Technical Feasibility Study & Design of Electro chlorination Technology at Spur Road Reservoir Site Freetown (Sierra Leone)

Joint Venture CIRPS-GSF

Prepared for

ACTION CONTRE LA FAIM

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ACRONYMS

ACF	Action Contre la Faim
CCU	Consortium Coordination Unit
DFID	Department for International Development
EDSA	Energy Distribution Service Authority
FCC	Freetown City Council
FRC	Free Residual Chlorine
FWC	Freetown Water Consortium
GIS	Geographic Information System
GPS	Global Positioning System
GWTP	Guma Water Treatment Plant
GVWC	Guma Valley Water Company
MOWR	Minister of Water Resources
NPG	National Power Grid
OSEC	On Site Electro Chlorination
O&M	Operation and Maintenance
WHO	World Health Organization
CE	European Commission
PN	Nominal Pressure
ND	Nominal Diameter
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
GRP	Glass-reinforced plastic
NSF	National Science Foundation
IP	International Protection

INTRODUCTION

The general purpose of this consultancy is to offer a competitive and effective feasibility study for a sustainable technical solution for an Electro chlorination System at Spur Reservoir Site in Freetown, which will feed the International Tender planned by ACF.

For this consultancy, two Organizations joined their wide expertise in order to strengthen the efficiency, also considering the amount of deliverable requested in the short time schedule assigned for the work.

The two organizations are:

CIRPS (Inter-university Research Center for Sustainable Development) that is Research Center based in Rome, Italy, with pluridecennial expertise in Sustainable Developing Technologies in several countries.

GSF-Onlus (Geology Without Borders, Italy) that is a Geologists/Natural Scientists No-Profit Association with decennial expertise worldwide in environmental and natural resources management concerned to the local communities and ecosystem needs.

This work intends to be the main guide for the next phases for the realization of an electro chlorination plant at Spur Road.

1 CONTEXT OF THE STUDY

1.1 General Context

Drinkable water is a huge problem for Freetown, the main reservoir of the town is Spur Road Reservoir where it isn't guaranteed a sufficient Free Residual Chlorine (FRC) so the distribution network can't assure safe water to the population.

The insufficient FRC of the water provided for the aqueduct of Freetown is a huge problem and the first cause of the frequency of cholera outbreaks and water-related illness.

Currently the water network in Freetown is facing many technical issues: the leakages of water is estimated to be around 40% by GVWC and the network presents a low level of free residual chlorine.

The most important factors contributing to this situation are:

Length of the transmission network (around 15 Km from the treatment plant to the main reservoir and around 3 hours for the transfer).

Problems in **Guma Water Treatment Plant** (GWTP) such as leak of sands from the sand filters (concrete structure is actually damaged)

Characteristics of the **pipes** (old, internal corrosion (DN550) and loss of the internal protection).

High water **temperature** (pipes not buried, etc) causes a decrease in the stability of the free chlorine and creates a suitable environment for bacterial growth.

Low water supply, it results a variable level of water in the different points of the network, because of this there is water stagnation which allows pathogens to enter into the pipes in areas with leakages, etc.

Low pressure in transfer pipes and consequent low level in Main Town Reservoirs

Low pressure in distribution pipes allow external contamination

1.2 Objective of the study

The objective of the present study is to design the most efficient and sustainable chlorination system.

In this specific context, an adequate chlorination system at Spur Road Reservoir, in a proper water network context, should guarantee free residual chlorine (0.2-0.5 mg/litter) in low supply zone, as stated in the Term Of Reference (TOR) of this consultancy.

It is an important advantage to chlorinate water at Spur Road Reservoir level since it is the main reservoir for Freetown low zone. From this point, water flows for gravity, through different smaller reservoirs, to the low zone of the town and, by a pumping station, to a higher little area.

The preliminary documents, field visits and meetings held so far revealed the difficulties in determining a complete and reliable model of the aqueduct, then it results impossible to predict the FRC in low supply zones.

An affordable solution is to maximize the concentration of chlorine in the water effluent (outlet) from Spur Road Reservoir.

According to the WHO guidelines on drinking water and consultants experience, a FRC level should be around 1 mg/l at the outlet to guarantee drinkable water in the larger part of the aqueduct avoiding that water has unpleasant taste close to Spur Road Reservoir neighborhood. This value has to be considered as a starting point for the calibration because it can be reduced or increased up to 2mg/l.

Considering also that FRC level arriving at Spur Road varies from 0 to 0.2 mg/l, as it is already chlorinated, we can say that the “chlorine demand” has already been satisfied, we can expect that most of the added chlorine can be FRC.

1.3 Area of the study

1.3.1 Water network

1.3.1.1 Current situation

The main source for Spur Road Reservoir is Guma Dam, located at 15 Km distance, inside the forest reserve at an elevation around 270m above the sea level.

Then water flows to the GWTP (Guma Water Treatment Plant), with an elevation of 230m above sea level at around 2 Km distance from the dam. The treatment process consists of pre-chlorination (when needed), pH correction, coagulation/ flocculation/ sedimentation, rapid sand filtration, and disinfection (post chlorination).

Then, from GWTP water flows to Spur Road Reservoir by a twin bulk transfer main: one with diameter 700mm and one with diameter 550 mm. The 700mm pipe brings water only to Spur Road Reservoirs and fills up both of them. The 550 one, instead, has 11 connections between GWTP and Spur Road Reservoir to give water to the coastal communities, after this distribution water reach the east Reservoir. When there is not enough pressure in the network, the valves at the 11 connections (during fixed days: Monday, Wednesday, Friday) are locked.

1.3.1.1 Renovation work in progress

GVWC is currently renovating the line from GWTP to Spur Road Reservoir. There will be two pipes: 700 mm and 550 mm diameter, as described above. On the 550 mm line two new reservoirs, supposed to be constructed by DFID support (3 million liters each), in Marjay town and Angola town; it is planned to increase up to 11 reservoirs in the future, in order to guarantee a certain autonomy to the coastal communities when the valves will be closed.

Below the current water network (sketch updated at 12 August 2016 with GVWC directions), renovation work in progress:

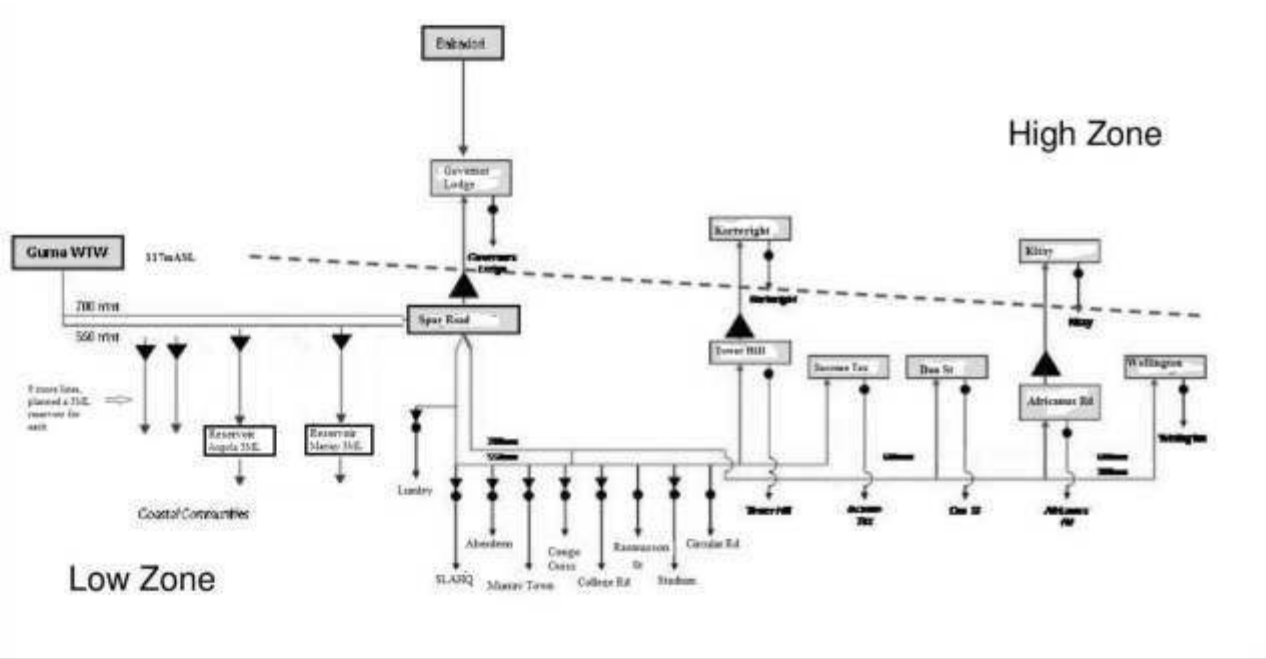

Figure 1 Current water network

1.3.1.2 Renovation work plan

Under this scenario, according to the Engineering Review Report Draft, May 2016, several actors (DFID, GVWC and CCU/FWC MOWR, FCC) are planning a renovation plan of the aqueduct to provide safe drinking water to a larger part of the Freetown population.

According to the plan, we can outline some main areas of intervention:

Rehabilitation of existing treatment facilities

Rehabilitation of transmission system

Rehabilitation of distribution network

Enhancing other existing water supply sources

Replace Spur Road Pumping facilities

As part of this larger renovation plan, the aqueduct will get a reduction of leakage from the current 45% to 25 %.

1.4 Appropriateness of an intermediate electro chlorination at Spur Road

The water coming from Guma Dam is already treated (pre-chlorination, flocculation, settling, filtration and disinfection with gas chlorine).

According to the monitoring data from GVWC, the FRC is between 0.1 and 0.3 mg/l, which is not enough to guarantee chlorinated water to the distribution network

As required from ACF and GVWC we can state that the most appropriate intermediate disinfection to guarantee an FRC 0.2-0.5mg/l to the water network can be chlorination in Spur Road Reservoir for these reasons:

- it is extremely effective disinfectant for the inactivation of bacteria and viruses;
- the production of a residual for the maintenance of water quality in distribution systems;
- it is the easiest and least expensive disinfection method, regardless of distribution system size;
- the technology for chlorination is well developed as it is the most widely used and best known disinfection method;
- chlorine is available as calcium and sodium hypochlorite whose solutions are safer and require less complex equipment and instrumentation compared to chlorine gas;

In the previous feasibility study from Veolia, the technology chosen for the intermediate chlorination of the water network was calcium hypochlorite in Tower Hill, but GVWC's preference moved to electro chlorination in Spur Road

Calcium hypochlorite is sold as a white powder and as tablets and it is typically used to boost chlorine concentration in service reservoirs or sometimes for chlorination at small works.

The use of calcium hypochlorite is not appropriate for large flows which are usually treated by liquid sodium hypochlorite (in commercial or site generated form) or chlorine gas.

Application in tablet form tends to be limited to small chlorine usage (<500m^3/day) due to the cost and the practical difficulties of making up aqueous solutions of hypochlorite from the solid product.

These tablets are typically used in conjunction with tablet erosion feeders.

Calcium hypochlorite in solid must be stored in a cool, dry place because of its reaction with moisture and heat.

It also forms a precipitate following mixing with water due to additives mixed with the chemical.

On-site electro chlorination is based on electrolysis of dilute brine to produce batches of sodium hypochlorite on demand. The electrolyzer system is designed to produce hypochlorite with a chlorine concentration usually in the range 7 to 10g Cl2/l (or 0.7 to 1% w/v)

The product is stable at these low concentrations and is typically stored for no more than 36-48 hours, although up to 72 hours should not lead to excessive degradation if storage tanks are clean.

The equipment uses softened water to prevent scaling of the electrodes. Hydrogen gas is a by-product –the explosion hazard is addressed by forced venting of storage tanks such that the atmosphere in the tank is not explosive.

The hypochlorite product is relatively stable, although degradation does occur, principally due to:

- conversationalist of chlorine (accelerated during forced air venting);
- chemical reaction to form chlorate (very slow relative to commercial hypochlorite because of relatively small hypochlorite concentration).

The electro chlorination at Spur Road is the most appropriate technology. All the indicators taken in consideration are summarized in the table below.

Table 1 Indicators of the present study

Impacts	Very low to zero impact, the electrolytic production of sodium hypochlorite solution comes from salt, water and electricity and no chemicals are used.
Coverage	In order to cover a wider area of the network (around 700.000 inhabitants), the electro chlorination is the most reliable technology because of the flow to threat
Sustainability	The components are robust and elementary, the system is completely automatic and low-maintenance is required
Coherence	The strategy of using an electro chlorination system is coherent with the policies of GVWC, as they are planning to renovate the network and the chlorination system will be able to meet also the required target of water quality.
efficiency	The disinfection efficiency is generally close to 100% for total coliform groups after a detention time of 30 minutes

1.4.1 Investigation about the disinfection performance

The WHO recommendations for the use of chlorine as a disinfectant stipulated a minimum free chlorine concentration of 0.5 mg/l (C) after 30 minutes contact time (t) at a pH of less than 8 and turbidity less than 1 NTU.

The product of these two values C X t is the commonly used term to describe the efficacy of chemical disinfection systems that form residual concentrations in the water following chemical dosing.

The recommended WHO value for chlorination corresponds to a Ct of 0.5 x 30 = 15 mg.min/l, but this is a very generic recommendation, as we should take into account

- The levels of contamination with pathogens expected;
- The extent and performance of treatment prior to final disinfection;
- The design of the contact tank, in relation to short-circuiting;
- Expected variations in temperature and pH.

According to the international standards, in the intermediate disinfection system (like the one in Spur road), the achievement of Ct based on downstream contact volume and chlorine concentration is not required, but, due to the bad conditions of the system, it is important to take into consideration the effectiveness of chlorination to guarantee an appropriate FRC to the low zone.

1.4.2 Effective contact time

The ideal contact time is tc = V/Q, but such ideal flow is never observed in real systems because a proportion of the water may short-circuit the tank or recirculate and thus have a residence time less than tc.

A common approach to dealing with the non ideal of flow in disinfection systems is to consider tx/tc, where tx is defined as the time in which the fastest flowing x% of liquid passes through the tank.

In a perfect plug flow reactor (PFR), residence time is uniform, and hence (tx/tc) = 1.0 and tx =tc.

US EPA guidance (USEPA, 1999) for disinfection is based on x = 10 i.e. t10 value, which is associated with 90% of the water passing the contact volume having a greater residence time than this value.

The tc, and therefore tx can be readily determined by means of tracer tests.

In a tracer test, an inert indicator is dosed at the inlet of a tank, and is monitored in the outlet.

Chlorine can be used as a tracer by monitoring chlorine residual at the tank because the chlorine demand is stable over the duration of the test and the rate of chlorine decay is not excessive if we have good quality treated water.

In the absence of tracer test data, an initial estimate of non-ideal can be made by consideration of the tank design, in particular provision of baffling. Values of t10/tc suggested by USEPA (1999) are shown in Table below:

Table 2 Suggested Values of t10/tc

Condition	t10/tc	Description
Unbaffled	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.

Poor	0.3	Single or multiple unbaffled inlets and outlets, no intrabasin baffles.
Average	0.5	Baffled inlet or outlet with some intra-basin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect	1.0	Very high length to width ratio (pipeline flow).

Source; US EPA, LT1ESWTR Disinfection Profiling and Bench-marking Technical Guidance Manual 2003

Some of the conditions (poor and superior) are shown in the following figures

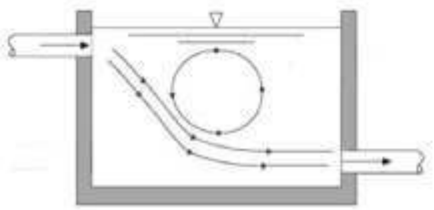

Figure 2 Poor baffling arrangements in contact tank

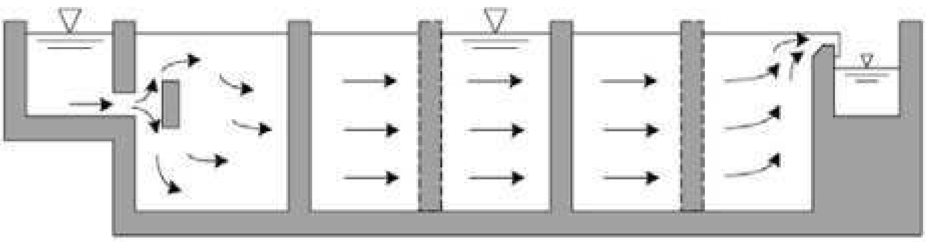

Figure 3 Superior baffling arrangements in contact tank

Even if we know that the reservoirs are compartmentalized we don't know the internal geometry and layout of the reservoirs.

For this reason it is not possible to assume a contact time for the disinfection.

1.4.3 Decay of Chlorine

The prediction of free residual chlorine in a specific location of the whole system is a problem whose solution is not yet absolutely mastered. Chlorine is relatively unstable, may react with a variety of organic and inorganic compounds in the bulk water and pipe wall and there is reaction of biofilm with chlorine.

It is very difficult to precisely predict the chlorine concentration because of the complexity of water distribution system and uncertainty of the reactivity of chlorine. In order to have a control of free residual chlorine, a simulation has to be done with the EPANET model in order to calculate the decay of chlorine, taking into consideration the phenomena of chlorine reaction with chemical species at bulk fluid and with pipe walls.

The equation which allows us to calculate the concentration of chlorine in the water (C), throughout the transportation time (t) when it is known the concentration (C_0) at the beginning of the transportation.

$$C = C_0 e^{-kt}$$

The adjustment coefficient (K) is calculated based on laboratory results of the analysis conducted in batch reactors.

The decay constant values vary with water quality, water temperature, flow rate, pipe diameter, pipe materials, inner coating and pipe roughness.

Since the EPANET model is still not available at the time of the consultancy, it’s not possible to estimate the decay curve.

1.5 By-products and health effects

Where chlorine is obtained from hypochlorite, chlorate and bromate formation can be an issue depending on bromide content of salt used in manufacture and subsequent conditions of storage of hypochlorite.

The most commonly found chlorine disinfection by-products are the trihalomethanes (THM). They are formed by reaction with natural organic matter in water.

There is some limited evidence of possible health effects from disinfectant by-products from chloroform and the other trihalomethanes and by-products, based on high-dose animal studies.

Epidemiological studies conducted do not provide any evidence that disinfectants and their by-products affect human health at the concentrations found in drinking-water.

Adequate disinfection of drinking-water is the most important priority to assure a safe water supply, and Cholera outbreak of 2012 is a dramatic evidence of the importance of adequate water disinfection.

We can say that the choice of microbiological quality must always take the precedence on the by-products. Furthermore, if the disinfection is efficient and system is well managed and maintained, we can consider negligible the health risk of by-products .

2 METODOLOGY

In order to prepare the technical feasibility study and design of Electro chlorination Technology at Spur Reservoir Site, the consultancy team has adopted the methodology outlined below:

2.1 Discussions/meeting with Partners

During the whole consultancy

ACF (NGO Action Contre La Faim)

GVWC (Guma Valley Water Company)

CCU (Consortium Coordination Unit)/FCC (Freetown City Council)

FCC (Freetown City Council)

Other Stakeholders involved

2.2 Current water network investigation

CIRPS studied the sizing and hydraulic capabilities and network service, which will be carried out on the basis of already acquired project documents, in the previous GVWC initiatives, and other Partners studies:

Water network updated on the basis of GVWC engineers directions and direct observations by consultants: connections, main distribution lines, transmission lines

Site visits at water treatment plant, water network reservoir sites (Spur road and Tower Hill etc...)

Analysis of FRC measurements monitoring data at water treatment plant, Spur road received by GVWC.

Single verification measurement of FRC in Spur Road Reservoirs and in a neighborhood house at the time of this consultancy, done by consultancy staff.

GVWC water monitoring data analysis (FRC, NTU, PH, other parameters available)

2.3 Geology/Topography and site mapping

Topography and elevations of the whole water network plant, on the basis of GPS data and topography maps.

Review of geologic formations from literature data at Spur Road Reservoir site.

Supervision of a local Topographer to carry out a new survey with total station and CAD sketch at Spur Reservoir site (e.g. survey scale 1:100)

2.4 Energy supply investigation for the Electro chlorination

Energy needs for the Electro chlorination plant.

Different supply options comparison: technical feasibility, Cost and O&M constraints.

Hybrid system options: combination of National energy grid and Renewable power (hydropower/solar) and generator.

Reliability of National Power energy supply at Spur Road Reservoir (e.g. frequencies of breakages): analysis of energy supply bills of the last 2 years.

Connections need for the selected energy supply system

2.5 Salt procurement investigation

On the base of GVWC directions Investigate local salt vendors and producers.

Investigate alternative import solution from abroad by consultants' initiative.

Investigate the quality of salt, concentration of main elements according to international standard regulation.

2.6 Proposed technology applicability to the context (current water network vs renovated network)

Review of:

Rehabilitation works in progress: detailed technical design, hydraulic model, predicted completion.

Plans for rehabilitation in each part of the network: detailed technical design, hydraulic model, predicted completion.

Plan of O&M operation and maintenance of the future renovated water network.

3 SPUR ROAD RESERVOIR

3.1 Hydraulic setting of Spur Road Reservoir

The overall hydraulics system of Spur Road Reservoir has been investigated on the base of:

- The functional sketch represented on the topographical map (in scale 1:2500) and validated by the GVWC engineers.
- Direct observations on the field.

The hydraulic system can be described as follow:

Spur Road Reservoir Compound is made of a fenced area of around 2.2 hectares. There are 2 water reservoirs with total volume (in Atkins Report 2008) 18.400 m^3 .

The two water reservoirs are:

- Partially buried and partially elevated from the ground
- Their external geometry is parallelepiped, while the geometry underground is not known
- Supposed construction by the 1960's
- In the present study we have called them Reservoir WEST and Reservoir EAST.

- The two reservoirs are not connected to each other.

3.1.1 Flow

The values of inflows assumed, provided from GVWC, as the flow meter at spur road reservoir are not functioning:

Current water network flow:

- Maximum water flow: 75 million liters/day, coming from the WTP
- Minimum water flow: 40% of the water coming from the WTP (30 million liters/day)

The future water network flow expected after rehabilitation:

- Maximum water flow: 89 million liters/day (from the WTP)
- Minimum water flow: 50% of the water coming from the WTP (44,5 million liters/day)

3.1.2 Hydraulic arrangements

The Water to Spur Road Reservoir arrives from Guma Water Treatment Plant by two inlet pipes along a distance of around 15 Km. One pipe with diameter 700mm and one pipe with diameter 550mm.

The 550 diameter pipe before Spur Road Reservoir has many connections to serve coastal communities, as shown in the general water network sketch (in 1.3.1.1) . Once in Spur Road it brings water only to the reservoir EAST.

The inlet pipe 700mm is directly connected to Spur Road and brings water to both reservoirs.

After a valve, the 700mm pipe is divided in two branches of 600mm diameter to bring water to both reservoirs.

No documents and data are available for the material of pipes, the pressure and the head variation in Spur Road as well as in the whole network. According to the information received from GVWV, we can assume the following data:

- The pipes of 550 mm are made of steel, the ones of 700 mm are made of ductile iron.
- The maximum pressure assumed is PN16, as communicated by GVWC.

Figure 4 East reservoir Inlet and Outlet

The following functional sketch has been validated by GVWC engineers, and therefore used for this feasibility study and technical design.

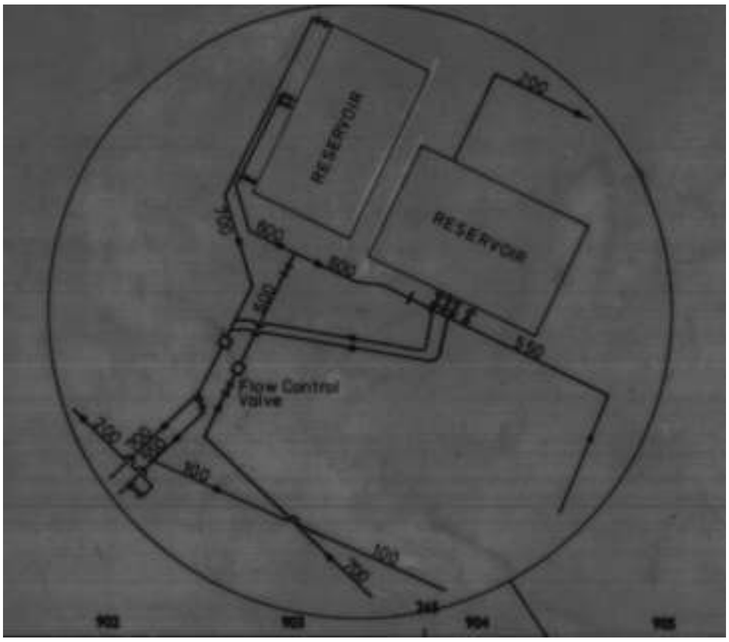

Figure 5 Spur Road Reservoir Functional Sketch

Each reservoir has its own outlet pipes as described below:

3.1.2.1 RESERVOIR EAST

It has one internal partition which divide 2 equal volumes, the two partitions should be in communication as the same water level suggests. It has 2 outlets pipes, one for each partition.

The measures of the plant view are: 58mX40m, the geometry of the underground part is unknown.

There are 3 Outlets pipes:

- 2 main outlets exit from the south part of the east reservoir and bring water to the main pipeline for the Low Zone of Freetown.
- 1 smaller diameter 200 exits from the north part of the east reservoir and serves an upstream community

A construction in the south of the reservoir contains all outlets and inlets connections, except of the small 200 outlet.

3.1.2.2 RESERVOIR WEST

It has one internal partition which divides the reservoir in 2 equal volumes parts (North and South).

In the South partition there are installed two pumps in order to send water upstream to Governor's Lodge.

The pumping systems have been installed afterward the construction of the 2 reservoirs.

The measures of the plant view are: 37m X 58m, the geometry of the underground part is unknown.

It has 3 outlets:

- 2 outlets exit from the West part of the reservoir and bring water to the main pipeline for the Low Zone of Freetown.
- 1 outlet receives water from 2 pumps, installed on the south part of the reservoir to serve the Governor's Lodge (currently one pump is out of service).

3.1.3 Recommendations:

The general conditions of Spur Road Reservoirs are not adequate. Spur Road represents the main public water reservoir for the whole low zone of Freetown, a town recently hit by Cholera outbreak, Ebola outbreak.

It needs renovations and ordinary maintenance to guarantee minimum safety and hygiene to the most important water network supply.

We suggest the following recommendations:

- **Emptying** the reservoirs, one by one in order to be able to measure the geometry and volume. It is an opportunity to clean and have more effective and cheaper water chlorination.
- Cut the **grass** and plants that are currently covering and hiding the most of the piping inspection holes.
- Install proper **covers** (easily to be opened for maintenance) on each of the ground inspection holes.
- Maintenance of the valves.
- Check the proper functioning of all **valves** periodically.
- Install proper **covers** on all inspections holes on the top of the 2 reservoirs (the most of them are currently non covered and lizards and other small animals are entering frequently)
- Rehabilitation of the **Office** building
- General check of the **transformer and connections**, implement all measures to make it safe (e.g. Extinguisher, fence, warning signals).
- Remove **ground** fallen on the West reservoir and plants growing on both Reservoir.
- Rehabilitation of the **Pump** control room, list not exhaustive: door, windows, control panels, cables, etc…
- Rehabilitation of the **inlet/outlet house** of Reservoir East, list not exhaustive: door, windows, security measures…

3.2 Water investigations at Spur Road Reservoir

3.2.1 Temperature

No historical data are available on the temperature. Three samples have been taken for the measurement of the temperature:

- at the inlet of the east reservoir: 26 °C
- in the east reservoir: 25,5 °C

- in the west reservoir: 26 °C

Sensitivity of the thermometer: 0,5 °C

3.2.2 Water quality

The monitoring data of water quality have been delivered from GVWC

These are the parameters available for Spur road, done by GVWC using a Delagua kit.

Table 3 Water Quality Monitoring Data, GVWC

Date	Residual Chlorine (mg/l)	pH	Tubidity (NTU)	Thermo Tolerant (CFU/100ml)
1/10/2016	0.2	6.8	<5	Nil
1/17/2016	0.3	6.8	<5	Nil
1/23/2016	0.2	6.8	<5	Nil
1/23/2016	0.3	6.8	<5	Nil
2/8/2016	0.2	7.2	<5	Nil
2/15/2016	0.3	6.8	<5	Nil
2/22/2016	0.2	6.8	<5	Nil
2/29/2016	0.3	6.8	<5	Nil
3/7/2016	0.2	6.8	<5	Nil
3/14/2016	0.2	7.1	<5	Nil
3/21/2016	0.3	6.8	<5	Nil
3/28/2016	0.3	7	<5	Nil
4/4/2016	0.3	6.8	<5	Nil

3.2.3 FRC monitoring

During the consultancy, some FRC and PH measures have been taken in both reservoirs by pool tester.

Table 4 FRC and PH in West Reservoir

date	time	FRC (mg/l)	PH
6/8/2016	morning	0.1	6.8
12/8/2016	morning	0.1-0.2	6.8
18/08/2016	4:30 PM	0	6.8
24/08/2016	11.00 AM	0	-
25/08/2016	11.30 AM	0	6.9
26/08/2016	12.00AM	0	6.8

Table 5 FRC and PH in East Reservoir

date	time	FRC (mg/l)	PH
6/8/2016	morning	0.1	6.8
12/8/2016	morning	0.1-0.2	6.8
18/08/2016	4:30 PM	0	6.8
25/08/2016	11.30 AM	0	-
26/08/2016	12.00AM	0	6.8

Table 6 FRC and PH in Spur Road Neighborhoods, linear distance 200 m

date	time	FRC (mg/l)	PH
6/8/2016	morning	0	-

3.2.4 Water samples analysis by Lab

Total **hardness** (mg/l) of 2 samples of water from Spur Road Reservoir (one from reservoir WEST and one from reservoir EAST) have been analyzed by the laboratories of Ramsy Medical Laboratories in Freetown, and results are showed in the table below:

Table 7 Water hardness analysis

	Analyte	Unit	Result
Reservoir EAST	Total Hardness	mg/L	0
Reservoir WEST	Total Hardness	mg/L	0

The original analysis report can be seen in annex 11.6

The 0 mg/l has to be considered not as demineralized water but enough soft to state that we don't expect problems of precipitation of calcium carbonate.

3.3 Site investigation

3.3.1 Geology

3.3.1.1 General Geology of the peninsula

The Freetown peninsula and the Banana Islands are part of an apparently funnel-shaped body of gabbroic rocks of which the greater part lies out to the sea. The complex consists of a 6 Km thick series of cumulate rocks of gabbroic composition, containing layers of dunite, troctolite, olivinegabbro, gabbro, leucogabbro and anorthosite.

The complex is intruded into the gneisses of the **Kasila Group** and overlain by sediments of the **Bullom Group** whose lower beds are of Eocene age. Sedimentation structures such as cross-bedding are common in the gabbro layers and some 6,000m of thickness is exposed.

The complex has been reliably dated as 193 million of years.

The outcrop limits of the complex define an arc. Layering dips radially inwards from this arc, and a hypothetical 'center' is deduced to lie 16 Km WSW of York. The layering may be divided into 4 major zones on the basis of large scale variations in mineralogy and topographic expression. Each zone can be seen as the result of a single magmatic event. The base of each zone is olivine rich, and the top anorthositic. Within the zones are many rhythmic units on a hectometre scale, and within each rhythm is a centimeter to meter scale banding. Both zones and rhythms tend to be more olivine rich at their bases and plagioclase rich at their tops, so in effect rhythms are small scale duplications of zones.

Rhythmic layering and banding is more developed in the basal portions of zones and rhythms, while massive, lenticular anorthositic rocks, which are locally transgressive into overlying rocks, characterize the tops of zones.

Mineralogically, the Freetown Complex displays few of the characters expected in large layered intrusions. The minimal cryptic layering present is unrelated to height above the base of a zone or rhythm. Order of cumulus crystallization is ilmenomagnetite as immiscible droplets, olivine, pyroxene, plagioclase; this gives rise to the following stratigraphy of rhythms and zones:

Top: Anorthosite Leucogabbro Gabbro Olivine gabbro Troctolite

Bottom: Ilmenomagnetite rich troctolite.

Sulphides are ubiquitous but occur in small amounts, either as crystallized droplets of immiscible liquid trapped as inclusions in olivine and plagioclase, or as late stage hydrothermal veins and replacements. Copper, nickel, platinum and gold have been recorded in association with sulphides

Bullom Group

It is typical sediment which occupies the low-lying coastal plain of Sierra Leone. These deposits extend up to 50Km inland and are found at heights of up to 40m above present sea level. Outcrops are rare and generally poor with the exception of 25m high sea cliffs at Bullom, N of Freetown. The Bullom Group consists of a laterally variable sequence of poorly consolidated, near horizontal, often iron-stained gravels, sands and clays with occasional intraformational laterites and lenticular seams of lignite. The clays are generally kaolinitic, red, purple and white in color and in the Bullom cliffs contain plant remains. In a borehole drilled to a depth of 120 m (100m below present sea level), E of the Freetown Peninsula, a sparse fish and mollusc fauna obtained from borehole sludge's indicated an age not older than Eocene and possibly as young as Miocene for near basal sediments. The sands, sometimes graded, but rarely cross-bedded, are generally poorly sorted, with a clay matrix; partially disintegrated feldspars occur. Quartz grains are very angular and under the scanning electron microscope show no evidence of marine or prolonged fluvial activity. Interbedded with the sands are occasional grit beds, stringers of rounded quartz pebbles, and horizons of kaolin clay clasts. Intraformational laterites occur within the sands and often form puddingstone horizons. Rare, thinly bedded calcareous clays and grits have also been recorded.

Kasila Group

A distinctive group of mafic gneisses and granulites lies along the south-western part of the West African craton in Sierra Leone and passes south-eastward into Liberia. They consist of gabbros, amphibolites, hornblende schists, garnet-mica schists, and charnockitic andanorthositic granulites with a predominantly north-west to southeastern strike and showingsome signs of isoclinal folding and intensive shearing.

The lithology of the Kasila Group is dominated by fine to medium grained basic granulites with minor horizons of quartz magnetite, quartz diopside, and sillimanitic rocks. The granulites are intruded by deformed gabbros, anorthosites, and ultramafics in which relict igneous textures have survived the Pan-African reworking in zones where shearing was less intense.

3.3.1.2 Geology of Spur Road Site

Before the excavation for the Reservoir, we can imagine the site morphology should be an almost uniform slope descending toward South-West, within the same geological formation. The Geological formation of the site can be described by the shallow alteration of the Freetown magmatic Complex, made of gabbroic rocks. The magmatic complex consists of a 6Km thick series of cumulate rocks of gabbroic composition, containing layers of dunite, troctolite, olivinegabbro, gabbro, leucogabbro and anorthosite. It is now covered by the recent soils.

For the construction of the Reservoirs (estimated to be done around 60 years ago), large excavation was done in order to allow the reservoir volume and to reach the more massive and not weathered magmatic rock layers. The big volume spoils rock of the excavation has been accumulated downstream on the slope. Nowadays the proof of the spoil rock deposition is the big hill at the south est pf the site, which interrupts the natural slope trend.

3.3.1.3 Geology considerations of the area for electro chlorination plant buildings

The area identified for construction of new buildings necessary for the electro chlorination plant is located in a flat area, next to road used by resident car movement in front of the Reservoir EAST.

The borders of the area are the road above mentioned at NORTH-EAST, a small house used as store for the Spur Road Reservoir operation at NORTH-WEST, a small house with toilet at SOUTH-EAST, a large flat area, with grass at SOUTH-WEST .

The selected area for new building (see figure 10) is not considered by the present study at risk of landslide. It is out of the hill made of spoils rock resulted from Reservoir excavation. It is at 50 meters distance from the hill escarpment. Maximum escarpment height of the hills is 20 meters at 50 meters distance from the construction area and this escarpment height decreases gradually to zero toward the area of construction; it is zero already 20meters before the area of construction. The building to be constructed is at ground level only.

3.3.1.4 Earthquake risk

From a research done on the web of the Seismic History in Sierra Leone we can say that the main earthquakes with magnitude greater than M 4 are happening (with frequency every 5-10 years) generally offshore along the Mid-Atlantic Ridge and the transform faults located north of Ascension Island as shown in the pic below

Figure 6 Historical earthquakes records

One earthquake happend the 30th of August 2016, was heard in Freetown, but didn`t cause any casualty or damage. It was 7.1 magnitude, 10 Km depth. The location confirmed by USGS was offshore along the Mid-Atlantic Ridge on the transform faults located north of Ascension Island.

Moreover other earthquakes M 1.5 or greater records happened onshore in Sierra Leone neighbor countries are shown in the pic below.

Figure 7 Historical records of main earthquakes near Sierra Leone

Regarding record of Earthquakes happened with hypocenter in Sierra Leone, we found only these 5 records:

October 3, 1995 1:01 AM UTC. Depth 2 Km. Magnitude 3.00 mL. Probable locations involved in the earthquake: Kenema District-Pujehun Districk-Pokpa.

August 14, 1995 10:28 AM UTC. Depth 34 Km. Magnitude 3.30 mL. Probable locations involved in the earthquake: Kisi-Prefecture de Guekedou-Guma-Gbandi.

February 22, 1995 3:32 AM UTC. Depth 34Km. Magnitude 3.60 mL. Probable locations involved in the earthquake: Pujehun District-Tewo-Kone-Robertsport District-Grand Cape Mount Country.

December 7, 1992 12:58 PM UTC. Depth 2Km. Magnitude 3.10 mL. Probable locations involved in the earthquake: Southern Province-Bo District.

March 3, 1992 3:46 AM UTC. Depth 3Km. Magnitude 3.40 mL. Probable locations involved in the earthquake: Kono District.

Figure 8 Locations of the Sierra Leone earthquakes

3.3.2 Maps

The most detailed topographical maps are the ones at scale 1:2500, contour level every 10 meters, done by Howard Humphreys and partners for GVWC in May 1979 (last revision December 1980). We received the Whole Freetown maps collection coverage from the GVWC. These maps detail also the Water Distribution System in Freetown.

The sheet W117 Spur Road covers the Spur Road Reservoir area. On this map it is drawn the hydraulic network at the reservoirs. A functional sketch is also shown on the side of the map.

Satellite images of the area (updated at March 2016) can be seen on Google Earth.

By overlapping the topographical map and the satellite images above mentioned, it is possible to locate approximately the main pipes and connections of the Spur Road water supply system. Therefore only excavation can give the confirmation for position and depth. See the overlaping in the pic below:

Figure 9 Spur Road configuration

3.3.3 GPS survey

A control check of this matching (sat image and topo-maps) mentioned in the previous paragraph was done by the consultant with GPS. The GPS locations (coordinates) of the main water valves , reservoirs and existing building taken, corresponded on the map (Sat +Topography).

GPS surveys were also done by consultants at Spur Road Reservoir in order to:

georeferencing (coordinates) the 2 reservoirs, main existing building, water valves position

(georeferencing is necessary to share maps/data trough CAD, Google Earth, other GIS software, etc..)

Sizing the area

Identification of the area need (m^2) which depends on the technology adopted for the Electro chlorination plant (power supply, electro-chlorinator device)

3.3.4 GIS

GIS data for the whole peninsula were shared by GVWC to the consultant. We used ArcGis to analyze the data. For instance, elevation data (contour lines at 10meters) in GIS were used to cross check main elevation point of the water network.

3.3.5 Area for Electro-chlorination plant

According to the TOR “The Consultant will undergo in-depth topographic and profile surveys required for the design and construction of the physical structures and buildings”, the joint venture had planned an area of around 400 m^2 to set the arrangements of the overall plant and associated structures. Moreover, the whole Spur Road Site compound (not including the reservoir part) is 1.2 hectares, according to GPS data.

The structure includes:

Salt stock: Area predicted 50m^2 close to the chlorination house.

Chlorination house: predicted 4 tanks for Hypochlorite, control room, brine tanks, electrolytic cells, and other ancillaries.

Power house: generator, inverter, connections, UPS, etc.

Guard house

In order to make easier costruction and O&M of the electrochlorination, we propose a unique and compact building structure. For this purpose 3 option areas were considered for this new building structure.

Table 8 Comparison between 3 option areas:

	On the flat area, next to the existing road, front of the Reservoir EAST	**On the slope, next to the road, front of the reservoir WEST**	**Rear of the Reservoirs**

Accessibility	Easier (flat zone, road ready), no new road construction need. Truck operating space OK. .	Access road on the slope not existing. Need new construction. Truck Operating space limited.	Access road not existing. Need new road to be constructed on one side of the reservoirs. Two options: 1. East side reservoir right side. 2. West reservoir left side has many inspection holes. Truck operating space very limited for both.
Construction concern	Digging for foundations	Slope excavation to make a flat zone, digging for foundation. Escavation to make access road.	Slope escavation to make flat zone, digging for foundation. Escavation to make access road.
Economy	Works predicted: Foundations calculation for the buildings, Surface water evacuation channels. Need to move some spare pipes currently on part of these flat area.	Works predicted: Access road design, land slide protection measures for access road, geotechnical calculation and design for protection wall at the back, foundation calculations for the buildings, ground water infiltration measures, surface water evacuation channels	Works predicted: Access road design, land slide protection measures, geotechnical calculation and design for protection wall at the back, foundation calculations for the building, ground water infiltration measures, surface water evacuation channels
Stability and Geologic concerns	Risk of flooding for surface water, need foundations Far no more than 20 meters from the hill slope, not landslide risk, no concerns for ground water infiltration	Possibility to have ground water infiltration (and consequent risk of stability) Land slide risk for the buildings, it is not compact rock, but upper alteration of bottom formations Land slide risk for the access road	Possibility to have ground water infiltration (and consequent risk of stability) Land slide risk for the buildings from the back: the upper meters are not compact rock, but upper alteration of bottom formations.

		Evaluate increase of instability risk for the existing road (used also by resident)	
Distance from the injection pumps	45m	45m	90m
Availability of closer field yard	YES	NO	NO
Cover the pipes layout	NO	NO	NO
Trucks operating space concern	NO	YES	YES
Remaining space for spare pipes deposit	YES	YES	YES

Therefore for the whole Electro-chlorination plant new building (salt store, power house and ancillaries, guard house. etc.) we identified as the more suitable area the one shown in the following Fig 10.

Moreover taking into consideration the need to deposit spare pipes in the compound, the building area is located at the south east side of the reserovir East. In this way it will remain enough space (around 1000 m^2) in flat area for spare pipes deposit and access to them is guaranteed during electrochlorination device operating.

Figure 10 Construction area

3.3.6 Topography survey in depth

The requested area for construction and installation of the Electro chlorination plant has been surveyed and plotted in CAD, as shown in the sketch below.

For this purpose an in depth topographic survey has been commissioned by the consultant to ``Edward Davis & Associated, LTD, Consulting Engineers, Sierra Leone``. The survey has been conducted with GPS and Total Station devices in the area included between the South edge of the reservoirs and the south part of the slope area of Spur Road compound. The survey details the position and height of the existing buildings, the position of the threes, position of the inspection holes included in the area identified in order to allow a detailed design of the plant and his connections.

Some permanent benchmarks, used for this survey, have been positioned in the area to ensure the georeferencing correspondence between map and site, and for any future need of further topographic measurements. All data has been plotted in CAD. All coordinates (survey area and benchmarks) are in Annex 11.1, file name “Topography Boundary and Benchmarks”.

This area surveyed largely contains the area need for construction/installation above identified as more suitable.

The survey includes 3 cross sections, shown in the sketch with blue lines.

1 cross section is longitudinal across the edge of the 2 reservoirs, showing as well the height of the structures crossed.

The other 2 cross sections are orthogonal the first one. For complete drawings in DWG and PDF see annex 11.1

On these plots is designed the Electro-chlorination plant. The two reservoir and the solar plant as shown in the sketch are a representation added by the consultant.

For the details of the building and ancillaries see the Annex 11.2

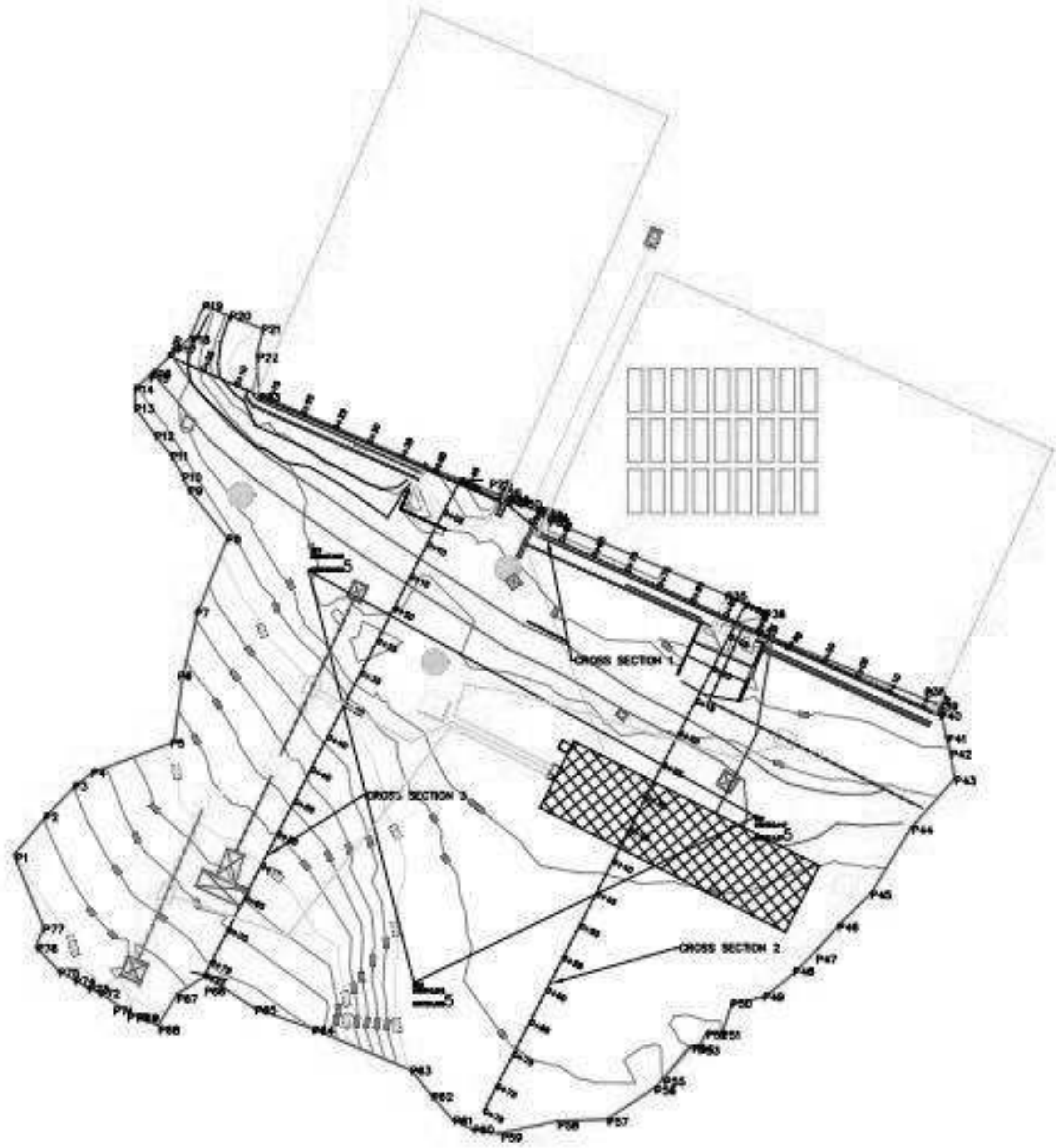

Figure 11 Surveyed area topography

NOTE: The details arrangement or eventual vertical overlapping and the exact depth of inlet/outlet pipes connections for the designed electro-chlorination plant will be identified by excavation to be done at the time of installation by the implementing company.

3.4 Energy (Energy requirements, Electricity network or other energy system)

The system will be powered from the combination of a solar power system and National Power Grid.

The solar system will be installed on the east reservoir and will produce the energy to run the system.

The battery storage will guarantee the continuity switch from PV or the Grid to the diesel generator.

The national grid is not completely reliable as at the moment it is estimated to cover the supply only for 75% of the year (in the future it is supposed to be increased up to 90%)

A generator will be used to support the energy supply during the cloudy days in the rainy season and during the breakages of the grid as the reparation time cannot be predicted.

In case of any break of the generator the GVWC has to use the DFID generator.

3.4.1 Power viability from the NPG

The only current load in Spur road compound consists of two pumps (one duty and one stand by) on the west reservoir.

They are powered directly by the transformer of 630kVA.

Figure 12 West Reservoir Pumping station

Figure 13 Spur Road site transformer

The load study carried out the 16th August 2016 at Spur Road Pumping Station shows that the 630kVA transformer is currently about 63% (396.9kVA) utilized with 37% (233.1kVA) free. We can state, then, that the power viability is enough to run the electro chlorination system. The study is reported in the ANNEX 11.4 Guma Pumping Station-Spur Road.xls

4 ELECTRO CHLORINATION PLANT DESIGN

4.1 Design data and assumptions

The system has been designed to chlorinate the maximum inflow coming in the reservoirs in the current situation as well as after the water network will be renovated.

In the following table are summarized the data utilized for the design

Table 9 Design data

Maximum flow	3750 m^3/h
Concentration of Chlorine	2mg/l
Water temperature	26°C
Water hardness	0 mg/l

4.2 Decay and contact time

As described in the chapter 1.4.3 the data available have not allowed us to estimate a decay curve and an appropriate contact time.

In order to mitigate these uncertainties, we have chosen to inject chlorine in the inlet to guarantee an enough mixing and contact time in the reservoirs, even if it is not possible to estimate exactly the contact time because of the missing data. As we expect to receive chlorinated water in the reservoirs, the concentration of chlorine should not change between inlet and outlet, but this is just an assumption as we don't have any data about the internal arrangements of the reservoirs.

Furthermore, as we can't estimate the decay curve a correction of the chlorine concentration is expected at the outlet.

4.3 Operation of the chlorination system (production and Injection of sodium hypochlorite)

The required water for the production of the brine solution is pumped from the east reservoir through a booster pump. Even if it has proven that the hardness of water it is not relevant, a softener has to be provided for eventual increasing of hardness during the dry season. A softwater tank of 23 m^3 is used as storage for the autonomy of one day, during the maintenance.

The sodium chloride solution is supplied from a salt saturator where crystalline salt is dissolved in softened water to give saturated brine that is diluted in the process.

The two brine tanks can provide two weeks storage of brine.

In order to avoid the formation of by-products brine solution is pumped to a chiller to decrease the temperature from 26 °C to a range of 5° - 15 °C and then to the electro chlorinator system.

In order to have a reliable chlorination system, we have planned to use two devices for the

production of sodium hypochlorite.

The overall chlorination plant will be able to produce a total of 7,5 kg/h of equivalent chlorine.

During low request period, the electro chlorination PLC control must stop the production when the NaOCl tanks are full and reactivate the production when the storage is 50% of total capacity.

The hypochlorite solution, from the two devices, will feed four tanks in parallel of 20 m^3 each, for a total 80 m^3. This storage will guarantee almost four days of autonomy during the maintenance.

From here, the solution will be pumped in the 2 different inlets of the reservoirs.

The flow of NaOCl will be pumped according to the water flow in two inlets (flow meters are

planned) and the FRC of water in the inlet (sensors are planned) in order to guarantee a maximum injection of 2 mg/l at the corresponding outlet.

In order to have a control of all the gravity system, a free chlorine sensor and another dosing pump will be placed on the main outlet, after the joint of the different outlets. The sensor will check the FRC of the chlorinated water coming from the reservoirs and will give the input to the dosing pump to increase or decrease the concentration of chlorine at the outlet.

Each pumping point is provided by 4 booster pumps, these pumps must switch automatically each 6 hours.

We suggest considering offers where brine saturators are provided of automatic agitator system. In our opinion, it's not a necessary solution and increases the power requirement, but it is possible that the producers could propose this kind of solution according to the technology of the proposed devices.

4.4 Maintenance

Cleaning and maintenance must only be carried out by authorized and qualified staff.

The operators working on cleaning and maintenance must receive an adequate formation from device producer.

The operators must shut down and separate the plant before any work at systems, components and lines and respect any security standard suggested by the manual of maintenance of the device.

The maintenance must be periodic and respect a schedule that could be different depending on the device.

In this document we suggest a tentative schedule to give an idea of the main operational and maintenance actions, but the operators must follow the schedule suggested by the producer of the installed device.

4.4.1 Weekly maintenance

Once a week an operator must check the level of brine tank and re-fill with salt, if necessary.

Once a week the Electro chlorinator should be visually inspected by operational staff to look for signs of leaks, calcium carbonate precipitation on the electrodes, correct running volt levels of the electrolyzer, salt levels in the brine tank, water softness, and product strength.

4.1.2 Monthly maintenance

- Visually inspect electrodes in electrolyzer cell
  Only acid-clean, if significant scale has built up– Unless there is a softening fault, or poor quality water/salt is being used, there should be no need to acid-clean more frequently than at the two-year maintenance.
- Check electrical connections for signs of overheating and tighten, if required.
- Check that the protective insulation is installed properly.
- Fill in operator's log.

4.4.3 Six Month maintenance

Inspect the operators log to look for any trends which may indicate the failure of key components.

- Check all lines are free of restrictions/blockages or air traps.
- Check correct operation of the brine tank float valve.
- Check electrolyzer connections at both the electrolyzer and the PLC control to ensure there is no corrosion or loose connections.
- Check all hydraulic fittings are tight and show no signs of leaks.
- Check correct operation of air flow sensor.
- Check high and low volt alarms.
- Inspect all electrical components for signs of wear / burnout, replacing if necessary.
- Manually force the water softener into regeneration and test the water softness.
- Check dosing pump flow rate (dosing pump option only)
- Complete all checks required for a weekly inspection and complete operators' log.

4.4.4 Two yearly maintenance

Every two years the Electro chlorinator unit should be given an overhaul replacing all high-risk components, this service can take the place of the second yearly service.

As this service involves the removal and replacement of key components to the Electro chlorinator, one-day shutdown should be planned to let the competent and properly trained engineer to complete the service. The system should be correctly electrically isolated where necessary to complete the tasks safely. The engineer should ensure that the product storage tank contains enough hypochlorite solution to allow the site to continue dosing while the Electro chlorinator is isolated.

- Remove and overhaul solenoid valve replacing any worn of leaking seals, replacing the 24V actuator.
- Remove and replace brine tank float valve.
- Remove the water softener and replace the Ion exchange resin, before replacing the water softener.
- Remove and replace PLC control temperature switch.
- Inspect electrolyzer for any signs of precipitation / wears on the electrodes, acid washing if necessary.
- Inspect all fasteners for signs of hypochlorite corrosion and replace if necessary.
- Remove and replace run and fault relays.
- Remove and replace MCB's.
- Remove and replace the power supply.

As this replaces a scheduled service all of the actions detailed for the yearly service should also be undertaken and the operators log completed.

4.4.5 Five Years maintenance

After five years of maintenance, it could be necessary substitute the electrolytic cells. Some producers declare that, if the management it's perfect, the cells could be substituted each 7 years.

4.5 Chlorination equipment

The chlorination technology choice is the aim of the present study report. The technology chosen is the electro chlorination system for the production of sodium hypochlorite on site, with an automatic dosing system to inject the chlorine solution in the pipes.

The chlorination system will be composed of:

4.5.1 Pumping units

They are all provided with duty and stand by ones

- Booster pumps: submerged or centrifugal pumping water from the east reservoir to the softener, the choice between submerged and centrifugal depends on the geometry of the reservoir actually unknown.

Technical specifications:

  - Pumped liquid: Drinking water
  - Liquid temperature range: 5 … 60 °C
  - Flow rate: 100 l/minute

- Power (P2) main pump: 1.1 kW
- Hydraulic head: 10 m
- Mains frequency: 50 Hz
- Rated voltage: 3 x 380-415 V
- Rated current: 8.1 A
- Start. method: electronically
- Enclosure class (IEC 34-5): IP54
- Maximum operating pressure: 16 bar
- Maximum inlet pressure: PN 16 bar
- CE Marking

- Feed booster pumps: From the softener to the salt saturator

Technical specifications:

- Pumped liquid: Drinking water
- Liquid temperature range: 5 … 60 °C
- Flow rate: 100 l/minute
- Power (P2) main pump: 1.1 kW
- Hydraulic head: 10 m
- Mains frequency: 50 Hz
- Rated voltage: 3 x 380-415 V
- Rated current: 8.1 A
- Start. method: electronically
- Enclosure class (IEC 34-5): IP54
- Maximum operating pressure: 16 bar
- Maximum inlet pressure: PN 16 bar
- CE Marking

- Brine pumps: from the salt saturator to the chiller

Technical specifications:

The pump must be specific for brine and can be made of: Polypropylene, Polyvinylidene Fluoride (PVDF), Polyvinyl chloride (PVC) or Stainless steel.

316Ti (AISI)

- Pumped liquid: Brine
- Digital dosing pumps
- Liquid temperature range: 5 … 60 °C
- Flow rate: 10 l/minute
- Power (P2) main pump: 1.1 kW
- Hydraulic head: 10 m
- Mains frequency: 50 Hz
- Rated voltage: 3 x 380-415 V
- Rated current: 8.1 A
- Start. method: electronically

- Enclosure class (IEC 34-5): IP54
- Maximum operating pressure: 16 bar
- Maximum inlet pressure: PN 16 bar
- CE Marking

4.5.2 Water softening

- Softener: for the reduction of hardness, if required

Technical specifications:

- Pumped liquid: Drinking water
- Liquid temperature range: 5 .. 60 °C
- max 150 l/min
- Maximum operating pressure: 16 bar
- Maximum inlet pressure: PN 16 bar
- Rated voltage: 3 x 380-415 V
- Rated current: 8.1 A
- Start. method: electronically
- Enclosure class (IEC 34-5): IP54
- NSF/ANSI 44 (The scope of NSF/ANSI 44 includes material safety, structural integrity, the accuracy of the brine system, product literature, and the reduction of hardness and the reduction of specific contaminants from a known quality water source).
- CE Marking

- Tank: storage of softened water

Technical specifications:

- high-density polyethylene tanks of 23 m3
- 82/711 EEC, 90/128 EEC and 92/39 EEC
- Recycling: Polyethylene up to 100%
- Provided with level indicator
- CE Marking

4.5.3 Salt saturator brine tank

Technical specifications:

- GRP (Glass Reinforced Plastics)
- Brine Storage tank 7 m^3 usable capacity (2x100%) with fittings, ladder, safety cage and hand rails
- ASTM standards
- Provided with level indicator and brine sensor
- CE Marking

4.5.4 Chiller

Technical specifications:

- Power: 3.5 kW
- Max flow 4.5 mc/h
- Tmin +5C° Tmax +15 C°
- EN 14511, AHRI standard 550/590
- CE Marking

4.5.5 Filters

Technical specifications:

- 20 mm, 10'' (x 2 pieces)
- NSF61 Certification
- CE Marking

4.5.6 Hypochlorite Generation Units

Technical specifications

- output capacity 180 kg/d total flow 5.7 m^3/d

It has to be associated with the following equipment:

Electrolyzer - Cell high temperature switch on the last cell of the series only, cell level switch on each cell, DC cable connectors + & - end of each cell, low brine inlet temperature switch, pressure sensor, flow sensor and temperature sensor combo unit, drain flow switch, brine pump, sample ports, grounding targets, DC cable jumper interconnecting multiple cells and automatic Acid Cleaning system.

Electrolytic Cells –DSA titanium electrodes temp/level controls, DC Copper connection points and safety covers, assembled in Acrylic cell housing

The electrolyzer will be furnished of:

Transformer/rectifier appropriate to its working specifications.

Motor control center will drive the water pumps, the dosing pumps and the valves.

Temperature sensors will check the temperature of the process.

The cell of the electrolyzer will be in a transparent shell to permit easy visual inspections.

PLC Control programmed to manage the electrolyzer, the pumps, the sensors and the valves.

International standards:

- Machinery Directive (2006/42/EC).
- Low Voltage Directive (2006/95/EC).
- Standard used: EN 61010-1:2001 (second edition).
- EMC Directive (2004/108/EC).

- Standards used: EN 61326-1:2006, EN 61000-3-2:2006 + A1:2009 + A2:2009, EN 61000-3-3:2008
- CE Marking

The Hypochlorite Generation Units furniture will comprise the adequate following sensor for plant operating:

Low Pressure Alarm

Flowmeters

Flow regulators

Pressure indicators

4.5.7 Sodium Hypochlorite Storage Tank

Technical specifications:

- GRP Sodium Hypochlorite storage tank having 68 m3 usable capacity (x4) with fittings, ladder, safety cage and hand rails.
- ASTM standards, BS 4994:1973
- Provided with level indicator
- CE Marking

4.5.8 H2 blower

Technical specifications:

- Power: 2.2 kW
- Flow: 3600 lt/min (x 6)
- CE Marking

4.5.9 Flowmeter installation

A flowmeter must constantly measure the flow in the main inlet pipes to control the injection of chlorine solution in the relative pipe.

The injection of hypochlorite will be done in a pipe of ND 700 and a pipe of ND 550, information on the diameter of the pipes come from the maps and answers given by GVWC.

4.5.9.1 Pipe ND 700 Flowmeter

A flowmeter will be put on the inlet ND 700 pipe above the reservoir, the exact point is indicated in the topography map.

The flowmeter will be an electromagnetic flow sensor for pressure pipes ND 700. The Contractor shall specify the selected equipment according to the specific site conditions and describe the setup of the equipment with all necessary fittings (reducers, adaptor connecting piece, etc.).

The present flowmeter must respect, as minimum necessary requirement, the following specs:

- Measuring pipe:
  - ND 700
  - Body and flanges: carbon steel
  - Measuring tube: stainless stain
  - Electrodes: stainless stain
  - Protection category: IP 66
  - Inner lining: neoprene/PTFE/customer
- Electronic control unit:
  - Remote control
  - Bi-directional measurement
- Accuracy:
  - Maximum typical accuracy: no more than 1% of the measured value for flow rates between 4% and 100% of the full scale set.
- CE Marking

4.5.9.2 Pipe ND 550 Flowmeter

On the present market electromagnetic flowmeter for ND 550 are not sold because the diameter of the pipe is out of market, in this case it is preferable to use an ultrasound non invasive clamp-on flow meter.

This type of flowmeter fires ultrasound through the pipe wall at 90 degrees to the flow via a tangentially mounted high-output ceramic. Ultrasound is refracted at angles across the axis of the flow and is then reflected from bubbles, particles and vortices in all directions and at a wide range of frequencies.

The returned signal is analyzed by a digital signal processing platform to derive flow information. The platform analyses and integrates the received signals over a wide frequency range, then slices them for real-time analysis and flow rate calculation.

The present flowmeter must respect, as minimum necessary requirement, the following specs:

- Clamp-on transducer for pipes ND 550
- Communication port: RS 232
- Maximum fluid speed: 12 m/s
- Accuracy: ± 1 % of measured value
- CE Marking

4.5.10 Free Chlorine sensor

A free chlorine sensor must constantly measure the Free Residual Chlorine in the output pipe to control the injection of chlorine solution in the relative pipe.

The present free chlorine sensor must respect, as minimum necessary requirement, the following specs:

- Amperometric sensor

- Measuring range: 0 to 4 mg/l
- Cross sensitivity: Bromine, ozone and ClO2 (chlorine dioxide)
- Temperature Range: 0 to 45°C
- Communication port: RS 232
- Maximum Pressure: 8 Bar
- Flow Range: 7.6 – 303 l/h
- Accuracy: ± 2 % of measured value
- CE Marking
- There are two possible solutions to bring the water to the free chlorine sensor:
- A welded socker with a sluice valve:

The welded socker must respect, as minimum necessary requirement, the following specs:

- ND 25
- EN 10226-1
- CE Marking

The sluice valve must respect, as minimum necessary requirement, the following specs:

- ND 25
- PN 16
- CE Marking
- TEE fitting.

The TEE fitting must respect, as mimic necessary requirement, the following specs:

- ND 700
- Adapt to connect with a steel pipe
- Derivation flange DN 200 or less
- Respecting ISO 2531
- PN 16
- CE Marking

On the TEE fitting it will be installed a reduction flange or a system of reduction flange

- ND 200 – 25
- Respecting EN 545
- CE Marking

The choice of the more appropriate joint has to be done after a direct inspection of the pipes and depends on the state of the pipes.

The option “b)” is more expensive but it is recommended on old and ruined pipes were a joint as described in the “a)” could have problems and last less years.

In the BoQ we consider the option b) as the more expensive case.

4.5.11 Injection point

A connection to inject the chlorine solution will be operated after each flowmeter and before the free chlorine sensor.

The Injection point it's composed by an Injection nozzles fixed on the pipe, to fix it could be necessary one working day with water flow interruption.

The Injection nozzle must respect, as mimic necessary requirement, the following specs:

- DN 15
- Must have a non-return valve
- PN 10 bar
- Flow max: 1m^3/h
- CE Marking

4.5.12 Dosing Pump

The dosing pump must be designed for hypochlorite pumping:

Technical specifications:

- Flow rates: 937.5 l/h
- Power: 7.5 kW
- Max pressure 12 bar
- Ambient temperature: -10°C +40°C
- Fluid operating temperature: 0°C - +50°C
- Accuracy ± 1 % on the turndown ratio 10:1
- Double diaphragm and diagnostic of the rupture
- API 675 compliance
- CE marking
- ATEX II 2 G c IIB T4 compliance
- Protection: IP 55
- Epoxy painting at 125 micron
- CE Marking

4.5.13 Air Blower

To guarantee an air ventilation and avoid system overheating it is necessary and air blowing system in the Electrolyzer room.

The air blower must respect the following specifications:

- Air flow 3600 m^3/h
- EN 60079-0
- EN 60079-7
- EN 61241-0
- EN 61241-1
- Temperature range 0°C – 50°C
- IP 65

- CE Marking

4.5.14 Piping[1]

4.5.14.1 Feed pipes

Technical specifications:

The chlorination system will be fed through an ND 25 mm HDPE pipe from the reservoir to the dosing pumps connection.

- EN 12201
- ISO 4427
- EN ISO 15494
- EN 1622
- CE Marking

4.5.14.2 Injection pipes

Technical specifications:

The hypochlorite solution will be transported from the NaOCl tanks to the injection point through an ND 25 mm HDPE pipe.

- EN 12201
- ISO 4427
- EN ISO 15494
- EN 1622
- CE Marking

4.5.14.3 Plant pipes

Technical specifications:

The internal plant pipes will be an ND 25 mm HDPE pipe.

- EN 12201
- ISO 4427
- EN ISO 15494
- EN 1622
- CE Marking

[1] The definitive ND of pipes and configuration depends on the producer and the procurement constructor

4.5.15 Valves[2]

4.5.15.1 Ball Valve

All valves must be driven by the plant control system to switch the pumps and any operating necessity.

Technical specifications:

- ND 25
- Electric actuator
- Max pressure 10 bar
- EN 61010-1,
- EC directives 2004/108/EC (EMC) and 2006/95/EC
- CE Marking

4.5.15.2 Ball check Valve

Technical specifications:

- ND 25
- Max pressure 10 bar
- CE Marking

4.5.15.3 Pressure Regulating Valve

Technical specifications:

- ND 25
- Electric actuator
- Max pressure 10 bar
- EN 61010-1,
- EC directives 2004/108/EC (EMC) and 2006/95/EC
- CE Marking

4.5.15.4 Flange Connection

Technical specifications:

- ND 25
- Max pressure 10 bar
- EN 1092-1
- CE Marking

[2] The definitive ND of valves and configuration depends on the producer and the procurement constructor

4.6 Electro chlorination Spare Parts

Spare parts depend on the producer and the product. We evaluate that the following list would be a good spare parts list but it depends on exclusively on the device.

4.6.1 2 Year spare parts

- 5 Cartridge Filter – Replacement Cartridges for filters
- 1 Temperature Sensor - 4-20 mA analog output to control panel
- 2 Tank Level Indicator – One level indicator each for the brine and hypochlorite storage tanks
- 2 Temperature Switch – 24vdc switch for electrolytic cell temperature monitor
- 1 Level Switch – 24vdc switch for electrolytic cell liquid level monitor
- 1 Solenoid Valve – 2-way diaphragm for use on electrolytic rack assembly
- 1 Differential Pressure Switch – For monitoring of hydrogen dilution system operation
- 1 Water Chiller Spare Parts Kits
- 1 Transformer/Rectifier Spares Kits

4.6.2 5 Year spare parts

- 15 Cartridge Filter – Replacement Cartridges for filters
- 3 Temperature Sensors - 4-20 mA analog output to control panel
- 6 Tank Level Indicator – One level indicator each for the brine and hypochlorite storage tanks
- 6 Temperature Switch – 24vdc switch for electrolytic cell temperature monitor
- 3 Level Switch – 24vdc switch for electrolytic cell liquid level monitor
- 3 Solenoid Valve – 2-way diaphragm for use on electrolytic rack assembly
- 3 Differential Pressure Switch – For monitor of hydrogen dilution system operation
- 3 Water Chiller Spare Parts Kits
- 3 Transformer/Rectifier Spares Kits
- 3 Booster pumps, one for each pumping station

5 ENERGY SUPPLY

The strategic importance of the electro chlorination plant requires an affordable energy supply system.

Sierra Leone offers a good solar irradiance during the dry season but the rainy season doesn’t guarantee an adequate insulation, a PV system should be extremely oversized to supply the plant.

Furthermore, the PV plant operates only during the sunny days, during night and rainy days it doesn’t work, so the plant needs another energy source. It could be possible to provide energy in non-operational conditions of the PV plant with a battery storage bank. In this case, the PV plant should be oversized, and the cost would increase for the big size of the needed PV plant and battery storage bank avoiding any economic appropriateness.

The most affordable energy supply system is a diesel generator working during grid blackouts and supported by an UPS to guarantee a no-stop service.

A PV plant can contribute to reduce the energy delivered by the grid, so the intent should be a complete self-consumption of energy produced by the PV plant during the solar radiation.

In this case it's necessary the installation of an Energy Manager System to manage the switching from the different energy systems: National Grid, Photovoltaic Plant, UPS and Diesel Generator.

5.1 Energy Manager System/UPS

The Energy Manager/UPS must guarantee the continuity of the service during national power grid shut down, it must switch to the diesel generator and maintain the power alimentation to the plant.

In the case of a problem with diesel generator, it must close all the necessary valves to avoid chlorine dispersion.

The Energy Manager System/UPS must respect, as minimum necessary requirement, the following specs:

- Output power: 90 kW
- Maximum output current: 200A
- Battery bank to guarantee the continuity of the service during national grid shut down
- Frequency: 50/60 Hz
- Efficiency: 95%
- Ambient temperature: 0°C- 50°C
- Relative humidity: 0-95%
- Supply Voltage 380 → 480 V
- Protection class: IP20
- Safety: IEC / EN 62109-1; IEC / EN 62109-2
- Software: IEC / EN 60730-1
- EMC: EN 61000-6-1; EN 61000-6-2
- EN 61000-6-3; EN 61000-6-4; EN 55011
- EN 61000-3-2; EN 61000-3-12
- EN 61000-3-3; EN 61000-3-11
- Performance: - IEC 61683
- IEC 62116
- IEC 61727
- EN 50530
- EC Marking

The battery suggested is Li-ion, lithium polymer or Ni-Cd.

5.2 Diesel Generator

The Diesel Generator must respect, as minimum necessary requirement, the following specs:

- Output electric power 90 kW
- N° phases: 3
- EN 590
- Water cooled
- Electronic governor
- Sound Attenuated Enclosure
- EC Marking

The Diesel Generator must be furnished of a fuel tank capable of giving almost 4 days of autonomy, it depends on the consumption of the Generator proposed, and we evaluate almost 2 m^3. It's preferable a sub-base fuel tank.

5.3 Air Blower

To guarantee an air ventilation and avoid batteries and electronic system overheating it is necessary and air blowing system in the control room.

We suggest discussing the air ventilation with Energy Manager System/UPS and inverters producer to respect the required standards of the installed devices.

The air blower must respect the following specifications:

- Air flow 3600 m^3/h
- EN 60079-0
- EN 60079-7
- EN 61241-0
- EN 61241-1
- Temperature range 0°C – 50°C
- IP 65
- EC Marking

5.4 Photovoltaic Plant

The total estimated annual consumption of the Electro chlorination plant is 533,630 kWh, the equivalent cost of this amount of energy due to EDSA is around 106,726 €/y.

We propose the PV plant to reduce the cost of electric energy.

The PV plant will be installed on the roof of the east reservoir with a nominal power of 60 kWp and it will be able to produce 95,700 kWh/y, that is the complete amount which will be consumed by the electro chlorination plant.

Cost, consumption, and saves are estimated considering an average cost of electric energy of 0,2 €/kWh (cost communicated by the EDSA).

5.4.1 PV plant

The main components of the PV plant are the following

5.4.1.1 PV panels

The PV panels must respect, as minimum necessary requirement, the following specs:

- Polycrystalline silicon modules
- Maximum power almost 250 W
- Efficiency >15%
- Weigh= 20 Kg
- Life time: >20 years
- Recycling: up to 95% of its weight

- Manufactured according to IEC 61215, IEC 61730 standard and CE
- UNI 9177 Reaction to Fire: Class 1
- Maintenance: ordinary surface cleaning and land care, avoiding vegetation's growth
- CE Marking

5.4.1.2 Supporting structures

- Supporting structure in galvanized steel
- Inclination of 20 °
- Life time: >30 years
- Maintenance: anti-rust for steel, five years
- Recycling: steel up to 100%
- CE Marking

5.4.1.3 DC equipment

- Insulated cables (copper or aluminum) and relative equipment
- Life time: >20 years
- Recycling: up to 100%
- CE Marking

5.4.1.4 Field switchboards-DC side/Parallel switchboard-AC side

Field switchboard-DC side must respect, as minimum necessary requirement, the following specs:

- made of PVC for outdoor use
- 4 inputs
- 4 channels
- Power IN= 230 VAC, equipped with release coil
- 1 parallel switchboard-AC side
- CE Marking

5.4.1.5 DC/AC Inverter

Field switchboard-DC side must respect, as minimum necessary requirement, the following specs:

- Power Rating 30 kW
- Phase 3
- Supply Voltage 380 → 480 V
- Current Rating 66 A
- Frequency: 50/60 Hz
- IP Rating IP20, IP21, IP41, IP54
- Output Frequency 0.1 → 1000Hz
- Control Panel Yes
- Ambient Temperature -10 → +50°C
- ANSI/ESD S20.20:2007
- BS EN 61340-5-1:2007
- Safety: IEC / EN 62109-1; IEC / EN 62109-2
- Software: IEC / EN 60730-1
- EMC: EN 61000-6-1; EN 61000-6-2

- EN 61000-6-3; EN 61000-6-4; EN 55011
- EN 61000-3-2; EN 61000-3-12
- EN 61000-3-3; EN 61000-3-11
- Performance: - IEC 61683
- IEC 62116
- IEC 61727
- EN 50530
- CE Marking

5.4.2 Operation and maintenance

Safety is a serious concern when servicing PV installations. Safety considerations require that qualified personnel use properly rated equipment and be trained for servicing the higher voltage systems.

A solar PV plant requires the following types of maintenance

Preventive Maintenance (PM) which includes routine inspection and servicing of equipment which help prevent breakdowns and reduce energy yield losses. PM is usually a scheduled activity.

Corrective Maintenance(CM) or breakdown Maintenance(BM) includes repair of broken down equipment and is usually reactive.

Preventative Maintenance (PM)

Panel cleaning (~1-2x/year or as needed)

Water drainage (variable)

Retro-commissioning (1x/year)

Upkeep of data acquisition and monitoring systems (e.g., electronics, sensors)

Upkeep of power generation system (e.g., inverter servicing, BOS inspection, tracker maintenance (~1-2x/year)

Visual check of cables and connections (every two week)

The quick vegetation growth will be not a problem for the panels, because of their installation on the reservoir roof, but we recommend to clean often the space around plants and cables to avoid out of orders.

Corrective maintenance (CM)

We suggest a Condition-based maintenance by active monitoring and warranty enforcement, the continuous monitoring will permit to programme equipment replacement which is strongly linked to the operating conditions.

5.5 Energy Mix

The Hybrid configuration, National Power Grid, Photovoltaic and Diesel Generator, is evaluated to work as the following graphic.

We considered the National Power Grid 75.4% of the time, almost 275 d/y.

The plant should work mainly during sunny hours (avoid the night when possible) to maximize the use of the energy produced by the Photovoltaic Plant.

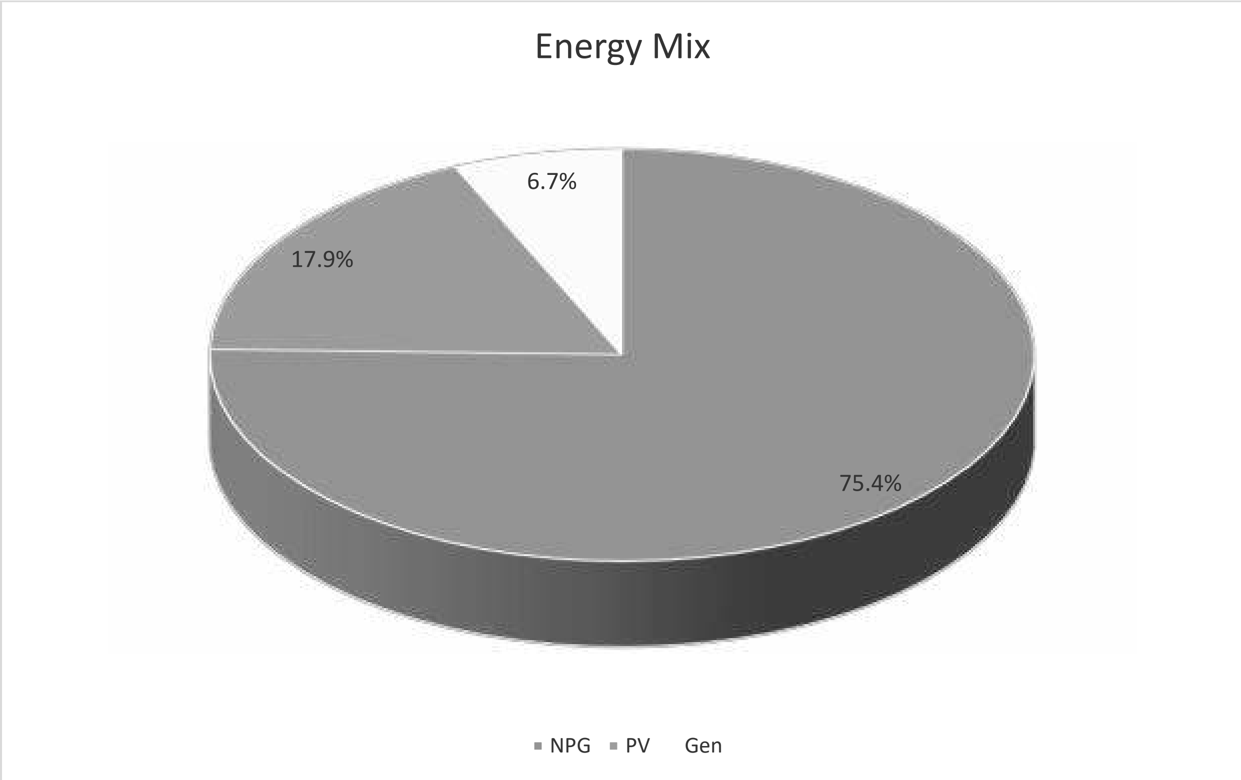

Figure 14 Energy Mix

5.6 Electrical layout

The following table shows the values of Power demand, obtained as a function of the loads powered

Table 10 Power demand

Load	Power: 87 kW
Generator	Power: 90 kW
Solar system	Power: 60 kW
National power (EDSA)	Voltage: 400/230 V. Frequency : 50 Hz. Transformer power: 630 kVA

The distribution of electricity is developed according to the diagram shown in Annex 11.4

It has to be considered as a general electrical sketch suggested, as the device has not decided yet

In the following figure it is shown the parallel of the different power sources to the load

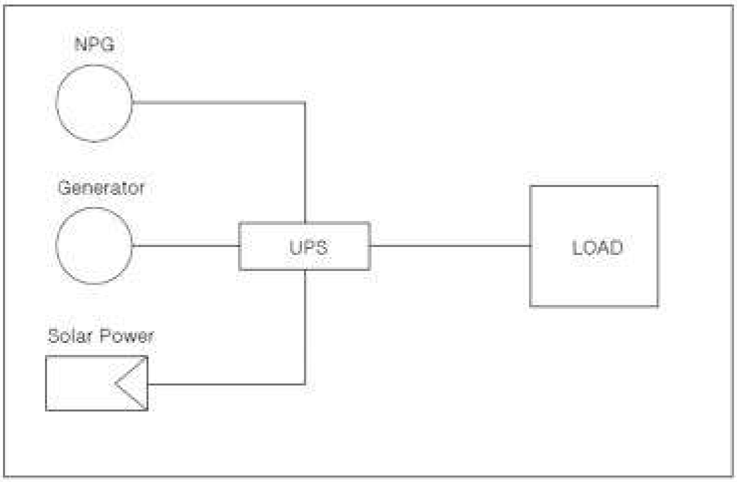

Figure 15 Electrical parallel with different power sources

Overload protection

Overload protection, made with circuit breakers, must meet the following assumptions:

Ib <In <Iz

where:

- Ib is the operating current of the line;
- In is the rated current;
- Iz is the cable capacity.

Indirect contact protection

The protection against indirect contact has to be ensured by the presence of differential modules in a suitable position. It is not currently possible to give exact specifications of the differential modules as the device has not been chosen yet.

Protection against indirect contacts is performed with an automatic interruption.

Since all the circuits of the general framework of low-voltage circuits are protected by differential protection.

For all the circuit breakers the it shall be stated the rated current of the differential intervention, the short time maximum current, the operating voltage and type of breaker (AC, A, B).

Sections of the conductors

Conductor sections have to be calculated in function of the power used and the length of the circuits (the voltage drop does not exceed 4%) will be chosen among those unified.

Ground plant and potential equalizing

The land system consists of:

Sinks

Ground conductor: that ensures the connection of the ground equipotential node with the dispersion plant;

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Ground collectors will be made with a copper bar perforated installed on suitable insulating supports

Equipotential connections, that ensures the potential equalization via the connection to the grounding of all extraneous conductive parts.

6 CIVIL WORK

6.1 Civil work structural design

6.1.1 Structural design of a building in concrete for all necessary Electro chlorination servicing

Structure 1 Structure 2

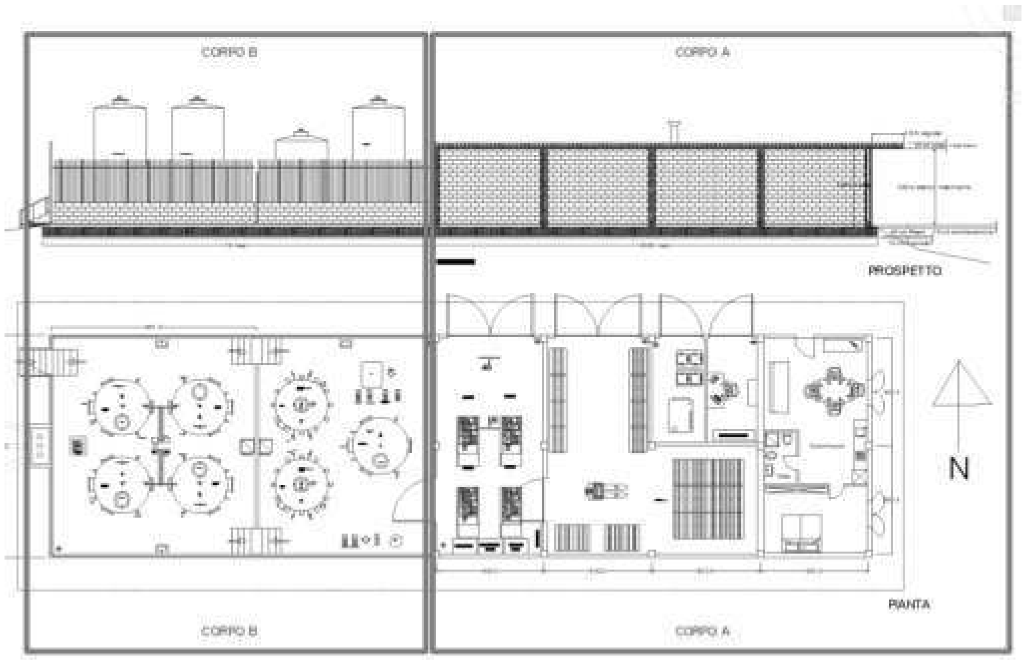

Figure 16 Structural design

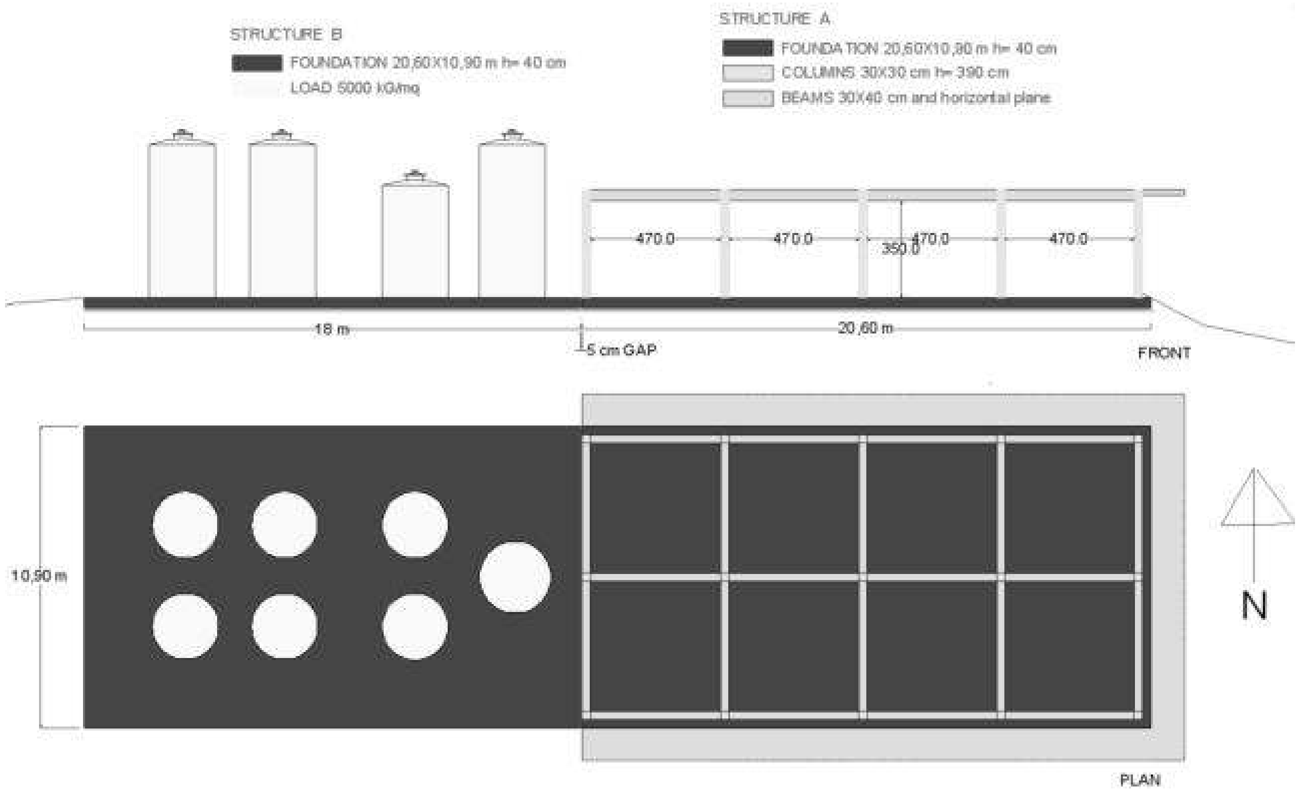

Figure 17 Global view

Following the analysis of the architectural design, structural design is divided into two separate parts:

Structure A and Structure B by a 5 cm of gap in the foundation.

In *Structure A* will be realized the offices, the generator room and all the services necessary for the chlorination of the water, in *Structure B* will be positioned the storage tanks and the foundation is designed to withstand such loads (5000 kg/m^2).

STRUCTURE A: Building at a single elevation, with foundation mat high 40 cm in reinforced concrete **C25/30** with steel **B450C** (plan dimension 20,60 x 10,90 m), resting on 10 cm of lean concrete, 15 columns (dim. 30x30 cm) and beams (dim. 30x40 cm) in reinforced concrete **C25/30** with steel **B450C** with a regular distribution in plan, as in figures below, and flat roof in reinforced concrete and hollow tiles mixed floor (h=21 cm).

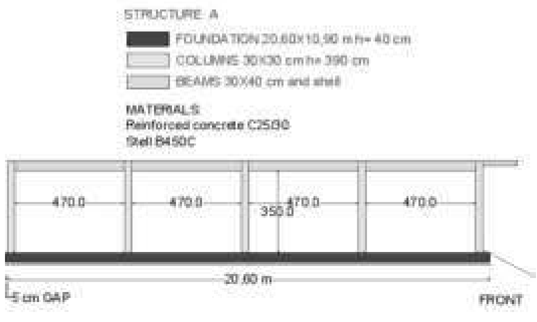

Figure 18 Structure A Front View

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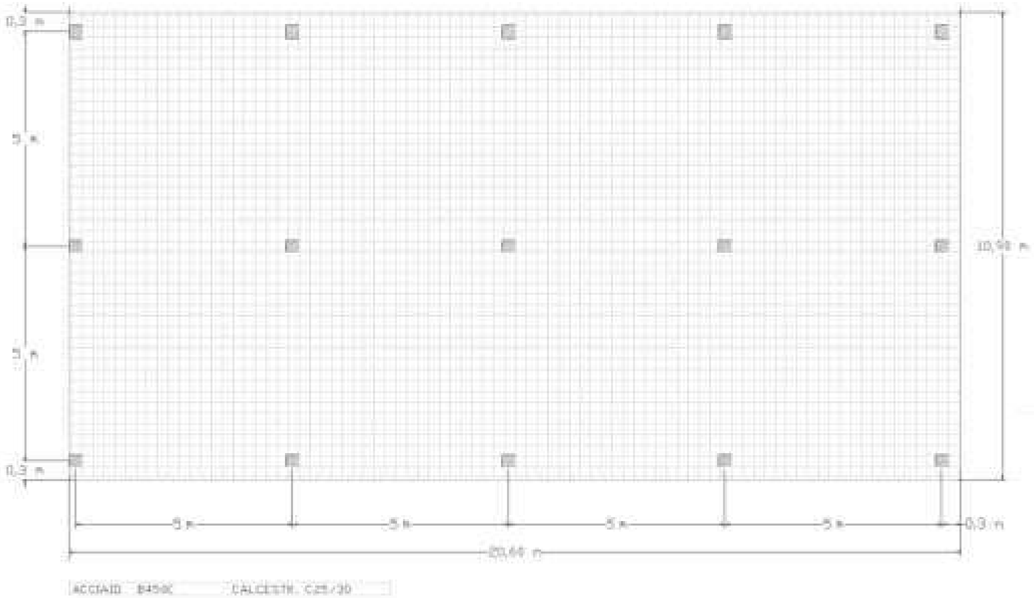

Figure 19 Structure A – Foundation mat

Structure B:

Structure B is a foundation mat high 40 cm in reinforced concrete **C25/30** with steel **B450C** (plan dimension 20,60 x 10,90 m), resting on 10 cm of lean concrete. Over this concrete bed on which will be placed two water tanks by 10 m^3, one to 15 m^3 and four 20 m^3 as well as various pumps, filters, pipes, etc.

Figure 20 Structure B foundation mat (iron net)

Geological characteristics of the site.

The subject of structural design work is located at an altitude of about 100 meters above sea level.

Geological report (see chapter 3.3.1.3) said that the site is flat, there is no slope and it is not affected to differential soil compactation. The soil is homogeneous and is forecast landslides in this area. The land is not clay, nor is loose sands. It is carried over and alteration of hard lava rocks, compacted, non-porous rock

above blocks of metric size (same composition hard magmatic rocks) at low depth.
Foundations are only provided to anchor the buildings to the ground, to counter the only risk is that by flooding for heavy rains.

During the insertion of the elements in the calculation software, it has been considered a flat area of Catania (Sicily) with similar characteristics including the ant seismic ones (for Earthquake risk of the area see Chapter 3.3.1.4). It is worth to outline that structures parameters used in this study are the ones standard for Catania (Italy) which is a high seismic risk area in Italy.

6.1.2 GENERAL INFORMATIONS ON THE ANALYSIS DONE

APPLICABLE LAW

D.M 14/01/200 - Italian "Nuove Norme Tecniche per le Costruzioni".

MEASURE OF SAFETY

The safety verification method adopted is that of the Member Limit (SL) which provides two sets of controls respectively for the states last limit and limit states.
The safety is therefore guaranteed by designing the various elements resistant so as to ensure that their resistance calculation is always greater than the corresponding question in terms of computing actions.

CALCULATION MODEL

As models of computation those explicitly mentioned in the Italian laws D.M. 14/01/2008.

7 SALT

An assessment has been done by the consultant about the possibility to provide salt of high quality to the system, giving a great attention to the local companies in order to stimulate local economy.

Two salts producers have been identified in the Country with the support of GVWC, both currently closed at the time of the consultancy because of the rainy season.

They are:

Fogbo, a coastal fishing village in the Western Area Rural District of Sierra Leone (proximity to the town of Tombo).

Mapotolo, in Kambia District (near the Guinea border). In this case it was not possible to take a sample because the road was not accessible due to rain.

Also a company supplier in Freetown (Benco) importing salt from Senegal has been identified. They provided to us their own salt analysis (see ANNEX 11.5).

To avoid corrosion and fast aging of electrolytic cells some salt composition parameters need to be respected.

In order to guarantee a high quality of salt minimum requirements have to be respected.

We considered the US standard (NFS/ANSI Standard 61), that establishes minimum requirements to minimize adverse health effects from contaminants.

The consultant analyzed 2 samples of salts (from Sierra Leone and from Senegal). The tests have been done by one of the best laboratories of the town, Ramsy Medical Laboratories, and results are showed in the table below:

Table 11 Salt Analysis

Category	Analyte	Units	Detection limits of the Lab instrument	Results (Fogbo)	Results (Senegal)	US Standards
Total metals	Arsenic	mg/l	0	0	0	0.001
	Chromium	mg/l	0.02	0.33	0.1	0.01
	Copper	mg/l	0.03	2.1	1.1	0.13
	Lead	mg/l	0.002	<0.002	<0.002	0.0015
	Bromate	mg/l	N.A.	N.A.	N.A.	0.003
Quality indicator	% Sodium Chloride			96.82	98.24	Depends on the device

In annex 11.5 the lab test analysis of the salt samples.

All the data available of 3 salt providers are summarized in the following data

Table 12 Information of the salt investigation

Salt Provider	Price (SLL)/ kg		Transport	Distance	Composition (for USA Standard)	Contact person
	Rain season	Dry season (production)				
Benco (imported from Senegal)	1520.08	1520.08	Not included	Freetown port	Almost good	Jiad Swaid (077605800)
Fogbo	1466.67	1000	Not included	Around 50 Km	mediocre	Almamy J. Kargbo (077570797)
Mapotolo	1000	1000	Not included	Around 135 Km	Not analyzed	Almarmy M. Conteh (078028052)

From our investigation, we can say that the salt from Senegal is more suitable, even if it doesn't meet all the requirements. For this reason we suggest, just at the beginning, to import salt from Europe.

In the meantime, we suggest pushing local producers to improve their quality in order to reach the required standards in the time.

8 ECONOMIC VIABILITY

According to our investigation, the Electro chlorination in Spur is the best solution for an intermediate chlorination. Due to some relevant externalities, it is not possible to establish the economical affordability of the Electro chlorination in Spur road compared to the hypochlorite chlorination proposed at Tower Hill from Veolia.

The table below shows some general data available from previous Veolia Feasibility Study compared to the present study.

Table 13 Comparison table: Veolia Feasibility Study VS CIRPS/GSF Feasibility Study

	Veolia (2014)	CIRPS-GSF (2016)
Location	Tower Hill Reservoir	Spur Road Reservoir
Technology	Calcium hypochlorite chlorination	Electro chlorination
Max Yield treated	1,000 m^3/h	3,708.000 m^3/h
Chlorine produced	1 Kg/hour	7.5Kg/hour
Max injected chlorine	1 mg/l	2 mg/l
# Beneficiaries	254,000 inhabitants	700,000 inhabitants (including Tower Hill)

As it is possible to see from the table, the coverage of water treated and reached people of the present study is much greater. It is not possible to evaluate the economic value of contributing to avoid a new cholera outbreak and value of lives saving and/or the medical care cost for other water-related illnesses.

8.1 Economic viability of the Electro chlorination at Spur Road Reservoir

The Electro chlorination systems are characterized by relevant Capital Expenditure and low Operational cost.

The BoQ of the present feasibility study are the following.

Table 14 BoQ Summary

	Spur Road Electro chlorination System	AMOUNT IN €	AMOUNT IN SLL	AMOUNT IN USD

F.1	CIVIL WORKS	€ 155,800.42	SLL 1,110,044,205.05	$ 174,948.29
F.2	CHLORINATION SYSTEM	€ 546,837.42	SLL 3,896,097,986.59	$ 614,043.74
F.3	ENERGY SUPPLY	€ 71,350.00	SLL 508,353,271.33	$ 80,118.92
F.4	PHOTOVOLTAICS	€ 178,000.00	SLL 1,268,211,384.68	$ 199,876.20
F.6	OPTIONS	€ 115,000.00	SLL 819,350,051.90	$ 129,133.50
	TOTAL	€ 1,066,987.84	SLL 7,602,056,899.55	$ 1,198,120.65

The complete BoQ is consultable on the Annex 11.7.

The total amount includes spare parts for 5 years of operations and maintenance of the plant, their cost is 67,342 €.

The business plan, Annex 11.8, includes the separate operative cost of:

- Salt cost, for the yearly salt cost it's considered a total cost of 200 €/ton as the price of the salt from Senegal sold by Beko, we considered it ; a local salt would cost at maximum 410 €/ton including shipment cost from EU.
- Energy Consumption Power Grid, energy bought from EDSA each year, we consider 341 days of furniture, in these days is considered the self-production of energy with a PV plant which offers the opportunity to reduce the total amount of 19,140 €/y.
- Diesel Consumption, it is the consumption of the diesel generator to work 24 days, in National Power Grid breakdown, for the consumption, it is considered a consumption of 21 liters/h.

- Spare parts, we considered separately specific Electro chlorination System spare parts and generic spare parts for this kind of industrial plant.

The NPV value after 20 years is € € 3,839,600.24.

The following graphic indicates the cumulative cost of the plant in 20 years.

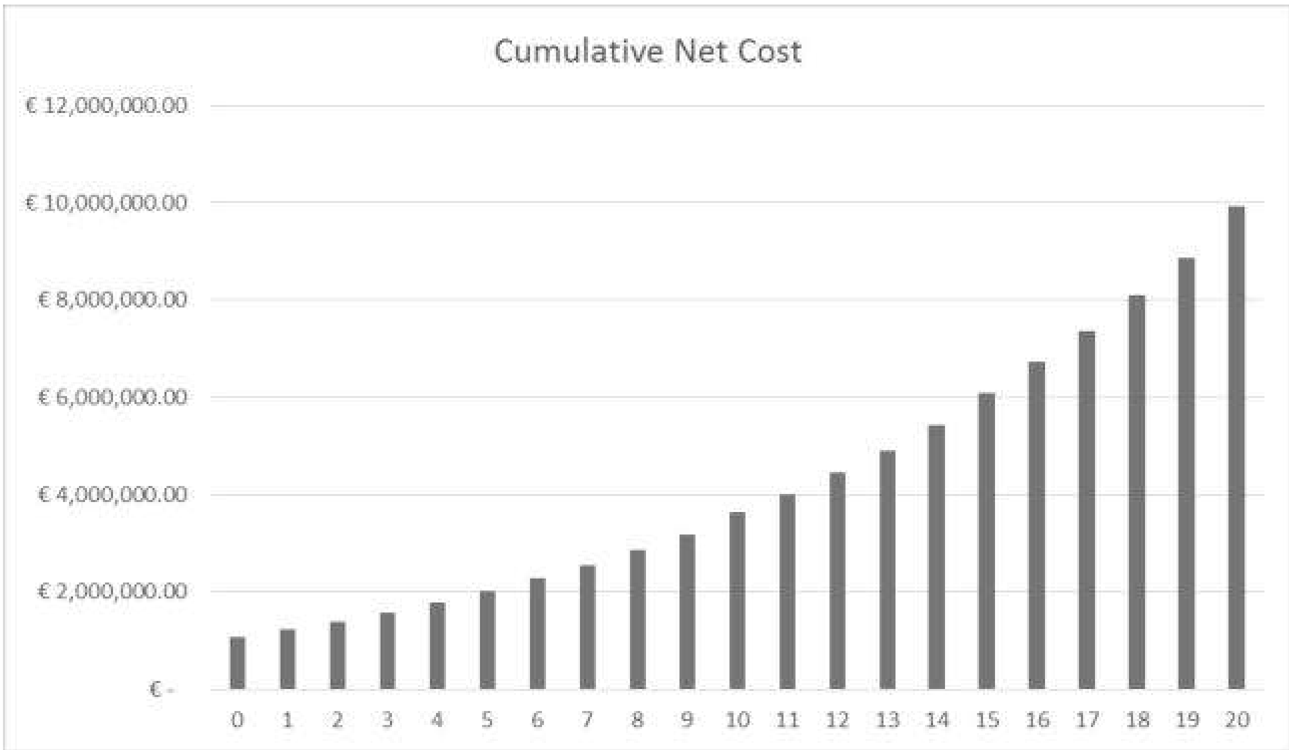

Figure 21 Cumulative Net Cost

The economic evaluation considers net present costs.

9 KEY FINDING AND RECOMMENDATIONS

For a centralized Electro chlorination system of the low zone of Freetown water network, Spur Road Reservoir represents the best location for installation of the elctrochlorination system.

The Electro chlorination system proposed in this study is sized to ensure a maximum production of 7.5 kg/h of active chlorine.

Since the maximum expected inflow in spur road is 89,000 m^3/d, the electro chlorination device allows an injection of chlorine at the concentration up to 2 mg/l.

The injection will be done in two steps:

1. The first step will be done in the inlet pipes of the reservoirs
2. The second step will be done in the outlet pipe

This configuration will permit a total flexibility of the injection in order to guarantee a maximum concentration of chlorine of 2 mg/l measured by the outlet sensor.

The chlorination system will be completely automated, the injection pumps in the inlet are controlled by the inlet flow meter, while the outlet injection pump is controlled by an FRC sensor.

The electro chlorination will be supplied by hybrid power sources (NPG, PV, Diesel Generator).

9.1 Recommendations

- Implementation phase

The selected company must ensure, for the implementation phase, some preliminary activities:

  - Excavation in order to locate the exact position and the depth of the inlet and outlet pipes for the injection pumps installation. It will also allow verifying the position of the pipes on the topographic map if needed.
  - Carryout almost two cores at two ends of the new building construction area to confirm the depth of the rocks
  - Renovation of entry road

- Reservoirs study

A complete study of the two reservoirs will have the aim of producing a model of structures and water flow in order to evaluate:

  - Internal state of the structures
  - Reservoirs planimetry
  - Identification of inlet and outlet pipes
  - Evaluation of water permanence time, eventual to calculate the contact time
  - Evaluation of possible short-circuits or recirculation in the reservoirs

- Capacity building

Training to be done for electro chlorination operators: at least 6 technicians for two weeks

- FRC Monitoring system at distribution level

It is needed an FRC monitoring by mean of pool tester (or similar devices) at the following strategic points of the low zone water network, with weekly frequency:

In all main Freetown reservoirs

At the main distribution points/ kiosks

This FRC monitoring and data analysis has double target:

To check the efficiency of the electro chlorination

To set the injection value of chlorine at the outlet of Spur Road Reservoir

- Salt procurement and storage

Storage should not be for more than 3 months, in order to avoid to be spoiled by humidity.

We suggest pushing the local producers to improve the quality of salt (international standards have to be respected) in order to use it in the future and foster local economy.

- Photovoltaic Plant

Before the design of the PV plant, it is necessary a structural study of the reservoir, the study will investigate the effect of the weight on the reservoir roof.

9.2 Final considerations

This project develops an important update to the state of progress concerning the drinking water service in Freetown, in particular on specific aspects that have already been studied and resolved in the designs described in the report.

It should be emphasized that this report makes feasible the next steps i.e. the purchase, implementation and achievement of objectives in a short time.

This project makes possible the activation of a treatment unit that guarantees adequate disinfection before distribution to users, injecting proper chlorine values in order to prevent a possible microbiological attack, which represents one of the most critical aspects of the Water Service.

This intervention can become the first example in time and modality of the best-practice intervention of rehabilitation (and upgrading) of drinking water service.

The choice of the installation point (Spur Road Tank) provides to the maximum possible number of service utilities, with an application that could be ready in a very short time and strategic for the future.

As already planned for the future from GVWC, it is necessary to start the simultaneous beginning of several adjustment paths as qualifying, recovery, modernization of the service in its entirety and supplying pipes, valves, civil works and control systems.

The past reports of Projects and Planning, carried out during last 8 years, stated the bad conditions of the networks, service works and machinery, confirmed during our investigations.

This condition is, mostly, due to a not proper maintenance, which should be a primary goal of the service to ensure an adequate quality of the service.

It is also necessary a quick start up of a well-organized Management System, to reach a sustainable level of functionality and productivity.

9.2.1 Adaptation and evolution paths:

- Knowledge of the reality of the service equipment.
  Adaption of the existent Geographic Informative System (GIS) to the territorial services, this tool must be able to verify in real time the state of the distribution network and FRC and locate critical points. This tool will permit an easy setting of the hydraulic parameters to improve the management of the whole water network
- Collection, updating and correlation of the various instruments of design management

- Improvement of tools of the GVWC: Technical Scientific and Financial tools required to ensure the maintenance of the service
- Organization of a Management Manual of ordinary and extraordinary activities
- In case of necessity, due to local problems of the distribution network, evaluate the possible installation of local intermediate chlorination point

10 REFERENCES

Guidelines of drinking water, WHO, 2011

Chlorine in drinking water, WHO, 2003

Manual of Water Supply Practices—M65, First Edition, On-Site Generation of Hypochlorite, AWWA, 2015

White's handbook of chlorination and alternative disinfectants. – 5th ed., 2010

ATKINS main report 2008

Workshop presentation Freetown Strategic Water Supply and sanitation Framework 13th march 2008

Feasibility studies of intermediary disinfection on GVWC October 2012

Strategic water supply and sanitation framework DFID August 2008

Intermediate chlorination feasibility study Freetown, Sierra Leone (ACF-Veolia) 2014

Water network Renovation plans (in progress and future)

Updated current general network sketch of the whole network

Topography maps, scale 1:2500, GVWC.

General network sketch of Spur Road Reservoir (Veolia Report)

National Power Energy bills at Spur Road Reservoir

PV System Operations and Maintenance Fundamentals, www.solarabcs.org, Josh Haney, Adam Burstein, Next Phase Solar. Inc. 2013.

11 ANNEXES SUMMARY

11.1 Topography and sketch

Georeferenced Map of Spur Road Reservoir, detailed topo map of construction and installation area; topographic map in scale 1:2500 DWG, PDF, Spur Road Reservoir functional hydraulic sketch

11.2 Drawings

Electro-chlorination plant and civil engineering works in CAD (PDF and DWG format)

11.3 Structural Design

Design and Calculations DWG, PDF

11.4 Energy

Guma Pumping Station-Spur Road-Spur Road.xls, electrical layout

11.5 Salt test

11.6 Water test

Hardness Water test analysis, FRC monitoring

11.7 BoQ

11.8 Business Plan

11.9 Portfolio (commented pics)

11.10 ToR

11.11 Answers to final comments