

Puntland State of Somalia

Water, Energy and Natural Resources Corporation (PSAWEN)

Garowe Water Agency (NUWACO Co.)

Garowe Water Supply

Master Plan Study

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Summary

The present population in Garowe is estimated to be 150.000, in 2040, the end of the project period, should be $\pm$ 323.500.

Garowe has a desert climate, the mean rainfall is 133 mm/year spread over ten months with one period from July to September with greater frequency, the highest mean temperature is 33,9 °C, in these climatic conditions the UN Organizations estimated the minimum demand for survival to be 15 lit/pro-capita/day (lit/pc/d), a supply of 25 lit/pc/d is a reasonable target to achieve a low standard life, and 35 lit/pc/day for a mean standard life in developing countries.

According to the above figures the water demand (WD) will be:

- a) in 2015: with the WD of 15 lit/p.c.= 2.250 cum/day; with the WD of 35 lit/p.c.= 5.250 cum/day
- b) in 2025: with the WD of 15 lit/p.c.= 3.068 cum/day; with the WD of 35 lit/p.c.= 7.159 cum/day
- c) in 2040: with the WD of 15 lit/p.c.= 4.854 cum/day; with the WD of 35 lit/p.c.= 11.325 cum/day

The water supply service of Garowe is managed by NUWACO Co. this is a private shareholder company; at present in 2015 NUWACO supplies averagely 1784,73 cum/day, equivalent to $\sim$ 11,9 litres/pro capita/day.

A minor contribution is given by the shallow hand dug wells (HDW.s) which produce heavily polluted water, the HDW.s are mainly utilised for watering the cattle and other non domestic uses, but the poorest people use these waters also for cooking and drinking; this practice, however, creates diffuse water borne diseases.

The sole surface water sources are lined and unlined ponds of small capacities (*berkats and balleys*), their contribution to the urban water supply is insignificant, large structures to give a real provision are not present and are not available in the Garowe area.

All groundwater resources are brackish with the Water Electrical Conductivity (WEC) ranging between 3.640 to 8.000 μ S/cm, the equivalent Total Dissolved Solids (TDS) ranging from 2.730 to 6.000 mg/lit.

The water produced is bitter, absolutely disagreeable, and generally has laxative effects caused by the high content of sulphate of magnesia. These waters contain also heavy metals and fluorides exceeding the recommended limits for human consumption.

The hydrogeological study implemented on behalf of the present service contract identifies two promising zones to support the near future water demand in Salaxley Village and in the Jabagale Areas; other zones with lower chances have been identified along the Salaxley River at the junction with the Garowe River and in the Garowe Urban Area. For the moment NUWACO prefers developing the resources in the urban area because of the shortage of water and the lack of financial resources to implement large infrastructures. The water resources to secure the supply to the town beyond the project period will be searched in the Nugal Valley, which is the largest catchment basin of northern Somalia.

The distribution network is well designed for a town of about 60.000 inhabitants, the fitting to the present and future needs will be implemented with the construction of two reservoirs and the installation of new pipelines.

In Garowe wealthy people are used to drinking bottled water, the price of one bottle of 1,5 litre is 0,80 US\$, therefore the cost for each litre is 0,53 US\$, while middle class and poor people drink the water supplied by the piped system.

To overcome this difficult situation we propose the implementation of a system which will produce fresh water at affordable prices and manageable by NUWACO personnel. The proposed technology is the nano-filtration which removes between 85÷90 per cent of sulphates, carbonates and heavy metals; practically it will produce a water with total dissolved solids equal to 600 ÷ 800 mg/lit. The drinkable water will be distributed through dedicated public fountains (*kiosks*), no private connections are forecast.

At the beginning the production cost of drinkable water will be 2,66 US\$/cum, in the future when the technicians take confidence, this figure will be considerably reduced. In the computation of production cost all factors have been considered including amortization and mismanagement risks.

The selling units in Garowe is the jerry can by 20 litres capacity, the production cost for one jerry can of drinkable water will be 5,3 cents of US\$, for each litre it will be 2,7 mill. of US\$.

The executive designs of the main infrastructures concerning the distribution system are already available, the development of water sources outside the urban area, the extension of primary and secondary networks and the drinkable water system are at the level of preliminary design.

The investment costs are listed below:

Actions		Costs (US\$)
1	Execution of two exploratory/productive boreholes in the urban area (<i>ex Lot 1</i>)	137.279,09
2	Construction of a 1.000 cum Ground Reservoir (<i>ex Lot 2</i>)	580.146,01
3	Construction of a 500 cum Ground Reservoir (<i>ex Lot 3</i>)	373.795,40
4	Construction of pipeline connecting 1.000 to 500 cum Reservoirs (<i>ex Lot 4</i>)	404.675,78
5	Construction of pipelines connecting 1.000 and 500 cum Reservoirs to the Distribution systems (<i>ex Lot 5</i>)	909.915,01
6	Construction of pipelines connecting the old boreholes to the 1.000 cum Reservoir (<i>ex Lot 6</i>)	390.119,80
7	Construction of pipelines connecting the new boreholes to the 1.000 cum Reservoir (<i>ex Lot 7</i>)	461.173,87
8	Construction and equipment of n° 3 pump stations on new boreholes (<i>ex Lot 8</i>)	154.630,96
9	Construction of the desalinization plant	450.775,00
10	Construction of the distribution network of drinkable water (<i>elevated reservoir + pipelines + public fountains</i>)	291.402,98
11	Drilling and completion of n° 3 productive boreholes in Salaxley Village Area	251.079,00
12	Drilling and completion of n° 4 productive boreholes in Jabagale Area	360.299,00
13	Construction and equipment of n°3 pump stations in Salaxley Village Well Field	168.375,50
14	Construction and equipment of n°4 pump stations in Jabagale Well Field	207.810,50
15	Trunkline connecting Salaxley Village Well Field to 1.000 cum Reservoir	1.504.269,58
16	Trunkline connecting Jabagale Well Field to 1.000 cum Reservoir	3.217.519,46
17	Primary and Secondary Distribution Network, <i>extension to secure the service</i>	727.756,14
18	Hydrogeological and geophysical studies with boring tests in Nugal valley	235.819,50
Total investment (US \$)		10.826.842,57

For more details in the formation of cost estimations see also Tab.7 and Annex 2.

1 - Background

During the 19th century, Garowe and much of north-eastern Somalia were an integral part of the Majeerteen Sultanate.

The city would later be incorporated into Italian Somaliland during the colonial period.

Following independence, Garowe was made a district center of Bossasso. The city would subsequently be reassigned in the early 1970s as the regional capital of an area consisting of Las Anod and Eyl. Straddling the Nugal Valley, this new administrative division would be named Nugal.

Following the outbreak of the civil war in 1991, a home-grown constitutional conference was held in Garowe in 1998 over a period of three months. Attended by the political elite of the area, traditional elders (*Issims*), members of the business community, intellectuals and other civil society representatives, the autonomous Puntland State of Somalia was subsequently officially established so as to deliver services to the population, offer security, facilitate trade, and interact with both domestic and international partners.

The water supply of Garowe is managed by the Nugal Water Company (NUWACO Co.), this is a private share company established on 25th July 2006. The scope of the association is to provide safe drinking water and expand water services to all Garowe town population through operating, managing and connecting the water supply system to the customers of the capital city Garowe.

2 - The water supply

2.1 - Population dynamics

The population living in Garowe is estimated to be 150.000 people including the internal displaced people (IDP) and refugees mainly living in two settlements located in the eastern outskirts of the town.

This figure has been released by the Administration.

The population of Garowe grew abnormally during the war in southern Somalia, presently the inflow of IDP or refugee people has practically come to an end.

The natural growth in the Somali Region is estimated to be 3,2 %/year, the forecasts of population growth on this basis are reported in Tab.2.

With the peace that lies ahead in the near future many IDP or refugees will probably return to their homeland, accordingly the growth may be expected less than estimated in Tab.2.

In the Nugal Region live more than 100.000 nomads spread over an area of about 80.000 sqkm, these people are attracted by Garowe as State capital, but as it is not possible to foresee this flow towards urbanization, the figures listed in Tab.2 will be adopted in the present study.

2.2 - The water demand

Garowe has a hot desert climate (*Köppen climate classification BWh*). As such, the weather is generally hot, sunny and dry; the monthly and yearly averages are listed below.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	30 (86)	29 (84)	30 (86)	31 (88)	34 (93)	39 (102)	41 (106)	41 (106)	38 (100)	33 (91)	31 (88)	30 (86)	33.9 (93)
Average low °C (°F)	24 (75)	24 (75)	24 (75)	26 (79)	27 (81)	30 (86)	32 (90)	31 (88)	29 (84)	25 (77)	25 (77)	23 (73)	26.7 (80)
Average rainfall mm (inches)	15 (0.59)	0 (0)	1 (0.04)	15 (0.59)	5 (0.2)	5 (0.2)	33 (1.3)	20 (0.79)	15 (0.59)	14 (0.55)	5 (0.2)	5 (0.2)	133 (5.25)

Tab. 1 – Major figures of Garowe climate

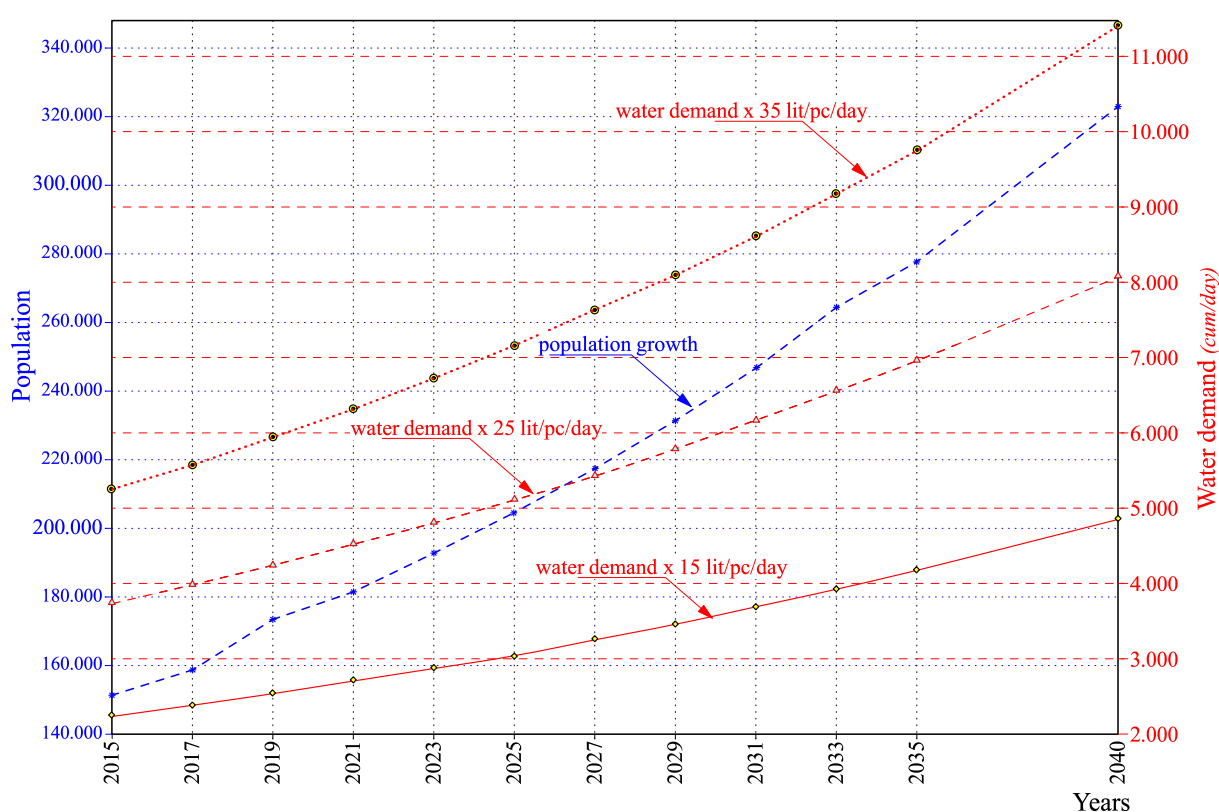
The mean rainfall in Garowe is 133 mm/year distributed over a period of ten months, see Tab.1 here above. The rainfall varies in a wide range, the recorded driest year is 1966 with only 6,0 mm.

In general it is assumed that only the part of rainfalls over 10 mm seeps underground, whereby due to the low amount of rainfall and the wide distribution only very few events recharge the aquifers.

In these environmental conditions the minimum demand for survival is estimated to be 15 lit/pro-capita/day (lit/pc/day), a supply of 25 lit/pc/d is a reasonable target to reach a low level normal life. UN Organizations recommend minimum 35 lit/pc/day for low life standard in hot urban areas.

In Tab. 2 are reported the forecasts of water demand in the project period, computed in the hypothesis to supply 15, 25 and 35 litres pro capita day (*l/pc/d*), see below.

		Years											
		2015	2017	2019	2021	2023	2025	2027	2029	2031	2033	2035	2040
Population	n°	150.000	159.600	169.814	180.683	192.246	204.550	217.641	231.570	246.391	262.160	278.938	323.568
Water demand x (15 lit/pc/ day)	cum/day	2.250	2.394	2.547	2.710	2.884	3.068	3.265	3.474	3.696	3.932	4.184	4.854
	lit/sec	26,0	27,7	29,5	31,4	33,4	35,5	37,8	40,2	42,8	45,5	48,4	56,2
Water demand x (25 lit/pc/ day)	cum/day	3.750	3.990	4.245	4.517	4.806	5.114	5.441	5.789	6.160	6.554	6.973	8.089
	lit/sec	43,4	46,2	49,1	52,3	55,6	59,2	63,0	67,0	71,3	75,9	80,7	93,6
Water demand x (35 lit/pc/ day)	cum/day	5.250	5.586	5.944	6.324	6.729	7.159	7.617	8.105	8.624	9.176	9.763	11.325
	lit/sec	60,8	64,7	68,8	73,2	77,9	82,9	88,2	93,8	99,8	106,2	113,0	131,1



Tab. 2 – Population and water demand forecasts

2.3 - Present water demand satisfaction

The inhabited centre of Garowe was established because of the presence of shallow groundwater, which has been traditionally tapped with shallow hand dug wells (HDW.s).

The aquifer tapped by the HDW.s is perched type, its base is a thick horizon of clay; the aquifer is recharged by the flow of the Garowe River and the small tributaries.

The HDW.s produce more or less saline water, the quality decreases straying from the river course.

At the beginning of the seventies there were about 15 HDW.s in total, in the following years there was a proliferation and some HDW.s dried; today with the urban spread the wastes pollute the HDW.s that are still productive, this is evident from the smell of the waters abstracted.

These HDW.s are mainly privately owned, but some are public, all HDW.s are mainly utilised for not potable uses, but extremely poor people use these waters also for cooking and drinking.

Other traditional water sources are the small ponds, *balleys*, and the buried cisterns, *berkats*, which collect surface runoff of small catchments. These water sources produce very low salinity fresh water, but are not perennial water sources because they are too small, in the case of balleys the seepage and evaporation restrict the water availability to two max three months after the rainy season, in the case of berkats the water is available for a maximum of four months. Another reason of unreliable water sources is the fortuity of rainfalls.

Balleys are mainly utilised for watering the cattle, berkats are utilised for domestic uses, in any case these waters in urban environment are highly polluted and are not suitable for human consumption.

Data or statistics on the utilisation of traditional water sources do not exist.

In 1976 the research of deep aquifers started with a borehole 160 m deep drilled by WDA, in 1979 and 1981 GTZ drilled two other productive boreholes.

Today in Garowe there are seven boreholes dedicated to the water supply: five are productive and connected to the system, two have been completed recently and are waiting to be connected to the system.

The water produced by deep boreholes is generally saline, the Water Electrical Conductivity (WEC) ranges between 3.640 to 8.000 $\mu\text{S}/\text{cm}$.

The Total Dissolved Solids (TDS) in each groundwater type has a constant relation to WEC, in the case of Garowe ground waters the constant is about 0,75, it means that the TDS varies from 2.730 to 6.000 mg/lit.

The water produced is bitter, absolutely disagreeable, and creates laxative effects. This effect is caused by the high content of sulphate of magnesia, see two water analysis in Annex 1.

In the Garowe Area surface there are no water sources suitable for urban water supply and it is not possible to plan because of low and random rainfalls, due to the flat morphology and the nature of the bedrock made by limestone and gypsum which are affected by sink-holes due to karst.

In synthesis: the sole secure water source is the deep groundwater, traditional water sources can be utilised only for non domestic uses, besides their provision is and will be marginal.

The NUWACO boreholes are not equipped with reliable water meters; accordingly the real production is unknown.

The only data concerning the water production are those of the water sold in the months of January, February and March 2015, see Tab. 3 hereinafter.

According to these data, households + kiosks, it results that the mean daily supply is ~ 1.784,73 cum, equivalent to ~ 11,9 litres/pro capita/day.

This is about three litres below the minimum survival level of water supply in desert climate urban areas.

		Total production Jan.-March 2015 (cum)	Percent (%)	2015				
Category	Rate (1cum/US\$)			January	February	March	Total	
HOUSEHOLDS	1,3	157.352	94,80%	Billed	65.104	69.763	68.771	203.638
				Cashed	57.988	65.897	65.971	189.856
INDUSTRY	0,85	3.440	2,07%	Billed	1.033	866	1.025	2.924
				Cashed	476	567	478	1.521
KIOSKS	0,65	3.274	1,97%	Billed	573	777	783	2.133
				Cashed	682	304	702	1.688
MOSQUES (MASJID)	0,5	1.408	0,85%	Billed	204	254	244	702
				Cashed	207	65	188	460
PUBLIC PLACES	0,2	478	0,29%	Billed	22	23	50	95
				Cashed	0	0	30	30
STAND PIPE	1,25	0	0	Billed	0	0	0	0
				Cashed	0	0	0	0
TOTAL (Jan÷March 2015) cum		165.952	Totals (US\$)	Billed	66.976	71.877	71.078	209.930
				Cashed	59.363	66.84	67.369	193.572

Tab. 3 – Water sold and cash-flow

(relative to the months of January, February and March 2015)

Looking at the water analysis, see Annex 1, we note the presence of some heavy metals like: boron, mercury, nickel, lead and fluorides exceeding the limits recommended by World Health Organization (WHO). The human body up to the levels recommended by the WHO has the capacity to expel these compounds; above these limits the heavy metals are stored and create several diseases, some of which are seriously dangerous.

We could not find any figures or statistics concerning diseases related to heavy metals, probably local physicians are not sensitized to these problems.

Many sources informed us about the presence of water borne diseases, like: hepatitis “A”, salmonellosis, dysentery, cholera, etc., in our opinion these are caused by the polluted waters abstracted from shallow hand dug wells.

Another problem related to the water distributed by NUWACO Co. is the excess of sulphate of magnesia, which produces diarrheal effects due to the laxative properties of this compound, in general the people of Garowe are adapted to these waters, but in cases of weakness they manifest their unpleasant aspect.

2.4 - Water supply targets

In Tab. 2 we analyse the water demand on the basis of three hypothetical levels of supply: 15, 25 and 35 lit/pc/day.

The target of the Administration is to achieve the supply of 35 lit/pc/day as soon as possible.

This is a minimalist target, it is our opinion that tomorrow water will be available and if the present selling price is maintained the water demand will increase largely above that limit.

The groundwater exploited up to now is a regional aquifer, which will secure further development.

The hydrogeological study carried out on behalf of the present service contract identifies three locations outside the urban area favourable to further developments. Water with EC $\pm$ 3.700 μ S/cm, equivalent to $\sim$ 2.750 mg/lit is expected in these locations.

This is the best water available in the Garowe area, but within the limits fixed by the WHO it is not potable, to obtain potable water a water treatment will be mandatory; this subject will be developed in Chapter 6.3, see below.

2.5 - The cost of water

In Tab. 3 at the column 2, see above, are listed the prices applied by NUWACO Co., these are in line with the rates applied in the Horn of Africa.

3 - The water service

Garowe is subdivided into 8 administrative districts: 1st August, Hantiwadaag, Hilaac, Hodan, Horseed, Israac, Waaberi and Wadajir.

The distribution system consists of about 52 km of pipelines spread over 618 hectares of urban area, plus some 6,2 km to connect two IDP.s camps located in the eastern outskirts of the town.

The distribution network is spread relatively evenly, therefore the service could be made in a uniform manner; the major problem is the scarcity of resources.

Recently NUWACO drilled three new boreholes, two have not been connected to the system up to now, when both are connected, the water available will increase considerably.

3.1 - Water policy and management

The Puntland Water Policy includes:

- i - the Government of Puntland should be responsible for overall planning, coordination and regulation of the water sector.
- ii - the survey and design of water supply developments in Puntland should be done with the approval of the Government. This will include environmental impact assessment where required.
- iii - the Government should also approve water abstraction / supply, management and waste water discharge arrangements.
- iv - the Government should examine, develop and promote appropriate means to ensure that the water is of adequate quality for human and livestock consumption.
- v - the Government of Puntland should facilitate and encourage investment and activity in the sector by recognised members of the private sector, civil society organisations and international agencies. Foreign investment enjoys the protection of law in Puntland. Puntland State Law n° 3 (1999).
- vi - the Government of Puntland should develop plans and programmes concerning the monitoring and evaluation of the water sector so as to fulfil the role of water sector regulator in the interests of protecting the public.
- vii - the Government of Puntland should develop plans and programmes for human resource development as well as for effective capacity building in sector research, analysis and training.
- viii - the Government of Puntland should aim to ensure that water engineering and management works are undertaken at a suitable standard. The role may include certification of suppliers and works as well as requirements for inspection and on site supervision as appropriate.
- ix - the Government should directly or indirectly study and analyse how the operational and financial sustainability of water supplies in Puntland can be achieved. This may include the promotion and testing of particular approaches and the development and adoption of state guidelines.
- x - the Government should establish the legal power to act as supplier of last resort. This means that the Government can take over the management of the supply on behalf of the public in cases where supply operators clearly fail to provide an adequate service. The government should then ensure that adequate supply is restored and returned to an effective operator as quickly as possible.

- xi - the Government should establish powers to close water supplies which are an immediate hazard to human health, and should aim to facilitate an alternative supply as appropriate. Where appropriate, Government should facilitate dispute settlement in line with the principles of the water policy.
- xii - because of the present constraints of available financial and human resources in the water sector the Government may delegate its powers and responsibilities to appropriate public and private sector bodies. Delegation should be enabled and protected using approved agreements based on the law.
- xiii - the Government of Puntland should enable its citizens to satisfy their fundamental needs for water and provide protection against discrimination and exploitation and equality of rights; special consideration should be given to women, children and the poor as established in this policy.

After the civil war, water committees were formed and their roles limited to facilitate and monitor projects funded by INGO.s and United Nations Agencies. The Presidential Decree number 20 dated 14th December 2000 created the Puntland State Agency for Water, Energy and Natural Resources (PSAWEN) as evolution of the former Water Committee. PSAWEN became fully operational in 2001 as the sole institution responsible for water, energy and minerals and was established as an autonomous agency under the Office of the President. PSAWEN has five offices headed by water coordinators in Bari, Karkar, Nugal, Mudug, and Las Caanood regions, with plans to open more offices in Sanaag and Boohoodle regions. In each regional office there are two divisions - one for sales with fee collectors, and the other for regional coordination. The current mandate of the agency is to report on the water situation, plan locations for service delivery in collaboration with implementing partners, and put into operation projects funded by partners through private companies or local NGOs. The water agency participated in the drafting of the Water Supply Policy Green Paper (JNA, 2006).

His Excellency the President of Puntland State with his letter MW/DPS/253/2014 dated 31 March 2014 addressed to all Ministries, the United Nation Organizations, and all INGO,s operating in Puntland State, confirmed the role of PSAWEN here above described.

The water supply of Garowe is managed by the Nugal Water Company (NUWACO Co.), this is a private share company established in 25th July 2006. The scope of the association is to provide safe drinking water and expand water services to all Garowe town population through operating, managing and connecting the water supply system to the customers of the capital city Garowe. NUWACO Co. operates as concessionaire of State owned infrastructures under the close supervision of PSAWEN.

3.2 - Status of the infrastructures

The existing water infrastructures have been topographically surveyed in the period from 26 June 2013 to 20 June 2014 by Eng. Ahmed Mohammud Adan assisted by NUWACO personnel, the survey has been carried out with a LEICA differential GPS 1230 Type, (*composed by one static + one rover instruments*), which gives a centimetric accuracy in differential; global

coordinates have been converted into local UTM of Zone 39 using a special software prepared by LEICA.

The infrastructures have been mapped on high-resolution satellite imageries at the scale 1:2.000 (49 plates + 1 adjoining sheet in format A3) and at the scale 1:5.000 in two sheets in format A1Super.

The contour lines with 10,0 m interval, obtained from satellite imageries in radar frequency have been drafted on the maps and calibrated with the topographical survey data.

3.2.1 - The productive boreholes

The boreholes n° 1, 5 and 7, see Tab. 4 below, pump into the Elevated Reservoir, the boreholes n° 4 and 9 pump into the distribution system directly.

The borehole n° 1 was drilled in the seventies by GTZ, it is lined with Ø 8" steel casing, see Photo 4.

All the other productive boreholes used by the NUWACO were drilled after 2000 and are lined with PVC casings, see Photos 5 and 6.

Borehole	Easting	Northing	Elevation (m asl)	Depth (m bgl)	Yield (lit/sec)	Production (cum/day)	Pumping time (hours/day)	SWL (m bgl)	WEC (µS/cm)
Bh - 1	221.449,02	928.888,40	475,97	135	7,5	648	24	-	4450
Bh - 2	221.248,65	928.695,93	472,05	224	0,8	abandoned	0	-	-
Bh - 3	221.626,44	928.648,09	472,76	250	0	abandoned	0	-	-
Bh - 4	221.506,51	929.848,56	468,69	285	4,2	?	?	80	5350
Bh - 5	220.894,88	928.892,43	474,41	100	6,4	322	14	-	3.800
Bh - 6	220.649,07	928.709,30	475,81	100	0	abandoned	0	-	-
Bh - 7	221.115,03	929.349,41	472,23	105	12,5	1080	24	19,76	4360
Bh - 8 (Duurey)	220.106,15	930.929,34	476,31	302	4,2	0	0	23,35	5600
Bh - 9 (Washington)	225.386,90	931.333,75	453,32	84	12,2	-	-	8,35	4600
Bh - 10 (North-East)	226.081,92	932.663,62	449,69	282	7	0	0	4,2	4300

Tab. 4 – The main figures of boreholes managed by NUWACO Co.

The main problem of boreholes in Garowe is the aggressiveness of the water against metallic parts that cause the corrosion of steel casings, pumps and rising mains, and the laying of thick crusts where the water evaporates.

The only solution is to use plastics piping for well lining and the rising main and pumps fully made with stainless steel AISI 316.

Another problem is related to the power cables of submersible pumps, in general in Puntland fully insulated ones with PVC are utilised. Under pressure PVC is not absolutely waterproof and after a period underwater some humidity penetrates into the cable causing the short circuit or leakages between the copper cables thus provoking the burning of electrical engines. The only solution is to adopt cables cased with polyurethane, or similar waterproof plastic compound.

3.2.2 - The distribution network

The existing plant is fully made with U-PVC NP10 pipes with push-fit joints; this was installed in 2002 by UNICEF and afterwards expanded by NUWACO.

The structure of network can be defined “loop type”, except for some sub-urban areas where it is branched type. The design of the network of Garowe can be defined excellent in relation to the available water resources.

In the opinion of NUWACO technicians the leakages are insignificant, and when they happen they are quick at repairing them.

These good results are the outcome of good installation and the operation at low pressure.

Originally the network was fed by a 650 cum reservoir, 13 meters elevated, recently borehole n° 4 and n° 9 have been connected directly. In pressurized water supply this insertion would create dysfunctions, mainly water hammering, but in the situation of Garowe these problems do not arise because of the extremely low pressure of the system and due to the fact that all private connections are equipped with private reservoirs.

The Elevated Reservoir was implemented with 1,20 x 1,20 m prefabricated panels made with galvanised steel for a total volume of 692 cum, on a frame made “H” sections constructed with galvanised steel, see Photo 7.

The Garowe groundwater is too aggressive and rusts also the galvanised steel, especially in the connections between the panels. This fact produces diffuse leakage, which is noticed by an observer standing in the surrounding of the reservoir because of a diffuse spray wetting the face.

The crisis of the Elevated Reservoir is not impending, but it is not possible to considerate this as a long-term infrastructure.

3.2.3 - Recently implemented infrastructures

Recently NUWACO Co. implemented:

- the drilling and completion to productive of boreholes n° 4, 8, 9 and 10,
- the construction, equipment of pumping stations of boreholes n° 4 and 9 and the direct connection to the distribution system.

3.2.4 - The infrastructures foreseen by Immediate Measures Project

The urgent problem to be solved as soon as possible is the quantity of water available to the town in a manner to cover the demand at the minimal level and stop the use of HDW.s.

By the recent experiences carried out by NUWACO Co. this problem can be solved with some other boreholes drilled in the surroundings of the town, the only problem is related to the heterogeneities of the aquifer caused by the karst, whereby in a very narrow space one borehole can be highly productive while the neighbouring dry.

With boreholes in the surroundings of the town it will be possible to pump directly into the distribution system and alleviate the water demand.

When the water is more abundant and some pressure is present in the system this management method will create water hammering which will damage the existing piping system.

Currently the submersible pumps are managed with direct on-off or with star-triangle switchers, modifying the starting system with the introduction of inverters with pressure switches installed in the distribution system the flow will be regularized and the water hammering effects will be negligible.

Clearly the solution to drill productive boreholes in the urban area can be considered a solution to solve the present emergency but it is not valid for future developments.

3.2.5 - Abuses

The abuses on the water service can be defined by relating the production to the billed amounts.

The production is not recorded; consequently it is not possible to judge the level of abuses analytically.

In the opinion of the technicians charged with the management of the network the abuses are very few and represent a small percentage of water billed.

3.3 - The rendered service

As stated before the network is functional to the present water availability, the only real problem is the scarcity of resources to distribute.

3.4 - The hand dug wells

Garowe is not served by a piped sewerage system, consequently waste waters of sewers seep into the ground and pollute the perched aquifer tapped by the shallow hand dug wells (HDW).

As soon as possible all public HDW.s, must be sealed to prevent their use.

3.5 - Trucking service

In past times the trucking services was loaded from the stand pipe close to the borehole n° 1, today this facility is no more available, the truckers fetch water from boreholes owned by private citizens.

Some truckers fetch water from balleys and berkats outside the town, these waters are mainly utilised for the last rinse after the washing of clothes.

No statistics on this service exist.

4 - The sources to satisfy the water demand

As stated before the sole water source available in Garowe area is the confined groundwater present in limestone and chalky series.

Our aim is to create a water resource scenario valid also after the project period.

4.1 - Ground waters

According to the data of existing boreholes we deduce the presence of two deep aquifers one with static water level (SWL) at ~ 445 m asl and one with SWL at ~ 385 m asl.

The difference of 60 metres between the two aquifers implies the presence of a continuous aquiclude. This fact is not evident in the recorded drilling logs and also the geophysical study does not make evidence of this fact.

4.1.1 - Geological appraisal of Nugal Basin

The town of Garowe is located in the western side of the so-called “Nugal Basin”. This is a tectonic trench opened during the Mesozoic Era, oriented North-South and filled with a series of sandstones and limestone, in the Mid-Cretaceous the trench was replenished and the sedimentation kept on with the same sedimentation style as the surrounding territories.

The "Nugal Basin" is the most promising oil bearing structure of the whole Somalia, whereby since the fifties the Garowe area has been studied; the findings are not accessible because they constitute the industrial secrets of oil companies, the main information we got is:

- the thickness of sedimentary series is estimated to be over 3.500 m,
- the town of Garowe is located near the Western border of the trench, the long-line, direct fault, passes just at the western outskirts of the town,
- the Nugal Valley has been subjected to subsidence also after the Cretaceous because of the compaction of thick sediments,
- the Nugal Valley is the largest catchment of the whole northern Somalia, about 81.500 sqkm wide, drains up to the mountain range between Sheick and Ceerigabo where rainfall is over 500 mm/year,
- the river course is no more evident because the change of climate, after the "Bovide Period" around 20.000 years B.C., reduced the rainfall and the river flow now stops in the flat plains southward of Beer,
- surely several buried river beds, with coarse material, occur about two kilometres eastward of Jigabale,
- Jigabale area is located in the western side of the Nugal Valley, this is a depressed zone due to the erosion produced by a minor tributary after the rainy period, here the water table is at the shallow depth, in our opinion this aquifer is connected to the main aquifer of the valley.

In DWG 1 is reported an abstract of the geological map of the Garowe Area, produced by AGIP Mineraria for oil prospecting.

4.1.2 - Sedimentary rocks

The stratigraphic sequence of rocks outcropping in the Garowe Area can be synthetized as follows:

PRE-RIFTING SEDIMENTARY COVER OF THE GULF OF ADEN	Recent Alluvium (Q)	River deposits: <i>silty and clayey sands</i>	Plio-Pleistocene
	Karkar Formation (Ek)	<u>Upper Member</u> : <i>nodular limestone with abundant large foraminifera</i>	Middle and Upper Eocene
		<u>Lower Member</u> : <i>nodular , fossiliferous limestone interbedded with shales with microcrystalline gypsum and anhydrite</i>	Middle Eocene
	Taleh Evaporites (Et)	<u>Upper Member</u> : <i>anydrites and gypsum, dolomitic limestone with chert nodules and rare large foraminifera</i>	Lower Eocene
		<u>Lower Member</u> : <i>dolomitic limestone, greenish shales and marls, locally with large foraminifera and molluscs</i>	
	Auradu Limestone (Ea)	<i>Well bedded limestone interbedded with thin marly layers and nodular micritic limestone and dolomitic limestone. Outcrops only in the El Tebet Area</i>	Lower Eocene ÷ Paleocene

Tab. 5 – The geological units outcropping in Garowe Area

The three sedimentary rocks outcropping in the area are characterized by the absence of primary hydraulic conductivity (*or permeability*). They are affected by karst that generates secondary permeability with a system of interconnected gaping fractures.

The dissolution of rocks and the relative enlargement of fractures, the karst, is created by the rainy waters enriched by carbon dioxide, CO₂, below the aerate zone of the rock the opening size is greatly reduced.

The specific storage of these rocks is generally low, only a few per cent of the total masses.

The presence of water is confined in the open fractures, the productive capacity of a borehole depends on the size and the number of fractures tapped.

The optimization of drilling sites is preliminarily carried out with the study of aerial photos in stereoscopic vision, which, with the maps of surface geology, give the trend of the fracture systems and the location of the most favourable areas.

In Africa only the rifting drives the tectonic; with the creation of trenches (*grabens*) separated by tectonic highs (*horsts*). So the blocks of crystalline basement are tilted with two systems of fractures: the major ones are parallel to the trenches, *direct faults*, these are sub-vertical with immersion toward the horsts. The secondary systems are generated by the breakage of blocks, these have perpendicular orientation to direct faults and are vertical. In general the fractures associated to the secondary systems are open, namely water bearing.

In isotropic rocks, like granites, sandstones, etc., the crossings of two systems produce a halo of minor fractures which in part are open, the diameter of the halo depends on the magnitude of relative movements. In layered limestone and gipsy rocks the earth movements develop on single or very few surfaces mainly filled with clayey deposits and only a few are open, which then foster the karst.

The precise siting of open vertical or sub-vertical fractures is practically impossible because the morphology and the planes of fractures are irregular, and no geophysical method has sufficient preciseness to detect these situations with the accuracy necessary to the drilling diameter.

In conclusion in limestone and gipsy rocks it is not possible to secure in advance the productive capacity of planned boreholes.

4.1.3 - Recent sediments

The Garowe Area at the end of the Eocene emerges from the sea and no more sedimentation has taken place.

Riverine sediments were deposited in the Plio-Pleistocene period that are mainly made by silty to clayey sands, the drilling records of boreholes indicate the presence of indurated clayey horizons thick up to about ten metres.

The recent sediments contain perched aquifers that are rather thin; these aquifers have some interests in rural water supply, but not certainly for urban necessities.

4.2 - Groundwater potentialities

The bedrock practically has a horizontal arrangement, some shifting occurs in correspondence with the rifting, but the sloping is very low.

The aquifers held in the bedrock have regional character, so it makes no sense to relate the recharge to local rainfall.

The presence of karst facilitates horizontal exchanges, whereby the productive boreholes recall water also from a distance.

In conclusion the water resources in the bedrock will satisfy the demand also for the distant future.

5 - Future water sources

After taking everything into account we come to the conclusion that the future water supply should be secured by the aquifers held in the bedrock without limits of resources as previously said. The problems to be solved will be:

- i - find fragile zones where the chances to intercept open fractures will be statistically high,
- ii - find zones where the water is less saline.

5.1 - The prospective water sources

The hydrogeological study carried out on behalf of the present service contract tries to solve the questions of points “i” and “ii” here above, and locate some promising areas in the surroundings of the town, see DWG 2, the findings are summarised in the following chapters.

5.1.1 - Jabagale Area

This area is surely the most promising place in the surroundings, especially the one marked 1.1, see DWG 2.

In this area the water table is close to the surface, and the water is the least saline in the whole territory, see Tab 1 of the Hydrogeological Report.

Probably the favourable situation for the implementation of productive boreholes is connected to the presence of a fault involving the bedrock but not evident on the surface, see Annex “B” cross-sections “jiba-1” and “jiba-4” of the Hydrogeological Report.

The Jabagale Area is an oasis with intensive plantations, in this area there are n° 4 productive boreholes and several hand dug wells, probably some sociological problems will arise with farmers, but in our opinion the aquifer has the capacities to sustain the abstractions both for the farmers and the town needs, because this is a regional aquifer.

5.1.2 - Salaxley River

In the lower course of the Salaxley River, at the connection to the Garowe River, two areas that appear to be promising according to the surface geology have been studied, see DWG 2.

The Area 2.1 by the geophysical survey appear to have more chances, see Tab. in DWG 2, instead the Area 2.2 has low hopes of success.

5.1.3 - Salaxley Village Area

The surface geology suggests that the surroundings of the Salaxley Village is a promising area for drilling productive boreholes, see DWG 2.

The geophysical survey found, in this area, some stratigraphic anomalies that probably entail the presence of some accident in the bedrock not evident on the surface, see Annex “B” cross-sections “salax-1” and “salax-3” of the Hydrogeological Report.

5.1.4 - Garowe Urban Area

The Garowe Urban Area has been studied following a precise request expressed by NUWACO Co.

In the studied areas 4.1 and 4.2 the geophysical survey found important heterogeneities in the bedrock, which suggest the presence of faults in the bedrock.

5.2 - Productive capacity and quality of water sources

Gipsy and limestone rocks do not have primary permeability, whereby the productive capacities of boreholes depend on the size of crossed fractures. Unluckily it is not possible to locate the large fractures that secure high yields. Besides, the fractures in stratified sedimentary rocks develop on irregular planes and also in case of detection on the surface it is not possible to follow them in the depth.

Up to the sixties dynamite was used to stimulate the productivity of boreholes drilled in gipsy and limestone rocks, today this practice is no longer possible due to the security constraints associated to the use of explosives.

Today the only possible chance to drill high yielding boreholes in gipsy and limestone rocks is to execute high detailed geophysical surveys in the areas supposed to be favourable in order to increase the statistic possibilities.

In the Garowe Area all aquifers are brackish, the best quality water has been found in Jibagale, but also in this case the water electrical conductivity (WEC) is 3.640 $\mu\text{S}/\text{cm}$ equivalent

to about 2.730 mg/lit of total dissolved solids (TDS). So even this type of water is absolutely far from potable water standards.

5.3 - Drilling programme

The impending actions to be implemented are oriented to satisfy the water demand of Garowe, i.e. to secure the water source in terms of sufficient quantity and best quality.

The Hydrogeological Study identifies the Jabagale and the Salaxley Village areas as the most promising aquifer zones, therefore we recommend starting with additional geophysical studies in these areas to detail the local hydrogeological assets and execute exploratory boreholes, designed in case of success to be completed as productive for urban needs.

In the drilling programme we recommend extending the study area Eastward of Jabagale, in the Nugal Depression, to evaluate the potentiality of this area to satisfy the water demand beyond the project period.

5.3.1 - Detailed geophysical surveys

Additional geophysical studies must be carried out to optimize the drilling sites in the localities recommended to secure the water supply to the town. The geophysical studies will be composed by:

- vertical electrical soundings (VES)
- electrical profiling (*tomography*).

The geophysical studies can be extended to a depth of about 100 metres below the forecast bottoms of boreholes listed in the table of DWG 2.

Probably the electrical profiling will encounter some difficulties in penetrating deeper into salted terrains, so the survey can be fully executed with VES.

The origin and the end of each electric line must be topographically surveyed.

The interpretations of VES must be drafted like stratigraphic columns and correlated as fence diagram on a map at the scale 1:2.000 with contours spaced by 1,0 m, the contours obtained by satellite imageries will be calibrated with the topographical survey.

Only for budgeting purposes we suppose 80 VES with $AB/2 = 600$ m, or 30 profiles, each one 500 m long.

5.3.2 - Bore testing

Geophysical surveys give relative data that can be calibrated with the information from boring tests to obtain the real hydrogeological asset.

The data required for the boring tests are:

- a - the stratigraphic reconstruction of crossed terrains,
- b - the quality of water found,
- c - the productive capacities of crossed aquifers.

The supposed maximum depths of investigation are listed in the Table annexed to DWG 2.

The suitable technology to give the above information is the dry cable tool with temporary lining installed in progress; this technology is the cheapest but it takes a very long time.

An alternative is drilling with roller bit and clean with pressurized air, the open hole will be supported with temporary casings drive-in with SIMCAS methodology, this is an unknown technology in Puntland.

The minimum diameter of open holes must be 10" (254 mm).

The other technologies applied in Puntland do not give the requested answers.

The productive capacity of an aquifer will be tested with the execution of the following activities:

- installation of a temporary steel screen in the sector to be tested,
- airlifting so as to obtain clear water,
- execution of step drawdown tests, minimum n° 4 steps x 2 hours each.

Also in this case for budgeting needs we suppose it will be necessary to provide:

- i - n° 6 boreholes dug with a dry cable tool, or rotary air drilling, for a total of some 1.100 metres,
- ii - n° 30 water samplings for testing,
- iii - n° 12 aquifer testing

Drilling activities must be directed and attended by a skilled hydro-geologist.

The basic chemical analysis: temperature, electrical conductivity, sulphates, carbonates, fluorides, mercury, nickel and lead must be executed on site with pocket instrumentation or photogrammetric kits.

5.3.3 - Boreholes completion and development to productive

It will be possible to plan the completion of test bores to productive boreholes with the aquifer testing and the data of expeditious analysis.

The characteristics of productive boreholes must be:

- lining with screens and blind pipes made with U-PVC or other approved plastic material,
- the minimum diameter of the sector where the pump will be installed must be no less than 8" (OD 225 x 10,8 mm),
- the gravel pack made with selected 4/6 siliceous gravel, the installation method can be approved by the work supervisor,
- development with airlifting, the procedure and the duration will be prescribed by the work supervisor,
- testing:

- step drawdown test = n° 4 step tests for 4 hours each,
- long term drawdown test = after the full recovery 72 hours pumping at $\frac{3}{4}$ of critical yield defined with the step drawdown test,
- recovery = up to 95 % of drawdown.

5.4 - Implementation of pipeline systems toward the Storage tank

In absence of certain data we speculate the future water resources will be produced in a very small part by the Salaxley Village Area and mostly by the Jabagale Area, the whole resource will be pumped to the planned 1.000 cum Reservoir, see below.

For a preliminary quantification of the investment we forecast the two pipeline systems having the following major figures:

- Salaxley Village ÷ 1000 cum Reservoir
 - well field production = 30 lit/sec
 - elevation at the origin = 516 m asl,
 - elevation at the reservoir inlet = 495 m asl
 - total length of pipeline = 15.300 m
 - pipe = OD 250 mm U-PVC NP 16
 - J = 2,33 m/km
 - total pumping head $\Delta H = 86,7$ m
- Jabagale Area ÷ 1000 cum Reservoir
 - well field production = 70 lit/sec
 - elevation at the origin = 397 m asl,
 - elevation at the reservoir inlet = 495 m asl
 - total length of pipeline = 19.400 m
 - pipe = OD 315 mm U-PVC NP 16
 - J = 3,63 m/km
 - total pumping head $\Delta H = 188,5$ m

The estimated water demand at the end of the project period will be 11.325 cum/day, equivalent to 131,1 lit/sec, the supposed productive capacities of Salaxley and Jibagale jointly will be 100 lit/sec, the difference = 31,1 lit sec will be provided by the boreholes already present in the urban area.

5.4.1 - Optimization of pipeline routes and design of pumping systems

On DWG 2 are drafted the Salaxley and Jibagale production areas, flowlines collecting water from the boreholes and the trunk-lines toward the town are not drafted because there are not any locations of origin at the moment.

Probably the pipelines from Salaxley toward the 1.000 cum Reservoir will be installed in uncultivated and deserted terrains, the soil profile along the pipeline route will be at constant descent.

The pipeline from Jibagale to the 1.000 cum Reservoir will probably be installed mainly along the expressway Bossasso-Garowe.

The quantification of works at prefeasibility study level will be made in accordance with the above hypothesis.

When the productive boreholes are drilled, completed to productive and tested, the consultant must carry out the following activities:

- i - land acquisition study, to be carried out in collaboration with the Administration;
- ii - optimization of pipeline routes with topographical and geotechnical surveys;
- iii - design of pumping systems, an attentive analysis must be placed to the convenience of pumping toward the town by means of submersible pumps or by means of surge tanks and booster stations;
- iv - design of pipeline.

6 - The distribution network

The existing distribution network was designed for a town of about 60.000 inhabitants and for a water availability of about 1.000 cum/day. In these water supply conditions the rendered service was excellent.

Today the inhabitants have doubled with a prevision in 2040 of more than 300.000, with the distribution of approximately 11.000 cum/day, see Tab. 2 at pag. 3, it is clear that the network must be modified and adapted to the future service.

There are several indicators on the future asset of the town, but not sufficiently sure to support a design.

Garowe is characterised by single storey houses with courtyards, it is a low density agglomerate, whereby a great part of the inhabitant growth will be absorbed by the present housed area and the rest will be spread around the town.

6.1 - The operative philosophy of the future distribution system

Considering that the only water available in Garowe Area is brackish, not potable, with unpleasant taste and bearer of diseases, and the fact that our service contract foresees a twenty-five years' planning, it is mandatory to look for a viable solution.

Presently wealthy people use bottled water for drinking, at the costs of 16.000 So.Sh (0,8 US\$) for a bottle of the capacity of 1,5 litre, these costs are not accessible to middle and low level classes.

In rich countries like Saudi Arabia and the Gulf States the shortage of potable water has been overcome with desalinization plants where the production costs are fully subsidized by the Governments.

The situation in Puntland is completely different; here it is not conceivable to distribute desalted water for all needs.

On the basis of the above considerations our proposal is:

- a) expand the water service with raw water to supply the town needs, with private connections and some kiosks selling water at the prices listed in Tab. 3, pag. 5,
- b) install a small desalinization plant feeding a minor distribution network, which will distribute drinkable water through public fountains (*kiosks*) fully dedicated to this scope, without any private connection. The selling cost of drinkable water will be sufficient to cover the production costs; the policy of not subsidised costs will prevent improper uses and dissipation.

6.2 - Raw water distribution network

The town stretches on a surface of 618 hectares and is splayed in between 470 m asl, in the quarter at the extreme South-West of the town, to 458 m asl, in the quarter at the extreme North-East near the river, see also Chapter 3.2.2.

Presently the town is supplied by a prefabricated steel reservoir having the capacity of about 650 cum installed on a frame 13 metres high above ground level; the ground level at the reservoir is 474,18, it follows the static water level, when the reservoir is empty, it is 487,2 and when it is full 492,0.

This reservoir accuses diffuse leakages, for this reason the construction of a new one is recommended.

The new reservoir is planned to be “ground type” made with reinforced concrete, and must have the capacity of 1.000 cum, the location has been selected jointly with the Administration in front of the New Jail where the soil has the elevation of about 489 m asl, the bottom of the reservoir will be at 490,85 m. asl and the maximum water level will be at 494,85 m asl.

The planned 1.000 cum Reservoir, or Northern Reservoir, will be able to feed the South-Western quarters only with the installation of very large pipes, whereby a subsidiary reservoir of 500 cum has been designed on a hill in the southern outskirt of the town where the soil has the elevation of about 479,0 m asl; the maximum water level is planned to be at 483,0 m asl, whereby the subsidiary reservoir, or Southern Reservoir, will be fed by the Northern Reservoir by gravity.

Presently the water is not sufficient to cover the demand, probably tomorrow it will exceed the demand, the present study faces the problem of finding a distribution scheme valid for both states, the solution adopted can be summarized as follows:

The working assumptions for the study analysis are:

- each house is connected to the water system, the number of houses present in the urban area have been physically counted on behalf of the present study, the counting has been carried out on high definition satellite imageries, the houses are clearly distinguishable;
- each water connection has a private ground reservoir of the capacity of about 2,5 cum;
- each water connection corresponds to a house of 6,5 inhabitants;
- in case of a weekly filling of domestic reservoirs the water available will be ~ 54,95 lit/pro capita/ day.

To satisfy the above assumptions the town has been divided into 15 zones, see DWG 3, where:

- n° 12 will be connected to the 1.000 cum Reservoir, those marked “NA” ÷ “NL”;
- n° 3 will be connected to the 500 cum Reservoir, those marked “SA” ÷ “SC”;

6.2.1 - Mathematical modelling of water distribution system

The mathematical modelling of a water distribution system has been developed with the following softwares:

- EPANET 2.0, released by Environmental Protection Agency (EPA) of U.S.A.
- DXF to EPA free download modified for our needs,
- Vectorworks 2012 by Nemetschek Inc., Columbia (U.S.A.)

6.2.2 - The scheme of the proposed network

The major features of the proposed network will be:

- the existing network in Garowe is mainly looped type, only in the suburbs it is branched type,
- the best performances are given by looped networks, accordingly the proposed distribution network will maintain or improve the existing characteristics,
- the proposed plan will adapt the distribution system to higher levels of service with the introduction of new pipes which can be implemented little by little depending on the needs.

6.2.3 - Reservoirs

The construction of 1.000 cum Reservoir will take several months to be completed, for this reason it is mandatory to build the new one with the old one still in service.

6.2.3.a - Ground reservoir

The new 1.000 cum Reservoir should be built not far from the border of a terrace, where the bedrock is sub-outcropping.

The reservoir has been designed fully made with reinforced concrete, this building technology has been selected because suitable rocks for masonry are not available in the area.

The inlet and outlet piping systems have been designed stainless steel made.

After the commissioning of 1.000 cum Reservoir, the 650 cum Reservoir must be dismantled, several parts will be turned out because they are rusty and no more serviceable for further uses, but some parts will be useful, that is why an accurate selection of materials is recommended.

For more details see the executive design of Lot 4, already prepared and submitted to PSAWEN.

6.2.3.b - Satellite reservoir

In Garowe all users have their own reservoir, for this reason the peaks of water demand are very smoothed and the Southern Reservoir has been designed by the capacity of 500 cum only.

The 500 cum Reservoir has been designed at the elevation of 479,0 m asl, i.e. 11,85 m below the new 1.000 cum reservoir.

The 500 cum Reservoir has been designed on a low and smooth hill, where, it is supposed, the bedrock is sub-outcropping.

The foundation has been designed placed on fresh bedrock; this solution will avoid the stability problems characteristic of large buildings erected on high grounds.

Also in this case the whole reservoir will be made with reinforced concrete.

The inlet and outlet piping systems will be made with stainless steel.

For more details see the executive design of Lot 3, already prepared.

6.2.4 - Trunk-line connecting the 1.000 cum Reservoir to 500 cum Reservoir

The trunk-line connecting 1.000 cum Reservoir to 500 cum Reservoir will be a fully dedicated pipeline to this purpose, no connections to the distribution system will be installed, otherwise it will not operate as planned, see below.

6.2.4.a - Dimensioning and design

The trunk-line connecting the 1.000 cum Reservoir to the 500 cum Reservoir has been dimensioned for a flow rate of 30 lit/sec, this will secure 2.765 cum/day to the Southern Reservoir, and this flow rate will secure the service even after the project period.

The pipeline in the first 1.275,8 m, from 1.000 cum Reservoir, will be installed in a land presently free of urbanization works, the route has been plotted on the basis of the probable urban expansion, but this is not sure, some changes in the pipeline route may be necessary at the time of construction.

From the progr. 1.275,8 to the progr. 1.458,4 the pipeline will cross the Garowe River; in this section the riverbed is slightly incised and apparently it is not in erosive status. In these conditions it will be sufficient to increase the burial depth so as to have the extrados of 2,0 metres, to secure the pipe against the risks of flush-floods.

From the progr. 1.458,4 to the progr. 3.839,6 the pipeline will be buried along the roads of the town, to minimise traffic problems, the pipeline has been designed along wider roads.

From the progr. 3.839,6 to the progr. 3.938,46 the pipeline will cross a small tributary of the Garowe River; in this section the riverbed is slightly incised and apparently it is not in erosive status. In these conditions it will be sufficient to increase the burial depth so as to have the extrados of 1,5 metres, to secure the pipe against the risks of flush-floods.

From the progr. 3.938,46 to 4.199,3 the pipeline will be installed in the northern side of a small hill presently free of urbanization works, where the Talex Formation sporadically outcrops.

6.2.4.b - Selection of materials

The static pressure will be 2,2 bar, assuming a water hammering coefficient of 1,5, it results the maximum pressure will be 3,35 bar, consequently we have adopted pipes made with U-PVC (un-plasticised polyvinyl chloride) with max operating pressure (NP) equal to 10 bars.

In the Garowe urban area the Talex Formation outcrops extensively and is sub-outcropping in the remaining parts, for the installation of this pipeline the excavation of 1.182 cum in eluvial soils and 4.027 cum in Talex Formation have been estimated.

6.2.5 - Primary and secondary distribution network

In DWG 4 the primary network is drafted with red lines, the full lines represent the existing pipes, and the dotted lines are the pipes to be installed.

The same in DWG 4 the secondary network is drafted with yellow lines, the full lines represent the existing pipes, and the dotted lines are the pipes to be installed.

The primary network includes pipes of diameters 250, 200 and 160 mm, the secondary network includes pipes of 110 and 90 mm; below these sections the pipelines are considered tertiary network.

6.2.5.a - Dimensioning and design

The target of the present service contract is to give a design of a distribution network valid for the water demand in 2040, see Tab 2 at page 3 here above; unfortunately a real census of population and certain forecasts on future developments are not available for Garowe Town.

As stated before we have assumed that the increased population will spread mostly in the present inhabited area and cause a rise in density, while a smaller part of these people will be distributed homogeneously in the outskirts of the town.

The implementation timing of the works planned by the present study is totally uncertain; to avoid dysfunctions in the water supply service in the intermediate phases we are studying a management plan to secure equitable sharing of available resources.

The operative plan involves:

- i - the partition of the town into 15 zones, 12 zones branched to 1.000 cum Northern Reservoir and 3 zones branched to the 500 cum Southern Reservoir;
- ii - each zone will be fed by a single inlet pipe and separated from the nearest zones with the installation of valves;
- iii - the inlet valves are indicated in DWG 3 with the lower case letter “v”; the valves to be installed to separate the zones are indicated with a red border;
- iv - each zone is relatively homogeneous, the water demand of each zone has been estimated by the physical counting of the houses clearly distinguishable in high resolution satellite imageries and assuming 6,5 inhabitants in each house;
- v - in Tab. 6, at pag. 27-a, the weekly plan of the opening times of valves is listed,
- vi - the durations of opening times have been defined with the numerical modelling in function of the water demand of each zone

6.2.5.b - Selection of materials

The maximum pressure in static status will be approximately 31 metres, equivalent to 3,1 bars.

In Garowe the static status will never be obtained because of the presence of private reservoirs, which drain all water available.

From this consideration it would be sufficient to adopt the type of piping having minimal pressure among those available in commerce equivalent to 6 bars or 60 metres, which have the acronym NP 6.

The soils of Garowe are very salty due to the presence of sulphides and chlorides generated by the weathering of gypsy rocks, U-PVC is very suitable in this environment because it is never affected by the acid solutions generated by the above salts.

The NUWACO technicians are familiar with the installation of U-PVC pipes, push-fit types.

For the considerations above said we recommend the use of U-PVC pipes for future works. The U-PVC pipes of class NP 6 are very thin and are subject to collapses in case of external pressures like the ones generated by car traffic, for this reason we recommend using pipes of NP 10.

6.2.5.c - Pipes laying, soil workability

All pipes will be installed along roads in the urban area, the greatest part of the excavations will be in the road embankments and alluvial soils, but in some lengths the trenches will be excavated in weathered bedrock; the bedrock in the urban area is made of Talex Formation.

Long operating life can be expected by U-PVC pipes if the following operative conditions are assured:

- the pipes cannot be affected by any shocks, because even minimal shocks produce abnormal tensions in the structure, which with time, due to the internal pressure, will be converted to cracks,
- the sockets, the elastomeric ring and the plain ends must be properly cleaned at the installation,
- the pipes must be installed on a bed and covered with duly compacted silty or sandy terrains free from angular gravel, the thickness will be specified by the engineer according to the diameter,
- the trenches can be filled with the material of excavation, free of coarse materials, like cobbles and stones, and duly compacted,
- at each change of direction the pipe must be duly fixed with anchor (*trust*) blocks to counteract the axial strengths, the characteristics of the anchor blocks will be defined by the engineer.

6.2.5.d - Fittings and valves

In the aggressive environment of Garowe we recommend the use of fittings and valves fully made with plastic materials or made with ductile iron bonded with thick epoxidic paint.

6.2.5.e – Metering

The way-out of the reservoirs and the inlet pipes in each zone must be provided with water meters.

The installation of mechanical types water meters, like Woltman Type, is recommended.

6.2.6 - Tertiary networks

The scheme of the tertiary pipes necessary to secure water to all users is drafted in DWG 4. this scheme is valid also in case of scarcity of resources and in the future when the water is abundant and the service is rendered as pressurized network.

The tertiary network includes all pipes below 90 mm, the estimated quantities are:

- OD 63 mm = 13.560 m
- OD 32 mm = 3.660 m

Also in this case the adoption of U-PVC NP 10 pipes is recommended.

Concerning the tertiary network no cost estimation has been prepared because the installation of tertiary pipes, fittings and ancillaries will be charged to the costumers.

6.2.6.a - Public fountains (*kiosks*)

In DWG 7 is represented the recommended scheme of public fountain, *kiosk*.

This is a very simple and inexpensive installation and it is relatively secure during the periods when the attendants are not present.

6.2.6.b - Public and private connections

In DWG 7 are represented three configurations of private connections; practically they will give solution to any possible situation.

To prevent water robberies the water meter should be sealed with a plumb bob and the doors closed with a padlock and the keys must be available only to the NUWACO Co. technicians.

6.3 - Drinkable water distribution system

The targets are:

- i - supply drinkable water at costs affordable also by poor people
- ii - eliminate the side effects and the diseases created by the chemical compounds present in the raw water.

6.3.1 - The treatment plant

The best known demineralization processes of water are:

- a) water softening with sodium chloride: this process with the aid of exchange resins converts sulphates and carbonate of calcium and magnesia into sulphates and carbonates of sodium which have a higher solubility degree and do not produce crusts with boiling. They remove the bitter flavour of water, but do not reduce the salt content. The sodium is an electrolyte and the equilibrium with the potassium is fundamental in the pumping activity of the heart, but a high concentration produces hypertension and induces heart attacks. In synthesis this method is not recommendable, especially in Somalia where cholesterol is generally high due to the widespread use of palm oil.
- b) vacuum boiling : practically the brackish water is heated above the boiling point in a vacuum vessel and the vapour is cooled down to obtain water completely free of salts. This was the oldest method applied in desalinisation, the management is simple, the major problem is related to the high demand of fuel for heating up the water, so this method is convenient only in case the fuel is very cheap.
- c) reverse osmosis : this method operates according to the different osmotic pressure having two liquids with different salinity in cells separated by a semipermeable septum. The water produced by this process is practically free of salts. The pressure to be applied to the cell with brackish water is between 30 to 100 bars but the process requires an attentive management, i.e. the energy costs are too high and in case of mismanagement they may become excessive, in our opinion this process is not suitable for the water utilities in Somalia.
- d) nano-filtration : the process is based on the filtration of water through membranes filtered with nano-pores which stop the flow of large ions like sulphates, carbonates and heavy metals up to 85÷90 per cent. With brackish water like the one present in the Garowe Area it is possible to produce potable water with a residual salt content of 600 ÷ 800 mg/lit. The operative pressure is a ± 5 bars and the management is simpler than with reverse osmosis. In our opinion this method is applicable in Garowe and manageable by NUWACO Co. technicians.

6.3.1.a - Description of process

The nano-filtration plant will be composed by the following units, *see also DWG 6*:

- i - the productive borehole : producing very clean water and fully dedicated to the nano-filtration plant, equipped with a submersible pump by the capacity of 10 cum/hour (2,8 lit/sec) with a ΔH equivalent to a residual pressure at the plant of 2,0 bar;
- ii - the ultra-filtration modules : they are necessary to remove all impurities from water, which will clog the nano-filtration modules. The ultra-filtration modules require about 1,5 ÷ 2,0 bars for normal operation and for backwashing, these modules will operate with the residual pressure of the submersible pump. We foresee the plant equipped with three modules, two to secure the production also during backwashing times, the third is spare in case one of the operational modules is out of service. The exchange between the two operational modules will be automatic, and controlled by the panel managing the whole plant. The insertion of the third module will be automatic with the possibility to act manually. Each ultra-filtration module will have the capacity of 10 cum/hour (2,8 lit/sec).

- iii - the centrifugal pumps : each module should be assisted by a pump which raises the pressure to 7,0 bars: 5,0 bars will be necessary to the nano-filtration plus 2,0 bars to reach the inlet point of the elevated reservoir.
- iv - the nano-filtration modules : also in this case we foresee three modules for the same reasons seen at the ultra-filtration plant, also in this case the modules will be designed for 10,0 cum/hour (2,8 lit/sec).
- v - the elevated reservoir: having the capacity of about 80 cum, with the bottom at 489,0 m asl, i.e. 15 m above ground level; this reservoir will secure the supply of water to the whole kiosks spread in the town, *see DWG 5*. The Elevated Reservoir has been designed made with reinforced concrete because the other types erected in Puntland suffer from leakages after a short time.

The plant will be housed in a 6,0 x 6,0 m building for security purposes.

The whole piping inside the plant area has been designed made with stainless steel.

6.3.1.b - Management and production costs

The management will be fully automatic, but in any case an experienced technician must be always present to control the machineries so if any type of problem arises he will take the necessities actions.

The production costs for each cubic meter of potable water will result by the following analysis:

Cost item		Amortization (years)	Cost of water (US\$ / cum)
1	Pumped water from borehole	20 years	0,15
2	Desalinization plant installed in Garowe = 180.000 US\$ x 88.300 cum/years	6 years	0,34
3	Building + elevated reservoir = 160.000 US\$ x 88.300 cum/year	20 years	0,09
4	Energetic cost 15 kWh x 10 cum/hour at 1,0 US\$ x 1,0 kWh	-	1,50
5	Spare parts = 25.000 US\$ x 88.300 cum/year	yearly	0,28
6	Salaries to the operators 450,00 US\$/month x n° 3 x 88.300 cum/year	-	0,18
7	Unexpected costs 10.000,00 US\$/year x 88.300 cum/year	-	0,11
Production cost in US Dollars for each cubic meter of drinkable water			2,66

The selling units in Garowe is the jerry can of 20 litres capacity, the production cost for one jerry can of drinkable water will be 5,3 cents of US\$, for each litre will be 2,7 mill. of US\$.

In Garowe the prices for a bottle of drinkable water by 1,5 litre is 0,80 US\$, the cost for each litre is 0,53 US\$.

The production costs here above estimated will cover investments and running costs at the beginning. Increasing the experience in the plant management the costs of points 5, 6 and 7 will be significantly reduced, and if NUWACO produces electricity in private the costs of points 1 and 4 will be halved, and finally in case of a grant aid the amortization costs of points 2 and 3 will not be considered or computed at a lower level. In conclusion the production cost of drinkable water can be less than half of the here above estimation.

6.3.1.c - Mismanagement risks

The operators charged with the management of the future desalinization plant will be trained conveniently, the best training will be the direct participation in the installation of the plant and following the start-up and commissioning activities.

The estimated cost of the plant includes also the assistance by an expatriate technician for a period of two months after the commissioning.

The plants will be equipped with control devices, which raise the alarm or put the plant in shutdown in case of malfunctions.

The damages to the plant will arise if some control devices do not operate conveniently or in case of alarm or shutdown the operator does not follow the procedure specified by the manufacturer of the plant.

The malfunctions not correctly controlled will increase the costs of spare parts, point 5, of analysis here above.

6.3.2 - The scheme of the proposed network

This water system is fully dedicated to supply drinkable water through public fountains (*kiosks*) without any private connections.

The scheme of the drinkable water distribution system is drafted in DWG 5.

The Plant and the Elevated reservoir are planned near the UNICEF Elevated Reservoir, which in future will be dismissed and dismantled. This location has been selected because it is one of the most elevated points of the inhabited area and because it is close to the NUWACO Co. workshop; the first point will reduce the elevation of the reservoir, the second will facilitate the future management.

The distribution system of drinkable water will consist of 12 public fountains (*kiosks*) distributed throughout the urban area and two in the refugee camps located in the Eastern outskirts, in total there will be 14 watering points.

The guidance in siting the kiosks in the urban area has been:

- each kiosk will subtend an area having a radius of about 300 mm,

- the density of kiosks is related to the users, i.e. they are denser downtown and fewer in the periphery,
- the kiosks are located where free spaces to build them are available.

6.3.3 - The plant

The major characteristics of the plant area will be, see also DWG 6:

- i - n° 3 ultrafiltration modules of the capacity of 2,8 lit/sec each, cylindrical type, installed horizontally on rack made with electrowelded stainless steel,
- ii - centrifugal pumps n° 3 x 2,8 lit/sec x 7,0 bars each installed on inertial blocks,
- iii - n° 3 nano-filtration modules of the capacity of 2,8 lit/sec each, cylindrical type, installed horizontally on a rack made with electrowelded stainless steel,
- iv - piping ND 100 x 2,5 mm fully made with electrowelded stainless steel,
- v - control unit managing the whole plant, housed in a heavy duty and waterproof FRP cabin. The control unit must be equipped with automatic and manual control devices.
- vi - building housing the plant: 6,0 x 6,0 x 3,50 m high, lateral walls made with 30 cm heavy duty hollow blocks installed on a foundation slab 20 cm thick made with reinforced concrete duly sleeked inside the building. The floor slab will include n° 3 inertial blocks where the centrifugal pumps will be installed. The building will be roofed with panels made with high insulating rigid plastic foam externally and internally bonded with pre-painted galvanised plates, installed on a supporting frame made with electrowelded and duly painted steel.

6.3.4 - Elevated reservoir

The elevated reservoir will feed the whole distribution system by gravity, the main features will be, see also DWG 6:

- a - capacity = 80 cum, equivalent to eight hours' production by the plant without any abstraction;
- b - elevation = 15 metres above ground level (*m agl*), the minimum water level will be 489,0 metres above sea level (*m asl*), the maximum water level will be 492,5 m asl, the inlet level will be 493,5 m asl;
- c - reservoir internal diameter 5,20 m x 4,0 m high, fully made with reinforced concrete, installed on a frame with n° 4 column made with reinforced concrete. Internally the reservoir must be painted up to a thickness no less than 3,0 mm with osmotic cement to prevent leakages, except the roof.

6.3.5 - Distribution network

The scheme of the distribution network is displayed in DWG 5.

The design network is branched type. This configuration is mandatory because of the geometry of the town and because of the low quantity of water to be distributed.

This configuration saves large investments as regards the most efficiently looped configuration.

6.3.5.a - Dimensioning and design

The dimensioning inputs are:

- plant production = 2,8 lit/sec = 241.920 litres in 24 hours;
- the kiosks will be open 16 hours a day;
- in the hypothesis that the kiosks distribute the same quantity of water, it results that each kiosk will distribute 17.280 litres in 16 hours with a mean flow of some 0,30 lit/sec.

The network shown in DWG 5 has been verified with the formula di Hazen-Williams imposing velocities not over 1,0 m/sec.

In the hypothesis of fully open kiosks the minimal pressure will be ~ 0,5 bars.

In accordance with the above figures the maximum diameter of the network will be OD 110 mm.

In consideration of the small sizes of the pipes we recommend adopting high density polyethylene (HDPE) PE 100 type NP 12,5 pipes in rolls of 100 or 50 metres each, the connections and the whole fittings made with pressure joints (Plasson Type). This solution will reduce the number of connections considerably and consequently the number of critical points.

6.3.5.b - Public fountains (*kiosks*)

The sector 1 of DWG 7 represents a recommended scheme of public fountain, kiosk.

These installations are very simple and inexpensive, and they are relatively secure during the periods when the attendants are not present.

7 - Implementation programme

In DWG 8 has been drafted a possible Implementation Programme, this can be considered as representative of the time duration of different activities, since the implementation depends on the will of the Administration.

7.1 - Immediate measures

The most important problem of the water supply service in Garowe is the shortage of water, this gap must be solved as soon as possible in order to provide a minimal quantity of water and stop the abstractions from shallow wells which originate water borne diseases.

This goal can be achieved with new boreholes drilled in the surroundings of the town and in the Salaxley River at the junction with the Garowe River, these locations will be easily connected to the distribution network.

7.2 - Short-term activities

The promising areas of Salaxley Village and Jibagale must be studied and developed to productive to satisfy the water demand in relation to the growing of the town.

The trunk-lines adducting the new resources to the town and the major facilities related to the development of the distribution network must be implemented together with the availability of the waters from these areas.

Another recommended activity to be implemented very quickly is the creation of a system to supply drinkable water.

For the people living in rural areas the use of brackish water is not a big problem since the intense sweating removes from the body a great part of the salts acquired in this way and prevents their build-up.

The sweating of people living in urban environments is greatly less and the salts acquired with the use of brackish water will be accumulated thus producing several diseases, some of which very serious.

7.3 - Medium term activities

In the medium term we recommend completing the implementation of distribution network facilities in order to face the increase in water demand, due to the population growth and the rise in life standards.

In the near future we also recommend studying the water resources present in the Nugal Valley to develop and secure in advance the water sources for the future.

Garowe is a capital town, in these situations the population dynamics do not follow the normal evolution and consequently the forecasts made in Chapter 2.1 are possibly underestimated.

8 - Cost estimation

The investment costs to implement the necessary works to satisfy the water demand in 2040, the end of the project period, have been estimated and itemized in Annex 2, the total funds to be financed, works + technical and management costs, are synthetized in Tab 7, see pag. 35.a.

