}	Q_d	V(m/s)	h_l(m)	El.(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-286	131+724	WP-43	150	GI	100	40	0.641		0.641	0.51	2.45	918.43	171.10	230	25	16.32	I-PT
P-61	26+550	27+085	535	DCI	110	150		19.074	19.074	1.08	6.32	2015.48	213.30	230	25	11.81	
P-190	90+000	90+025	25	DCI	110	200	2.348	8.884	11.232	0.36	0.03	1214.73	208.01	230	25	1.10	
P-164	67+800	WP29	75	GI	100	65	5.185		5.185	1.56	5.53	1456.44	165.47	229	25	73.70	MW-PT
P-318	143+785	WP50	462	GI	100	40	0.39		0.39	0.31	3.01	919,39	57.68	229	25	6.51	W-PT
P-221	103+986	104+542	556	DCI	110	200	1.582	8.884	10.466	0.33	0.53	1215.49	192.92	229	25	0.96	
P-193	91+000	91+325	325	DCI	110	200	2.348	8.884	11.232	0.36	0.36	1215.52	205.80	229	25	1.10	
P-162	65+400	66+575	1175	DCI	110	150	8.769	0	8.769	0.50	3.30	1456.99	173.05	229	25	2.81	OL-PT-EX
P-287	131+724	132+493	769	DCI	110	150	8.822		8.822	0.50	2.18	921.38	168.42	227	25	2.84	
P-285	131+543	131+724	181	DCI	110	150	9.643		9.643	0.55	0.61	921.44	170.54	227	25	3.34	
P-316	141+632	142+918	1286	DCI	110	100	6.418		6.418	0.82	14.53	921,55	68.33	227	25	11.30	
P-289	132+572	132+662	90	DCI	110	150	8.822		8.822	0.50	0.26	922.22	167.10	226	25	2.84	
P-329	150+913	WP55	100	GI	100	50	1.447		1.447	0.74	2.49	922.30	23.37	226	25	24.88	BM-PT
P-34	17+525	18+100	575	DCI	110	400	10.75	24.067	34.817	0.28	0.18	2019.85	224.15	226	25	0.31	
P-284	131+186	131+543	357	DCI	110	150	9.643		9.643	0.55	1.19	923.65	168.94	225	25	3.34	
P-31	14+825	17+325	2500	DCI	110	400	11.616	24.067	35.683	0.28	0.80	2020.64	223.59	225	25	0.32	
P-194	91+325	WP33	89	GI	100	25	0.212		0.212	0.43	1.84	1219.96	199.51	225	25	20.69	BARG-PT
P-160	63+790	65+400	1610	DCI	110	150	11.99	0	11.99	0.68	8.06	1461.15	172.18	225	25	5.00	
P-288	132+493	132+572	79	DCI	110	150	8.822		8.822	0.50	0.22	925.02	164.56	224	25	2.84	
P-32	17+325	WP7	1494	GI	100	40	0.866		0.866	0.69	42.53	2022.28	179.42	223	25	28.47	K-PT
P-201	93+798	95+176	1378	DCI	110	200	1.582	8.884	10.466	0.33	1.32	1221,42	196.00	223	25	0.96	
P-185	87+811	88+088	277	DCI	110	200	2.348	8.884	11.232	0.36	0.30	1221,47	203.39	223	25	1.10	
P-60	26+550	WP13	295	GI	100	40	0.61		0.61	0.49	4.39	2023.30	207.41	222	25	14.89	SQ-PT
P-161	65+400	WP28	327	GI	100	65	3.221		3.221	0.97	9.99	1464.11	159.24	222	25	30.55	E-PT
P-290	132+662	133+206	544	DCI	110	150	8.822		8.822	0.50	1.54	927.39	160.39	221	25	2.84	
P-184	87+730	87+811	81	DCI	110	200	2.348	8.884	11.232	0.36	0.09	1223,57	201.60	221	25	1.10	
P-53	22+575	23+035	460	DCI	110	300	5.051	24.067	29.118	0.41	0.41	2025.19	215.66	220	25	0.89	
P-222	104+542	105+845	1303	DCI	110	200	1.582	8.884	10.466	0.33	1.25	1224.22	182.94	220	25	0.96	
P-220	102+723	103+986	1263	DCI	110	200	1.582	8.884	10.466	0.33	1.21	1224.32	184.63	220	25	0.96	
P-62	27+085	27+835	750	DCI	110	150		19.074	19.074	1.08	8.86	2025.98	193.94	220	25	11.81	
P-57	23+875	25+325	1450	DCI	110	300	4.297	24.067	28.364	0.40	1.23	2027,35	211.54	218	25	0.85	
P-101	34+400	35+950	1550	DCI	110	250	10.204	9.615	19.819	0.40	1.64	1826.66	209.50	217	25	1.06	
P-297	133+206	134+137	931	DCI	110	150	7.639		7.639	0.43	2.02	932.61	153.14	216	25	2.17	
P-59	25+700	26+550	850	DCI	110	200	0.61	19.074	19.684	0.63	2.63	2029.86	205.24	216	25	3.09	
P-186	88+088	88+200	112	DCI	110	200	2.348	8.884	11.232	0.36	0.12	1229,50	195.24	215	25	1.10	
P-49	21+875	22+350	475	DCI	110	300	5.841	24.067	29.908	0.42	0.44	2030.77	210.70	215	20	0.93	
P-299	134+137	135+681	1544	DCI	110	150	7.232		7.232	0.41	3.03	935.09	147.63	214	25	1.96	
P-200	93+409	93+798	389	DCI	110	200	1.582	8.884	10.466	0.33	0.37	1232,38	186.36	212	25	0.96	
P-139	53+900	55+825	1925	DCI	110	100	1.453	9.516	10.969	1.40	58.63	1668,71	110.57	212	20	30.46	
P-283	130+200	131+186	986	DCI	110	150	9.643		9.643	0.55	3.30	936.83	156.95	212	25	3.34	
P-188	88+500	89+450	950	DCI	110	200	2.348	8.884	11.232	0.36	1.04	1232.79	190.58	212	25	1.10	
P-189	89+450	90+000	550	DCI	110	200	2.348	8.884	11.232	0.36	0.60	1232.79	189.98	212	25	1.10	
P-158	62+800	63+734	934	DCI	110	150	11.99	0	11.99	0.68	4.67	1474.13	167.54	212	25	5.00	
P-159	63+734	63+790	56	DCI	110	150	11.99	0	11.99	0.68	0.28	1474.13	167.26	212	25	5.00	
P-181	84+750	87+575	2825	DCI	110	200	2.348	8.884	11.232	0.36	3.10	1233.48	191.94	211	20	1.10	
P-298	134+137	WP-47	335	GI	100	40	0.407		0.407	0.32	2.36	937.69	145.71	211	25	7.04	BDh-PT
P-48	21+525	21+875	350	DCI	110	300	5.841	24.067	29.908	0.42	0.33	2035.35	206.57	210	20	0.93	
P-187	88+200	88+500	300	DCI	110	200	2.348	8.884	11.232	0.36	0.33	1234,34	190.07	210	25	1.10	
P-306	138+380	138+782	402	DCI	110	100	6.825		6.825	0.87	5.09	938.79	100.80	210	20	12.66	
P-183	87+600	87+730	130	DCI	110	200	2.348	8.884	11.232	0.36	0.14	1234.83	190.42	210	20	1.10	
P-54	23+035	23+375	345	DCI	110	300	5.051	24.067	29.118	0.41	0.31	2036.69	203.86	209	25	0.89	
P-291	0+000	1+381	1381	GI	100	50	1.183		1.183	0.60	23.67	939.74	124.37	209	25	17.14	
P-103	36+475	36+800	325	DCI	110	250	10.204	9.615	19.819	0.40	0.34	1834.66	200.60	209	25	1.06	
P-35	18+100	WP8	344	GI	100	40	1.039		1.039	0.83	13.72	2036.89	193.39	209	25	39.87	C-PT
P-168	74+800	WP30	2550	GI	100	65	2.349		2.349	0.71	43.44	1477.02	94.66	209	25	17.03	BDG-PT
P-36	18+000	19+250	1250	DCI	110	400	9.711	24.067	33.778	0.27	0.36	2037.05	206.59	209	25	0.29	
P-182	87+575	87+600	25	DCI	110	200	2.348	8.884	11.232	0.36	0.03	1236.21	189.19	208	20	1.10	
P-292	1+381	WP44	268	GI	100	40	0.395		0.395	0.31	1.79	940.86	121.46	208	25	6.66	DH-PT
P-315	140+972	141+632	660	DCI	110	100	6.418		6.418	0.82	7.46	941,09	63.32	208	20	11.30	
P-307	138+782	138+900	118	DCI	110	100	6.825		6.825	0.87	1.49	943.15	94.95	206	20	12.66	
P-63	27+835	28+175	340	DCI	110	150		19.074	19.074	1.08	4.02	2043.42	172.49	202	25	11.81	
P-308	138+900	138+940	40	DCI	110	100	6.825		6.825	0.87	0.51	946.78	90.81	202	20	12.66	
P-313	139+900	140+972	1072	DCI	110	100	6.825		6.825	0.87	13.57	947.30	64.57	201	20	12.66	
P-296	7+209	WP46	70	GI	100	40	0.394		0.394	0.31	0.46	947.81	69.45	201	25	6.63	G.T. School
P-141	56+175	WPextg	46	GI	100	40	1.453		1.453	1.16	3.41	1680.08	85.13	200	25	74.15	DA-PT
P-304	137+826	138+380	554	DCI	110	100	7.232		7.232	0.92	7.81	949.02	95.66	200	20	14.09	
P-198	93+334	WP34	140	GI	100	40	0.554		0.554	0.44	1.74	1245.20	172.25	199	20	12.46	BRTD-PT
P-295	6+714	7+209	495	GI	100	40	0.394		0.394	0.31	3.28	949.29	68.43	199	20	6.63	
P-195	91+325	92+185	860	DCI	110	200	2.136	8.884	11.02	0.35	0.91	1247.08	173.33	198	25	1.06	
P-51	22+450	22+575	125	DCI	110	300	5.841	24.067	29.908	0.42	0.12	2048.26	193.00	197	20	0.93	
P-140	55+825	56+175	350	DCI	110	100	1.453	9.516	10.969	1.40	10.66	1683.31	85.31	197	20	30.46	
P-314	140+972	WP49	422	GI	100	40	0.407		0.407	0.32	2.97	951.85	57.05	197	20	7.04	B-PT
P-199	93+334	93+409	75	DCI	110	200	1.582	8.884	10.466	0.33	0.07	1248.49	170.63	196	25	0.96	
P-52	22+575	WP9	73	GI	100	40	0.79		0.79	0.63	1.75	2050.00	189.51	196	20	24.02	DT-PT
P-305	138+380	WP-48	145	GI	100	40	0.407		0.407	0.32	1.02	953.52	90.14	195	20	7.04	L-PT
P-293	1+381	6+714	5333	GI	100	50	0.788		0.788	0.40	43.10	953.67	67.34	195	20	8.08	
P-142	56+175	56+300	125	DCI	110	100		9.615	9.615	1.22	2.98	1685.75	79.89	195	20	23.87	DA-R5
P-303	137+426	137+826	400	DCI	110	100	7.232		7.232	0.92	5.64	954.40	98.09	194	20	14.09	
P-50	22+350	22+450	100	DCI	110	300	5.841	24.067	29.908	0.42	0.09	2051.56	189.82	194	20	0.93	
P-300	135+681	136+665	984	DCI	110	100	7.232		7.232	0.92	13.87	954.95	113.90	194	20	14.09	
P-294	6+714	WP45	150	GI	100	40	0.394		0.394	0.31	0.99	956.03	63.98	193	20	6.63	Qac-PT
P-301	136+665	137+149	484	DCI	110	100	7.232		7.232	0.92	6.82	956.38	105.65	192	20	14.09	
P-196	92+185	93+145	960	DCI	110	200	2.136	8.884	11.02	0.35	1.02	1253.82	165.57	191	25	1.06	
P-104	36+800	37+000	200	DCI	110	250	10.204	9.615	19.819	0.40	0.21	1853,03	182.02	190	20	1.06	
P-38	20+075	WP10	1523	GI	100	40	1.148		1.148	0.91	73.04	2055.26	115.10	190	20	47.96	D-PT
P-280	129+797	130+200	403	DCI	110	150	10.156		10.156	0.57	1.48	958.31	138.77	190	20	3.68	
P-311	139+267	139+869	602	DCI	110	100	6.825		6.825	0.87	7.62	958.43	67.40	190	20	12.66	
P-309	138+940	139+198	258	DCI	110	100	6.825		6.825	0.87	3.27	958.66	75.67	190	20	12.66	
P-312	139+869	139+900	31	DCI	110	100	6.825		6.825	0.87	0.39	959.12	66.32	190	20	12.66	
P-157	62+780	62+800	20	DCI	110	150	11.99	0	11.99	0.68	0.10	1496.35	150.00	189	20	5.00	
P-156	62+300	62+780	480	DCI	110	150	11.99	0	11.99	0.68	2.40	1497.76	148.69	188	20	5.00	
P-281	0+000	5+333	5333	GI	100	40	0.693		0.693	0.55	100.52	961.89	34.67	187	20	18.85	
P-282	5+333	WP42	200	GI	100	40	0.693		0.693	0.55	3.77	962.30	30.49	186	20	18.85	SB-PT
P-310	139+198	139+267	69	DCI	110	100	6.825		6.825	0.87	0.87	962.73	70.72	186	20	12.66	
P-106	37+375	37+515	140	DCI	110	250	10.204	9.615	19.819	0.40	0.15	1858,46	176.05	185	20	1.06	
P-180	82+500	84+750	2250	DCI	110	200	2.348	8.884	11.232	0.36	2.47	1260.95	167.57	184	20	1.10	
P-197	93+145	93+334	189	DCI	110	200	2.136	8.884	11.02	0.35	0.20	1262.35	156.84	182	25	1.06	
P-123	43+450	44+300	850	DCI	110	200	6.467	9.615	16.082	0.51	1.81	1862,31	160.42	181	20	2.13	
P-224	107+259	107+313	54	DCI	110	200	1.582	8.884	10.466	0.33	0.05	1264.38	141.37	180	16	0.96	

Element	From CH	To CH	L(m)	material	C	D(mm)	Q_{p-h}	Q_{m-d}	Q_d	V(m/s)	h_l(m)	El.(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-224	107+259	107+313	54	DCI	110	200	1.582	8.884	10.466	0.33	0.05	1264.38	141.37	180	16	0.96	
P-44	20+380	20+725	345	DCI	110	300	5.841	24.067	29.908	0.42	0.32	2065.68	177.31	180	20	0.93	
P-302	137+149	137+426	277	DCI	110	100	7.232		7.232	0.92	3.90	969.31	88.82	179	20	14.09	
P-46	20+975	21+225	250	DCI	110	300	5.841	24.067	29.908	0.42	0.23	2066.46	176.06	179	20	0.93	
P-226	107+748	107+890	142	DCI	110	200	1.582	8.884	10.466	0.33	0.14	1265.51	139.68	179	16	0.96	
P-223	105+845	107+259	1414	DCI	110	200	1.582	8.884	10.466	0.33	1.36	1266.59	139.21	178	16	0.96	
P-47	21+225	21+525	300	DCI	110	300	5.841	24.067	29.908	0.42	0.28	2068.39	173.85	177	20	0.93	
P-278	128+192	128+712	520	DCI	110	150	10.156		10.156	0.57	1.91	971.95	130.61	177	20	3.68	
P-279	128+712	129+797	1085	DCI	110	150	10.156		10.156	0.57	3.99	973.10	125.46	176	20	3.68	
P-276	126+307	128+063	1756	DCI	110	150	10.156		10.156	0.57	6.46	973.63	131.32	175	20	3.68	
P-124	44+300	45+250	950	DCI	110	200	6.467	9.615	16.082	0.51	2.02	1868.57	152.13	175	20	2.13	
P-225	107+313	107+748	435	DCI	110	200	1.582	8.884	10.466	0.33	0.42	1269.77	135.56	175	16	0.96	
P-155	62+280	62+300	20	DCI	110	150	11.99	0	11.99	0.68	0.10	1513,73	135.12	172	20	5.00	
P-277	128+063	128+192	129	DCI	110	150	10.156		10.156	0.57	0.47	976.66	127.81	172	20	3.68	
P-125	45+250	45+500	250	DCI	110	200	6.467	9.615	16.082	0.51	0.53	1871.78	148.39	172	20	2.13	GD-PT-EX
P-100	34+150	34+400	250	DCI	110	250	10.204	9.615	19.819	0.40	0.26	1871.89	165.92	172	25	1.06	
P-154	61+960	62+280	320	DCI	110	150	11.99	0	11.99	0.68	1.60	1514,62	134.33	171	20	5.00	
P-45	20+725	20+975	250	DCI	110	300	5.841	24.067	29.908	0.42	0.23	2076.00	166.76	170	20	0.93	
P-105	37+000	37+375	375	DCI	110	250	10.204	9.615	19.819	0.40	0.40	1874,32	160.33	169	20	1.06	
P-18	10+550	11+250	700	DCI	110	250	0.798	34.343	35.141	0.72	2.14	2116.62	147.72	168	16	3.06	
P-138	53+600	53+900	300	DCI	110	100	1.453	9.516	10.969	1.40	9.14	1713,61	124.30	167	16	30.46	
P-84	7+576	WP72	169	GI	100	50	1.654		1.654	0.84	5.38	2095.05	32.02	164	20	31.86	QD-PT
P-134	50+725	52+500	1775	PVC	130	150	1.453	9.615	11.068	0.63	5.62	1880.55	118.21	163	16	3.17	BPT-1
P-39	20+075	20+380	305	DCI	110	400	8.563	24.067	32.63	0.26	0.08	2083.89	159.42	162	20	0.27	
P-83	4+839	7+576	2737	GI	100	80	3.215		3.215	0.64	30.37	2098.31	34.15	161	20	11.10	
P-86	9+576	WP73	100	GI	100	40	0.842		0.842	0.67	2.70	2099.35	14.41	160	16	27.03	DhB-PT
P-17	7+975	10+550	2575	DCI	110	250	0.798	34.343	35.141	0.72	7.87	2126.52	139.96	159	16	3.06	
P-153	61+920	61+960	40	DCI	110	150	11.99	0	11.99	0.68	0.20	1528,28	122.27	157	16	5.00	
P-227	107+890	109+416	1526	DCI	110	200	1.582	8.884	10.466	0.33	1.47	1287.71	116.02	157	16	0.96	
P-37	19+250	20+075	825	DCI	110	400	9.711	24.067	33.778	0.27	0.24	2089.65	153.75	156	20	0.29	
P-152	61+400	61+920	520	DCI	110	150	11.99	0	11.99	0.68	2.60	1530.04	120.71	156	16	5.00	
P-97	33+600	33+965	365	PVC	130	250	10.99	9.615	20.605	0.42	0.31	1889.76	148.47	154	16	0.84	
P-85	7+576	9+576	2000	GI	100	65	1.561		1.561	0.47	16.00	2105.55	10.91	154	16	8.00	
P-117	41+000	41+468	468	PVC	130	200	8.03	9.615	17.645	0.56	0.87	1890.09	138.12	153	16	1.86	
P-98	33+965	34+150	185	PVC	130	250	10.99	9.615	20.605	0.42	0.15	1894.06	144.01	149	16	0.84	
P-121	42+750	43+450	700	PVC	130	200	8.03	9.615	17.645	0.56	1.30	1894,80	129.73	149	16	1.86	
P-122	43+450	WP18	25	GI	100	40	1.563		1.563	1.24	2.12	1894,95	127.46	148	16	84.87	GJ-PT
P-40	20+380	WP11	2679	GI	100	100	2.722		2.722	0.35	7.39	2098.62	137.31	147	16	2.76	AR-PT
P-107	37+515	37+775	260	DCI	110	250	10.204	9.615	19.819	0.40	0.28	1898.17	136.06	145	20	1.06	
P-119	41+800	42+125	325	PVC	130	200	8.03	9.615	17.645	0.56	0.60	1899.51	127.48	144	16	1.86	
P-232	110+257	110+420	163	DCI	110	200	1.582	8.884	10.466	0.33	0.16	1307,89	94.87	137	16	0.96	
P-99	34+150	WP16	482	GI	100	40	0.786		0.786	0.63	11.47	1906.88	119.72	137	16	23.79	I-PT
P-29	14+000	14+825	825	DCI	110	400	12.323	24.067	36.39	0.29	0.27	2111.00	134.03	135	16	0.33	
P-20	11+943	WP_4	326	GI	100	40	0.798		0.798	0.64	7.97	2150.87	103.38	134	16	24.47	BTD-PT
P-30	14+825	WP6	20	GI	100	40	0.707		0.707	0.56	0.39	2111.80	132.84	134	16	19.56	GM-PT
P-236	111+050	113+180	2130	DCI	110	200	1.582	8.884	10.466	0.33	2.05	1311.06	89.05	134	16	0.96	
P-233	110+420	110+583	163	DCI	110	200	1.582	8.884	10.466	0.33	0.16	1311.81	90.79	133	16	0.96	
P-228	109+416	109+884	468	DCI	110	200	1.582	8.884	10.466	0.33	0.45	1312.50	90.78	132	16	0.96	
P-230	109+986	110+087	101	DCI	110	200	1.582	8.884	10.466	0.33	0.10	1315,43	87.65	129	16	0.96	
P-238	113+671	WP36	167	GI	100	40	1.582		1.582	1.26	14.49	1316.87	68.27	128	16	86.79	HJ-PT
P-237	113+180	113+671	491	DCI	110	200	1.582	8.884	10.466	0.33	0.47	1318.78	80.86	126	16	0.96	
P-235	110+835	111+050	215	DCI	110	200	1.582	8.884	10.466	0.33	0.21	1318.79	83.37	126	16	0.96	
P-28	13+350	14+000	650	DCI	110	400	12.323	24.067	36.39	0.29	0.22	2122.40	122.91	123	16	0.33	
P-239	113+671	114+334	663	DCI	110	200		8.884	8.884	0.28	0.47	1321.44	77.72	123	16	0.71	
P-229	109+884	109+986	102	DCI	110	200	1.582	8.884	10.466	0.33	0.10	1322.09	81.09	122	16	0.96	
P-242	114+432	114+488	56	DCI	110	200		8.884	8.884	0.28	0.04	1322.14	76.92	122	16	0.71	
P-41	WP_{11}	J2	2658	GI	100	80	2.076		2.076	0.41	13.13	2123,29	99.50	122	16	4.94	
P-118	41+468	41+800	332	PVC	130	200	8.03	9.615	17.645	0.56	0.62	1921.16	106.44	122	16	1.86	
P-151	61+000	61+400	400	DCI	110	150	11.99	0	11.99	0.68	2.00	1563.81	89.54	122	16	5.00	
P-96	31+750	33+600	1850	PVC	130	250	10.99	9.615	20.605	0.42	1.55	1922.80	115.73	121	16	0.84	
P-177	80+700	81+900	1200	DCI	110	200	4.374	8.884	13.258	0.42	1.79	1324,08	107.80	121	20	1.49	
P-108	37+775	38+700	925	DCI	110	250	10.204	9.615	19.819	0.40	0.98	1924.23	109.02	119	20	1.06	
P-240	114+334	114+386	52	DCI	110	200		8.884	8.884	0.28	0.04	1325.71	73.42	119	16	0.71	
P-19	11+250	11+943	693	DCI	110	250	0.798	34.343	35.141	0.72	2.12	2166.74	95.48	118	16	3.06	
P-243	114+488	115+266	778	DCI	110	200		8.884	8.884	0.28	0.55	1326.35	72.15	118	16	0.71	
P-241	114+386	114+432	46	DCI	110	200		8.884	8.884	0.28	0.03	1326.78	72.31	118	16	0.71	
P-126	45+500	47+400	1900	DCI	110	200	5.622	9.615	15.237	0.49	3.66	1926.60	89.91	117	16	1.93	
P-178	81+900	82+500	600	DCI	110	200	4.374	8.884	13.258	0.42	0.89	1328,27	102.72	116	20	1.49	
P-231	110+087	110+257	170	DCI	110	200	1.582	8.884	10.466	0.33	0.16	1329,85	73.07	115	16	0.96	
P-120	42+125	42+750	625	PVC	130	200	8.03	9.615	17.645	0.56	1.16	1929.34	96.49	114	16	1.86	
P-67	J3	WP70	1733	GI	100	40	0.553		0.553	0.44	21.52	2132.45	82.47	113	16	12.42	KR-PT
P-274	126+112	126+307	195	DCI	110	150	10.768		10.768	0.61	0.80	1036.37	75.04	112	20	4.10	
P-275	126+307	WP-41	45	GI	100	40	0.612		0.612	0.49	0.67	1038.16	72.58	111	16	14.98	S-PT
P-234	110+583	110+835	252	DCI	110	200	1.582	8.884	10.466	0.33	0.24	1335.38	66.98	109	16	0.96	
P-136	52+800	53+400	600	DCI	110	100	1.453	9.516	10.969	1.40	18.27	1772.01	81.13	109	16	30.46	
P-137	53+400	53+600	200	DCI	110	100	1.453	9.516	10.969	1.40	6.09	1772,70	74.35	108	16	30.46	
P-132	49+973	50+725	752	PVC	130	150	2.488	9.615	12.103	0.68	2.81	1936.31	68.08	107	16	3.74	
P-273	124+892	126+112	1220	DCI	110	150	10.768		10.768	0.61	5.00	1041.64	70.57	107	10	4.10	
P-64	0+00	4+150	4150	PVC	130	200	3.687	4.993	8.68	0.28	2.07	2139.79	97.03	106	10	0.50	
P-82	4+839	WP71	182	GI	100	40	0.505		0.505	0.40	1.91	2153.49	7.43	106	16	10.50	X-PT
P-65	4+150	J3	20	GI	100	100	2.72	4.993	7.713	0.98	0.38	2140.42	96.02	105	16	18.94	
P-66	J3	WP19	6	GI	100	65	2.167		2.167	0.65	0.09	2140.42	95.93	105	16	14.67	DG-PT
P-133	50+725	WP26	94	GI	100	40	1.035		1.035	0.82	3.72	1940.89	59.78	103	16	39.59	KA-PT
P-131	49+334	49+973	639	PVC	130	150	2.488	9.615	12.103	0.68	2.39	1942.04	65.16	101	16	3.74	
P-129	48+117	48+766	649	PVC	130	150	3.85	9.615	13.465	0.76	2.96	1943.43	68.74	100	10	4.55	
P-81	1+668	4+839	3171	GI	100	80	3.72		3.72	0.74	46.09	2159.45	3.38	100	10	14.54	
P-109	38+700	39+100	400	DCI	110	250	10.204	9.615	19.819	0.40	0.42	1944.49	88.34	99	20	1.06	
P-112	39+600	39+800	200	PVC	130	200	8.913	9.615	18.528	0.59	0.41	1945.08	86.33	98	10	2.03	
P-80	17+668	WP21	94.2	GI	100	50	1.51		1.51	0.77	2.54	2162,60	46.32	97	10	26.92	TL-PT
P-175	80+224	80+600	376	DCI	110	200	4.374	8.884	13.258	0.42	0.56	1348.16	85.65	96	10	1.49	

Element	From CH	To CH	L(m)	material	C	D(mm)	Q_{p-h}	Q_{m-d}	Q_d	V(m/s)	h_l(m)	El.(m)	h_{free}(m)	h_{st}(m)	PN	$h_{l/Km}$	Remark
P-110	39+100	WP17	164	GI	100	40	1.291		1.291	1.03	9.77	1949.06	74.00	94	10	59.59	BR-PT
P-173	80+150	WP31	190	GI	100	40	1.785		1.785	1.42	20.62	1351.68	62.19	93	10	108.51	F-PT
P-272	124+711	124+892	181	DCI	110	150	10.768		10.768	0.61	0.74	1055.77	61.45	93	10	4.10	
P-42	J2	WP66	767	GI	100	50	0.63		0.63	0.32	4.10	2152,80	65.90	93	10	5.34	O-PT
P-174	80+150	80+224	74	DCI	110	200	4.374	8.884	13.258	0.42	0.11	1351.79	82.58	93	10	1.49	
P-128	48+117	WP25	70	GI	100	40	1.772		1.772	1.41	7.49	1951.15	56.49	92	10	107.05	BB-PT
P-176	80+600	80+700	100	DCI	110	200	4.374	8.884	13.258	0.42	0.15	1352,45	81.22	92	10	1.49	
P-111	39+100	39+600	500	PVC	130	200	8.913	9.615	18.528	0.59	1.02	1953.13	78.68	90	10	2.03	
P-150	60+825	61+000	175	DCI	110	150	11.99	0	11.99	0.68	0.88	1595.52	59.84	90	10	5.00	
P-127	47+400	48+117	717	DCI	110	200	5.622	9.615	15.237	0.49	1.38	1953.52	61.61	90	16	1.93	
P-94	31+450	31+750	300	PVC	130	250	12.07	9.615	21.685	0.44	0.28	1954.47	85.61	89	10	0.92	
P-179	82+500	WP32	2349	GI	100	65	2.026		2.026	0.61	30.43	1357.07	43.48	88	10	12.96	GQ-PT
P-95	31+750	WP15	50	GI	100	40	1.08		1.08	0.86	2.14	1957.21	80.72	86	10	42.83	U-PT
P-92	30+550	31+015	465	PVC	130	250	12.07	9.615	21.685	0.44	0.43	1957.33	83.42	86	10	0.92	
P-116	40+713	41+000	287	PVC	130	200	8.03	9.615	17.645	0.56	0.53	1958.76	70.32	85	10	1.86	
P-27	J1	WP69	2576	GI	100	50	0.979		0.979	0.50	31.11	2161,48	38.67	84	10	12.08	AM-PT
P-68	4+150	7+000	2850	PVC	130	150	0.967	4.993	5.96	0.34	2.87	2163.62	48.43	82	10	1.01	
P-249	116+351	116+594	243	DCI	110	100		8.884	8.884	1.13	5.01	1313.79	59.79	82	10	20.62	
P-135	52+500	52+800	300	DCI	110	100	1.453	9.516	10.969	1.40	9.14	1798.96	72.45	82	16	30.46	
P-72	9+350	10+870	1520	PVC	130	150		4.993	4.993	0.28	1.10	2164,51	44.48	81	10	0.73	
P-79	0+000	1+668	1668	GI	100	80	5.23		5.23	1.04	45.54	2178,22	33.24	81	10	27.30	
P-271	124+156	124+711	555	DCI	110	150	10.768		10.768	0.61	2.28	1067,76	50.20	81	10	4.10	
P-93	31+015	31+450	435	PVC	130	250	12.07	9.615	21.685	0.44	0.40	1964.75	75.60	79	10	0.92	
P-147	59+600	60+700	1100	DCI	110	150	13.886	0	13.886	0.79	7.22	1608.11	48.75	78	10	6.57	
P-114	40+500	40+713	213	PVC	130	200	7.47	9.615	17.085	0.54	0.37	1966.49	63.12	77	10	1.75	
P-257	120+176	121+745	1569	DCI	110	150	11.878		11.878	0.67	7.72	1071.75	59.04	77	10	4.92	
P-149	60+700	60+825	125	DCI	110	150	11.99	0	11.99	0.68	0.63	1609.82	46.41	76	10	5.00	
P-43	J2	WP67	2407	GI	100	65	1.446		1.446	0.44	16.71	2173,42	32.66	72	10	6.94	M-PT
P-259	0+000	0+379	379	GI	100	50	1.11		1.11	0.57	5.77	1077.04	43.99	72	10	15.23	
P-260	0+379	2+339	1960	GI	100	50	0.555		0.555	0.28	8.28	1077.04	35.71	72	10	4.23	
P-261	2+339	WP39	109	GI	100	40	0.555		0.555	0.44	1.36	1077.04	34.34	72	10	12.50	GB-PT
P-148	60+700	WP27	399	GI	100	50	1.896		1.896	0.97	16.37	1614.59	25.90	71	10	41.02	WL-PT
P-172	78+737	80+150	1413	DCI	110	200	6.159	8.884	15.043	0.48	2.66	1376.57	57.91	68	10	1.88	
P-73	10+870	11+025	155	PVC	130	150		4.993	4.993	0.28	0.11	2178,32	30.56	67	10	0.73	
P-269	123+887	124+049	162	DCI	110	150	10.768		10.768	0.61	0.66	1083,41	37.26	65	10	4.10	
P-78	11+850	11+325	525	DCI	110	150	5.23		5.23	0.30	0.57	2194,09	62.90	65	25	1.08	
P-258	121+745	122+555	810	DCI	110	150	11.878		11.878	0.67	3.98	1084.27	42.53	64	10	4.92	
P-22	13+050	13+350	300	DCI	110	400	15.435	24.067	39.502	0.31	0.12	2181.35	64.17	64	16	0.39	
P-130	48+766	49+334	568	PVC	130	150	3.85	9.615	13.465	0.76	2.59	1979.46	30.13	64	10	4.55	KB-PT-EX
P-145	58+600	59+000	400	DCI	110	150	13.886	0	13.886	0.79	2.63	1622.06	45.96	64	10	6.57	
P-70	7+875	WP20	141	GI	100	40	0.967		0.967	0.77	4.92	2182.35	23.90	63	10	34.91	FM-PT
P-262	0+379	2+139	1760	GI	100	50	0.555		0.555	0.28	7.44	1085.48	28.11	63	10	4.23	
P-263	2+139	WP40	50	GI	100	40	0.555		0.555	0.44	0.62	1085.48	27.49	63	10	12.50	NQ-T
P-90	28+525	30+335	1810	PVC	130	250	12.07	9.615	21.685	0.44	1.66	1980,37	61.01	63	10	0.92	
P-270	124+049	124+156	107	DCI	110	150	10.768		10.768	0.61	0.44	1085,71	34.53	63	10	4.10	
P-91	30+335	30+550	215	PVC	130	250	12.07	9.615	21.685	0.44	0.20	1982.30	58.88	61	10	0.92	
P-171	76+200	78+737	2537	DCI	110	200	6.159	8.884	15.043	0.48	4.77	1384.36	52.78	60	10	1.88	
P-256	119+528	120+176	648	DCI	110	150	11.878		11.878	0.67	3.19	1088.48	50.02	60	10	4.92	
P-69	7+000	7+875	875	PVC	130	150	0.967	4.993	5.96	0.34	0.88	2186.69	24.48	59	10	1.01	
P-113	39+800	40+500	700	PVC	130	200	8.913	9.615	18.528	0.59	1.42	1986.54	43.44	57	10	2.03	
P-146	59+000	59+600	600	DCI	110	150	13.886	0	13.886	0.79	3.94	1630.33	33.75	55	10	6.57	
P-115	40+713	WP-75	3394	GI	100	50	0.883		0.883	0.45	33.86	1989.03	6.72	54	10	9.98	KW - PT
P-265	122+989	123+322	333	DCI	110	150	10.768		10.768	0.61	1.37	1094.30	29.36	54	10	4.10	
P-264	122+555	122+989	434	DCI	110	150	10.768		10.768	0.61	1.78	1095.55	29.47	53	10	4.10	
P-12	7+000	7+050	50	PVC	130	250	1.631	34.343	35.974	0.73	0.12	2232.15	44.36	53	10	2.34	
P-267	123+693	123+749	56	DCI	110	150	10.768		10.768	0.61	0.23	1096.34	25.56	52	10	4.10	
P-13	7+050	7+150	100	PVC	130	250	1.631	34.343	35.974	0.73	0.23	2233.52	42.76	52	10	2.34	
P-10	6+515	7+000	485	PVC	130	250	2.028	34.343	36.371	0.74	1.16	2234.18	42.45	51	10	2.39	
P-25	J1'	J1	133	GI	100	100	2.337		2.337	0.30	0.28	2195,40	35.86	50	10	2.08	
P-143	56+300	58+550	2250	DCI	110	150	13.886	0	13.886	0.79	14.77	1635.66	35.32	50	10	6.57	
P-245	115+494	115+526	32	DCI	110	200		8.884	8.884	0.28	0.02	1395,60	2.72	49	10	0.71	BPT-2
P-268	123+749	123+887	138	DCI	110	150	10.768		10.768	0.61	0.57	1100.48	20.86	48	10	4.10	
P-266	123+322	123+693	371	DCI	110	150	10.768		10.768	0.61	1.52	1100.58	21.55	48	10	4.10	
P-244	115+266	115+494	228	DCI	110	200		8.884	8.884	0.28	0.16	1397.99	0.35	47	10	0.71	
P-144	58+550	58+600	50	DCI	110	150	13.886	0	13.886	0.79	0.33	1639.54	31.11	46	10	6.57	
P-248	116+085	116+351	266	DCI	110	100		8.884	8.884	1.13	5.49	1350.74	27.85	45	10	20.62	
P-23	13+350	J1'	3960	GI	100	100	3.112		3.112	0.40	13.99	2201.11	30.43	45	10	3.53	
P-255	119+528	WP-38	569	GI	100	40	0.536		0.536	0.43	6.67	1105.85	29.17	43	10	11.72	M-PT
P-24	J1'	WP5	60	GI	100	50	0.775		0.775	0.39	0.47	2203.37	27.70	42	10	7.84	GT-PT
P-21	11+943	13+050	1107	DCI	110	200		34.343	34.343	1.09	9.59	2245.64	6.99	39	16	8.66	TD-R2
P-246	115+526	115+954	428	DCI	110	100		8.884	8.884	1.13	8.83	1356.60	30.17	39	10	20.62	
P-71	7+875	9+350	1475	PVC	130	150		4.993	4.993	0.28	1.07	2207.55	2.55	38	10	0.73	
P-76	12+750	11+850	900	DCI	110	150	6.329		6.329	0.36	1.38	2221.59	35.97	38	25	1.53	
P-26	J1	WP68	1380	GI	100	80	1.358		1.358	0.27	3.11	2209,07	19.08	37	10	2.25	AE-PT
P-77	11+850	WP22	20	GI	100	50	1.099		1.099	0.56	0.30	2226,77	30.49	32	10	14.96	EJ-PT
P-253	118+261	119+357	1096	DCI	110	150	12.414		12.414	0.70	5.85	1116.48	26.12	32	10	5.34	
P-9	5+883	6+515	632	PVC	130	250	2.028	34.343	36.371	0.74	1.51	2253.75	24.04	31	10	2.39	
P-11	7+000	WP_2	980	GI	100	40	0.397		0.397	0.32	6.59	2253.75	16.29	31	10	6.73	A-PT
P-247	115+954	116+085	131	DCI	110	100		8.884	8.884	1.13	2.70	1364.68	19.39	31	10	20.62	
P-254	119+357	119+528	171	DCI	110	150	12.414		12.414	0.70	0.91	1118.15	23.54	31	10	5.34	
P-15	7+950	7+975	25	PVC	130	250	1.631	34.343	35.974	0.73	0.06	2260.95	13.40	24	10	2.34	
P-14	7+150	7+950	800	PVC	130	250	1.631	34.343	35.974	0.73	1.87	2262.06	12.34	23	10	2.34	
P-75	12+750	WP23	29	GI	100	50	1.1		1.1	0.56	0.43	2236.23	22.28	23	10	14.98	EJ-PT
P-74	12+875	12+750	125	DCI	110	150	7.429		7.429	0.42	0.26	2236.43	22.51	23	25	2.06	
P-16	7+975	WP_3	67	GI	100	50	0.833		0.833	0.42	0.60	2264.19	9.56	21	10	8.96	GG-PT
P-4	3+250	4+050	800	PVC	130	300	2.896	34.343	37.239	0.53	0.82	2264.35	16.84	21	10	1.03	
P-5	4+050	4+250	200	PVC	130	300	2.896	34.343	37.239	0.53	0.21	2265.05	15.93	20	10	1.03	
P-7	4+800	5+883	1083	PVC	130	300	2.896	34.343	37.239	0.53	1.12	2268.19	11.11	17	10	1.03	
P-170	74+950	76+200	1250	DCI	110	200	6.159	8.884	15.043	0.48	2.35	1427.92	14.00	17	10	1.88	
P-8	5+883	WP_1	490	GI	100	50	0.868		0.868	0.44	4.74	2270.53	4.03	15	10	9.67	G-PT
P-252	118+261	WP-37	58	GI	100	40	0.911		0.911	0.72	1.81	1136.53	10.11	12	10	31.26	K-PT
P-2	1+900	2+075	175	PVC	130	300	2.896	34.343	37.239	0.53	0.18	2274.24	8.98	11	10	1.03	
P-1	0+299	1+900	1601	PVC	130	300	2.896	34.343	37.239	0.53	1.65	2274.29	9.11	11	10	1.03	
P-251	118+124	118+261	137	DCI	110	200	13.325		13.325	0.42	0.21	1138.66	9.79	10	10	1.50	
P-89	28+525	WP14	230	GI	100	65	2.1		2.1	0.63	3.18	2034.94	4.91	8	10	13.85	BJ-PT
P-6	4+250	4+800	550	PVC	130	300	2.896	34.343	37.239	0.53	0.57	2277.00	3.42	8	10	1.03	
P-3	2+075	3+250	1175	PVC	130	300	2.896	34.343	37.239	0.53	1.21	2279.18	2.83	6	10	1.03	
P-88	28+175	28+525	350	PVC	130	250	14.17	9.615	23.785	0.48	0.38	2040.83	2.21	3	10	1.09	
P-169	74+800	74+950	150	DCI	110	200	7.021	8.884	15.905	0.51	0.31	1443.13	1.14	1	10	2.09	

STATIC HEAD VARIATION IN THE SYSTEM

Maximum=321m and Minimum=1,5m)

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-55	23+375	WP12	3922	GI	40	321	25	DH-PT
P-214	101+173	101+993	820	DCI	200	269	25	
P-213	101+054	101+173	119	DCI	200	269	25	
P-208	97+501	98+663	1162	DCI	200	267	25	
P-209	98+663	98+753	90	DCI	200	265	25	
P-212	100+853	101+054	201	DCI	200	262	25	
P-210	98+753	100+723	1970	DCI	200	262	25	
P-216	102+338	102+452	114	DCI	200	259	25	
P-207	97+160	97+501	341	DCI	200	259	25	
P-211	100+723	100+853	130	DCI	200	257	25	
P-215	101+993	102+338	345	DCI	200	256	25	
P-217	102+452	102+639	187	DCI	200	253	25	
P-204	95+719	96+387	668	DCI	200	251	25	
P-219	102+684	102+723	39	DCI	200	248	25	
P-322	2+879	6+014	3135	GI	65	248	25	
P-323	6+014	WP52	150	GI	50	248	25	AT-PT
P-205	96+387	96+442	55	DCI	200	247	25	
P-250	116+594	118+124	1530	DCI	100	247	25	
P-320	0+000	2+879	2879	GI	80	246	25	
P-321	2+879	WP51	165	GI	40	246	25	DR-PT
P-206	96+442	97+160	718	DCI	200	245	25	
P-87	9+576	WP74	2654	GI	40	245	25	GL-PT
P-218	102+639	102+684	45	DCI	200	245	25	
P-327	148+869	WP54	178	GI	40	244	25	JN-PT
P-326	146+598	148+869	2271	GI	80	243	25	
P-324	144+240	146+598	2358	DCI	100	242	25	
P-203	95+681	95+719	38	DCI	200	242	25	
P-167	69+100	74+800	5700	DCI	100	241	25	DG-R6
P-325	146+598	WP53	416	GI	40	241	25	QO-PT
P-165	67+800	68+872	1072	DCI	100	239	25	
P-319	143+785	144+240	455	DCI	100	238	25	
P-192	90+050	91+000	950	DCI	200	237	25	
P-102	35+950	36+475	525	DCI	250	236	25	
P-166	68+872	69+100	228	DCI	100	236	25	
P-56	23+375	23+875	500	DCI	300	235	25	
P-317	142+918	143+785	867	DCI	100	235	25	
P-328	148+869	150+913	2044	GI	80	234	25	
P-33	17+325	17+525	200	DCI	400	234	25	
P-202	95+176	95+681	505	DCI	200	233	25	
P-58	25+325	25+700	375	DCI	200	232	25	
P-163	66+575	67+800	1225	DCI	150	232	25	
P-191	90+025	90+050	25	DCI	200	230	25	
P-286	131+724	WP-43	150	GI	40	230	25	I-PT
P-61	26+550	27+085	535	DCI	150	230	25	
P-190	90+000	90+025	25	DCI	200	230	25	

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-164	67+800	WP29	75	GI	65	229	25	MW-PT
P-318	143+785	WP50	462	GI	40	229	25	W-PT
P-221	103+986	104+542	556	DCI	200	229	25	
P-193	91+000	91+325	325	DCI	200	229	25	
P-162	65+400	66+575	1175	DCI	150	229	25	OL-PT-EX
P-287	131+724	132+493	769	DCI	150	227	25	
P-285	131+543	131+724	181	DCI	150	227	25	
P-316	141+632	142+918	1286	DCI	100	227	25	
P-289	132+572	132+662	90	DCI	150	226	25	
P-329	150+913	WP55	100	GI	50	226	25	BM-PT
P-34	17+525	18+100	575	DCI	400	226	25	
P-284	131+186	131+543	357	DCI	150	225	25	
P-31	14+825	17+325	2500	DCI	400	225	25	
P-194	91+325	WP33	89	GI	25	225	25	BARG-PT
P-160	63+790	65+400	1610	DCI	150	225	25	
P-288	132+493	132+572	79	DCI	150	224	25	
P-32	17+325	WP7	1494	GI	40	223	25	K-PT
P-201	93+798	95+176	1378	DCI	200	223	25	
P-185	87+811	88+088	277	DCI	200	223	25	
P-60	26+550	WP13	295	GI	40	222	25	SQ-PT
P-161	65+400	WP28	327	GI	65	222	25	E-PT
P-290	132+662	133+206	544	DCI	150	221	25	
P-184	87+730	87+811	81	DCI	200	221	25	
P-53	22+575	23+035	460	DCI	300	220	25	
P-222	104+542	105+845	1303	DCI	200	220	25	
P-220	102+723	103+986	1263	DCI	200	220	25	
P-62	27+085	27+835	750	DCI	150	220	25	
P-57	23+875	25+325	1450	DCI	300	218	25	
P-101	34+400	35+950	1550	DCI	250	217	25	
P-297	133+206	134+137	931	DCI	150	216	25	
P-59	25+700	26+550	850	DCI	200	216	25	
P-186	88+088	88+200	112	DCI	200	215	25	
P-49	21+875	22+350	475	DCI	300	215	20	
P-299	134+137	135+681	1544	DCI	150	214	25	
P-200	93+409	93+798	389	DCI	200	212	25	
P-139	53+900	55+825	1925	DCI	100	212	20	
P-283	130+200	131+186	986	DCI	150	212	25	
P-188	88+500	89+450	950	DCI	200	212	25	
P-189	89+450	90+000	550	DCI	200	212	25	
P-158	62+800	63+734	934	DCI	150	212	25	
P-159	63+734	63+790	56	DCI	150	212	25	
P-181	84+750	87+575	2825	DCI	200	211	20	
P-298	134+137	WP-47	335	GI	40	211	25	BDh-PT
P-48	21+525	21+875	350	DCI	300	210	20	
P-187	88+200	88+500	300	DCI	200	210	25	
P-306	138+380	138+782	402	DCI	100	210	20	
P-183	87+600	87+730	130	DCI	200	210	20	
P-54	23+035	23+375	345	DCI	300	209	25	
P-291	0+000	1+381	1381	GI	50	209	25	
P-103	36+475	36+800	325	DCI	250	209	25	
P-35	18+100	WP8	344	GI	40	209	25	C-PT

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-168	74+800	WP30	2550	GI	65	209	25	BDG-PT
P-36	18+000	19+250	1250	DCI	400	209	25	
P-182	87+575	87+600	25	DCI	200	208	20	
P-292	1+381	WP44	268	GI	40	208	25	DH-PT
P-315	140+972	141+632	660	DCI	100	208	20	
P-307	138+782	138+900	118	DCI	100	206	20	
P-63	27+835	28+175	340	DCI	150	202	25	
P-308	138+900	138+940	40	DCI	100	202	20	
P-313	139+900	140+972	1072	DCI	100	201	20	
P-296	7+209	WP46	70	GI	40	201	25	G.T. School
P-141	56+175	WPextg	46	GI	40	200	25	DA-PT
P-304	137+826	138+380	554	DCI	100	200	20	
P-198	93+334	WP34	140	GI	40	199	20	BRTD-PT
P-295	6+714	7+209	495	GI	40	199	20	
P-195	91+325	92+185	860	DCI	200	198	25	
P-51	22+450	22+575	125	DCI	300	197	20	
P-140	55+825	56+175	350	DCI	100	197	20	
P-314	140+972	WP49	422	GI	40	197	20	B-PT
P-199	93+334	93+409	75	DCI	200	196	25	
P-52	22+575	WP9	73	GI	40	196	20	DT-PT
P-305	138+380	WP-48	145	GI	40	195	20	L-PT
P-293	1+381	6+714	5333	GI	50	195	20	
P-142	56+175	56+300	125	DCI	100	195	20	DA-R5
P-303	137+426	137+826	400	DCI	100	194	20	
P-50	22+350	22+450	100	DCI	300	194	20	
P-300	135+681	136+665	984	DCI	100	194	20	
P-294	6+714	WP45	150	GI	40	193	20	Qac-PT
P-301	136+665	137+149	484	DCI	100	192	20	
P-196	92+185	93+145	960	DCI	200	191	25	
P-104	36+800	37+000	200	DCI	250	190	20	
P-38	20+075	WP10	1523	GI	40	190	20	D-PT
P-280	129+797	130+200	403	DCI	150	190	20	
P-311	139+267	139+869	602	DCI	100	190	20	
P-309	138+940	139+198	258	DCI	100	190	20	
P-312	139+869	139+900	31	DCI	100	190	20	
P-157	62+780	62+800	20	DCI	150	189	20	
P-156	62+300	62+780	480	DCI	150	188	20	
P-281	0+000	5+333	5333	GI	40	187	20	
P-282	5+333	WP42	200	GI	40	186	20	SB-PT
P-310	139+198	139+267	69	DCI	100	186	20	
P-106	37+375	37+515	140	DCI	250	185	20	
P-180	82+500	84+750	2250	DCI	200	184	20	
P-197	93+145	93+334	189	DCI	200	182	25	
P-123	43+450	44+300	850	DCI	200	181	20	
P-224	107+259	107+313	54	DCI	200	180	16	
P-44	20+380	20+725	345	DCI	300	180	20	
P-302	137+149	137+426	277	DCI	100	179	20	
P-46	20+975	21+225	250	DCI	300	179	20	
P-226	107+748	107+890	142	DCI	200	179	16	
P-223	105+845	107+259	1414	DCI	200	178	16	

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-47	21+225	21+525	300	DCI	300	177	20	
P-278	128+192	128+712	520	DCI	150	177	20	
P-279	128+712	129+797	1085	DCI	150	176	20	
P-276	126+307	128+063	1756	DCI	150	175	20	
P-124	44+300	45+250	950	DCI	200	175	20	
P-225	107+313	107+748	435	DCI	200	175	16	
P-155	62+280	62+300	20	DCI	150	172	20	
P-277	128+063	128+192	129	DCI	150	172	20	
P-125	45+250	45+500	250	DCI	200	172	20	GD-PT-EX
P-100	34+150	34+400	250	DCI	250	172	25	
P-154	61+960	62+280	320	DCI	150	171	20	
P-45	20+725	20+975	250	DCI	300	170	20	
P-105	37+000	37+375	375	DCI	250	169	20	
P-18	10+550	11+250	700	DCI	250	168	16	
P-138	53+600	53+900	300	DCI	100	167	16	
P-84	7+576	WP72	169	GI	50	164	20	QD-PT
P-134	50+725	52+500	1775	PVC	150	163	16	BPT-1
P-39	20+075	20+380	305	DCI	400	162	20	
P-83	4+839	7+576	2737	GI	80	161	20	
P-86	9+576	WP73	100	GI	40	160	16	DhB-PT
P-17	7+975	10+550	2575	DCI	250	159	16	
P-153	61+920	61+960	40	DCI	150	157	16	
P-227	107+890	109+416	1526	DCI	200	157	16	
P-37	19+250	20+075	825	DCI	400	156	20	
P-152	61+400	61+920	520	DCI	150	156	16	
P-97	33+600	33+965	365	PVC	250	154	16	
P-85	7+576	9+576	2000	GI	65	154	16	
P-117	41+000	41+468	468	PVC	200	153	16	
P-98	33+965	34+150	185	PVC	250	149	16	
P-121	42+750	43+450	700	PVC	200	149	16	
P-122	43+450	WP18	25	GI	40	148	16	GJ-PT
P-40	20+380	WP11	2679	GI	100	147	16	AR-PT
P-107	37+515	37+775	260	DCI	250	145	20	
P-119	41+800	42+125	325	PVC	200	144	16	
P-232	110+257	110+420	163	DCI	200	137	16	
P-99	34+150	WP16	482	GI	40	137	16	I-PT
P-29	14+000	14+825	825	DCI	400	135	16	
P-20	11+943	WP_4	326	GI	40	134	16	BTD-PT
P-30	14+825	WP6	20	GI	40	134	16	GM-PT
P-236	111+050	113+180	2130	DCI	200	134	16	
P-233	110+420	110+583	163	DCI	200	133	16	
P-228	109+416	109+884	468	DCI	200	132	16	
P-230	109+986	110+087	101	DCI	200	129	16	
P-238	113+671	WP36	167	GI	40	128	16	HJ-PT

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-237	113+180	113+671	491	DCI	200	126	16	
P-235	110+835	111+050	215	DCI	200	126	16	
P-28	13+350	14+000	650	DCI	400	123	16	
P-239	113+671	114+334	663	DCI	200	123	16	
P-229	109+884	109+986	102	DCI	200	122	16	
P-242	114+432	114+488	56	DCI	200	122	16	
P-41	WP_{11}	J2	2658	GI	80	122	16	
P-118	41+468	41+800	332	PVC	200	122	16	
P-151	61+000	61+400	400	DCI	150	122	16	
P-96	31+750	33+600	1850	PVC	250	121	16	
P-177	80+700	81+900	1200	DCI	200	121	20	
P-108	37+775	38+700	925	DCI	250	119	20	
P-240	114+334	114+386	52	DCI	200	119	16	
P-19	11+250	11+943	693	DCI	250	118	16	
P-243	114+488	115+266	778	DCI	200	118	16	
P-241	114+386	114+432	46	DCI	200	118	16	
P-126	45+500	47+400	1900	DCI	200	117	16	
P-178	81+900	82+500	600	DCI	200	116	20	
P-231	110+087	110+257	170	DCI	200	115	16	
P-120	42+125	42+750	625	PVC	200	114	16	
P-67	J3	WP70	1733	GI	40	113	16	KR-PT
P-274	126+112	126+307	195	DCI	150	112	20	
P-275	126+307	WP-41	45	GI	40	111	16	S-PT
P-234	110+583	110+835	252	DCI	200	109	16	
P-136	52+800	53+400	600	DCI	100	109	16	
P-137	53+400	53+600	200	DCI	100	108	16	
P-132	49+973	50+725	752	PVC	150	107	16	
P-273	124+892	126+112	1220	DCI	150	107	10	
P-64	0+00	4+150	4150	PVC	200	106	10	
P-82	4+839	WP71	182	GI	40	106	16	X-PT
P-65	4+150	J3	20	GI	100	105	16	
P-66	J3	WP19	6	GI	65	105	16	DG-PT
P-133	50+725	WP26	94	GI	40	103	16	KA-PT
P-131	49+334	49+973	639	PVC	150	101	16	
P-129	48+117	48+766	649	PVC	150	100	10	
P-81	1+668	4+839	3171	GI	80	100	10	
P-109	38+700	39+100	400	DCI	250	99	20	
P-112	39+600	39+800	200	PVC	200	98	10	
P-80	17+668	WP21	94.2	GI	50	97	10	TL-PT
P-175	80+224	80+600	376	DCI	200	96	10	
P-110	39+100	WP17	164	GI	40	94	10	BR-PT
P-173	80+150	WP31	190	GI	40	93	10	F-PT
P-272	124+711	124+892	181	DCI	150	93	10	
P-42	J2	WP66	767	GI	50	93	10	O-PT
P-174	80+150	80+224	74	DCI	200	93	10	
P-128	48+117	WP25	70	GI	40	92	10	BB-PT
P-176	80+600	80+700	100	DCI	200	92	10	
P-111	39+100	39+600	500	PVC	200	90	10	
P-150	60+825	61+000	175	DCI	150	90	10	
P-127	47+400	48+117	717	DCI	200	90	16	

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-94	31+450	31+750	300	PVC	250	89	10	
P-179	82+500	WP32	2349	GI	65	88	10	GQ-PT
P-95	31+750	WP15	50	GI	40	86	10	U-PT
P-92	30+550	31+015	465	PVC	250	86	10	
P-116	40+713	41+000	287	PVC	200	85	10	
P-27	J1	WP69	2576	GI	50	84	10	AM-PT
P-68	4+150	7+000	2850	PVC	150	82	10	
P-249	116+351	116+594	243	DCI	100	82	10	
P-135	52+500	52+800	300	DCI	100	82	16	
P-72	9+350	10+870	1520	PVC	150	81	10	
P-79	0+000	1+668	1668	GI	80	81	10	
P-271	124+156	124+711	555	DCI	150	81	10	
P-93	31+015	31+450	435	PVC	250	79	10	
P-147	59+600	60+700	1100	DCI	150	78	10	
P-114	40+500	40+713	213	PVC	200	77	10	
P-257	120+176	121+745	1569	DCI	150	77	10	
P-149	60+700	60+825	125	DCI	150	76	10	
P-43	J2	WP67	2407	GI	65	72	10	M-PT
P-259	0+000	0+379	379	GI	50	72	10	
P-260	0+379	2+339	1960	GI	50	72	10	
P-261	2+339	WP39	109	GI	40	72	10	GB-PT
P-148	60+700	WP27	399	GI	50	71	10	WL-PT
P-172	78+737	80+150	1413	DCI	200	68	10	
P-73	10+870	11+025	155	PVC	150	67	10	
P-269	123+887	124+049	162	DCI	150	65	10	
P-78	11+850	11+325	525	DCI	150	65	25	
P-258	121+745	122+555	810	DCI	150	64	10	
P-22	13+050	13+350	300	DCI	400	64	16	
P-130	48+766	49+334	568	PVC	150	64	10	KB-PT-EX
P-145	58+600	59+000	400	DCI	150	64	10	
P-70	7+875	WP20	141	GI	40	63	10	FM-PT
P-262	0+379	2+139	1760	GI	50	63	10	
P-263	2+139	WP40	50	GI	40	63	10	NQ-T
P-90	28+525	30+335	1810	PVC	250	63	10	
P-270	124+049	124+156	107	DCI	150	63	10	
P-91	30+335	30+550	215	PVC	250	61	10	
P-171	76+200	78+737	2537	DCI	200	60	10	
P-256	119+528	120+176	648	DCI	150	60	10	
P-69	7+000	7+875	875	PVC	150	59	10	
P-113	39+800	40+500	700	PVC	200	57	10	
P-146	59+000	59+600	600	DCI	150	55	10	
P-115	40+713	WP-75	3394	GI	50	54	10	KW - PT
P-265	122+989	123+322	333	DCI	150	54	10	
P-264	122+555	122+989	434	DCI	150	53	10	
P-12	7+000	7+050	50	PVC	250	53	10	
P-267	123+693	123+749	56	DCI	150	52	10	
P-13	7+050	7+150	100	PVC	250	52	10	
P-10	6+515	7+000	485	PVC	250	51	10	
P-25	J1'	J1	133	GI	100	50	10	

Element	From CH	To CH	L(m)	material	D(mm)	h_{st}(m)	PN	Remark
P-143	56+300	58+550	2250	DCI	150	50	10	
P-245	115+494	115+526	32	DCI	200	49	10	BPT-2
P-268	123+749	123+887	138	DCI	150	48	10	
P-266	123+322	123+693	371	DCI	150	48	10	
P-244	115+266	115+494	228	DCI	200	47	10	
P-144	58+550	58+600	50	DCI	150	46	10	
P-248	116+085	116+351	266	DCI	100	45	10	
P-23	13+350	J1'	3960	GI	100	45	10	
P-255	119+528	WP-38	569	GI	40	43	10	M-PT
P-24	J1'	WP5	60	GI	50	42	10	GT-PT
P-21	11+943	13+050	1107	DCI	200	39	16	TD-R2
P-246	115+526	115+954	428	DCI	100	39	10	
P-71	7+875	9+350	1475	PVC	150	38	10	
P-76	12+750	11+850	900	DCI	150	38	25	
P-26	J1	WP68	1380	GI	80	37	10	AE-PT
P-77	11+850	WP22	20	GI	50	32	10	EJ-PT
P-253	118+261	119+357	1096	DCI	150	32	10	
P-9	5+883	6+515	632	PVC	250	31	10	
P-11	7+000	WP_2	980	GI	40	31	10	A-PT
P-247	115+954	116+085	131	DCI	100	31	10	
P-254	119+357	119+528	171	DCI	150	31	10	
P-15	7+950	7+975	25	PVC	250	24	10	
P-14	7+150	7+950	800	PVC	250	23	10	
P-75	12+750	WP23	29	GI	50	23	10	EJ-PT
P-74	12+875	12+750	125	DCI	150	23	25	
P-16	7+975	WP_3	67	GI	50	21	10	GG-PT
P-4	3+250	4+050	800	PVC	300	21	10	
P-5	4+050	4+250	200	PVC	300	20	10	
P-7	4+800	5+883	1083	PVC	300	17	10	
P-170	74+950	76+200	1250	DCI	200	17	10	
P-8	5+883	WP_1	490	GI	50	15	10	G-PT
P-252	118+261	WP-37	58	GI	40	12	10	K-PT
P-2	1+900	2+075	175	PVC	300	11	10	
P-1	0+299	1+900	1601	PVC	300	11	10	
P-251	118+124	118+261	137	DCI	200	10	10	
P-89	28+525	WP14	230	GI	65	8	10	BJ-PT
P-6	4+250	4+800	550	PVC	300	8	10	
P-3	2+075	3+250	1175	PVC	300	6	10	
P-88	28+175	28+525	350	PVC	250	3	10	
P-169	74+800	74+950	150	DCI	200	1	10	

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