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DRAFT ROBERTSPORT WATER MASTER PLAN

LIBERIA MUNICIPAL WATER PROJECT

AUGUST 2012

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COVER PHOTO: The City of Robertsport, from the County Administrative Building, looking northeasterly towards the communities of Grassfields A & B with Fanti Town and Lake Piso in the background.

All photos in this report are by Tetra Tech, Inc.

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ACRONYMS AND ABBREVIATIONS

A&E IQC	Global Architecture and Engineering Services Indefinite Quantity Contract
AfDB	African Development Bank
APM	Advanced Participation Methods
CBO	Community-Based Organization
CDA	County Development Agenda
CHF	CHF International
COP	Chief of Party
COTR	Contracting Officer's Technical Representative
cfs	Cubic Feet per Second
DFID	UK Department for International Development
DIG	Development Innovations Group
ECHO	Humanitarian Aid department of the European Commission
EHELD	Excellence in Higher Education for Liberian Development
EMMP	Environmental Monitoring and Mitigation Plan
EPA	Environmental Protection Agency (Liberia)
EWG	Engineering Working Group
GEMS	USAID Governance and Economic Management Support Program
GF	Gender and Facilitation
GIS	Geographic Information System
GoAL WASH	Governance Advocacy and Leadership for Water, Sanitation and Hygiene
GoL	Government of Liberia
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HCC	Host Country Contracting

ICRC	International Committee for the Red Cross
IEE	Initial Environmental Examination
IIU	Infrastructure Implementation Unit
INGO	International Nongovernmental Organization
ISR	Institutional Strengthening and Reform
IWASH	USAID/Liberia Water, Sanitation, and Hygiene Project
IWRM	Integrated Water and Resources Management
LD	Liberia Dollar
LHS	Liberian Hydrological Service
LISGIS	Liberia Institute of Statistics and Geo-Information Services
L-MEP	Liberia Monitoring and Evaluation Project
LMWP	USAID/Liberia Municipal Water Project
lpcd	liters per capita per day
LWSC	Liberia Water and Sewer Corporation
M&E	Monitoring and Evaluation
MLME	Ministry of Lands, Mines and Energy
MoE	Liberia Ministry of Education
MoF	Liberia Ministry of Finance
MoHSW	Liberia Ministry of Health and Social Works
MoPEA	Ministry of Planning & Economic Affairs
MoPW	Ministry of Public Works
MOU	Memorandum of Understanding
NGO	Non-governmental Organization
NWRSB	National Water Resources and Sanitation Board
NWSHPC	National Water, Sanitation and Hygiene Promotion Committee
O&M	Operation and Maintenance
PMP	Performance Monitoring Plan
PSI	Population Services International
RFP	Request for Proposal
RoSCA	Rotating Savings and Credit Association
SA	Situational Analysis

SDC	Swiss Agency for Development and Cooperation
STA	Senior Technical Advisor
STA/M	Senior Technical Advisor/Manager
STTA	Short-Term Technical Assistance
SWA	Sanitation and Water for All
TWG	Transition Working Group
UL	University of Liberia
UL-PIRE	University of Liberia Pacific Institute for Research and Evaluation
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNMIL	United Nations Mission in Liberia
USAID	United States Agency for International Development
USD	Unites States Dollar
UWSSP	AfDB Urban Water Supply and Sanitation Project
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WSP	World Bank Water and Sanitation Program
WSSC	Water Supply & Sanitation Commission

EXECUTIVE SUMMARY

The Liberia Municipal Water Project (LMWP), funded by the United States Agency for International Development (USAID), will support the design, tendering, execution and operation of water supply infrastructure improvements in the cities of Robertsport, Sanniquellie, and Voinjama. LMWP will assist local and national authorities in developing plans for urban water supply and sanitation improvements, implementing short and medium-term water supply infrastructure improvements, and re-establishing local capability to sustainably operate and maintain the water supply improvements. During the four-year project base period, it is the goal of LMWP to help establish improved water supply access in each city, with infrastructure managed by locally-based entities capable of financially and technically sustaining the service. The improved water systems will provide public health and economic development benefits in the three target cities.

The responsibility for water service provision in urban areas (>5,000 population) and county capitals rests with the Liberia Water and Sewer Corporation (LWSC). The selection of the project's cities was done in consultation with the GOL who identified these three as priority cities for USAID assistance and USAID/Liberia has committed, subject to availability of funds, to support the GOL in improving water supply service in the three cities of Robertsport, Sanniquellie and Voinjama. This document is the Master Plan for the City of Robertsport.

Originally, it was planned to submit one Master Plan for the three cities at once. For scheduling purposes, it was commonly agreed with USAID since submission of the Situational Analysis report in April – to submit individual Master Plans for each city with the Robertsport Master Plan to be submitted first on the original due of the Draft Master Plan (August 31) and the Master Plans for Sanniquellie and Voinjama be respectively submitted end of September and end of October following finalization of the hydrogeological survey to be conducted.

The LMWP goal of establishing self-sufficient and sustainable water service provision necessitates a detailed understanding of existing technical, institutional and socioeconomic conditions, including customer preferences and ability and willingness to pay for water services.

The first major task of the project was the Situational Analysis (SA), designed to inform the subsequent design of appropriate infrastructure, management systems, and capacity building programs. The Master Planning stage is the second major task and precedes the actual detailed design and construction of both institutional and infrastructure systems to improve the level of water service to the City of Robertsport.

Former Municipal Water Systems

No portions of the former municipal water treatment and distribution systems were found to be operational, with the exception of the leaking raw water gravity main in Robertsport. Except for a limited number of components, most of the infrastructure from the previous municipal water system is not salvageable. The former water storage reservoirs and concrete structures at the treatment facilities and intake structure may be salvageable, subject to additional testing. None of the electrical, mechanical, and former distribution system piping and valves are salvageable. The majority of all mechanical and electrical components of the systems have been looted. Some transmission piping and some kiosks could potentially be salvaged and rehabilitated. Historic information related to the condition of the previous

water system, existing well locations, water quality, and other environmental and contextual data is limited due to lost or lack of record keeping.

Other Infrastructure Conditions and Challenges

Electricity from a public grid is not available in Robertsport, nor does any definitive plan to develop a grid-based power system appear to currently exist. Therefore, electrical power for future systems will need to be produced via generators, solar power, or other sources, at least in the short to medium term, and will represent a significant portion of operational costs.

Roadway access will be a significant challenge for the project, particularly during the rainy season when travel is slowed down by impassable roads. Travel challenges will increase operational costs and could delay the timely delivery of fuel and chemicals required for pumping and treatment activities.

The target cities generally lack the municipal infrastructure and service delivery experience that is necessary to support a fully functioning water supply system. Currently, the LWSC does not have any representation in Robertsport – except from a caretaker looking over the remnants of the water system infrastructure. There is a lack of experienced construction firms with water-specific construction experience in Liberia in general, and specifically in the target cities. Development of sustainable technology alternatives is also affected by the remote location of Robertsport resulting in challenges with respect to warranty service and supply of spare parts for maintenance.

Even with these various constraints and challenges the design and construction of a water system to improve access to water services for the residents of Robertsport can be accomplished.

Water Source Options

Although Liberia is fortunate to have high amounts of rainfall, the uneven distribution between the rainy season (April to October) and dry season (November to March) results in temporal fluctuations in surface water flows and quality.

The previously existing municipal water system in Robertsport relied on surface water. The former surface water supply watershed (Fasa Creek) remains mostly forested and has the best potential to serve as a long term source if watershed protection measures are established and implemented. Available information suggests that dry season flows in Fasa Creek can supply a safe yield of 8 liters per second and a withdrawal rate that is adequate to provide sufficient volume for a municipal supply system. Based on the values presented in the "Robertsport Water Supply Final Design Report, June 1983" by GKW Consultants study the abstracted quantity, which is also known as the withdrawal rate, is 4.37 liters per second or 69 gallons per minute (or a total daily rate of 99,360 gallons per day or 377 m3 per day).

There is currently a lack of skilled, trained staff to manage, operate, and maintain future infrastructure. Although one of the goals of LMWP is to develop needed capacity, this current lack of available capacity may limit consideration or reduce attractiveness of certain technological alternatives during the Master Planning process. As noted above, LWSC does not have a presence in Robertsport, with the exception of a caretaker responsible for looking over the former facilities. Due to lower treatment costs, reduced operational complexity, and associated lower technical capacity requirements, the utilization of groundwater or the previous slow sand filtration process may be the most appropriate source option. However, available information on subsurface hydrogeology indicates that obtaining sufficient flow from a groundwater source is unlikely and that significant water quality concerns exist. Therefore it is recommended that Fasa Creek be developed as the primary water source for the City of Robertsport. To

maintain the quality and quantity of Fasa Creek as the primary water supply source it is also recommend that steps be taken now to protect this source into the future. Proper management of wastewater is also required to reduce contamination of existing wells and hand pumps, which may continue to be used for non-drinking water purposes in the future.

Recommended Water System and Components

Based on the elevated location of the previous intake structure and the immediate need for cost-effective improvement of access to water services in Robertsport, LMWP recommends the installation of a gravity-fed water supply as the initial step in a series of phased improvements. The gravity-fed system utilizes the advantageous vertical relationship between the source and the service area, especially at those areas lying near sea level, such as the Fanti Town neighborhood. A key advantage of this recommendation is that it eliminates the high cost and complexity associated with independently powering a system that requires pumping. With the addition of a storage facility near the Fasa Creek intake structure and a simple (low technology) chlorination system, up to an estimated 80% of the Robertsport population could potentially be provided with a disinfected and improved water source. To reduce costs and simplify construction, the initial distribution of water is proposed by means of public dispensing points, such as strategically located kiosks or public stand pipes. In subsequent phases, service type would be converted to an increased percentage of direct house connections or yard taps. The service area fed by the gravity system is anticipated to also support the proposed West Africa Regional Fisheries Project [WARFP] funded by the World Bank to develop the fish landing site in the Fanti Town neighborhood.

The second phase of the Short Term projects includes the supply of water to the previous high service zone which prioritizes the restoration of service to the Robertsport Hospital. If the water quality from one of the two high yielding wells is confirmed as adequate through additional testing, the construction would include the disinfection and conveyance of the selected groundwater source to the previous upper reservoir and the restoration of the high service zone distribution system. If the groundwater supply alternative is determined not to be feasible due to water quality or other issues, an alternative would be to "tap" the gravity feed piping of the first phase to serve the high service zone. It is expected that the completion of this phase would serve up to 90% of the population and accomplish the project goal of increased access to improved water sources. It is anticipated that Short Term project would be completed in 2014.

While the Short Term Projects noted above primarily provide the supply of disinfected water to the service area, the recommended Medium Term Project is to restore the previous slow sand filters. The addition of the restored treatment facility to the water system will provide the needed multiple barrier approach (protected and quality water supply source and treatment) to serve the customers in Robertsport. The insertion of the treatment process into the gravity fed main necessitates the treated water be pumped to the users. With this requirement and commitment it is logical to restore the previous distribution to service the City of Robertsport.

The Long Term Project recommended includes the following:

- Improvements to Operational and Institutional Capacity to improve sustainability
- Improved delivery of water by converting from public dispensing locations (kiosks and public stand pipes) to more private connections (private stand pipes and house connections)
- Re-visiting and updating of the Master Plan for Robertsport (recommended every 5 years)
- Implementation and advancement of an Asset Management Plan should occur during construction and just after start of any new facility

- Continuous updating of the O&M manuals for the water system, its components, and its operational staff.
- Continuous training for the water system staff, as well as the development of a training program to assist other water utilities being developed in Liberia.
- Promotion of rainwater harvesting
- Development and implementation of a sanitation master plan
- Develop and implement program for decommissioning existing wells that do not meet acceptable water quality standards, or appropriately indicating and promoting their use for only non-potable water supply

Implementation and Affordability

The proper implementation of an improved water supply can overcome the restrictions and difficulties present in Robertsport, but it will require a strong and properly structured institutional framework. The institutional framework must ensure accountability to well-defined performance measures, incentives to meet performance targets, autonomy at the local level with regard to budgeting and operations, and staff with requisite capacity. In addition, water tariffs must reflect the actual operational costs of the system to ensure financial sustainability, while simultaneously allowing access for the poor. Having the institutional components in place is critical to sustainably providing municipal water services and a service that is both affordable and reliable. Development of an institutional framework is ongoing and is currently being addressed through local and national water steering committees. This Master Plan is focused largely on engineering aspects of the project.

Planning must include regular involvement of stakeholders within Robertsport to ensure their needs are being addressed and that their critical support is maintained during and after the Master Planning process. The general public will likely be interested in the level of service to be provided and the cost for such service. The cost of service will be based on the operational costs of the water system with the goal of having all operation and maintenance costs be borne by the customers. To assure that an efficient water utility is developed, the development of an operation and maintenance manual and an asset management plan and associated training are required and will be conducted as part of Task 4 of the LMWP project.

The planning effort will also require that USAID secure funding for the capital works phase of the project. The procurement method to solicit construction prices from private contractors will also need to be resolved along with land rights and land ownership issues.

The estimated capital costs and annual operating cost of the various alternatives are outlined in the table and figure below. As indicated, the LMWP recommendation is to proceed with Option #2 initially, then Option #4, then Option #5.

#	Alternative	Estimated Capital Costs[1]	Estimated Annual Operating Costs	Estimated Percent of Population Served	Recommended Alternatives for Phased Construction
0	No Action	0	0	0	No
1	Supply Area#1 Via Gravity from Fasa Creek	$1,180,000	$72,780	53%	No
2	Supply Area#1 and #2 Via Gravity from Fasa Creek, with Storage	$1,843,000	$86,040	83%	Recommended
3	Supply Area#1 and #2 Via Gravity from Fasa Creek, with Storage, plus Groundwater Supply to Area #3 Lower	$2,279,000	$128,180	92%	No
4	Supply Area#1 and #2 Via Gravity from Fasa Creek, with Storage, plus Groundwater Supply to Area #3 Upper	$2,251,000	$130,300	90%	Recommended
5	Restore WTP and Water System to serve all areas	$2,841,000	$193,200	~100%	Recommended
6	Package WTPs to serve all areas	$4,520,000	$383,680	~100%	No

[1] The capital costs presented are all components recommended by the described alternative and are independent of cost presented for other alternatives

The ability to carry out implementation of all recommended alternatives through to Option #5 and also ensure that the investments are sustainable is heavily dependent on local willingness and ability to pay for ongoing operation and maintenance services. While the initial household survey and focus group analysis gathered important information on this important subject as presented in the Situational Analysis Report, further engagement at the local level is needed to confirm and refine that analysis based on the specific recommendations and expected costs in the Master Plan. However, available information is sufficient to perform initial analysis of affordability.

As noted above, in order for the proposed systems to be sustainable without external subsidies, then at a minimum the cost of operation and maintenance must be recovered via water tariffs. Given currently estimated annual operating costs and water demand, the requisite average cost recovery tariffs are generally within the range of affordability in Robertsport when examined using several different metrics.

The estimated monthly water cost per household for water from the proposed systems can be expected to vary from approximately $12/month/household initially (after implementing Alternative #2) to approximately $23/month/household after completion of all recommended Medium Term Improvements. This cost represents between 7 and 12 percent of median household income as reported during the household survey. The estimated household monthly net (surplus) income in Robertsport is $35, as calculated based on results of the household survey.

It is important to compare expected tariffs with the prices currently being paid to water vendors, from whom about one fifth of Robertsport residents get their drinking water. The expected average tariff associated with the proposed new water system per jerrican volume equivalent (approximately $0.08/jerrican) is less than one-third of the current rate being paid to water vendors in Robertsport (about $0.25/jerrican). According to the household survey, the reported average household expenditure on water is around $10/month, although this figure includes residents who only obtain water from free sources. Only 56% of survey respondents reported paying for water from their main source.

1. MASTER PLAN SCOPE, PROCESS AND FORMAT

The Liberia Municipal Water Project (LMWP), funded by the United States Agency for International Development (USAID), will support the design, tendering, execution and operation of water supply infrastructure improvements in the cities of Robertsport, Sanniquellie, and Voinjama. LMWP will assist local and national authorities in developing plans for urban water supply and sanitation improvements, implementing short and medium-term water supply infrastructure improvements, and re-establishing local capability to sustainably operate and maintain the water supply improvements. During the four-year project base period, it is the goal of LMWP to help establish improved water supply access in each city, with infrastructure managed by locally-based entities capable of financially and technically sustaining the service. The improved water systems will provide public health and economic development benefits in the three target cities.

One of the cities and the subject of this Master Plan for the proposed projects is the City of Robertsport, situated along the Atlantic Ocean, approximately 12 miles southeast of Sierra Leone, and 50 miles northwest of Monrovia. The location of Robertsport and the other LMWP project cities of Sanniquellie and Voinjama are shown in Figure 1-1. Due to decades of civil war conflicts and poverty, this city has poor infrastructure. Robertsport is considered the political and economic center of Grand Cape Mount County, as well as its main fishing port.

The project goal is after four years, over 90% of the population in the project cities will have improved water supply access and improved infrastructure will be handed over to locally-based management financially and technically sustaining water supply service.

Improved water supply access is defined by the USAID contract as regular household access to a water source, a distribution system, or a delivery point, which by the nature of its design and construction is likely to protect the water source from external contamination, in particular from fecal matter, and which can be reached by the household in a round trip of 30 minutes or less. Improved water supply sources are: piped water into dwelling, plot, or yard; public tap/standpipe; tube well/borehole; protected dug well; protected spring; or rainwater collection. Unimproved water supply sources are: unprotected dug well; unprotected spring; cart with small tank/drum; tanker truck; surface water (river, dam, lake, pond, stream, canal, irrigation channel); and, bottled water.

Figure 1-1 Robertsport Vicinity Map

Following the Situational Analysis - and informed by its findings, - the master planning process is the main component of the project Task 2 – *Transitional Improvement of Water Services*. Its main objective is to evaluate the existing water needs and systems in Robertsport to identify water infrastructure and system improvements to achieve the project goal of 90% access after four years. Specifically, the Robertsport Master Plan presents options, for consideration by USAID and GOL authorities, of the most cost effective and feasible approaches for:

- Improving water supply access in the short-term;
- Improving water supply access in the medium-term (i.e., through end of the four-year task order); and
- Improving water supply and sanitation access in the long-term (i.e., after the end of the four-year task order).

As part of the Master Plan, the following items are addressed:

- Recommended water sources;
- Development of conceptual water supply and distribution system(s) throughout the city. Systems will be planned by zones based on phased construction and technical feasibility;
- Construction cost estimates for different components (sources, distribution, storage facilities, etc.) segregated in a list of sequential projects that can be funded separately. The Master Plan identifies the sequence in which each component must be implemented, e.g. source, storage and distribution – in that order;

- Estimated operation, maintenance and labor costs;
- Preliminary construction schedule for execution of projects; and
- Initial estimates of ability of Robertsport water system customers to fully cover ongoing operation and maintenance costs via water tariffs.

LMWP key stakeholders include the following: Robertsport Municipal Government, Liberia Water and Sewerage Corporation (LWSC), Ministry of Land, Mines and Energy (MLME), and Ministry of Public Works. To the extent practicable, input from the stakeholders was solicited during this planning process through exchanges during the monthly Engineering Working Group (EWG)[2] meetings, weekly LWSC meetings, and the constitution of the National Transition Working Group Committee. This Master Plan will be fully vetted with national and local stakeholders through additional meetings, public and focus group discussions among other methods.

The LMWP and this Master Plan are intended to represent the starting point of an ongoing process. The Master Plan presents a broad range of recommended projects, some of which are critical and some of which are lower priority. It is important to recognize that the recommendations of the LMWP are based on assessment of the existing water management conditions and practices, and on projected water demand growth. Changes in scope, details and phasing of certain projects may be required over time to respond to changes in population growth, new developments, new regulations, emerging technologies, etc. Although this Master Plan maps out major expenditures for the Robertsport water sector through 2031, conditions will change and flexibility is important in terms of infrastructure planning, operations, and management. The Plan should be reviewed and revised as necessary to reflect new initiatives and/or major changes in priorities or conditions. It is recommended that a complete review and written update be performed at least once every five (5) years.

The format of the Master Plan follows the process diagram presented in Figure 1-2: Robertsport Master Planning Process.

Section 2.0 of the Plan provides background information on the existing and projected population estimates and anticipated water demand rates. A complete summary of existing conditions was documented in the May 2012 Situational Analysis Report.

Section 3.0 describes water supply challenges, opportunities, and project-specific challenges at the national and local levels and recommendations for addressing them.

Section 4.0 outlines the water system components, including the potential sources of water, treatment options, storage options, distribution options and pumping systems.

Section 5.0 evaluates and recommends the source of water for the proposed improvements. Based on the proximity of the supply source to the demand centers, the quantity and quality of water available, and any seasonal conditions; the other components of the water system can be evaluated and recommended.

[2] LMWP formally established an Engineering Work Group (EWG) consisting of a core group of representatives including LWSC, MLME, and MoPW responsible for assisting with development of design criteria and reviewing technical reports relevant to the planning and design of water supply systems.

Section 6.0 presents planning-level construction cost estimates, as well as an estimation of the operation and maintenance (O&M) costs for the proposed options. It also contains a summary of the cost-benefit analysis conducted for the proposed improvements.

Section 7.0 summarizes Tetra Tech's recommendations regarding water infrastructure investment needs. The recommendations are categorized as Quick Impact Projects (QIPs), Short Term Projects (first 18 months), Medium Term Projects (18 to 48 months), and Long Term Projects (48+ months)

Section 8.0 outlines the funding, organizational, procurement and asset management, schedule, and considerations for the implementation of the project.

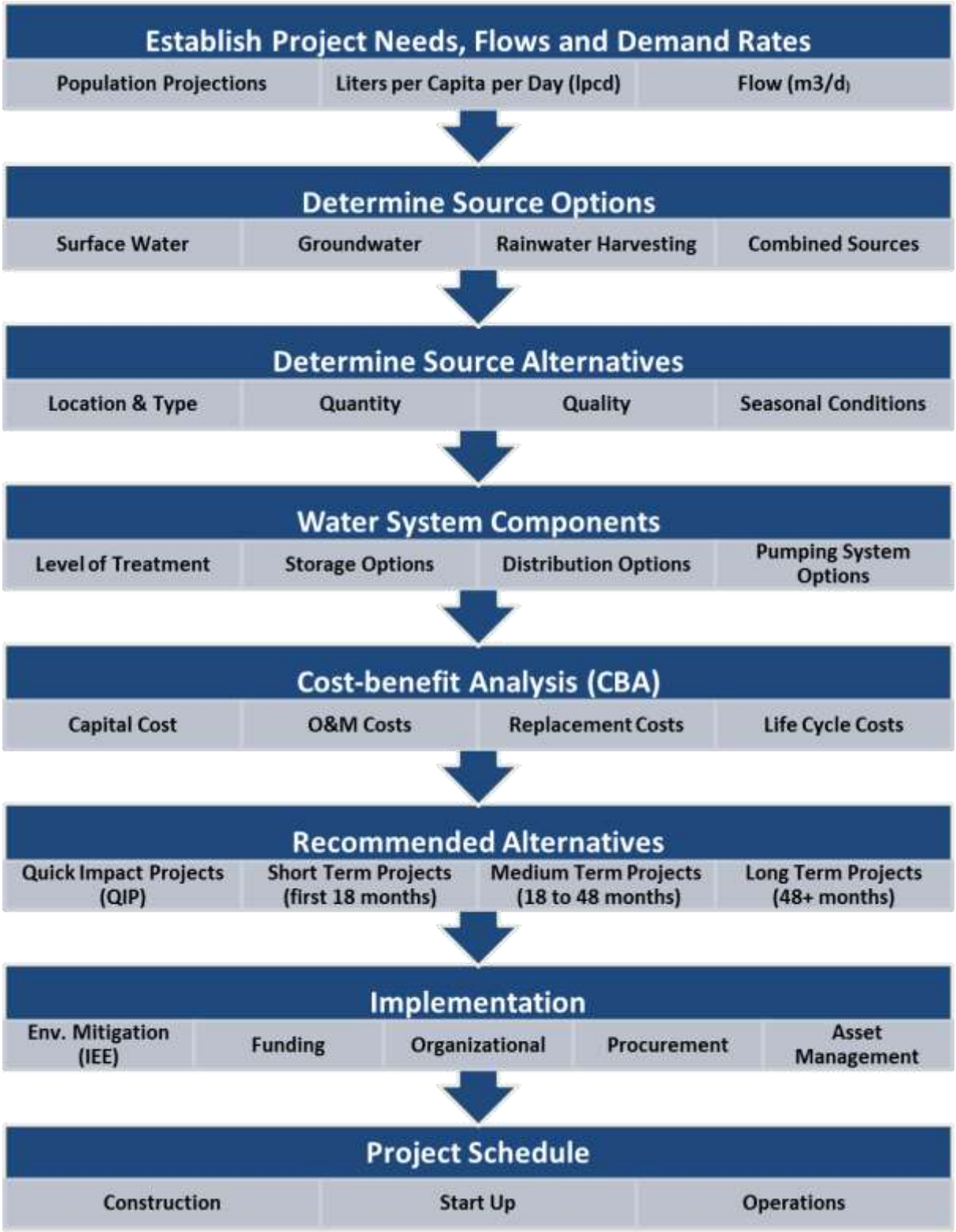

Figure 1-2: Robertsport Master Planning Process

2. DEMOGRAPHICS

2.1 POPULATION ESTIMATE

The population estimates for Robertsport will provide one of the building blocks for projecting water consumption and demand. For planning purposes the LMWP population estimates are forecasted to the year 2031 based on the 2008 Liberia National Census.

The estimated population as of 2011 is about 3,700 persons. Utilizing an exponential growth approach to project population (2% per year based on Grand Cape Mount county growth during the period 1984-2008), the estimated population in year 2031 is 5,500 persons. The projected population from 2011 to 2031 is presented in Table 2-3.

2.2 ROBERTSPORT CITY WATER DEMAND

Based on the household survey conducted by LMWP in early 2012 and presented in the Situational Analysis Report, per capita household water use in Robertsport is estimated to be approximately 20 liters per capita per day (lpcd), or around 80 to 100 liters per household per day[3]. This value includes water used for all purposes including cooking and cleaning. LMWP assumes that users may initially only obtain drinking water from a new piped supply and continue to rely on existing sources for non-drinking purposes, but eventually transition to utilizing piped water for most demands. Using the above population estimates, the water supply demand for Robertsport was developed considering a steady growth from an expected near "no access" initial level of service demand for piped water of less than 5.3 gpcd (20 lpcd) (Table 2-1). The projected future level of service is expected to exceed the required "basic access" and provide water within a 30 minute period and at rates greater than the 5.3 gpcd (20 lpcd) consumption demand. A project "goal" of 10 gpcd (38 lpcd) is being used for evaluation purposes in this Master Plan. A long term supply goal of 13 gpcd (50 lpcd) will be used for this master planning document. This rate is consistent with the demand rate utilized in the design of the previous water system for water obtained from public taps. It is important to note that projected flows are presented for conservative long term planning only, based on projected total Robertsport population. Actual demands by year will be dependent on service population, which is expected to be less than the total population. In addition, estimation of increased demand based on transitioning from distributed sources such as hand pumps, vendors, and surface water to piped water supply is difficult in Liberia given the lack of recent precedent for such a transition.

[3] In Robertsport, per capita consumption is estimated to be 24 liters per person per day in the dry season compared to 16 liters per person per day in the wet season.

Table 2-1 Level of Water Service[4]

Service Level	Consumption Demand	Access Measurement	Consumption Needs	Hygiene Needs	Level of Health Concerns
No access	Quantity collected often below 1.3 gpcd (5 lpcd)	More than 1000 m or 30 minutes total collection time	Cannot be assured	Not possible (unless practiced at source)	Very high
Basic access	Average quantity unlikely to exceed 5.3 gpcd (20 lpcd)	Between 100 and 1000 m or 5 to 30 minutes total collection time	Should be assured	Hand washing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access	Average quantity about 13 gpcd (50 lpcd)	Water delivered through one tap onsite (or within 100m or 5 minutes total collection time	Assured	All basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access	Average quantity 26 gpcd and above (100 lpcd+)	Water supplied through multiple taps continuously	All needs met	All needs should be met	Very low

http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

The Robertsport flow demand rate to be used for evaluation as part of this LMWP planning document is intended to increase from the substandard condition to a level exceeding the Basic Access Service Level as outlined in Table 2-2.

[4] Table was derived from *Domestic Water Quantity, Service, Level and Health* (WHO/SDE/WSH/03.02), World Health Organization, 2003. Available online: http://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

Table 2-2 LMWP Proposed Improvement to Service Level

Present	Immediate Need	Project Goal	Long Term
No Access Service Level	Basic Access Service Level	Improved Access Service Level	Approx. Intermediate Access Service Level
1.3 gallons per capita·day	5.3 gpcd	10 gpcd	13 gpcd
5 lite per capita·day	20 lpcd	38 lpcd	50 lpcd

These values are used for planning purposes to evaluate the potential of water supplies to sustain long-term needs and in selecting the water system components to be incorporated in the water improvements for Robertsport. Table 2-3 present the projected annual residential, non-residential and total daily flows for the City of Robertsport. The residential flows are based on populations and expected demand rates. The non-residential flows are estimated based on the of the following percentages of estimated residential demand: 20% unaccounted for water, 5% industrial, 3% commercial, 2% institutional, and 2% emergency.

Table 2-3 Population and Demand Flow Projections[5]

Year	Populations	Residential Demand		Residential Flow		Non Residential Flow		Total Daily Flow	
	(persons)	(gpcd)	(lpcd)	(gpd)	(m3/d)	(gpd)	(m3/d)	(gpd)	(m3/d)
2008	3,515								
2011	3,700	1.3	5	4,870	19	1,461	6	6,331	25
2012	3,800	1.3	5	4,940	19	1,482	6	6,422	25
2013	3,800	5.7	21	21,470	82	6,441	25	27,911	107
2014	3,900	10.0	38	39,000	148	11,700	44	50,700	192
2015	4,000	10.5	40	41,810	159	12,543	48	54,353	207
2016	4,100	10.9	41	44,700	170	13,410	51	58,110	221
2017	4,200	11.4	43	47,690	181	14,307	54	61,997	235
2018	4,300	11.8	45	50,760	193	15,228	58	65,988	251
2019	4,300	12.3	47	52,700	200	15,810	60	68,510	260
2020	4,400	12.7	48	55,910	212	16,773	64	72,683	276
2021	4,500	13.2	50	59,220	225	17,766	68	76,986	293
2022	4,600	13.2	50	60,530	230	18,159	69	78,689	299

[5] Projected flows are presented for conservative long term planning only, based on projected total Robertsport population. Actual demands by year will be dependent on service population, which is expected to be less than the total population.

Year	Populations	Residential Demand		Residential Flow		Non Residential Flow		Total Daily Flow	
2023	4,700	13.2	50	61,850	235	18,555	71	80,405	306
2024	4,800	13.2	50	63,160	240	18,948	72	82,108	312
2025	4,900	13.2	50	64,480	245	19,344	74	83,824	319
2026	5,000	13.2	50	65,790	250	19,737	75	85,527	325
2027	5,100	13.2	50	67,110	255	20,133	77	87,243	332
2028	5,200	13.2	50	68,430	260	20,529	78	88,959	338
2029	5,300	13.2	50	69,740	265	20,922	80	90,662	345
2030	5,400	13.2	50	71,060	270	21,318	81	92,378	351
2031	5,500	13.2	50	72,370	275	21,711	83	94,081	358

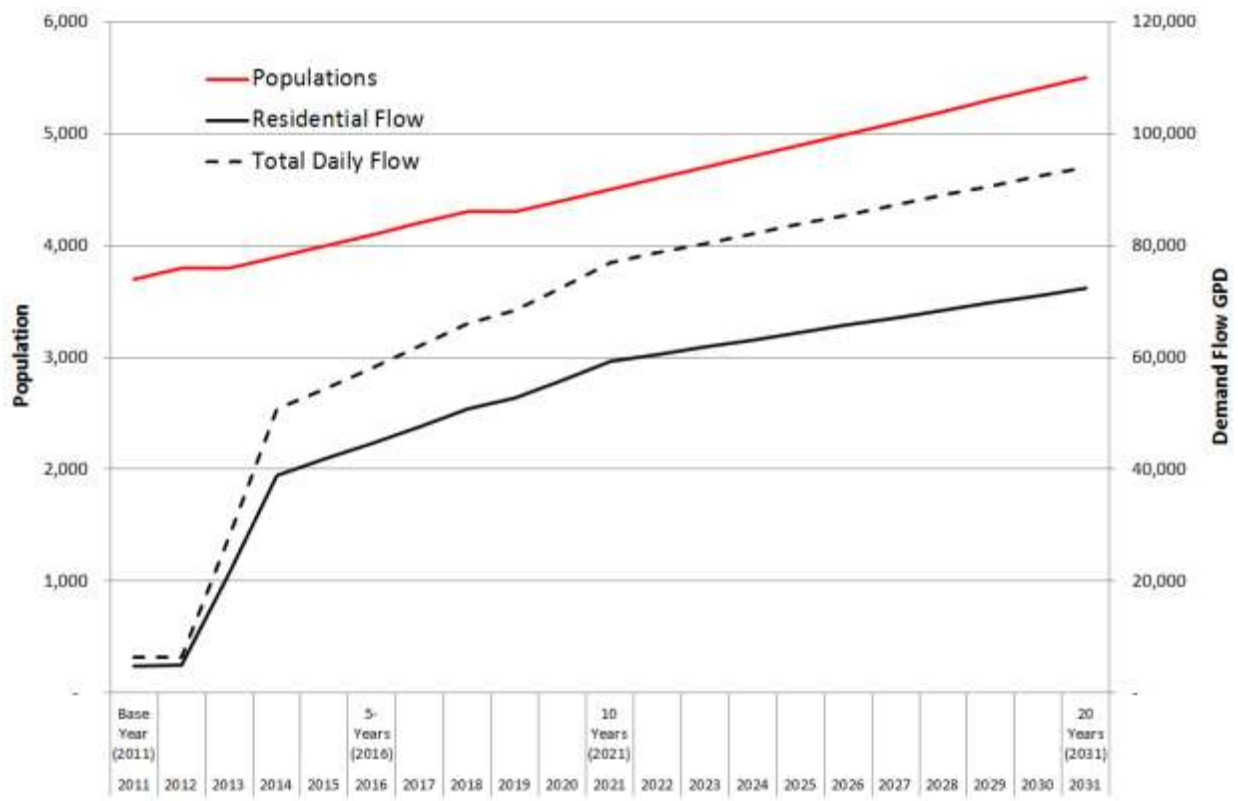

Figure 2-1 Population and Demand Flow Projections

2.3 ROBERTSPORT PREVIOUS WATER SYSTEM

The previous Robertsport water treatment is located on the main road connecting Robertsport and Monrovia. The old treatment plant's intake structure is located in a forested area uphill from the main road that connects Monrovia and Robertsport. The intake collects raw water from Fasa Creek and

transmits it to the Water Treatment Plant (WTP) located approximately 2,400 feet away. A schematic of the former system and treatment facility are presented in Figure 2-2 and Figure 2-3.

The WTP facility was constructed to include three slow sand filters, a treated water tank, treated water/effluent discharge pumps, backwash pumps, chlorine storage and application, power generation facilities and fuel tanks, and an office/staff building. Essentially, none of the components and appurtenances of the chemical storage/application and power generation systems remain. The majority of the mechanical, electrical, instrumentation, controls, and miscellaneous metal components of the previous water system components have been looted, and the remaining pieces are not salvageable.

When the WTP was operational, flow from the intake structure traveled to the WTP and entered one of the three slow sand filters through an inlet channel with control gates. The direction of flow through the filters was from top to bottom. The filters still contain the sand material but this material will require replacement or cleanup prior to any operation, since the surfaces of the filters are covered in vegetation. A tree has grown adjacent to the filters and should be removed to prevent any detritus vegetation from falling into the filters. The gradation of the existing sand in the filters is unknown, but will be replaced entirely if the plant is rehabilitated.

When the WTP was operational, chlorine could be added to the filtered water entering the treated water tank. This covered circular concrete tank was constructed adjacent to the effluent pump building. Operators could access the treated water tank through the effluent pump building, though ladders and safety equipment are necessary as no stair access was provided. Water is currently flowing into the tank via the inlet pipe and a faulty isolation valve on the side of the tank farthest from the pump room, flowing into the pump room via a disconnected pipe from the old pipe assembly, and flowing out via an open effluent pipe. The visible components of the treated water tank included a high level draw off pipeline and the remains of the level control device. The treated water tank and effluent pump building are expected to be salvageable. Additional inspections to determine the physical condition of submerged and generally inaccessible areas of the WTP will need to be conducted to determine the water tightness and structural integrity of the previous components (tanks, reservoirs and buildings).

When the WTP was operational, treated water was pumped from the WTP through dedicated transmission mains to two elevated water storage tanks. All flow passed through the elevated storage tanks before entering the distribution system. The elevated storage tanks were located to provide adequate pressure to the system and sized to provide adequate storage volume during periods of peak flow. The distribution system was composed of PVC (plastic) pipe, and distributed water to customers and users by means of private, metered building connections or standpipe kiosks.

The WTP facility includes a separate building intended to house an overhead monorail beam and cradles for chlorine storage. No components of the chlorine system remain, but it appears that chlorine gas cylinders were delivered and stored on concrete cradles. The remainder of the building appears to have been used as offices, storage, and possibly laboratories.

The WTP is secured with a gated entrance and fencing, but no security measures are in place for the intake structure. The WTP site is accessible directly from the main road. The site surface is cleared and unpaved.

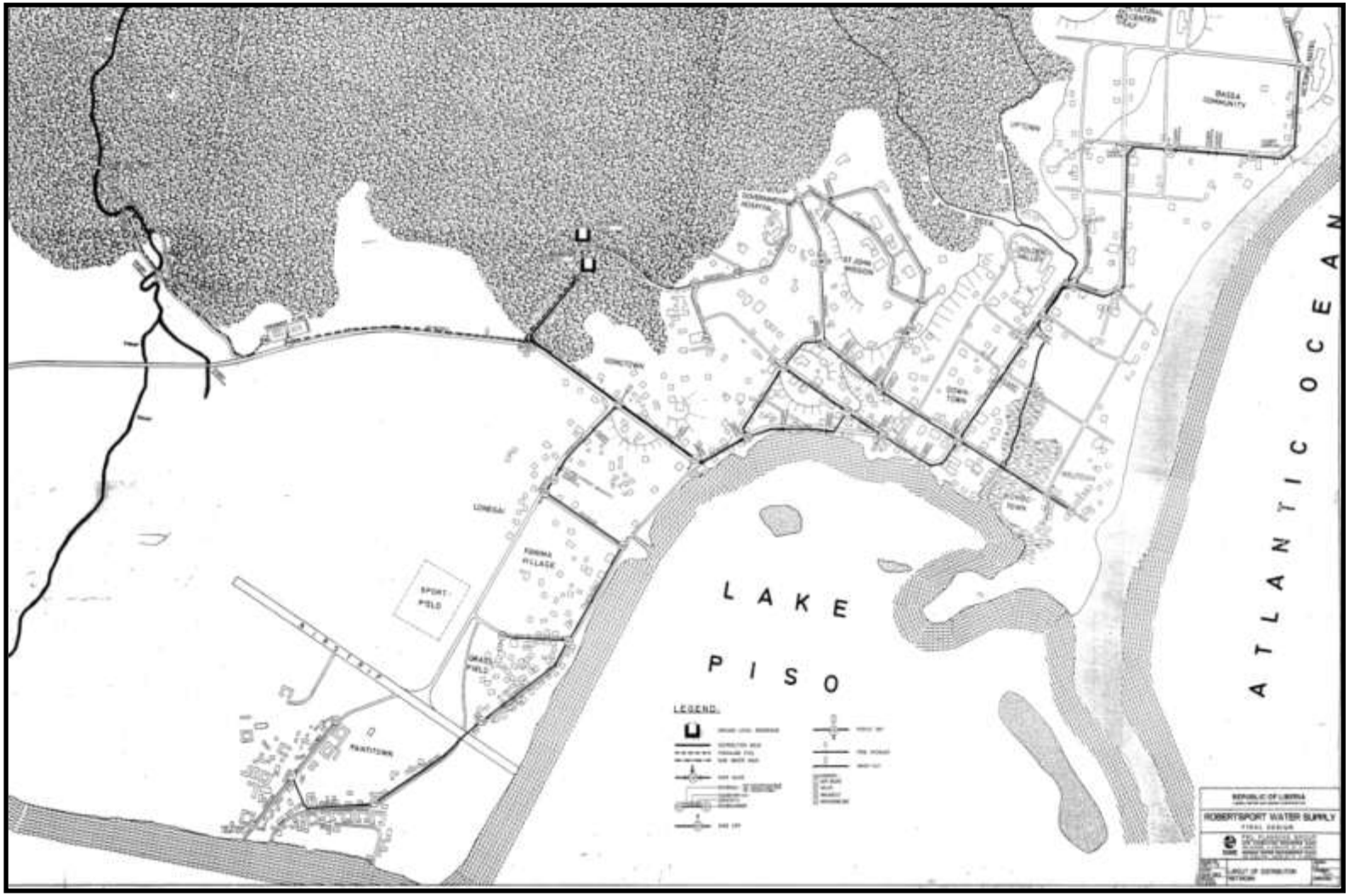

Figure 2-2 Layout of Previous Robertsport Water System

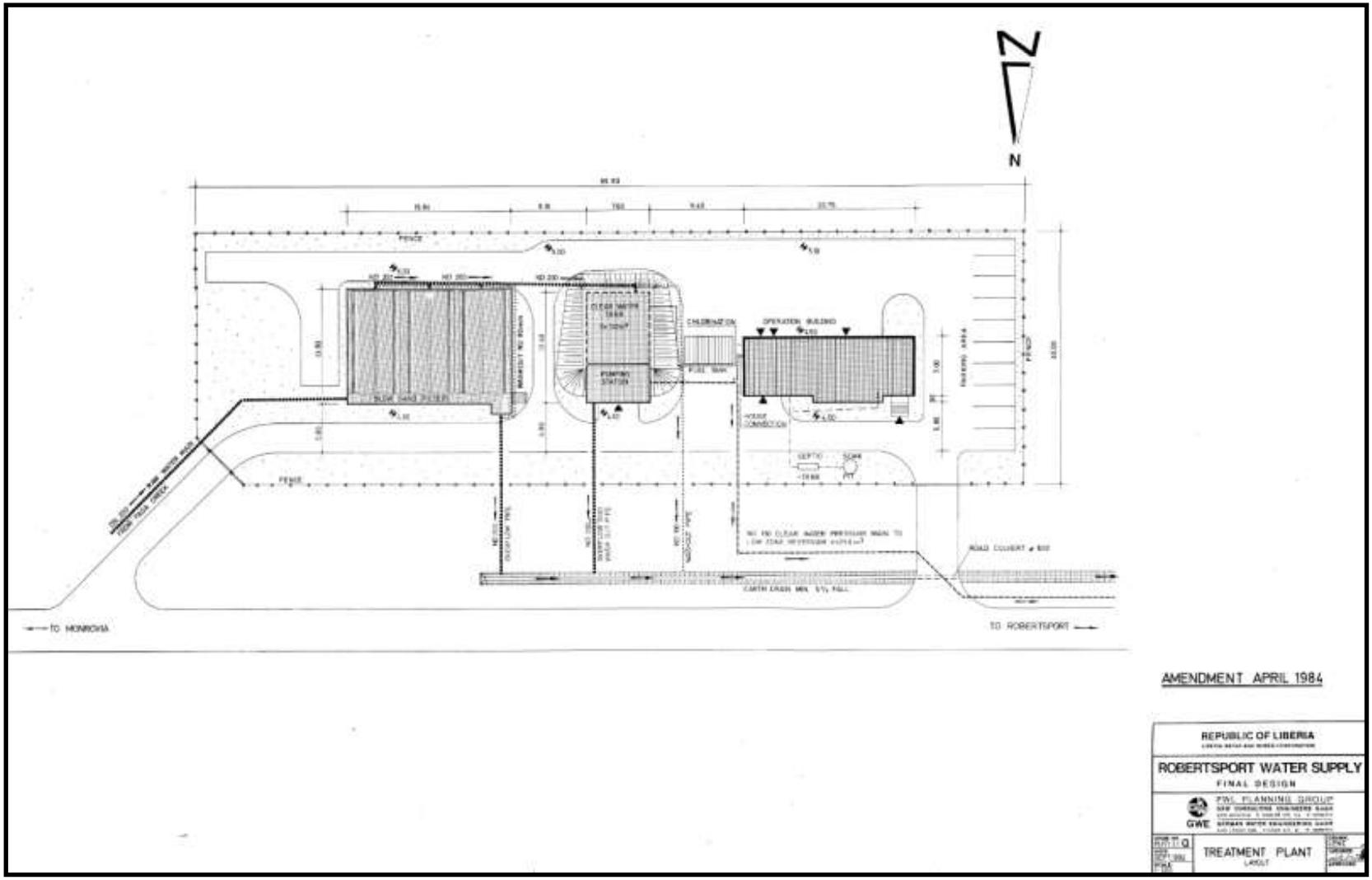

Figure 2-3 Flow Schematic of Previous WTP

3. CHALLENGES AND OPPORTUNITIES

3.1 WATER SUPPLY CHALLENGES

The primary difficulty present in Robertsport is the lack of a currently dependable source of safe drinking water available to the residents. Related challenges include:

- There is no existing municipal water supply, treatment, storage or water distribution system.
- According to the survey of 92 households in Robertsport conducted during the Situational Assessment, only 31% of households reported having regular access to safe drinking water within a 30 minute round-trip of their home.
- Although present water demands are being met by a variety of distributed sources such as dug wells with hand pumps, boreholes, and direct surface water abstraction, quality and quantity issues associated with these sources has resulted in insufficient access to improved water supplies necessary to meet daily needs and protect public health.
- For drinking and cooking purposes, approximately 60% household survey respondents reported using protected wells with hand pumps or dug wells as the main source of drinking water. Another 20% reported obtaining water from water vendors, who generally collect it from select surface water sources. Around 8% of residents get water directly from a surface water source.
- The primary source of water is from wells located throughout the city that are withdrawing water from the contaminated shallow aquifers. Testing conducted by LMWP and reported in the Situational Analysis Report indicated near-universal presence of coliform bacteria in existing wells, with over 95% of the 25 source samples from throughout the city indicating coliform presence. The consumption of contaminated water is detrimentally affecting the health of the residents. Twenty-nine percent (29%) of the household survey respondents reported that one or more members of their household had diarrhea within the last 30 days. Eleven percent (11%) reported that a household member had contracted dysentery and 4% had contracted typhoid in the last 30 days. Seven percent (7%) reported they had a death in the family in the past 12 months, and 50% of those cited the main causes of death being diarrhea.
- The residents have learned to avoid certain hand dug wells due to water quality problems, therefore limiting the number of source to draw water.
- With an emerging fishing industry and planned upgrades at the Fanti Town Fish Landing Site by the Government of Liberia and World Bank to promote this industry, an additional unmet demand for water has been identified.
- There is no local management structure or agency in place that is equipped or funded to operate or oversee operation of a municipal water supply system.
- There is a lack of coordination at the local and national levels regarding water supply development efforts.

- Robertsport does not possess a reliable source of electricity to provide power for water treatment processes and pumps, and LMWP is not aware of any clear plan or schedule for provision of power from a national grid.
- Robertsport lacks a wastewater and solid waste management system.
- The current methods of wastewater disposal permit wastewater to infiltrate and contaminate the shallow aquifer used to supply hand dug wells, resulting in bacterial contamination as identified by previous LMWP water quality testing.
- The migration of displaced or re-settled persons into and around Robertsport is expected to continue and impact the competition between demand and the supply for a safe drinking water supply.
- Prolonged dry seasons, drought, population increases, and economic needs have heightened competition for scarce water resources resulting in anecdotal reports of conflicts related to water.

3.2 WATER SUPPLY OPPORTUNITIES

There are number of opportunities for the LMWP to improve the water supply situation in Robertsport. These include:

- Strong market demand for improved water supply as evidenced by a thriving water vendor market. Roughly one-fifth of the survey respondents in Robertsport (21% in the wet season and 18% in the dry season) obtained water from vendors.
- Good economic prospects via tourism and fishing industries which would be enhanced by access to safe, convenient, reliable, and affordable water.
- The provision of water to unserved residents.
- The provision of a safe drinking water to a large population of Robertsport.
- The possibility to support existing plans to improve and expand the fishing industry in Robertsport and the new water demand generated by the construction of the Fish Landing Site.
- The ability to improve the quality of life by providing enhanced water service.
- The chance to reduce incidences of water borne disease and anecdotally reported conflicts related to the lack of water.
- The prospect to promote an awareness of the importance of a safe water supply.

3.3 PROJECT-SPECIFIC CONSTRAINTS

There are specific constraints/challenges in Robertsport that can affect the development and evaluation of various water system components and alternatives being considered in the master planning process:

- Collection of necessary survey and field data is hindered by the location of the project in a remote section of Liberia and quality of roadway and other access infrastructure.
- Operation and maintenance requirements may limit consideration of certain alternatives given local capacity limitations.
- Robertsport lacks all the components of an established and reliable municipal infrastructure that are necessary to support a fully functioning water supply system, particularly roadway access and electricity.
- Robertsport also lacks well-established supporting institutions to finance, maintain, and manage a water supply system.
- Existing water quantity and quality from the most widely used current water source, the shallow aquifer by means of hand dug well, are not adequate and suitable for human consumption

- Historic information related to the condition of the previous water system and existing well locations is limited due to lost or non-existent records.
- Development of alternatives is impacted by the location of the project and limited availability of spare parts and service for equipment.
- There is a lack of construction firms with experience directly related to municipal water supply infrastructure in Robertsport and Liberia
- Few records are available regarding minimum stream flows, seasonal water quality variations, and other environmental and contextual data.
- Robertsport lacks any historic records of previous water use that allow for developing water consumption rates, water use classifications, and the ability to determine average and peak demands for planning purposes.

4. WATER SYSTEM COMPONENTS

Outlined below are the water system components relevant to the various infrastructure improvement options being considered:

- Groundwater Supply Options
  - Existing Hand Pumps
  - Bore Holes
- Surface Water Supply Options
  - Fasa Creek and other Small Stream
- Pumping Power System Options
  - Solar Power
  - Wind Power
  - Dedicated Generators
- Water Treatment Options
  - Chlorination
  - Water Treatment Processes
  - Managed Water Treatment Systems
  - Packaged Water Treatment Systems
- Storage Options
  - Existing Water Storage Tank
  - Mini Tank-Zonal Nodes
  - Private Tanks
- Water Distribution Options
  - New Distribution Network
  - Tanker Truck Water Delivery

4.1 GROUNDWATER SUPPLY OPTIONS

The feasibility of developing a groundwater supply in Robertsport appears to be limited based on existing practices and water quality conditions. Given initial encouraging data on the available flow and water quality in Fasa Creek, its previous use as a water supply for Robertsport, and discouraging water quality data from groundwater sources within Robertsport, utilization of surface water is the preferred option. However, initial testing indicated that some existing groundwater wells may be of adequate quality and quantity for use to augment the quantity of supply for Robertsport.

4.2 EXISTING HAND PUMP WELLS

The majority of Robertsport residents obtain a portion of their water supply from wells. As noted above, for drinking and cooking purposes, approximately 60% household survey respondents reported using protected wells with hand pumps or dug wells as the main source of drinking water. Due to water quality concerns identified by the users, including the presence of high levels of iron and bacteriological contamination, many residents do not consume the groundwater directly. Half of the survey respondents (50%) reported treating their drinking water all the time, and 21% said they treated the water sometimes. The vast majority of the respondents (95%) who treated their water used chemicals (disinfectants) such as WaterGuard.

The hand pumps are mostly placed over and draw from hand dug wells of varying total and water columns depths. Only one hand pump was observed to be located above a bore hole. The supply of a groundwater source appears limited based on the Liberia "Feasibility Study for Manual Drilling – Mapping of Favorable Zones" by the Government of Liberia which notes (page 18)

> *"Most of the country is formed by geological units which are not favorable because of the nature of the bedrock, but can be covered by an important alteration layer, exploitable by manual drillings."*

Listed below are some general findings of the groundwater in Robertsport's hand dug wells during the March 2010 Detailed Analysis (DA) visit:

- Most shallow hand dug wells were pumped dry (or to a level in which the hand pump or submersible pump could not operate) before the planned 45 minute draw down period of the pump test was completed, even when the flow rate was as low as 3 gallons per minute (gpm).
- Many wells were noted to be impacted by the intrusion of salt or brackish waters.
- Many wells were visually observed as adversely impacted by the high concentrations of iron, apparently from naturally occurring sources.
- Many wells showed minimal recharge.
- Due to the extremely low flow produced by the tested hand dug wells and the limited capacity available resulting from the dry season conditions, the pump tests could not be conducted at an equilibrium condition in which the inflow to the well matched the outflow from the well.

The water quality of the groundwater from the Robertsport hand dug wells generally had a pH less than the minimum standard range of 6.5 to 8.5, indicating an acidic nature to the sampled water.

The low pH level was initially measured during the March 2012 Detailed Analysis visit by the Ministry of Health (MoH) Lab in Monrovia. Similar levels were measured again by the MoH lab in June 2012. In July 2012, the low pH was again confirmed by the MoH lab as well a portable field pH meter that was calibrated using pH standards of 4.0 and 7.0.

The March 2012 MOH analysis revealed levels of iron, fluoride, nickel, manganese, mercury, and lead, which initially indicated concentrations higher than the WHO and/or Ministry of Health drinking water guidelines, but additional investigations were conducted. Subsequent testing by the MoH in June and July 2012, as well as by the MPW's National Standard Lab in July 2012 reported similar results for these parameters. The analytical method available and used by these laboratories is a spectrophotometer. The spectrophotometer relies on the absorption or reflectance in the light beam that is at or near the ultraviolet-visible spectral region. With the addition of specific reagent to the water samples the device

measures the spectrum of the light beam to determine the concentration of the parameter. The presence of color, turbidity and other pollutants can interfere with the readings.

During the July 2012 sampling effort in Robertsport, identical sample were taken from eight sample sites. The collected samples were independently analyzed by the MoH lab, the MPW National Standard Lab, and a US based (Alpha Analytical of Westborough MA). The purpose of the additional collection rounds is to develop more data and quality control purposes. The 8 sample sites included:

Surface Waters:	Fasa Creek
Groundwater:	Well # R01, R06, R11, R12, R16, R17, and R18

The results for these sites are shown for various parameters in a series of bar graphs. A review, by parameter indicates the following

- pH – general consistent readings from lab to lab
- Copper – general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results were significantly less
- Fluoride - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results did not detect any concentrations
- Iron and Manganese - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results were either at non detectable levels but when detected at greater concentrations
- Mercury and Lead - general consistent readings from MOH Lab to National Standards Lab, but the US based Alpha Labs results at non detectable levels
- Nickel- the MOH results from March and June were consistent with the National Standards from July. Unfortunately the MOH lab was not equipped to test this parameter in July so a comparison

The US-based lab used a more advanced testing method, GC mass spectrometry, to analyze the split samples. This equipment is not likely to be available in Liberia. Based on these results, it is recommended that analysis of samples in the short term be considered to include shipping to the US. A summary of the US analyzed results indicate the following:

- Copper was present in four of the seven groundwater samples, from 0.014 mg/l to 0.053 mg/l as analyzed by the US based lab. These samples are greater the Liberian water quality standard of "not detectable" stated by the MoH Lab, but well below the WHO standard of 2 milligrams per liter
- Fluoride, Nickel and Mercury were not found to be present in any of seven groundwater samples analyzed by the US based lab.
- Iron was present in five of the seven groundwater samples, and three of the five samples were greater than the Liberian water quality standard of 0.3 mg/l stated by the MoH Lab.
- Lead was present in one of the seven groundwater samples, at 0.003 mg/l as analyzed by the US based lab. This sample is well less than Liberian water quality standard of <0.1 mg/l stated by the MoH Lab.
- Manganese was present in five of the seven groundwater samples, at concentrations below 0.05 mg/l as analyzed by the US based lab. These samples are less than Liberian water quality standard of <0.1 mg/l stated by the MoH Lab. The MoH results indicate that this parameter could be seasonal or diluted at higher flow rates in the wet season.

Total Coliform and E. coli were detected in the source water from the hand dug wells using a presence/absence testing method. Due to the shallow aquifer tapped by the hand dug well the presence of

bacteriological and other pollutants would be anticipated. Further bacteriological testing is to be conducted to assess the level of bacteriological contamination.

The option of continued use of shallow hand dug wells and hand pumps as the sole or partial source of drinking water without any form of treatment has been eliminated from further consideration. The use of these sources as a potential water supply for irrigation, wash water or other non-consumptive use is worth further consideration as a means to reduce the demand on potable water supply when or if a potable supply source is found to be limited. The continued use of the hand dug wells for non-consumptive use should be undertaken with continuous and ongoing education and awareness about safe drinking water practices.

The continued use of hand pumps for non-consumptive use may reduce the demand on the planned potable water system, but would likely impact the sustainability of the new system if users continue to use the free source that is likely to be substandard and unprotected.

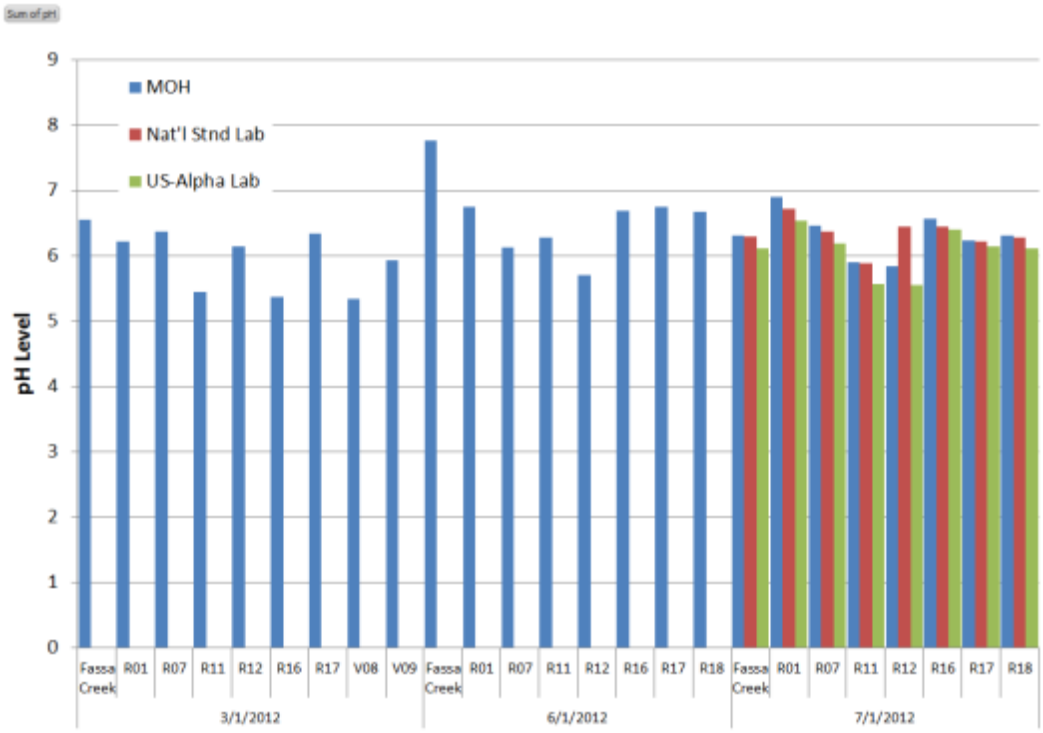

Figure 4-1 Comparison of pH Sampling

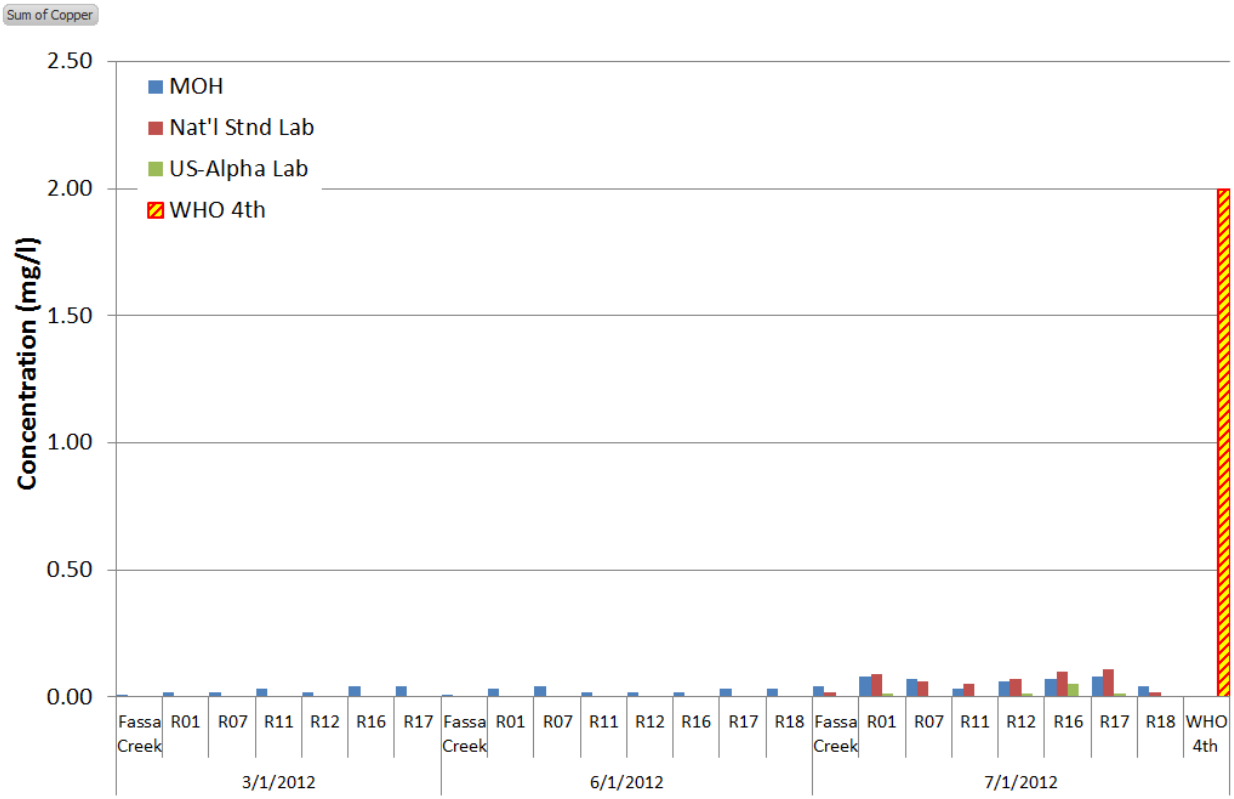

Figure 4-2 Comparison of Copper Sampling

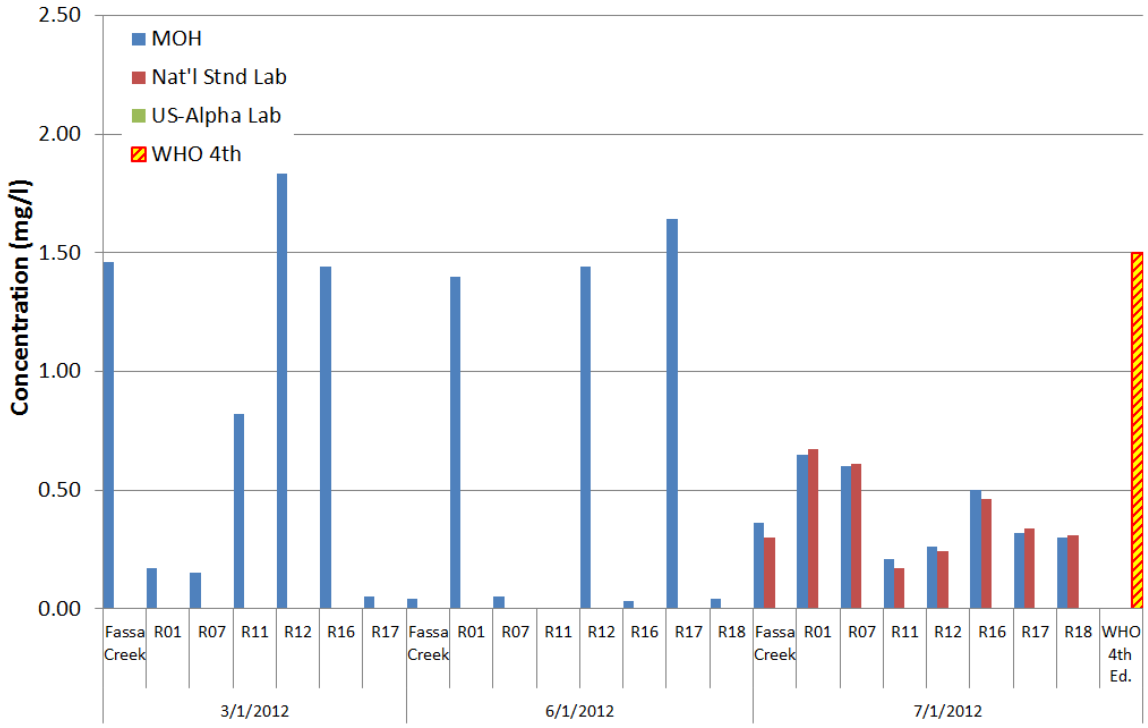

Figure 4-3 Comparison of Fluoride Sampling

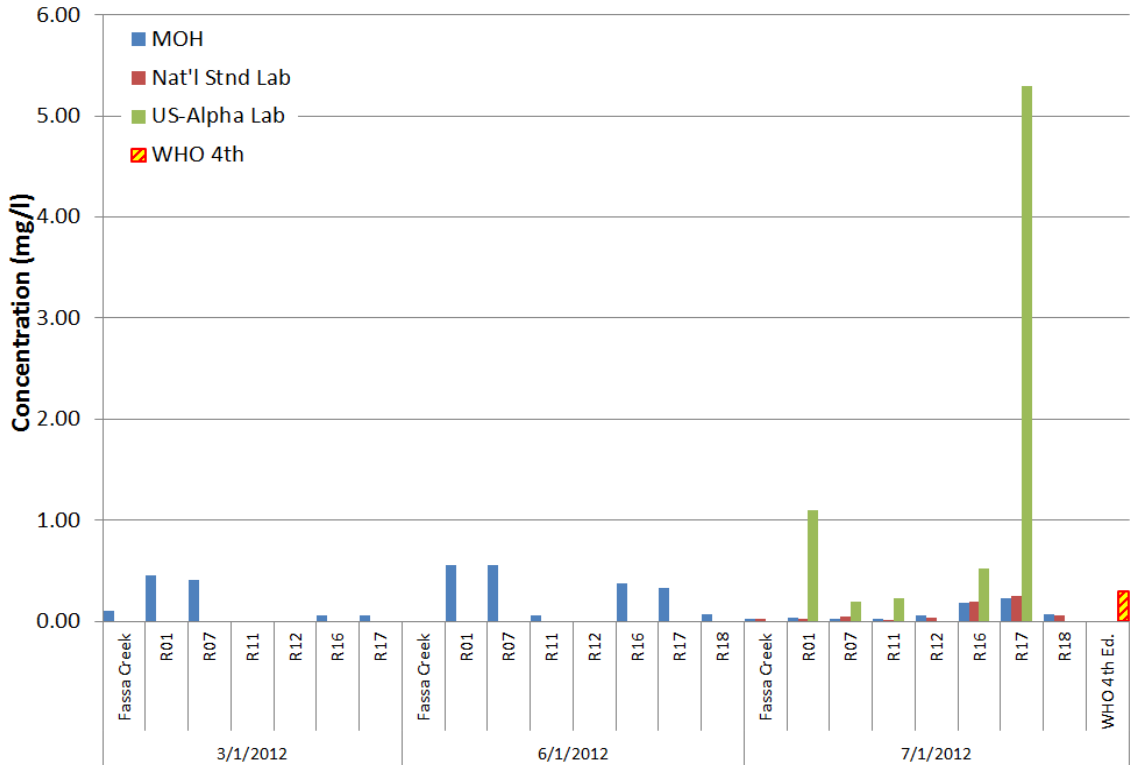

Figure 4-4 Comparison of Iron Sampling

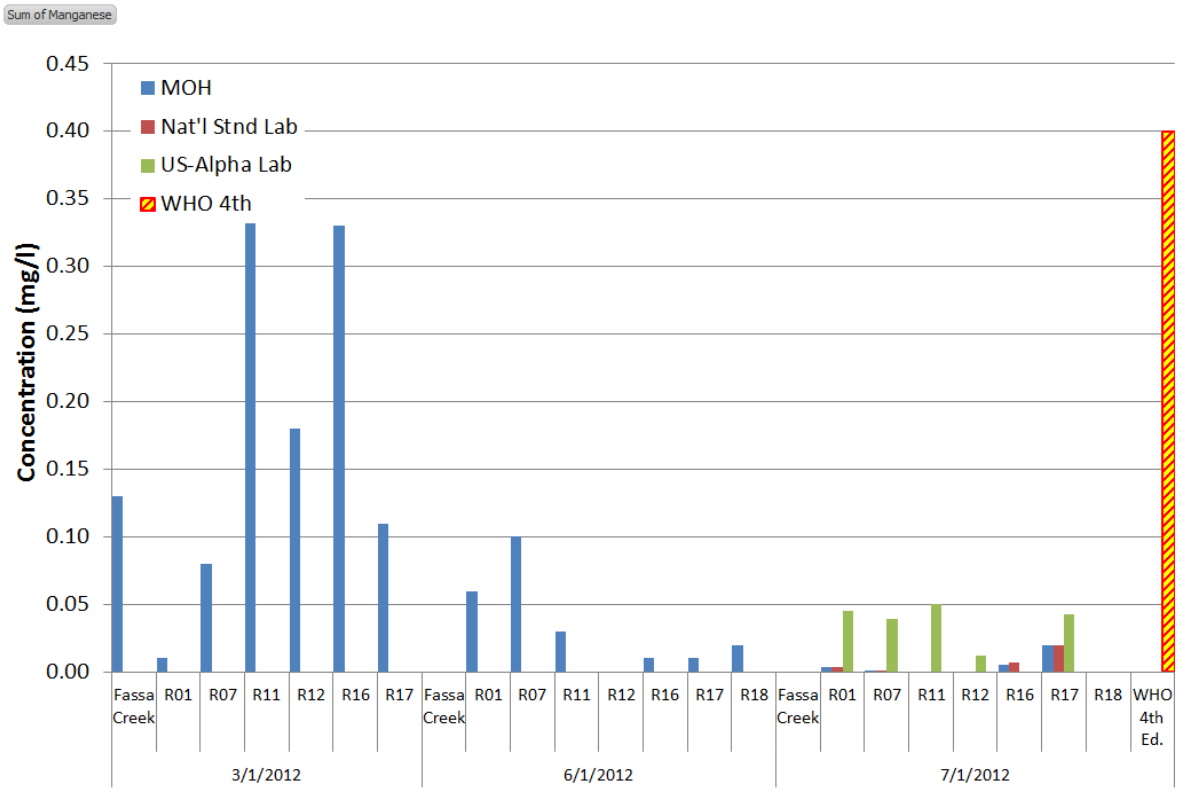

Figure 4-5 Comparison of Manganese Sampling

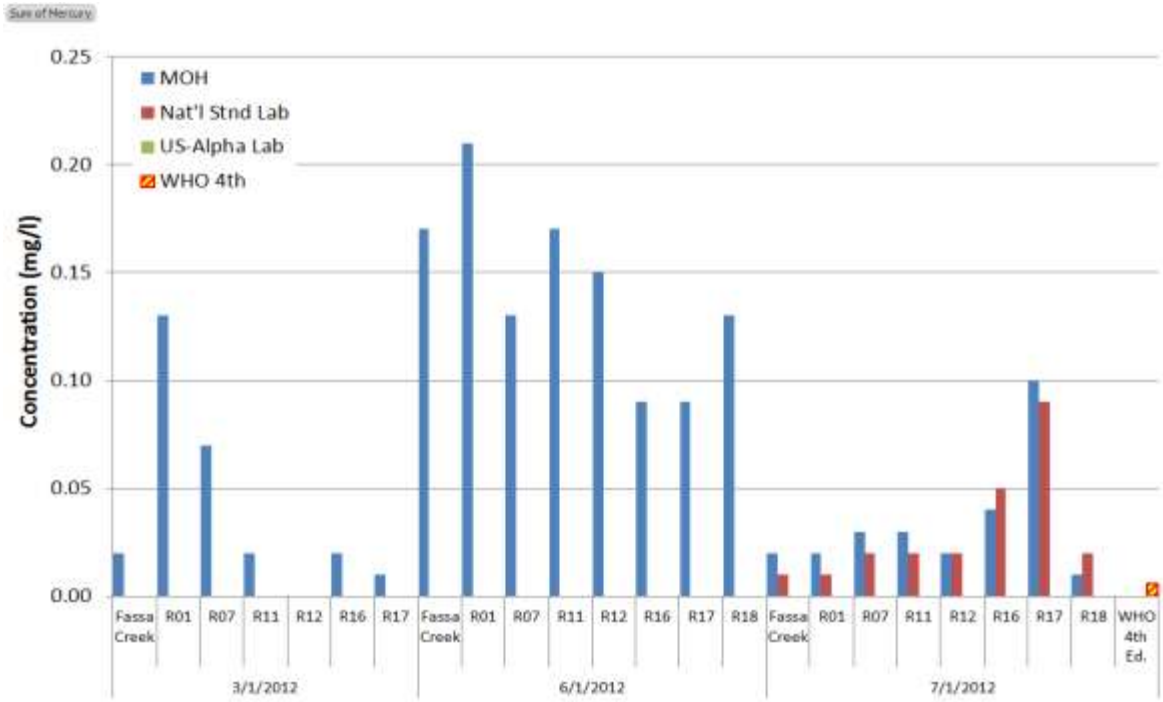

Figure 4-6 Comparison of Mercury Sampling

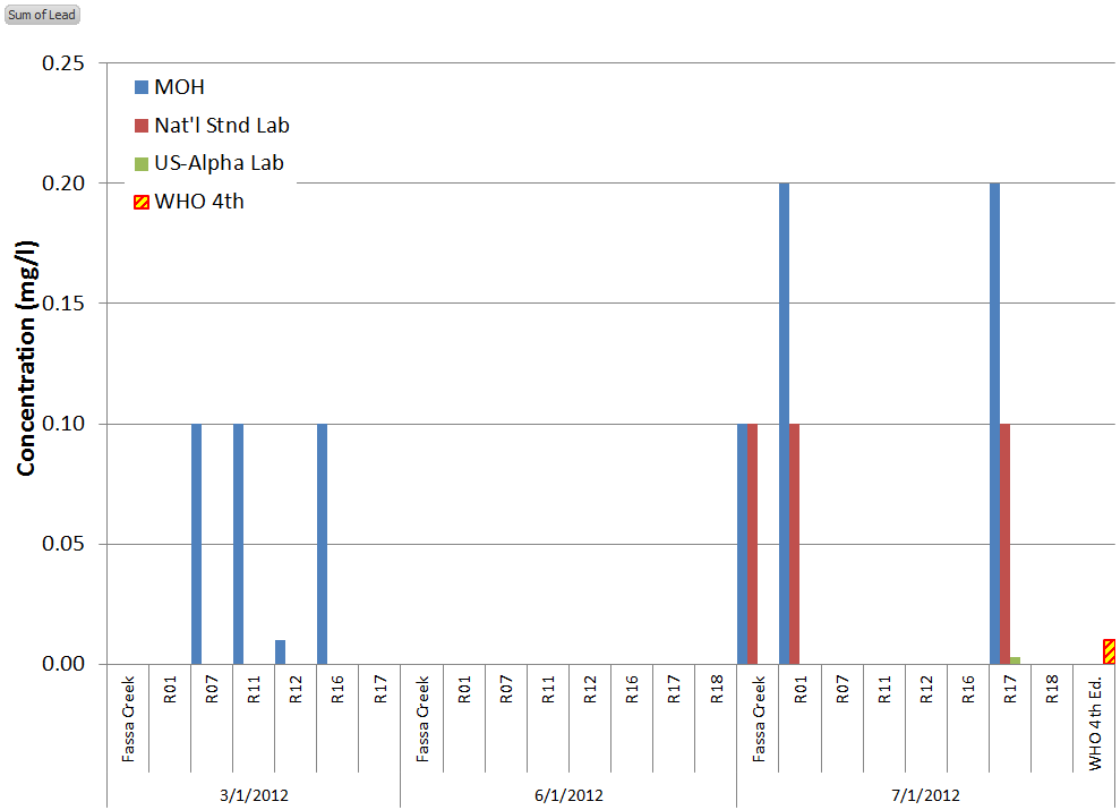

Figure 4-7 Comparison of Lead Sampling

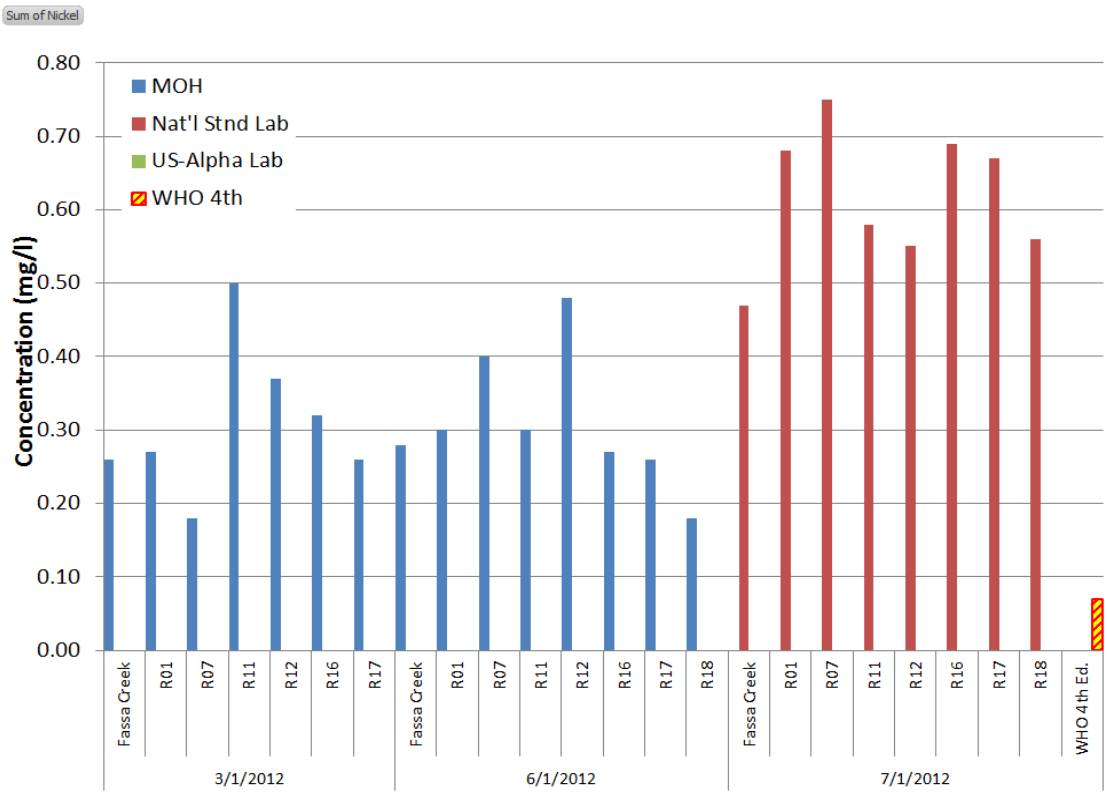

Figure 4-8 Comparison of Nickel Sampling

4.3 POTENTIAL SERVICE AREAS

An evaluation was conducted for the wells in Robertsport based on the results of the pump testing, the recharge capacity of the well, the estimated capacity of the individual wells, and the reported operating status by user (from the WSP survey). A theoretical service area for each well was established based capacity of the well, estimated demand per capita, and population density as follows:

- Determine estimated capacity of the well (gallons per day)
- Determine demand rate (gallon per capita per day)
- Divide the well capacity by the per capita demand rate to yields the number of people each well can serve number of persons for each well)
- Divide the number of people per well by the population density (estimated from Liberia census enumeration data) to yield the service area size of each well (km^2).
- Plot the service area of each well as a circle with the well in the center to show the approximate coverage area for each well.
- Additional evaluation of the operating status (all wells versus wells reported as good quality and quantity per WSP survey results from interviewing users or care takers) can be used to assess the actual use of each well based on WSP usage.

This analysis was used to develop the following two figures. As shown in the first graphic, there are currently 22 existing wells and these wells can theoretically cover the majority of Robertsport in terms of water quantity. However, the operating and usage status reported by the WSP survey and water quality testing conducted by LMWP reveals that many wells have poor water quality and should not be consider as reliable water sources without treatment. This is further justified by the relatively high use of surface water supplies by Robertsport residents including water from vendors who collect it from Fasa Creek. Only two wells (R10 and R16) are considered to be viable as drinking water sources due to water quality. Their estimated coverage areas are shown in the second graphic.

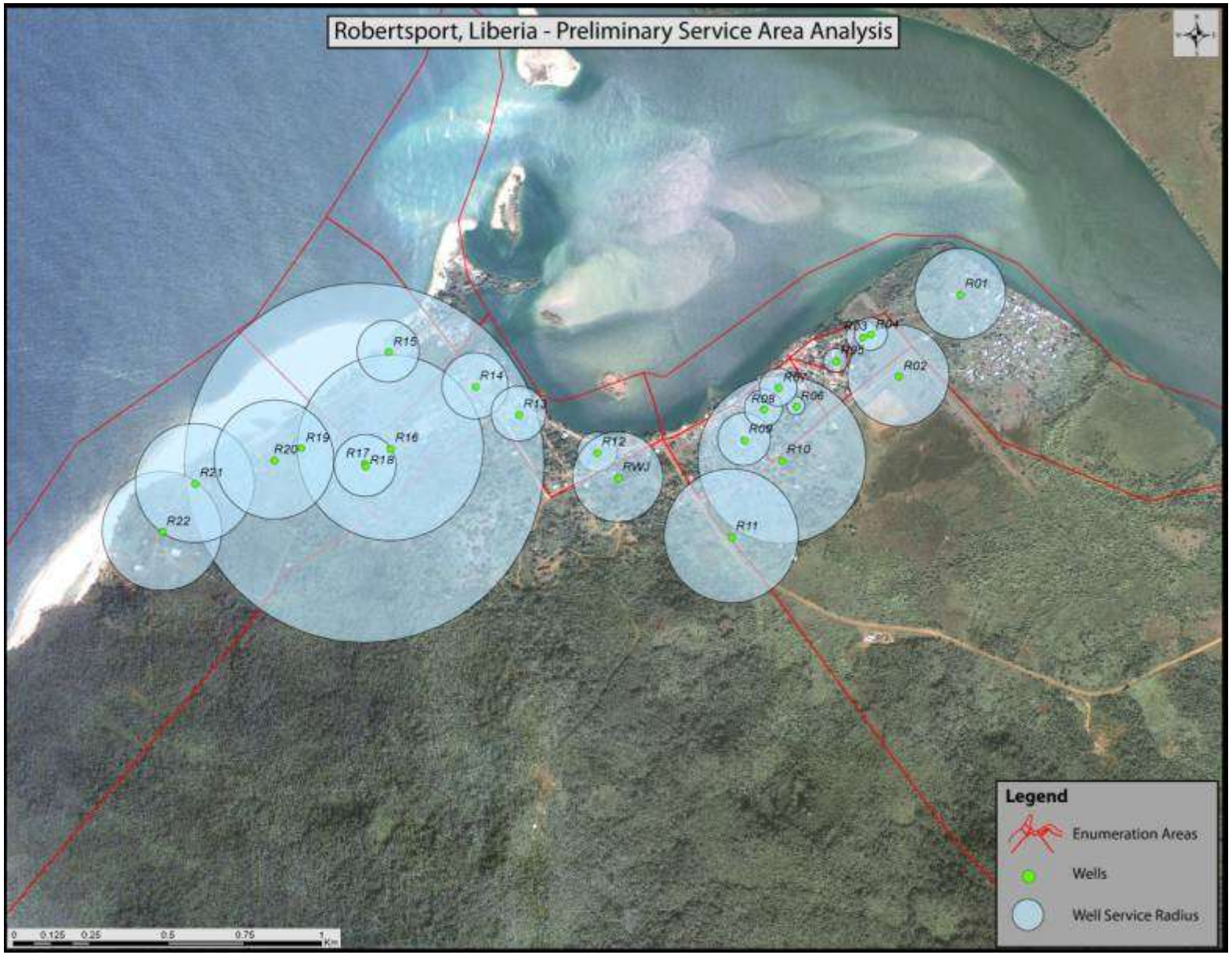

Figure 4-9 Estimated Coverage from "All" Existing Hand Dug Wells

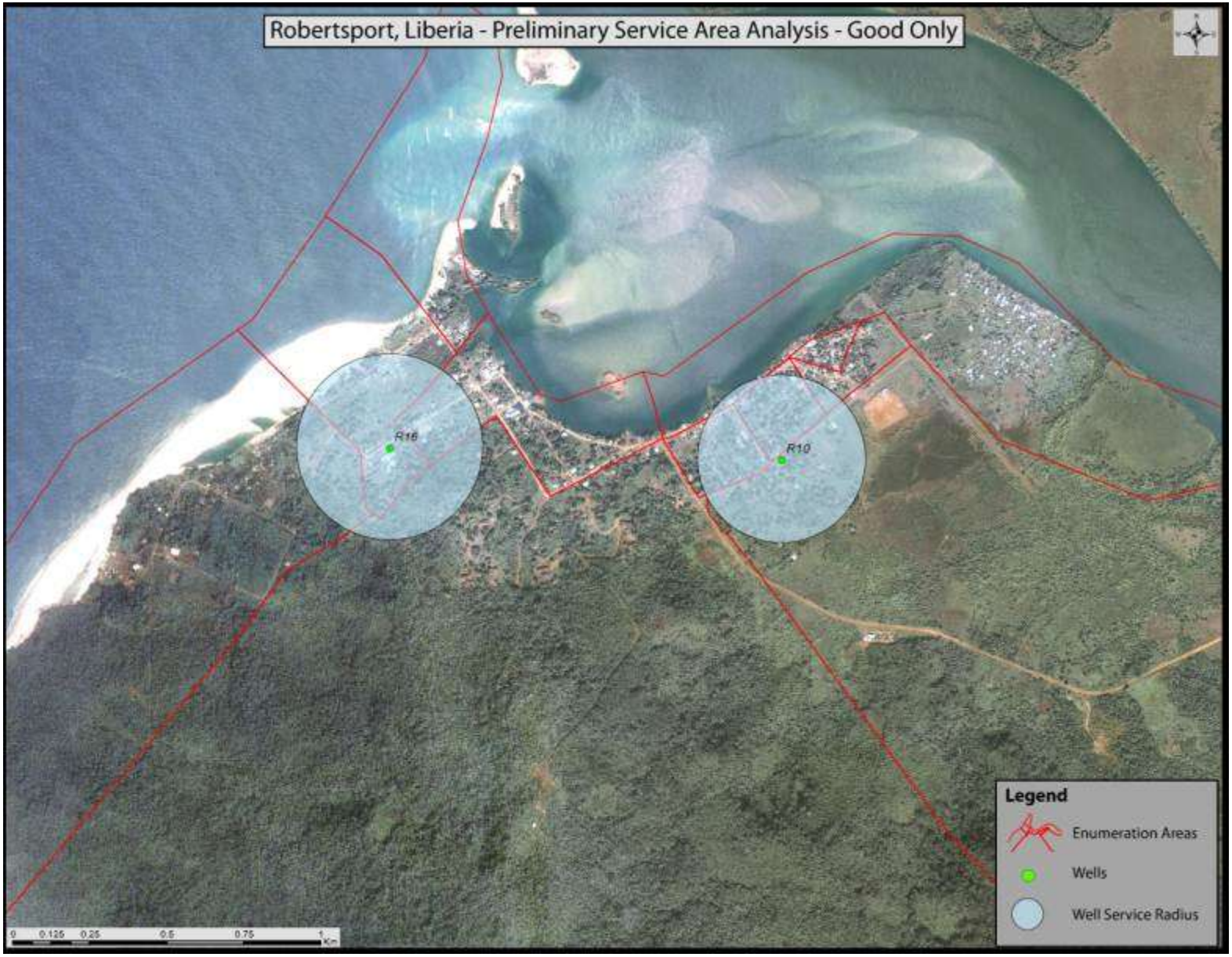

Figure 4-10 Estimated Coverage from Wells Reported with "Good Quality"

4.4 SURFACE WATER SUPPLY OPTIONS

The surface water alternatives for Robertsport were assessed using water resources data and reports from previous water investigations, particularly the 1983 study by GKW Consultants entitled "Robertsport Water Supply Final Design Report, June 1983". With the exception of Lake Piso (a brackish water system), there are no large lakes, ponds or impoundments. Given the limited number of large streams, there is a scarcity of water resources in the Robertsport area. This factor permitted the LMWP team to streamline its effort to quickly identify the previous source, Fasa Creek, as the most likely viable option. The area appears to include many small streams originating from Grand Cape Mount, but a lack of mapping and stream flow data significantly impacts the evaluation and development of these smaller streams.

Surface water in Robertsport and the surrounding coastal areas of Grand Cape Mount County is driven primarily by precipitation. Precipitation peaks in the months of June through August. The natural undeveloped setting of the tropical forest on the slopes of Grand Cape Mount provides a valuable natural water source that should be protected.

4.4.1 Fasa Creek and other Small Streams

The residents in Robertsport presently use surface waters, including Fasa Creek and other small streams, for washing and bathing and for some, drinking. At the previous intake/impoundment structure, Fasa Creek flows within defined banks. The smaller streams in the area are shallow and less than 5 to 10 feet in width. Surface waters appear to be a reliable source for irrigation by the farmers but are known to be inadequate during prolonged dry seasons.

The quality of the surface water is anticipated to vary between the flow conditions of the dry (October to May) and wet seasons (June to September). The total dissolved solids in Fasa Creek were found to be less than 30 mg/L during the dry season visit in March 2012. Despite the low total dissolved solid levels reported, the untreated water is likely not safe for consumption without disinfection. Further water quality testing, including samples sent to a US laboratory, is currently underway to more definitively draw conclusions regarding suitability of this source.

Fasa Creek was observed to be flowing during the March 2012 visit. The intake structure at Fasa Creek is located about 1.7 km from the center of Robertsport.

The "Robertsport Water Supply Final Design Report, June 1983" by GKW Consultants study indicates the following information concerning Fasa Creek:

Catchment Area	2.4 km^2
Probable Maximum Flood	27 cubic meters per second
Safe Yield	8 liters per second
	125 gallons per minute
Abstracted Quantity (1995 projection)	4.37 liters per second
	69 gallons per minute

According to the GKW flow estimates, the safe yield of Fasa Creek (approximately 180,0000 gallons per day) is sufficient to meet long term demands and maintain a base stream flow. The safe yield of the stream is considered to the historic minimum flow the stream's watershed can reliably produce. The

abstracted quantity is also known as the withdrawal rate. Based on the values presented in GKW Consultants study the base stream flow during low flow (safe yield) conditions would be 3.63 liters per second (= 8 lps – 4.37 lps, or 57 gallons per minute). The option of utilizing the Fasa Creek as the sole or partial source is recommended as the long term solution to improve the level of water service in Robertsport provided treatment can be established, maintained, and sustained. Stream gauging has been established by LMWP and data collected will be used to refine flow estimates.

Maintaining the environmental quality of the Fasa Creek watershed is critical to ensuring the sustained quantity and quality of water the surface stream is capable of providing. This issue was first raised in the 1980s. Maintaining the natural environmental setting and vegetation of the land area within the watershed must be protected. The watershed and its ability to supply relatively clean water to Fasa Creek was the foundation of the previous water system. The importance of watershed protection is also true for the other streams located on Grand Cape Mount. Implementing previous recommendations to protect critical watersheds remains a vital action for the City of Robertsport and LWSC. Providing watershed protection is a supportive step Robertsport can take to support the development of the water systems. The appendix material includes a recommended bylaw the City could enact and enforce. It is anticipated that implementation of watershed protections can be incorporated in the institutional efforts in developing a water utility in Robertsport.

The option of accessing water from the smaller streams is eliminated from further consideration as a source of water due to the lack of a year round supply.

4.4.2 Rainwater Harvesting

Rainwater harvesting practices are in place throughout Liberia, although less than 5% of household survey respondents in Robertsport indicated that they use rainwater as their primary source of drinking water. Rainwater harvesting is time-tested practice that preceded systems that rely on well drilling equipment and piped water supplies. In many parts of the world, rainwater collection remains a large contributor in meeting the daily water requirements.

Rainwater harvesting generally consists of:

- A collection area (usually a roof, to reduce the amount of cross-contamination)
- Piping, gutters, downspouts, or channels, and a method to divert the “first flush” containing potential contaminants
- A storage tank or cistern. Storage tanks or cisterns are commonly constructed of concrete, plastic or fiberglass, and can be located below-ground if desired.
- A system to distribute the water
- Filtration (in some systems)

The amount of storage is dependent on many factors that include the availability of alternative sources, the amount of rain, and the frequency of measurable rainfall.

A preliminary evaluation of the feasibility of harvesting the 2,954 mm (116.3 inches) of average annual rainfall that occurs in Robertsport was conducted based estimated monthly rainfall shown in Table 4-1.

Table 4-1 Robertsport Monthly Rainfall

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	38	5	18	180	254	485	803	927	927	371	114	84
Rainfall (inches)	1.5	0.2	0.7	7.1	10	19.1	31.6	36.5	36.5	14.6	4.5	3.3

Based on the rainfall monthly rates and the following assumptions, the requirements of the rainwater harvesting system (capture area and storage volume) for the subject dwelling is shown in Table 4-2:

Table 4-2 Typical Residential Rain Harvesting System

Rain Harvesting System Parameter	Description	
Rainfall	No rainfall and therefore no supply occurs during the four driest months of December, January, February and March	
Capture Rate (%)	A capture rate of 85% is used assuming that 15% of all rainfall in other months is not captured for use and lost	
Number of Person per Dwelling	6 persons per dwelling	
Demand (lpcd)	38 lpcd	20 lpcd
Capture Area (m^2)	25 m^2	14 m^2
Storage Required m^3 (gallons)	39.9 m^3 (10,500 gallons)	23.6 m^3 (6,200 gallons)

Based on the conceptual rainwater harvesting system, the preliminary evaluation compared the accumulated water stored versus the straight line cumulative demand. The maximum differential value located above the straight line cumulative demand and the accumulated supply curve in the first 12 months represents required storage volume. This relationship is shown in Figure 4-11.

The option of promoting and utilizing rainwater harvesting as an alternative source of water, especially for non-potable purposes such as irrigation or wash water, is advantageous. Rainwater harvesting by residents could provide a source of water at low cost for non-potable purposes, which would reduce the demand for more costly pumped and treated water sources.

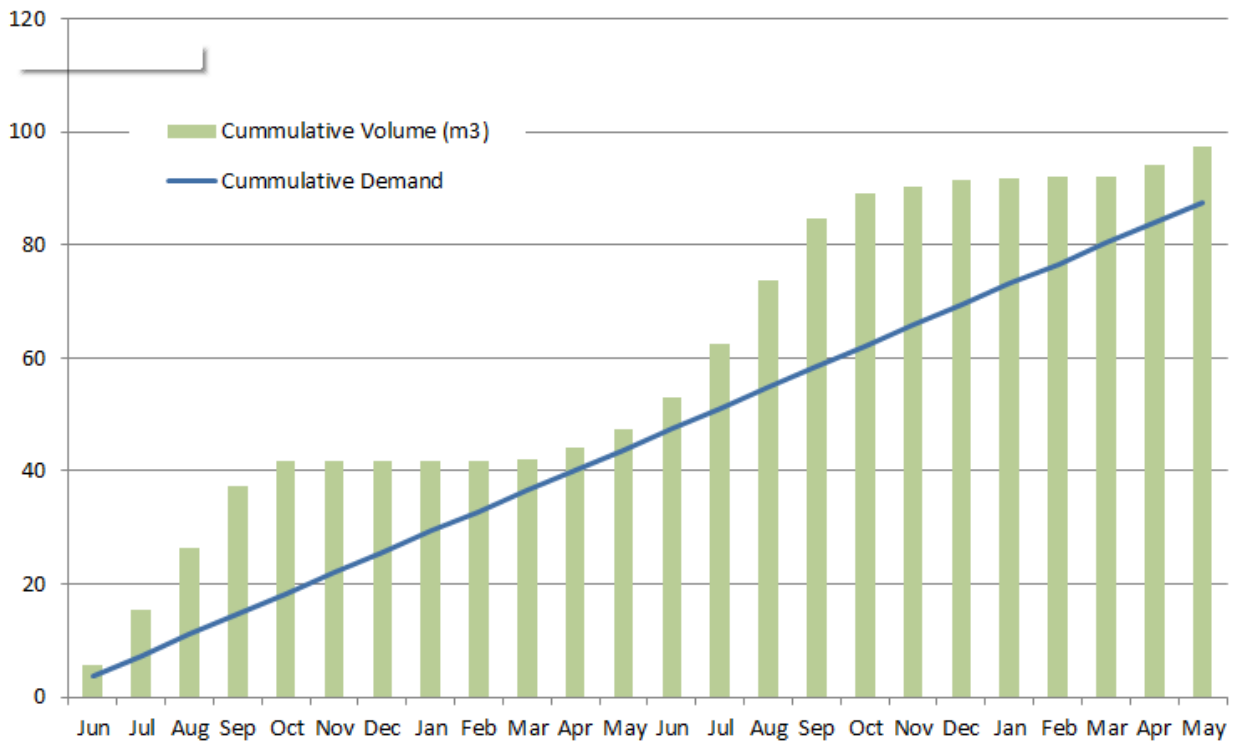

Figure 4-11 Robertsport Rain Harvesting Supply & Demand Curves

4.5 WATER TREATMENT OPTIONS

In the quantitative survey, half of the respondents (50%) reported treating their drinking water all the time, and 21% said they treated the water sometimes. The vast majority of the respondents who treated their water used chemical disinfectants such as WaterGuard. Water quality testing performed by LMWP indicated that most wells have coliform bacteria present. Given widespread water quality concerns, relatively low levels of household water treatment, and strong local demand for piped water supply, continued reliance on wells and direct collection of surface water is not recommended. Although point of use treatment such as WaterGuard should continue to be promoted during the interim, the medium term goal of LMWP is to move to a piped water supply that provides disinfected water.

The goal of water treatment is to protect public health by purveying a safe and reliable drinking water supply. In general, surface water supplies require treatment processes that are more complex than the treatment processes for groundwater supplies, in order to remove the expected higher levels of combined organic and inorganic contaminants. With the exception of brackish groundwater, groundwater typically possesses better quality, but as previously noted the existing shallow groundwater supply in Robertsport is contaminated by infiltration of sanitary and other wastewaters.

The design of treatment for Robertsport will be based on the following primary considerations: water quality, water demand, required staff capacity, cost, safety and reliability.

4.5.1 Chlorination

To provide disinfection, chlorine is commonly added to water supplies at the source, a distribution node, or storage tank. It can be added using any of several different methods. The water source characteristics determine the estimated amount of chlorine required for disinfection and other treatment purposes.

Based on a conservative application of 10 mg/L of chlorine to the raw water, a total daily demand of chlorine is estimated for various water demands shown in the following table.

Table 4-3 Chlorination Quantities by Type

Populations	Daily Flow	Chlorine Application	Chlorine Required	Hypochlorite Required	Storage	12% Bleach	Storage
(persons)	(gpd)	(mg/l)	(Lb./day)	(Lb./day)	(lb.)	(gpd)	(gal)
3,700	6,331	10	1	2	240	1	120
4,100	58,110		5	8	960	5	600
4,500	76,986		7	10	1,200	7	840
5,500	94,081		8	12	1,440	8	960

Chlorine can be directly applied in the form of different chemicals such as calcium hypochlorite or bleach, or a chlorine solution can be generated and injected on-site from chlorine gas.

Calcium hypochlorite can be provided in a powdered or solid/tablet form that will provide approximately 70% of its weight as chlorine. Therefore Robertsport would initially require 10 pounds of high test hypochlorite (HTH) daily. The application rate would increase as both the population and daily water demand increase. Dry chlorine can be simply but possibly inefficiently cast into the water, or added by means of in-line chlorinator. More advanced application methods require solution tanks, mixers, and chemical feed pumps. Outlined below are annual costs for consumption of chlorine tablets and the associated labor to apply chlorine tablets. The cost of the equipment, piping, and appurtenance is dependent upon the type and number of source waters and the complexity of the application (from manual casting of powder to chemical application systems). The cost of capital for the chemical application system can be incorporated into the cost estimate for the selected project alternatives. Table 4-4 is presented to describe the magnitude of O&M costs associated with the addition of chlorine using tablets.

Table 4-4 Chlorine Tablet Estimated Costs

	QTY	Unit	Unit Cost		Annual Cost
Chlorine Tablets	12	Lb./day	$10.00	per pound	$43,800.00
Labor	4	hr./day	$15.00	per hour	$21,900.00
O&M Costs					$65,700.00

Liquid bleach is generally available at a commercial grade of 12% (120,000 mg/l) as sodium hypochlorite. Liquid bleach will degrade and lose its concentration and potency over time at a rate of 20% each year, but the rate of degradation will increase when stored at temperatures greater than 20 degrees Celsius. Liquid chlorine application requires chemical feed pumps that withdraw directly from chemical vessels or totes.

Chlorine gas can be provided as one ton cylinders (907 kilogram containers) or as 150 pounds upright tanks/ bottles (68 kg). The handling and transportation of chlorine gas represents a safety hazard. Severe security and safety hazards associated with the gaseous chlorine can occur from accidental events and sabotage. The application of gaseous chlorine requires scales, evaporators, and regulators to inject the chlorine gas into the water flow. The previous water system used this method.

Another alternative source of chlorine could include on-site generation of chlorine. On-site generation generally includes a direct current power source that converts a salt water solution to a hypochlorous acid. In addition to the power supply source, the process requires a supply of saturated brine and softened water.

The previous options imply the application of chlorine at a central location such as a single supply or from the treatment plant, but another option for consideration is to add the chlorine at storage node tanks prior to consumption by the residents of Robertsport. At these sites in a distribution system the selection of the form of chlorine would be limited to the application of calcium hypochlorite due to storage and safety concerns.

If private storage tanks play a role in the water system improvements education should be provided regarding the concerns of safe drinking water and the practices of applying calcium hypochlorite to the water supply. The application of chlorine in a private tank would not eliminate the need to maintain a residual concentration to provide protection for public stand posts.

When chlorine is added to the water system an ongoing practice of monitoring for free chlorine in the system should be conducted using colorimetric methods.

The option of utilizing chlorine as calcium hypochlorite is recommended to improve the level of water service in Robertsport. Calcium hypochlorite is more cost effective and easier to perform for a simpler disinfection system. The recommendation of calcium hypochlorite is consistent with current LWSC practices of chlorination. The use of powdered calcium hypochlorite was observed in field visits to Kakata. The operators would mix a “day solution” and apply the chlorine solution to the water withdrawn from Kakata’s borehole number 2.

The use of chlorine bleach could be an alternative depending on the application and location.

The option of chlorine gas and on-site generation is eliminated from further consideration as a source of water due to complex system requirements, and significant O&M efforts and electricity requirement.

4.5.2 Water Treatment

As documented in prior reports and LMWP analysis, the surface water and groundwater in the Robertsport area requires treatment if it is intended to be used as a drinking water supply. The previous slow sand filtration and chlorination water treatment process could likely be used with sufficient provision of adequately train operators, and adequate financial and administrative support.

Simply adding chlorine will provide disinfection and oxidation to the raw water. If source water is only chlorinated, then other water quality issues which cannot be addressed by oxidation, such as turbidity, hardness, or phosphates, may still render the water unsafe for drinking as per WHO standards.

Listed below are two tables, the first outlining possible treatment processes that could be applied in Robertsport and the second outlining the removal methods for specific contaminants.

In general, the selection of a simple and low cost treatment system is highly preferred over more complex and resource-intensive treatment options due to requirements in terms of labor and capacity, chemicals, and maintenance. The factors favoring the simpler treatment option include:

- Lack of experienced operators
- Fewer operation and maintenance requirements
- Lack of the components of an established and reliable municipal infrastructure that are necessary to support a fully functioning water supply system
- Lack of well-established supporting mechanisms to finance, maintain, and manage a water supply system
- Difficulty to supply spare parts and equipment vendor service
- Lack of power available from an electrical grid.
- Lack of experienced in-country support services and sub-contractors to assist in maintenance of the treatment system

Table 4-5 Treatment Processes for Removal of Specific Constituents

Type of Process	Operation/Process	Description	Typical Application in Water Treatment
Physical Unit Process	Adsorption	The accumulation of a material at the interface between two phases	Removal of dissolved organics from water using granular activated carbon (GAC) or powdered activated carbon (PAC)
Physical Unit Process	Aeration	The process of contacting a liquid with air by which a gas is transferred from one phase to another: either the gas phase to the liquid phase (gas absorption) or the liquid phase to the gas phase (gas stripping)	Removal of gases from groundwater (e.g., H_2S, VOCs, CO_2, and radon); oxygenation of the water to promote oxidation of iron and manganese
Physical Unit Process	Filtration (media)	The removal of particulate material in a filter bed composed of a granular medium through transport and attachment to the filter media	Removal of solids following coagulation, flocculation, gravity sedimentation, or flotation
Physical Unit Process	Filtration (membrane—microfiltration	Membrane filtration used for the removal of colloidal material (0.1 to 1.0 µm) by means of straining (size exclusion)	Used to remove turbidity, bacteria, and protozoa like Giardia and Cryptosporidium
Physical Unit Process	Filtration (membrane—ultrafiltration)	Membrane filtration used for the removal of sub micrometer particles (0.001 to 0.03 µm) by straining (size exclusion)	Used to remove turbidity, some viruses, bacteria, and protozoa like Giardia and Cryptosporidium
Physical Unit Process	Flocculation	Aggregation of particles that have been chemically destabilized through coagulation	Used to create larger particles that can be more readily removed by other processes such as gravity settling or filtration
Physical Unit Process	Flow equalization	Storage basin in a process train, which can store water to equalize flow and minimize variation in water quality	Large storage tanks used to store waste wash water to permit constant return flow to head of treatment plant; clear wells used to store treated water to allow treatment plant to operate at constant rate

Type of Process	Operation/Process	Description	Typical Application in Water Treatment
			regardless of short-term changes in system demand
Physical Unit Process	Mixing	Mixing and blending of two or more solutions through input of energy	Used to mix and blend chemicals
Physical Unit Process	Nano filtration	High-pressure membrane filtration used for removal of dissolved sub micrometer particles (0.001 to 0.01 μm) by straining (size exclusion)	To produce potable water from ocean, sea, or brackish water; water softening; removal of specific dissolved contaminants such as pesticides and removal of NOM to control DBP formation
Physical Unit Process	Reverse osmosis	High-pressure membrane filtration used for removal of dissolved submicrometer particles (0.0001 to 0.005 μm) by solution/diffusion and exclusion	To produce potable water from ocean, sea, or brackish water; water softening; removal of specific dissolved contaminants such as pesticides and removal of NOM to control DBP formation
Physical Unit Process	Screening, coarse	Passing untreated water through coarse screen to remove large particles from 20 to 150 mm and larger	Used at the intake structure to remove sticks, rags, and other large debris from untreated water by straining (i.e., interception) on screen
Physical Unit Process	Screening, micro	Passing water through stainless steel or polyester media for removal of small particles from 0.025 to 1.5 mm from untreated water by straining (i.e., interception) on a screen	Used for removal of filamentous algae
Physical Unit Process	Sedimentation	Separation of settleable solids by gravity	Used to remove particles greater than 0.5 mm generally following coagulation and flocculation
Physical Unit Process	Ultraviolet light disinfection	Use of UV light to inactivate microorganisms	Inactivation of microorganisms such as viruses, bacteria, and protozoa, usually used in conjunction with a chemical that can produce a lasting residual in the distribution system

Type of Process	Operation/Process	Description	Typical Application in Water Treatment
Chemical Unit Process	Chemical disinfection	Addition of oxidizing chemical agents to inactivate pathogenic organisms in water	Disinfection of water with chlorine, chlorine compounds, or ozone
Chemical Unit Process	Chemical neutralization	Neutralization of solution though addition of chemical agents	Control of pH; optimizing operating range for other treatment processes
Chemical Unit Process	Chemical oxidation	Addition of oxidizing agent to bring about change in chemical composition of compound or group of compounds	Oxidation of iron and manganese for subsequent removal with other operations and processes; control of odors; removal of ammonia
Chemical Unit Process	Chemical precipitation	Addition of chemicals to bring about removal of specific constituents through solid phase precipitation	Removal of heavy metals, phosphorus
Chemical Unit Process	Coagulation	Process of destabilizing colloidals so that particle growth can occur during flocculation	Addition of chemicals such as ferric chloride, alum, and polymers to destabilize particles found in water

Developed from Table 4-6 of “Water Treatment Principles and Design” Second Edition by MHW

Table 4-6 List of Constituents & Potential Applicable Treatment Processes

Type of Parameter	Constituent Pollutant	Process	Treatment Applicability
Physical	Turbidity/ particles	In-line filtration[a]	Works well in low-turbidity, low-color waters. Pilot studies should be performed to establish performance and design criteria.
		Direct filtration[b]	Applicable for low to moderate turbidity and colored waters. Pilot studies should be performed to establish performance and design criteria. Shorter filter runs than conventional treatment.
		Conventional treatment	Works well in moderate- to high-turbidity waters. More operational flexibility than direct or in-line filtration options. Sedimentation basin detention time allows for NOM, taste and odor, and color removal in combination with sedimentation. Sometimes can be designed without piloting if local regulatory agency guidelines are followed
		Membrane filtration—microfiltration, ultrafiltration	Effective at removing turbidity, bacteria, and protozoa-sized particles. Viruses may be removed by some types of ultrafiltration membranes. Works well on low-turbidity waters or with pretreatment for particle removal. Natural organics can foul membranes. Pilot testing required to demonstrate particle removal and potential for organic fouling. Easily automated and space requirements are much smaller than conventional plants
		Slow sand filtration	Primary removal mechanisms are biological and physical. Works well in low-turbidity waters. When used in conjunction with granular activated carbon (GAC), effective at taste and odor removal. Surface loading rates are 50 to 100 times lower than rapid filtration so filters are very large. Most commonly used by small communities, but there are very large plants in operation throughout the world
Physical	Hardness	Lime soda softening	Applicable for moderate to extremely hard waters. Historically the most common method for removal of hardness
		Ion exchange	Most common in small installations. Disposal of regenerate solutions can be a problem
		Nanofiltration	Often referred to as low-pressure reverse osmosis (RO) membranes. Applicable for moderate to extremely hard waters. Disposal of concentrate may be the limiting factor in using nanofiltration

Type of Parameter	Constituent Pollutant	Process	Treatment Applicability
Physical	Total dissolved solids (TDS)	Reverse osmosis, ion exchange, distillation	Used for desalination with ocean, sea, and brackish water. Reverse-osmosis concentrate and ion exchange regenerate solution disposal may be the limiting factor in selecting these treatment processes
Inorganic Chemical	Nitrate	Biological dentrification, reverse osmosis, ion exchange	Biological denitrification requires the use of special organisms to reduce nitrate to nitrogen gas. Reverse osmosis will reduce nitrate levels in drinking water, but this process is used primarily for treating high TDS and salt water. Ion exchange with anionic resins is attractive when brine disposal is available.
Inorganic Chemical	Fluoride	Lime softening, coagulation/precipitation, activated alumina	Lime softening will remove fluoride from water both by forming an insoluble precipitate and by co precipitation with magnesium hydroxide [Mg(OH)2]. Alum coagulation will reduce fluoride levels to acceptable drinking water standards but requires very large amounts of alum to do so. Contact of fluoride-containing water with activated alumina will remove fluoride.
Inorganic Chemical	Arsenic	Coagulation/precipitation, activated alumina, ion exchange, reverse osmosis	Conventional coagulation with iron or aluminum salts is effective for removing greater than 90 percent of As(V) (with initial concentrations of roughly 0.1 mg/L) at pH values of 7 or below. As with fluoride, is strongly adsorbed/exchanged by activated alumina. Arsenic(III) is difficult to remove but is rapidly converted to As(V) with chlorine (Cl2).
Inorganic Chemical	Iron/ manganese	Oxidation, polyphosphates, ion exchange	Typically found in ground waters or lake waters with low dissolved oxygen. Removal is most commonly through precipitation by oxidation using aeration or chemical addition (e.g., potassium permanganate or chlorine) for removal by sedimentation or filtration. Greensand filtration in which oxidation and filtration take place simultaneously is also common. The use of polyphosphate precipitation is another method that can be used for the removal of iron and manganese. Iron oxidizes much more readily than does manganese
Inorganic Chemical	Sulfate	Reverse osmosis	Reverse osmosis is most common for removal of sulfate from seawater

Type of Parameter	Constituent Pollutant	Process	Treatment Applicability
Organic Chemical	Natural organic matter	Enhanced coagulation, adsorption, ion exchange, reverse osmosis	Enhanced coagulation (low-pH coagulation) can be used to remove significant amounts of NOM as measured by TOC and is the most widely used process for NOM removal. GAC adsorption, post filtration is also very effective in removing NOM. Ion exchange use is limited by disposal of the high-TDS regeneration brine. The high cost of RO and concentrate disposal issues limit the use of this process for NOM removal
Organic Chemical	Disinfection byproducts	Enhanced coagulation, adsorption, alternative disinfectants	Strategies for the control of disinfection by-products (DBPs) include alternative disinfectants (ozone, chlorine dioxide, chloramines, and ultraviolet light) or removal of DBP precursor material (NOM) through enhanced coagulation or adsorption on activated carbon [either GAC or powdered activated carbon (PAC)]. GAC can be used to remove bromate, a DBP formed from ozone and bromide
Microbial	Bacteria	Conventional treatment, membrane filtration, reverse osmosis, disinfection	Bacteria can be removed through conventional processes, including sedimentation and filtration. Membrane processes provide a positive barrier to most bacteria. Given sufficient dose and contact time, all common disinfectants (chlorine, chlorine dioxide, chloramines, UV, ozone) are effective at inactivation of bacteria
Aesthetics	Taste and odors[d]	Source control with copper sulfate and reservoir destratification (in situ aeration)	Many taste and odor problems are associated with algae growths and reservoir turnover. Copper sulfate applied in the source water is effective at controlling algae growth. Aeration is appropriate for use in relatively shallow raw-water storage areas where seasonal turnover of stratified water releases taste and odor compounds
		Oxidation with chlorine, ozone, potassium permanganate, and chlorine dioxide	Chlorine may be used to control taste and odors from H2S but is not effective at algal taste and odors and may even make these types of taste and odors worse. Chlorination of industrial chemicals such as phenols intensifies objectionable tastes. Ozone is viewed as one of the most effective oxidants for reducing taste and odors and has the additional benefit in that it can also be used for disinfection. Permanganate is effective for removal of some algae

Type of Parameter	Constituent Pollutant	Process	Treatment Applicability
			taste and odors at alkaline pH.
		Adsorption with GAC or PAC	Granular activated carbon as a filter medium can be very effective for low to moderate taste and odor levels. Replacement is usually on a 3–5-year cycle. In slurry form, PAC can be added to the coagulation process for taste and odor control. PAC is especially effective in contact clarification devices.
Aesthetics	Color	Coagulation/precipitation	High coagulation doses and low pH can be effective even for very high color levels. Bench or pilot testing is recommended
		Adsorption with GAC	Granular activated carbon bed life can be short depending on the levels and empty bed contact time (EBCT)
		Oxidation with chlorine, ozone, potassium permanganate, and chlorine dioxide; low pressure reverse osmosis	Effectiveness is generally ozone > chlorine > chlorine dioxide > KMnO4. pH can affect the efficiency and some colors may return after oxidation. Pilot or bench studies are recommended. Reverse osmosis is very effective but expensive.

[a] In-line filtration is comprised of coagulation followed by filtration. Also known as contact filtration in countries outside the United States.
[b] Direct filtration is comprised of coagulation followed by flocculation and filtration.
[c] Conventional treatment is comprised of coagulation, flocculation, sedimentation, and filtration.
[d] Total dissolved solids, which can also cause taste and odor problems, are considered under the heading physical parameters.

Developed from Table 4-6 of "Water Treatment Principles and Design" Second Edition by MHW

4.5.3 Robertsport's Slow Sand Filtration Process

Slow sand filtration is accomplished by passing raw water from the source through sand medium by gravity at a relatively low application rate. The low filtration rate, coupled with the use of small size of sand gradation, results the removal of particles from the raw water in the top layer of the sand bed. The surface of the bed forms a biological-active layer, called "schmutzdecke", consisting of organic and inorganic debris and particulate matter in which biological activity is stimulated. The schmutzdecke forms and provides an additional filtration layer, physically screening smaller particles, and the biological activity degrades some organic matter. Particulate (solids, algae, bacteria, etc.) can be removed through bio-adsorption and attachment to the sand grains.

Once the filter's head losses increase to a certain level due to the binding or clogging of the filter media, the filter is drained and the top 10 to 20 mm of media is scraped off, cleaned and stockpiled on-site, and then the filter is put back in service. In Liberia, it is expected that the labor-intensive process of removing the media would be performed manually given the availability of low cost labor and concerns regarding maintaining and powering equipment needed to accomplish this task mechanically. Each operation run of slow sand filter lasts weeks to months, depending on the raw water quality and flow rates. The operation and scraping cycle can be repeated many times, usually over a period of several years, until the sand reaches a minimum depth of about 0.5 m. Then the sand will be replenished with the stockpiled sand to restore the original depth. This operational procedure is called resanding. A filter with new media typically has a ripening period which may last several days to allow the schmutzdecke form and the effluent water quality improve.

Compared with other treatment technology, slow sand filtration has the advantages and disadvantages listed below:

Advantages:

- Simple, easy to operate and maintain
- Low construction/operation cost
- Gravity system, minor or no power consumption
- No requirement of coagulation pretreatment
- Low head loss and long run time

Disadvantages:

- Low filtration rate
- Large footprint, generally only applicable in small communities
- Has no or very low removal for dissolved components and colloids. Only applicable for raw waters which has good quality and low turbidity levels of less than 10 units
- Labor intensive

Water Quality

Slow sand filtration is only effective for certain source water quality. High content of suspended solids and precipitate will clog the filter and shorten the length of filter runs. Table 4-7 summarizes the recommended limits of source water quality parameters. Based on field observation in both the dry and wet seasons, the raw water quality Fasa Creek is considered to be in compliance with these limits. Additional analytical testing by a US based laboratory is planned to confirm these observations as part of the final design.

Table 4-7 Recommend Influent Concentrations for Slow Sand Filters

Parameter	Recommended Limit
Turbidity	<10 NTU
True Color	<10
Algae	<200,000/L
DO	> 6mg/L
Iron	< 1 mg/L
Manganese	< 1 mg/L

*turbidity must not be attributable to colloidal clay

Slow sand filtration generally removes particulates from the water. Typical treatment performance of slow sand filtration is presented in Table 4-8. Based upon the observed raw water quality and the anticipated performance of the slow sand filtration process, it is anticipated that the treated water quality will comply with WHO standards.

Table 4-8 Approximate Effluent Quality from Slow Sand Filters

Parameter	Effluent Concentration or Reduction Capacity
Turbidity	<1.0 NTU
Coliforms	1 to 3 log units
Enteric Viruses	2 to 4 log units
Giardia cysts	2 to 4+ log units
Total organic carbon	<15% to 25%
Biodegradable dissolved organic carbon	<50%

Filter Design Criteria

A sand filter generally consist of filter structure, sand bed, gravel support layer, underdrain and other configurations such as a filter-to-waste system.

1) Flow rate: typically the nominal rate is 45-150 gpd/ft^2 of sand area (1.8-6.1 m^3/day/m^2)

2) Filter media: cleaned and washed sand free from foreign matter. Effective size shall be between 0.15 and 0.30 mm. Maximum uniformity coefficient is 2.5.

3) Sand Bed: minimum initial depth is 0.76 m (30 in.). Minimum depth before resanding is 0.48 mm.

4) Gravel Support: 0.38 -0.6 m deep. Consists of five layers of various size gravels.

5) Underdrains: includes both main drain and an adequate number of lateral underdrains.

6) Depth of water on filter beds: 0.9-1.8 m minimum.

Robertsport Slow Sand Filter Sizing Required versus Available Area

The long term residential water demand is estimated at 275 m^3/day (5,500 people × 50 lpcd) for the city of Robertsport, plus additional demands (20% unaccounted for water, 5% industrial, 3% commercial, 2% institutional, and 2% emergency). This results in a total estimated demand of 358 m^3/day. Evaluating

various filter rates in the below table indicates the application of the estimated demand would result in an application rate of about 3.2 $m^3/day/m^2$ and would require a surface area of 112 m^2. This approximates the 115 m^2 provided by two of the three existing filter beds (considering one filter is out of service during maintenance and filter ripening period). The application rate of 3.2 $m^3/day/m^2$ is well within the typical recommended design range of 1.8 to 6.1 $m^3/day/m^2$. Without the ability to restore the existing plant or to conduct long term and seasonal pilot testing it appears the size of the previous slow sand filter beds is adequate for the projected flows.

Table 4-9 Filter Size Comparison - Required to Available

Filter Rates $m^3/day/m^2$	Flow Rate m^3/d	Required Surface Area m^2	Existing Filter Length m	Existing Filter Width m	# Tanks Available/Online	m^2
1.8	358	199				
2.5		144				
3.2		112	12	4.8	2	115.2
4		90				
5		72				
6.1		59				

4.5.4 Managed Water Treatment Options

In 2001, a packaged water treatment plant located in Caldwell, Liberia, was commissioned. The project was funded by the Coca-Cola Africa Foundation and was developed and is operated by Water Health International (WHI). While a private company, WHI has developed a business plan to provide long term operations, maintenance, and water services to selected service areas. WHI presently has over 450 decentralized treatment facilities in operation in India, Ghana, Bangladesh and the Philippines. An additional five facilities are planned to be constructed and operated in Liberia. The facilities include modular construction techniques that use commercially available treatment technologies. At the Caldwell facility, with the exception of the intake pump and raw water force main, all of the facility is located on a small site (100' by 100'), and does not include any off site distribution system. Water is dispensed from taps located at the site.

The development of a WHI project starts with site selection and a contract. Once a site is selected WHI enters into a long term (10+ years) agreement with the community to construct, operate and manage the treatment facility. The operation of the water will be entirely managed and maintained by WHI for the term of the contract. After the contract the project can be turned over to the community. WHI is responsible for managing the project within the revenue collected from customers. The water rates and tariffs are set at the time the contract is executed. The customers of the facility are given specific totes to carry water and maintain water quality. The cost of water at the Caldwell facility is about $0.15 USD for 20 liters (L$10 for a 20 liter jug).

4.5.5 Packaged Water Treatment Systems

To address the provision of clean and sustainable water during and after emergencies, portable packaged treatment systems have been developed. These treatment systems are designed for local water conditions and water quality and can include a combination of pretreatment/pre-filtration, mechanical filtration, carbon filtration, reverse osmosis (RO) filtration, ultra-filtration (UF), and ultra-violet (UV) treatment. Individual units can produce up to 31,500 gallons per day ($5m^3$ per hour) of drinking water from source water with up to 750 mg/l of Total Dissolved Solids (TDS) and turbidity of 250 NTU.

The units can be set up on a temporary or long-term basis. The systems are commonly mounted on trailer units which allow the system to be towed. They can be powered by a generator unit or solar panel arrays.

Presented below is an outline of the estimated capital cost for a series of treatment facility installations powered primarily by solar panels with an auxiliary generator unit. The single table includes the cost of an ultra-filtration (UF) treatment process and a reverse osmosis (RO) treatment process but excludes the cost of the surface water intake, bore holes, site work, and associated distribution and storage costs. Also included are the basic operation and maintenance annual costs.

Table 4-10 Package Treatment Plant Estimated Costs

Capital Costs	Capacity/Unit	Capacity	Treatment	#Units	Unit Cost	Costs
	gpd	gpd				
Package WTP Units	9,000	90,000	RO Option	10	$170,000.00	$1,700,000.00
			UF Option		$48,000.00	$480,000.00
Generators				10	$5,000.00	$50,000.00
Annual Labor Cost			Superintendent	1	$8,000.00	$8,000.00
			Chemist	2	$5,500.00	$11,000.00
			Operators	10	$4,000.00	$40,000.00
			Maintenance	4	$4,000.00	$16,000.00
			Distribution Operators	5	$3,000.00	$15,000.00
Annual O&M Supplies			UV Light Replacement		$150.00	$1,500.00
			UF Module Maintenance		$3,000.00	$30,000.00
			Filter Replacement		$50.00	$500.00
			Chlorine Supply		$400.00	$4,000.00
			RO Membranes		$350.00	$3,500.00
			RO Descaling Supplies		$4,500.00	$45,000.00
			Filter Media Replacement		$100.00	$1,000.00
			Fuel		$4,380.00	$43,800.00
Annual Operating Cost			RO Option			$189,300.00
			UF Option			$170,800.00

4.6 STORAGE OPTIONS

4.6.1 Existing Elevated Storage Tanks

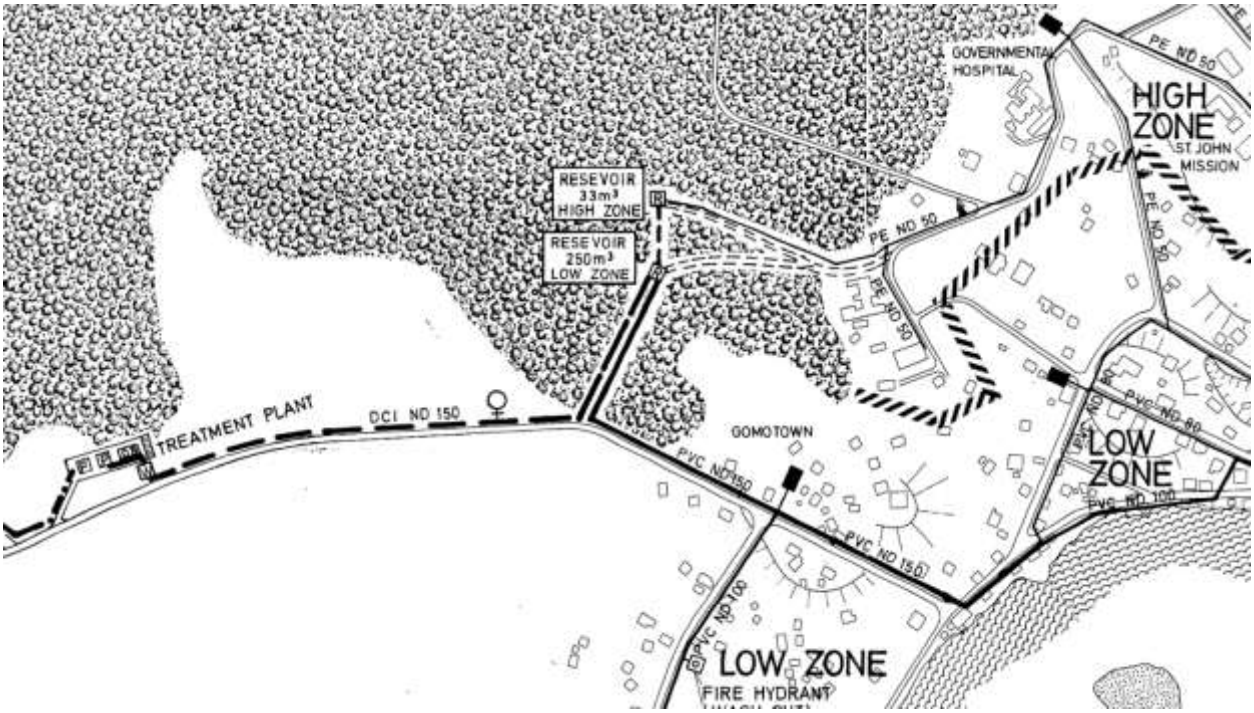

Figure 4-12 Previous Lower and Upper Zone in Previous Robertsport Water System

The previous Robertsport water system contained two at grade reservoirs that served two service zones, the larger low zone and the high zone. The lower zone reservoir was a 250cubic meter concrete structure that served the distribution system that was generally located between sea level and elevation of approximately 35 meters. The upper reservoir was a 33 cubic meter structure, and served the distribution system that was generally located between elevation 35 meters and approximately 70 meters. Pumps located at the lower reservoir fed the supply to the upper reservoir. The lower reservoir was fed by the high lift pumps located after the balancing tank located at the WTP site.

Both the upper and lower reservoir structures would need to be cleaned, repaired and disinfected prior to returning to service if the component is determined to be integral to the Robertsport water system improvements. Both reservoir sites are present overgrown with vegetation that will be required to be clear and the sites secured. The scope of the repairs will be based on a detailed inspection of the concrete structures and the level of effort to rehabilitate the structures and their appurtenances.

The volume of a storage tank is typically determined based on three components:

- Equalization Volume
- Volume Needed Fire Flow (if determined to be required during the design process)
- Volume for Emergency Storage

The following table outlines the storage time provide if the existing elevated storage tanks are rehabilitated and restored to service, and the daily flow increases. The previous ground storage tanks that served the low and high service areas did not provide any volume for needed fire flow demands. The storage tanks provide the volume that allows the distribution system to float of the pressure provided and to meet peak hourly demands. The diurnal peak hour demands are projected and actual demand rates will be based on the water use practices demonstrated by the consumers. The distribution modeling used a standard diurnal cycle with the heaviest demands occurring at the start (~6 AM) and the end (~6 PM) of the day. Based on the modeling effort, the capacities of the previous tanks are anticipated to be adequate for the projected demands.

Table 4-11 Durations of Storage in Elevated Tank

Year	Description	Daily Flow		Existing Storage Volume		Storage
		(gpd)	(m3/d)	(gal)	(m3)	(days)
2011	Base Year (2011)	6,331	25	74,474	283	11.3
2016	5-Years (2016)	58,110	221			1.3
2021	10 Years (2021)	76,986	293			1.0
2031	20 Years (2031)	94,081	358			0.8

The estimated 15 meters or 50 vertical feet from the base of the elevated storage area to the finish grade at the elevated storage tank site indicates 20 psi of static pressure is available at this location. A cursory review of the key or well-known areas in Robertsport indicates the majority of the town is located below the elevated storage tank site. This simplified evaluation does not address the head loss condition and pipe loss between sites.

Table 4-12 Comparison of Elevations throughout Robertsport

Location	Approximate Elevation (ft.)	Difference in Elevation with Respect to Elevated Storage Tank Site(ft.)*
Upper Reservoir	280	
Hospital Site	220	-60
Saint John's School Campus	190	-90
Lower Reservoir	215	
County Administration Building	80	-135
Gertrude Guest House	80	-135
WTP Site	25	-190
Fasa Creek Intake	100	-115
Fanti Town	10	-205
City Hall Building	15	-200

*(+) denotes a higher elevation and, (-) denotes a lower elevation

4.6.2 Mini Tanks/Zonal Nodes

Smaller storage facilities can be provided as a zonal node approach to reduce the requirements for system-wide elevated storage. The service area can be segmented into zones to ensure the resident's distance from a protected water supply does not exceed 30 minutes round-trip. This criterion can be developed in the definition of the zonal nodes and the location of zonal small storage tanks. From the small tanks, a smaller distribution system can provide service to local public stand posts or private yard and house connections. The small storage tanks and zonal systems can be developed independently to control pressures to protect individual communities from service breaks in the event of excessive demands from other communities. The small tank storage can maintain storage for peak demand for the community service area. This type of distribution system and tank configuration is also flexible and would permit chlorine to be added or boosted at each small tank location. In this configuration the use of calcium hypochlorite can be considered as a cost-effective method of chlorination.

As mentioned, it is recommended that the small storage tanks be sized to store to provide for the total daily demand for each community zone served, but the final volume should consider the supply source constraints. This could be greater than the half day (50%) storage used in more developed water systems. The excess storage is recommended due to the inconsistent power supply and other restrictive operational issues. When the system is operational with a proven, long-term operating record, this value could be reduced. The tank elevation and the expected operational range should provide adequate pressure for the one-story structures located throughout Robertsport.

Also, it is recommended to maintain a residual pressure at the public stand post of 15 psi.

4.6.3 Private Tanks

If individual private tanks become a conventional component of the water system, then residents could be trained to add chlorine powder to their tanks to provide chlorine residual. The overall system would be required to continue adding chlorine at some location to provide a chlorine residual at the public stand posts. The use of private tanks would also require the need for back flow prevention devices. The simplest backflow device is the use of an air gap. The air gap and other back flow device would safe guard against cross contamination from the private to the main distribution system. The back flow preventer would reduce the risk of a contaminated private tank's contents from be siphoned back into the main Robertsport supply system during periods of unusually low pressure (such as during a water main break).

The option of utilizing the previous elevated storage tank, small tank zonal nodes, or a combination of the two should be included for the immediate solution to improve the level of water service in Robertsport.

The option of private water storage tanks is eliminated from further consideration as a means of storage in the water due the risk of relying on private participation and the inability to identify and coordinate with specific potential location of private service connection at this stage of the master plan.

4.7 WATER DISTRIBUTION OPTIONS

The previous water distribution system was determined to be unsalvageable. No complete mapping of the distribution system was available for review or reference, but by various observations it appears the previous distribution system coverage once extended to the majority of the populated areas. Figure 2-2

shows the previous system was configured a branch system with lines extending to the more populated areas of Robertsport. The new pipe is proposed to follow the existing roadways and be located in the shoulder of the road. Even though some of the Robertsport roads are constructed of concrete slabs, many of the roads showed extensive erosion that resulted in vertical drops from building stairs to the roadway surface. At various locations the PVC pipe of the former water system was exposed due to the erosion and/or re-grading of the roadways.

A hydraulic analysis of the new distribution system was performed as part of the alternative analysis to design and evaluate system pressures and velocities under the initial normal demands of 10 gallons per day per person (38 lpcd) residential flow, plus 20% unaccounted for water, and an additional percentage for nonresidential flow for the areas of coverage. The evaluation was conducted to determine the requirements and conditions of the population and demands at the end of the study period. A looped system was use to provide a level of redundancy to sustain the level of service.

4.7.1 New Distribution Network

In order to determine how the initial distribution will operate during the initial improvement stages and how the Robertsport network expands, a hydraulic modeling approach was utilized. The inputs and results of the water distribution model provide a framework for assessing alternatives in expansion. The model is based on a simple distribution systems laid out to simulate the development of the phased construction of the new water system.

Based on the preliminary water supply scenarios that were modeled, the indication is that a gravity feed water distribution system can be implemented as the initial step for serving a large portion of the current residential areas. The phased construction approach includes the possibility of basic treatment (disinfection using chlorine) at the initial phases. The later stages of the improvement of the water system should include restoration of the slow sand filters at the previous WTP site and restoration of service to former high elevation service area.

Generally pipes will be sized to serve the residential areas at both the initial anticipated demand of 5 gpcd (20 lpcd) as well as the anticipated future residential demand of 13+ gpcd (50+ lpcd), plus nonresidential flows. The location of the water supply source and the areas to be served, as well as the amount of water to be provided are some of the key factors in developing the available alternatives to Robertsport. The modeling information is presented in the Appendix.

4.8 PUMPING POWER SYSTEMS OPTIONS

Due to the lack of a grid power supply, alternative power system needs to be developed to provide power for pumping of surface waters, groundwater, or treated water to the storage tanks or to the residents directly. The list of alternative power supplies includes:

- Independent electrical generator units
- Solar Power
- Wind Power

4.8.1 Independent Electrical Generator Units

Essentially all of the electricity used in Robertsport is from generator units owned and operated by private residents or businesses. The previous water system was also powered by an onsite generator located at the treatment plant. If properly sized, installed, and operated, a dedicated generator unit can provide power for the needed pumping and treatment.

Fuel cost and management would represent the single largest operational cost if generators are used for the project. Proper containment practices to safeguard the fuel from becoming a source of contamination at wells are critical. Due to the widespread use of portable generators in Liberia sufficient capacity to maintain and operate the units is expected to be present.

Table 4-13 Electric Generator for Pump Costs

Description	Qty.	Unit	Unit Cost		Cost
Diesel generator	1	LS	$3,000		$3,000
Generator house	1	LS	$6,000		$6,000
Submersible pump set	1	Each	$2,000		$2,000
Fencing	1	LS	$1,500.00		$1,500.00
Individual Generator and Pump Set					$12,500.00
(excludes bore hole, site work, storage and distribution)					
Annual Operation and Maintenance Cost					
Annual Replacement Costs	2%	Rate	20	Life , years	$760.00
Fuel Cost	$5.00	per Gal	8	hour/day	$8,760.00
	0.6	gph Fuel			
Miscellaneous Repairs					$500.00
Labor	1	hr./day	$15.00	per hour	$5,475.00
O&M Costs					$15,495.00

Derived from Unicef WASH Technology Information Packages

4.8.2 Solar Power

Advances in solar power technology have made solar a viable alternative energy option for water pumping. Several configurations of solar power devices may be viable. These configurations include the following:

Table 4-14 Solar Power for Pump Operation Alternatives

Components	Water service
Base Option: pump, switch box & Solar Panels	Only when solar panels are in operation
Addition of Storage Tank	Storage to provide service at night, when solar energy is inadequate
Addition of Backup Generator Unit	Alternate power source when solar energy source is not available or is inadequate
Addition of Backup Batteries	Alternate power source when solar energy source is not available

Solar radiation generally arrives at a maximum power density of about 1 kilowatt per square meter (1kW/m^2), but the actual recoverable rate depend on the geographical location, amount of cloud cover, hours of sunlight per day, and the efficiency of the solar panels.

The size of the solar panel array and system is based on the several factors including the population, flow rate, and total dynamic head for the pump. To estimate the flow the method used was based on a population of 5,500 persons in Robertsport, and maximum coverage rate of 3,000 persons per solar powered pump system, therefore four (4) installations are conservatively recommended. This will provide contingencies for expansion and for one of the solar pump systems to be out of service at a time. The evaluation can also be translated from a borehole application to a pumping facility located at a centralized location such as the previous water treatment plant.

Presented below is an outline of the estimated capital cost for a typical pump installation powered by a dedicated generator. It excludes the cost of the bore hole, site work, and associated distribution and storage costs. Also included are the basic operation and maintenance annual costs.

Table 4-15 Solar Power for Pump Costs

Capital Costs	QTY	Unit	Unit Cost	Cost	
Solar Panels, Peak watts, 20% cont.	576	peak watt	$2.50	$2,250.00	
Stand and Foundation for Panels	1	LS	$2,000.00	$2,000.00	
Solar pump	1	Each	$2,000.00	$2,000.00	
Fencing	1	LS	$1,500.00	$1,500.00	
Individual Solar Pump Set				$7,750.00	
(excludes bore hole, site work, storage and distribution)					
Operation and Maintenance Cost					
Annual Replacement Costs	2%	Rate	10	Life , years	$810.00
Labor	1	hr./day	$15.00	per hour	$5,475.00
O&M Costs					$6,285.00

Derived from Unicef WASH Technology Information Packages

4.8.3 Wind Power

While various styles of wind mills have been developed to generate energy, the scope of this evaluation is based on "lifting" windmills for pumping purposes. This approach reduces the loss of efficiency in converting mechanical power to electrical power and then back to mechanical power to transport the water. The traditional U.S. windmills have evolved over time but still provide the same service. The estimated cost of a traditional blade windmill, excluding the cost of the bore hole/well and the tower and support structure, is approximately $17,000 to $20,000 USD. The capacity for a windmill to lift water is based on wind speed, the diameter of the rotating blades, system inefficiencies, and the height the water is to be lifted. The below tables indicates the gallons per hour that can be pumped during light wind conditions.

Figure 4-13 Windmill powering well in Buchanan, Grand Bassa County

Table 4-16 Windmill Pumping Capacities

Size of Cylinder, Inches	Capacity (gallons per hour)		Elevation in Feet to Which Water Can Be Raised					
			Diameter of Windmill					
	6 ft.	8 ft. to 16 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
1 7/8"	3,000	4,320	120	175	260	390	560	920
2"	3,120	4,560	95	140	215	320	460	750
2 1/4"	4,320	6,240	77	112	170	250	360	590
2 1/2"	5,400	7,800	65	94	140	210	300	490
2 3/4"	6,360	9,240	56	80	120	180	260	425
3"	7,680	11,280	47	68	100	155	220	360
3 1/2"	10,560	15,360	35	50	76	115	160	265
3 3/4"	-	17,520			65	98	143	230
4"	13,680	19,920	27	37	58	86	125	200
5"	21,600	31,200	17	25	37	55	80	130
6"	-	45,000		17	25	38	55	85

Pumping capacities shown are approximate, based on the mill set on the long stroke, operating in a 15 to 20 mile-an-hour wind. The short stroke increases elevation by one-third and reduces pumping capacities by one-fourth

Ref http://aermotorwindmill.com/Sales/CommonQuestions.asp

Even though a wind-powered hand-dug well was observed in the City of Buchanan, in Grand Bassa County, Liberia, wind power has been eliminated as an option for the short and medium term due to the lack of adequate wind records to properly select the types and size of equipment, the possible lack of power during prolonged windless periods, and the lack of widespread usage and experience with this technology in Liberia.

4.8.4 Gravity Feed

Due to the elevated location of the intake structure on Fasa Creek, gravity feeding portions of the Robertsport service area is possible as either a temporary or permanent improvement. The solution could be established with the supply and distribution system piping operating under pressure provided by the elevated location of the intake. The elevation difference from the elevated intake structure to the low lying section provide the energy forces need to transport the flow through the pressurized pipe. This option would not likely include treatment, since the provision of treatment processes would interrupt the gravity feed and the pressurized pipe. The previous WTP is not located at a high enough elevation to allow gravity to fee the proposed service area, which is the reason why the WTP include pumps to feed the distribution and reservoirs.

The gravity system, like other systems, would be volume-limited by Fasa Creek's withdrawal or abstraction flow rate, stated in the previous GKW Design Report to be 4.37 liters per second (or 69 gallons per minute) unless storage is provided to meet periods of peak demands. If such storage is provided it would likely be located at and just below the intake structure in Fasa Creek. The storage tanks would supply the peak demand and the level in the tank would fall during this period. When the demand rate is less than the abstraction rate the storage tank would be filling. If the tank reaches an overflow condition, the extra flow will be piped back Fasa Creek.

The primary advantage to a gravity system is the non-reliance on a power supply to transport the needed water. Disadvantages include being restricted by the surface water body's flow rate.

5. ALTERNATIVE FORMULATIONS

A comprehensive water supply strategy for Robertsport included the identification of water source capacities, water treatment options, water storage options, and distribution system options.

The following consideration was the components to meet the initial water demand of 5 gpcd (20 lpcd), a project goal of 10 gpcd (38 lpcd), and the long-term projected demand of 13 gpcd (50+ lpcd). Based on available capacity and other constraints, emphasis is put on alternatives that utilize simple technology capable of future expansion and improvement with increasing demand and revenue.

Summary of "Possible" Water Supply Alternatives

- Water Source Options
  - Surface Water
    - Fasa Creek
  - Groundwater
    - Boreholes
  - Combination of Groundwater & Surface Waters
  - Ancillary Options
    - Promotion of rainwater harvesting to reduce demand for non-potable water

The use of a surface water source was determined to be the most feasible option, due to several factors:

- Past water supply practices
- Observed poor water quality from groundwater sources
- Observations of brackish water conditions in wells
- The relative high water quality of surface water present, and
- The low possibility of contamination in the watershed area where human activity is less-intense. The current practice of using surface waters as drinking water sources

With the selection of Fasa Creek as the preferred water supply source, the development of alternative was conducted to take advantage of the elevated supply source. The approach also needs to consider the withdrawal limitation of Fasa Creek, and the current access to water supply sources. The March 2012 survey of Robertsport residents indicated certain communities had greater access to water than others. Figure 5-1 Household Survey-Reported Percentage Access to an Improved Water Supply within 30-minute Round Trip indicates that Bombo Town, Fanti Town, Gbasslor communities have relatively low percentage of access to improved water supply sources within a 30 minute round trip (<20% access) according to the resident's survey responses.[6] However, it should be noted that low access was reported

[6] No survey response from Bassa Community results in a low percentage but warrants additional investigation to verify.

throughout Robertsport and no neighborhoods reported greater than 50% access. Therefore, current levels of access will have less of an impact on prioritization of areas and design than elevation and technical feasibility.

Service Area 1, as shown in Figure 5-2 Proposed Service Area Map, was developed based on its proximity to Fasa Creek, the low level of access in Fanti Town and Gbasslor communities and the vertical relationship to feed this area by gravity. Service Area was developed to improve the access to water for the Bombo Town and the adjacent communities. Area 3 Lower represents the remaining portion of the previous low service area, and Area 3 Upper represents the previous high service zone.

The short term recommendation is to provide service through metered public kiosks or public stand pipe. Certain facilities such as the Fish Landing Project and the Hospital would be served by dedicated metered service connections. The distribution system will be designed to allow the conversion from the metered public dispensing location to more private house connections or private yard taps as the water utility becomes further developed.

Table 5-1 Description of Service Areas

Breakdown of Service Area	Approximate Population	Approximate % of Population	Key Customers
#1	1,866 Persons	53 %	Fish Project
#2	1,049	30%	City Hall and School
#3 Lower	336	10%	Guest Houses
#3 Upper	264	7%	Hospital and School
#1 and #2 Areas	2,915	83 %	Fish Project, City Hall and School
#1, #2 and #3 Lower	3,251	90 %	Fish Project, City Hall and School, and Guest Houses
#1, #2 and #3 Upper	3,251	90 %	Fish Project, City Hall and School, and Hospital
All Areas	3,515	100 %	Fish Project, City Hall, Hospital and Schools and Guest Houses

Figure 5-1 Household Survey-Reported Percentage Access to an Improved Water Supply within 30-minute Round Trip

Figure 5-2 Proposed Service Area Map

5.1 PRESENTATION OF ALTERNATIVES

Alternative #0: No Action

Robertsport is not presently served by a reliable water system. The present situation is unacceptable due to the lack of water, the poor quality of drinking water that is characterized as unsafe, and the heavy reliance on hand-dug wells that were often constructed improperly but out of necessity during the emergency period. The current situation represents a threat to public health from contaminated water sources.

Evaluation of Alternative 0 (No Action Plan) includes:

Short and Medium Term (2012-2015)

- Continued water deficit
- Chronic vulnerability to dry seasons and drought conditions via continuously depleting the aquifer
- Continued health issue due to consumption of contaminated groundwater from the shallow source aquifer
- Continued risk of social uncertainty and conflict
- Loss of productive time spent fetching water that could be spent at work or school

Long-term (2016-2031)

- Continued water deficit
-
- Acute vulnerability to dry seasons to droughts
- Advancing depletion of the shallow aquifer
- Heightened risk of social uncertainty and conflict
- Additional health concerns resulting from worsening water quality
- Highly constrained economic development potential

Alternative 0 (No Action Plan) is eliminated as an option because it fails to meet basic access levels, maintains a perilous condition , and does not improve the access to a protected water supply to the City of Robertsport necessary for protecting public health and promoting economic development.

Alternative #1: Supply Area #1 with Gravity Flow from Fasa Creek

Based on the capacity of the Fasa Creek at the intake structure as stated in previous reports, a scenario was developed to initially supply Robertsport by gravity, without the need for any storage facilities. This scenario requires the withdrawal (4.37 lps) from Fasa Creek to be sufficient to handle peak hourly demands. Flow in the stream is maintained since the entire stream flow (8 lps) is not withdrawn for water consumption. The remaining stream flow is 3.63 lps and is the difference between the safe yield and the abstracted withdrawal rate.

Two distinct low-lying areas of Robertsport (Area #1 and #2) could possibly be served by gravity flow. A preliminary evaluation of these area was conducted using a distribution system modeling software (EPANet) and it was determined that only Area #1 could likely be served by Fasa Creek without any storage capacity, but in order to serve Area #2 additional storage would be required to handle peak hourly flow demands. The modeling software allowed the daily demand of the proposed fish project (roughly

estimated at 5,000 gpd) and the other water system demand (primarily domestic) to be preliminarily assessed to determine if the supply from Fasa Creek is adequate to meet the proposed service areas' peak demands.

Peak demand occurs when customers are using water. A diurnal pattern of when the residential and non-residential water use takes place was developed. A separate diurnal pattern was developed for the fish project demand. The two patterns are shown the graph. The graph shows that a 6AM is when the most flow is requested or demanded by customers and be the fish project. It was assumed the fish project would be a consistent flow rate at a peaking factor of 3.0 for a third of the day (6AM to 2PM). It also projects that a peaking factor of 3.2 occurs in the residential and non-residential at 6AM, with lesser peaks at noon time and 6PM. During the night time hours, lower hourly factors are project, while the compilation of the 24 hour rates represents the total daily flow.

One of the key benefits of this option is the lack of the need for a power source to supply the water. No water treatment is provided and the quality of the water would approximate that of the current surface water sources used for drinking water.

It is also possible to chlorinate this source of water, which is recommended to deactivate potentially pathogenic microorganisms. Possible methods of chlorination include:

- A solar powered metering pump which would apply chlorine solution
- Manual application of HTH at the Fasa Creek intake structure
- An inline chlorine chemical feeder (non-electrical)

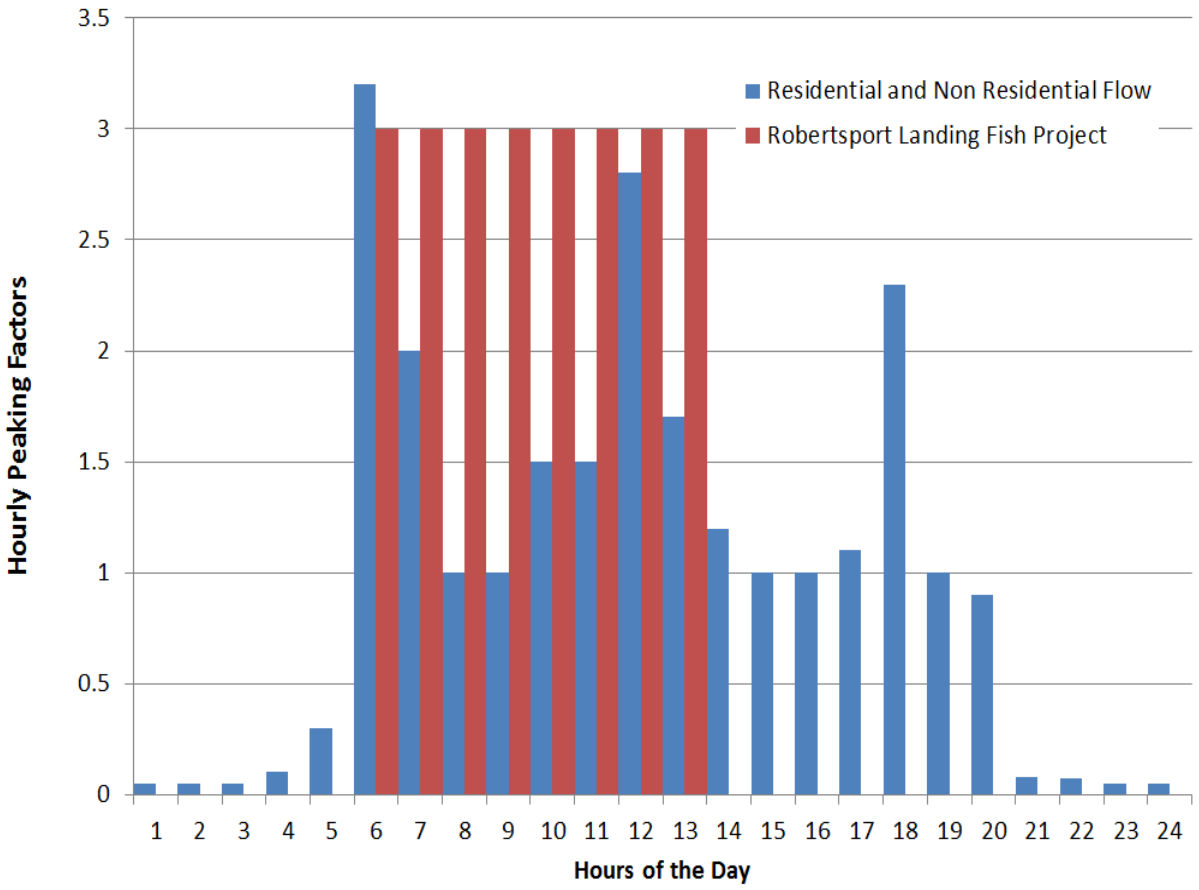

Figure 5-3 Diurnal Pattern of Hourly Peaking Factors

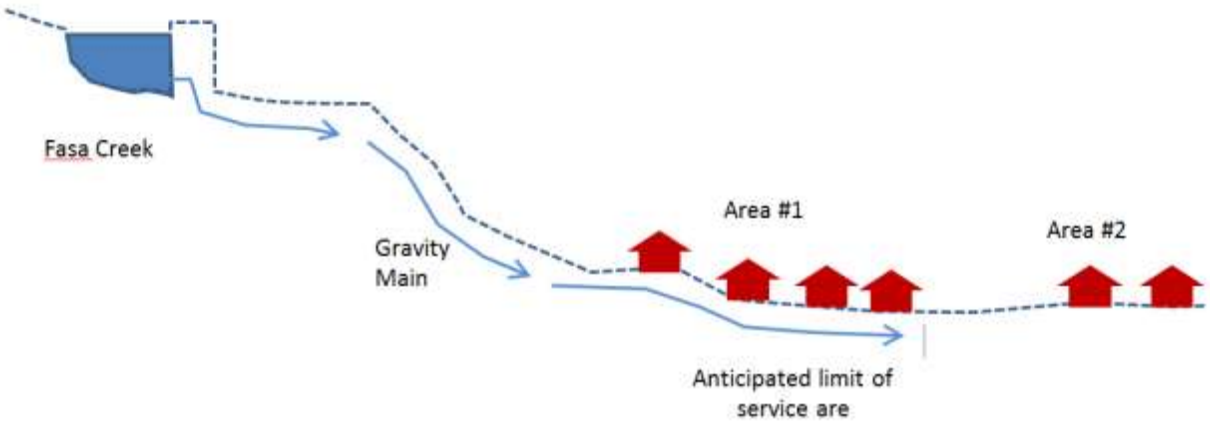

Figure 5-4 Schematic of Alternative #1

Alternative #2: Supply Area #1 and #2 with Gravity Flow from Fasa Creek with Storage

This alternative builds off of the previous alternative to provide gravity flow from Fasa Creek to the lower-lying areas of the City of Robertsport (Area #1 and Area #2) . With the addition of storage at or near the previous intake structure, a gravity transmission main could distribute water to Areas #1 and #2. During peak time, the water demand is expected to exceed the available abstraction from Fasa Creek. Therefore, storage is required to satisfy the anticipated peak demands from this service area.

Based on the water distribution modeling evaluation, the volume of storage required would be about 5,000 gallons (3,600 gallon minimum, based on a 10 foot diameter tank and an operating range of 6 vertical feet). This could be accomplished using one (1) tank or a series of tanks providing an equivalent total volume and operating range (i.e. volume curve). The location of the proposed storage tank would be near the intake structure. The elevation of the tank would be dependent on the water and pipe elevations at the intake structure.

The water quality provided by this option would be that as provide by the raw water source. The addition of chlorine would reduce the threat associated with water borne diseases and is therefore recommended.

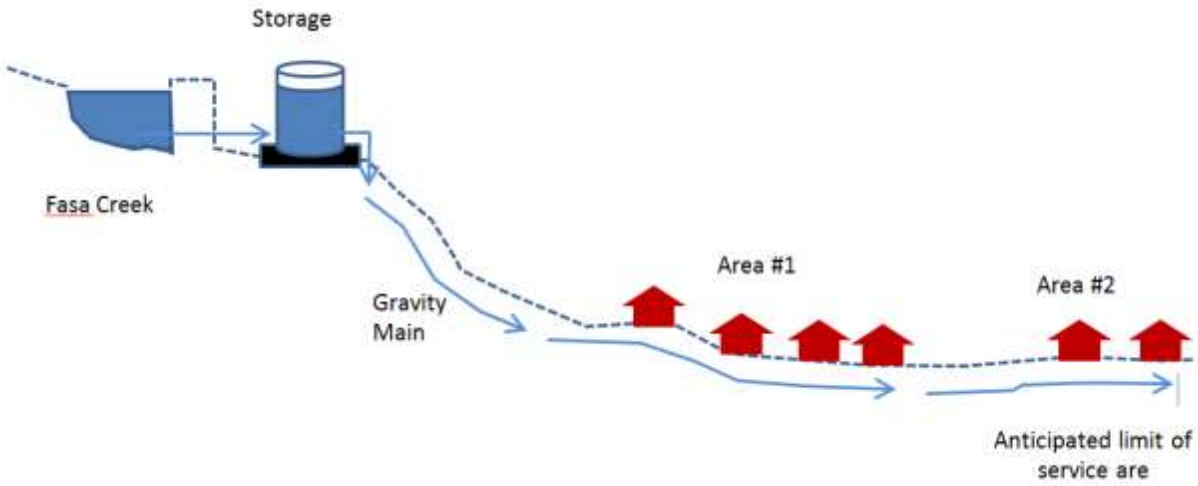

Figure 5-5 Schematic of Alternative #2

Alternative #3: Supply Area #1 and #2 with Gravity Flow from Fasa Creek with Storage, plus a Groundwater Source Improvement to serve Area #3 Lower

This alternative builds off of the previous two (2) alternatives to provide gravity flow from Fasa Creek to the lower-lying areas of the City of Robertsport and the upper section identified as Area #3 Lower. Storage is still required to handle the anticipated peak demands from this service area; these demands are projected to exceed the available abstraction from Fasa Creek.

The addition of Area #3 Lower would be accomplished by making improvements to the high-yielding groundwater sources located near the high school complex. The potential high-yielding groundwater sources include hand-dug wells R16 and R18 that were pump tested during the Detailed Analysis Visit. The selection of either high yield well will depend on the results of additional water quality sampling. The

population of Area #3 Lower is currently estimated at 336 persons. Therefore at a demand rate of 10 gpcd (38 lpcd), approximately 3,400 gallons per day would be required to meet the projected demand.

Table 5-2 List of High Yielding Wells

Robertsport LMWP Well #	Volume of Water Pumped (gals)	Estimated Number Of Draw-Fill Cycles per Day	Estimated Daily Capacity of Well (gpd)
R16	264	33	8,736
R18	1,258	26	32,559

The development of either of these groundwater sources (R16 or R18) would require confirmation of the water quality of these sources. The preliminary results from the US based testing lab indicated R18 appears to have relative good water quality but additional testing is required to confirm.

The water quality provided by this option would be that as provide by the raw water sources. It should be noted that use of shallow wells or borehole can increase the concentration of pollutants and potentially reduce the water quality provided (in comparison to other alternatives). The addition of chlorine at each source would reduce the threat associated with water borne diseases and is therefore recommended.

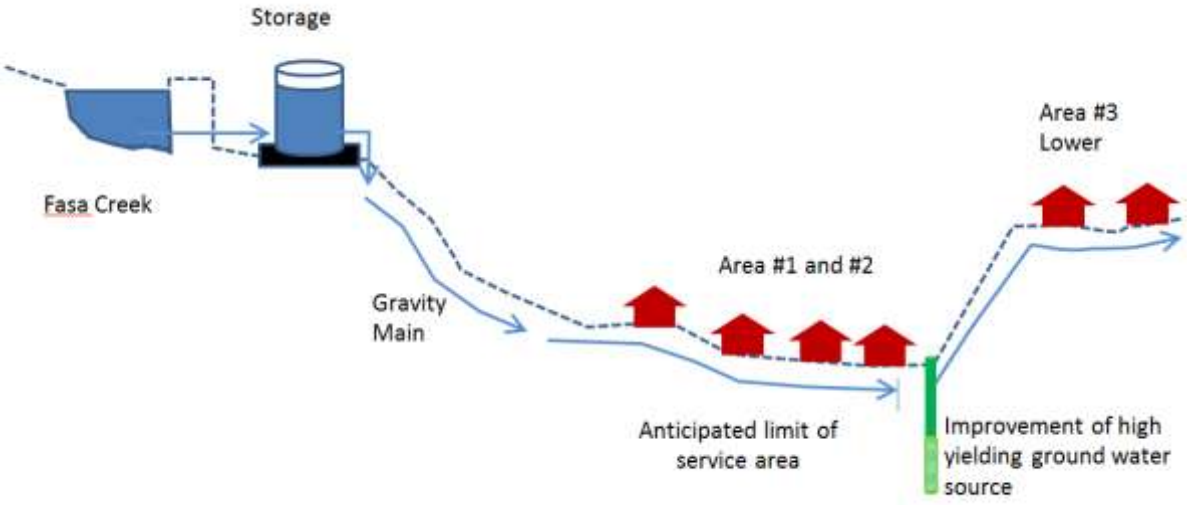

Figure 5-6 Schematic of Alternative #3

Alternative #4: Supply Areas #1 and #2 with Gravity Flow from Fasa Creek with Storage, plus a Groundwater Source Improvement to serve Area #3 Upper

This alternative is a minor modification to Alternative #4. Instead of serving Area #3 Lower with the improved groundwater source, this source of water would serve the section of Robertsport identified as Area #3 Upper. This modification was made to prioritize the former high service zone because it presently includes the hospital complex. A large pump will be required to meet the greater head conditions.

As noted in Alternative #3 the use of shallow wells or boreholes can increase the concentration of pollutants and potentially reduce the water quality provide (in comparison to other alternatives). The addition of chlorine at each source would reduce the threat associated with water borne diseases and is therefore recommended. If the water quality of R18 is confirmed, and the yield is proven over a period of time, the possibility of service both Area 3 Upper and 3 Lower could be evaluated.

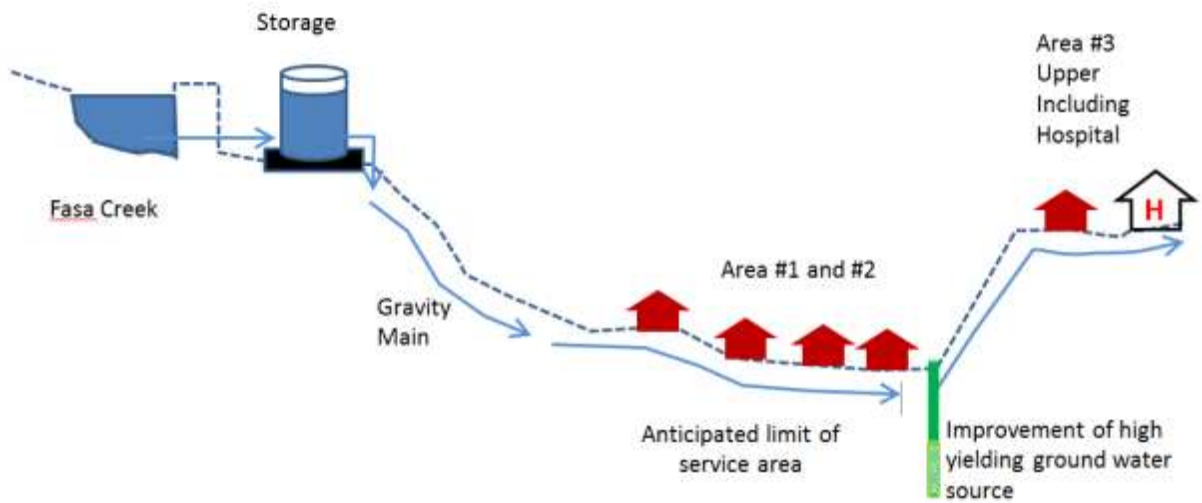

Figure 5-7 Schematic of Alternative #4

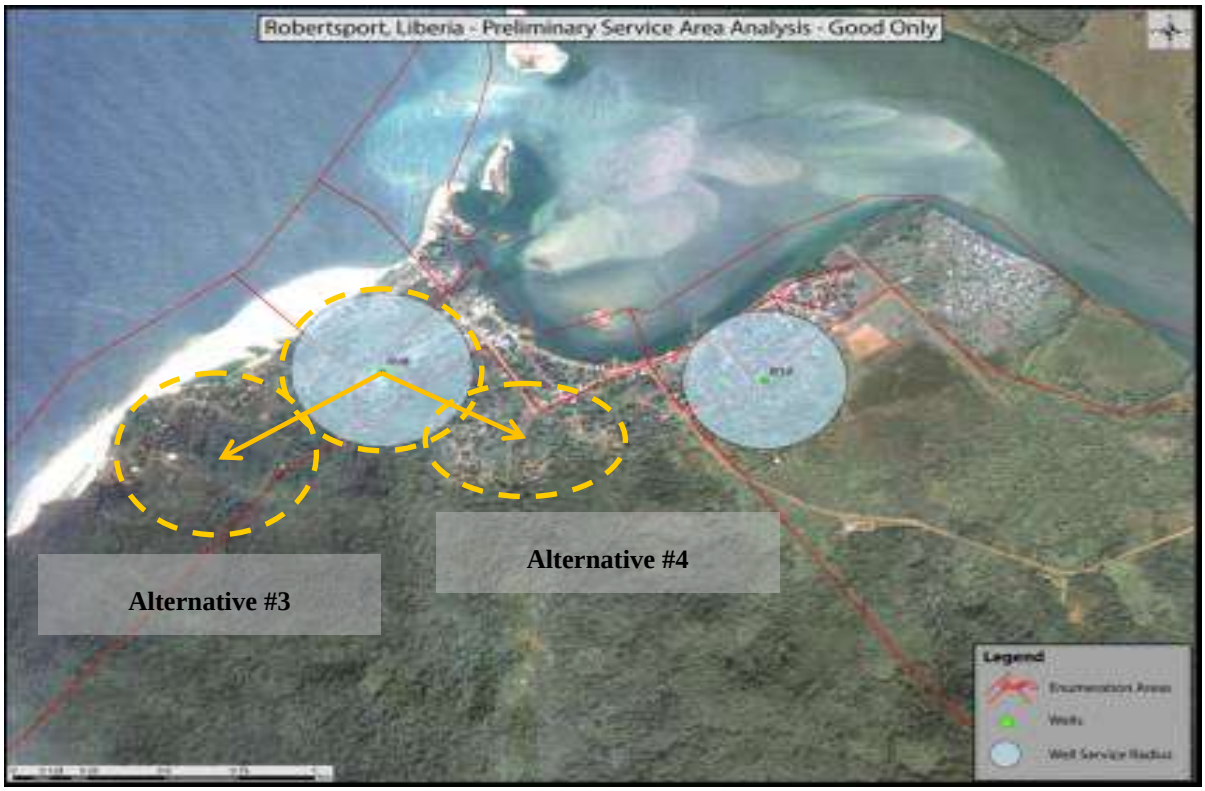

Figure 5-8 Potential Relocation of High Yield Well Service Area

Alternative #5: Supply Entire City from a Restored WTP with Pressure Distribution

Due to topographical constraints, the entire Robertsport service area cannot be served by a gravity feed from the previous WTP site. To serve Area #3, the previous and the future water systems would require flow from the WTP to be pumped. Area #3 Lower was part of the previous lower reservoir distribution system, and Area #3 Upper represents the area served by the previous upper reservoir.

The previous alternatives do not provide water treatment beyond simple chlorination and the water quality problem is not fully addressed. Alternative #5 will include the restoration of the previous WTP and the installation of a pressurized distribution network. Alternative #5 requires a significant increase in the level of equipment, energy, and operations than the previous alternatives, but would provide a level of service and treatment comparable to the originally installed system.
This alternative restores the following components of the previous water system:

- Intake Structure
- Slow Sand Filtration System
- Chlorination
- Pumping and Transmission Main
- Lower Reservoir
- Pumping and Upper Reservoir

A distinct benefit of this alternative is the restoration of the high service zone. This capacity would be capable of providing a reliable water supply to the sole hospital that services the City of Robertsport.

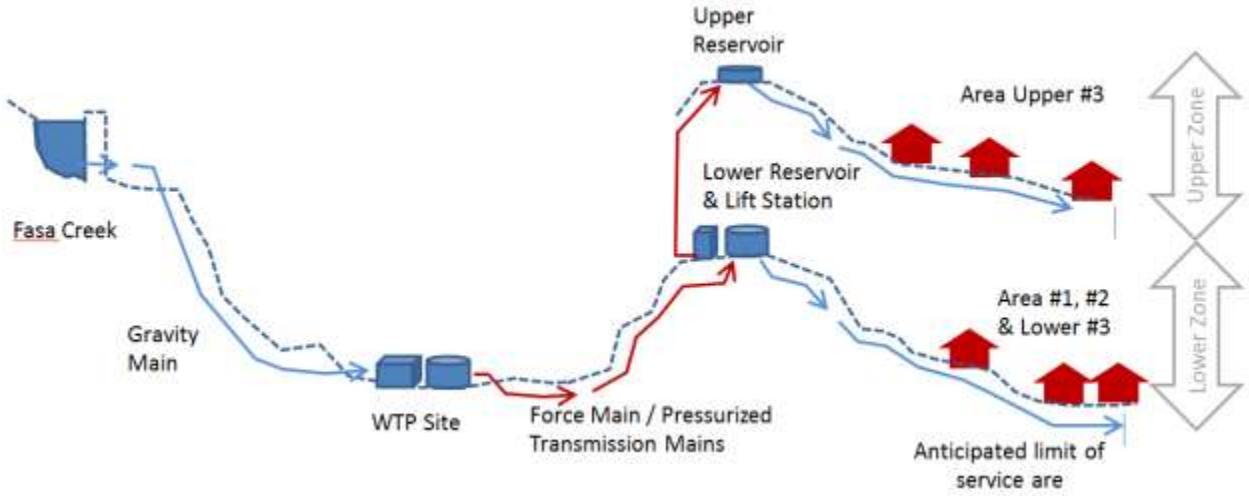

Figure 5-9 Schematic of Alternative #5

Alternative #6: Packaged Water Treatment Plants

This alternative builds off of the Alternative #5 to restore the water system with a water treatment plant, but instead of using the previous water system a series of ten (10) packaged WTPs would be sited either at a central location or at multiple decentralized locations depending on the selection of supply sources. It

is anticipated that the entire population would be served by this treatment process. Due to the high level of treatment that can be provided by package units, the effluent water quality may be the most improved of the alternatives considered.

Alternative #7: Promotion of rainwater harvesting to reduce demand for non-potable water

This document recognizes the importance and positive impact that rainwater harvesting can provide in supplying residents of Robertsport with a source of water. Unfortunately no credit for the volume of water supplied by means of rainwater harvesting can be taken due to the variability of rainfall, the small-scale nature of harvesting systems (very few of which currently exist), and the inability to responsibly rely on privately owned and operated systems.

This alternative can be considered an ancillary alternative to those previous. The operators of the facility(s) that will be providing the majority of the water to the residents of Robertsport by either groundwater or surface waters should support and promote the use of rainwater harvesting.

5.2 SOURCE ALTERNATIVE CONCLUSIONS

Table 5-3 presents the projected outcome of the other alternatives based on the anticipated supply rates.

Table 5-3 Alternatives Comparison

	Alternative #0: No Action Plan	Alternative #1: Supply Area #1 with Gravity Flow from Fasa Creek	Alternative #2: Supply Area #1 and #2 with Gravity Flow from Fasa Creek with Storage	Alternative #3: Supply Area #1 and #2 with Gravity Flow from Fasa Creek with Storage, plus a Groundwater Source Improvement to serve Area #3 Lower	Alternative #4: Supply Areas #1 and #2 with Gravity Flow from Fasa Creek with Storage, plus a Groundwater Source Improvement to serve Area #3 Upper	Alternative #5 and #6: Supply Robertsport from a Restored WTP and Water System
Areas Served	None	Area #1	Area #1 #2	Area #1 #2 and #3 Lower	Area #1 #2 and #3 Upper	All Areas
Resolves water deficit	No	Partial	Partial	Partial	Partial	Yes
Ability to meet initial demand of 5 gpcd	No	Partial	Partial	Partial	Partial	Yes
Addresses health concerns by consumption of groundwater from shallow source aquifer	No	Partial	Partial	Partial	Partial	Yes
Addresses risk of social uncertainty and conflict	No	Partial	Partial	Partial	Partial	Yes
Improves Access	No	Partial	Partial	Yes	Yes	Yes
Estimated population to be served by improved water system	0	1,860	2,920	3,250	3,184	3,515
Percent of city population	0%	53%	83%	92%	90%	~100%
High priority area covered (in addition to residential area)	None	Fish Project	Fish Project, City Hall and School	Fish Project, City Hall and School, and Guest Houses	Hospital Fish Project, City Hall and School	Hospital, Fish Project, City Hall, Schools and Guest Houses

6. COST ESTIMATES

Estimates outlined in this master planning document are intended to provide a theoretical level of data for evaluation and development of the recommended plan. They are considered preliminary estimates since they have been developed based only on a conceptual level of detail design or scheme. This level of design effort is which is consistent and constant with the current Master Planning phase of the LMWP project scope.

Cost estimates were developed using water system component designs, unit selection, sizing, upgrades, other infrastructure information provided by LWSC and other engineering sources. Local labor rates used wherever possible. The amount of data provided was limited.

Current difficulties associated with estimating construction and operation cost of water system components include:

- No large scale water construction project has been designed or constructed in more than 30 years.
- The current African Development Bank Project (in Monrovia, Kakata, Buchanan and Zwedru) has completed conceptual designs and estimates, but the designs are presently being reviewed before the projects are tendered. The current schedule is for the AfDB project to be tendered in December 2012 or January 2013.
- Until the AfDB project or the LMWP's Robertsport project is tendered and bid are solicited, For 30 years, no construction contractors have prepared pricing for large scale water projects in Liberia.
- Without the track record of submitted bid prices various key construction factors have not been completely determined and addressed. These factors include the cost associated with travel to and the supply of material to Liberia for non-Liberian water contractors, the cost of access remote sites (outside of Monrovia), and other unknown difficulties and costs of performing work in Liberia.

Table 6-1 Estimated Capital Cost for Alternative #1

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Current Population to be Served	Cost per Person Served
1	Gravity Feed	Restore Intake Road	600	meter road	$36,000	$1,224,000	1,866	$656
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Construct Chlorination System	2	- inline chlorinators	$8,000			
		Restore 8" DICL Gravity Main to WTP	2,600	LF	$260,000			
		Construct Gravity 8" PVC Main to Area #1	2,700	LF	$216,000			
		Construct Gravity 6" PVC Main to Area #1	8,800	LF	$528,000			
		Construct Metered Dispensing Locations	8	each	$16,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	2	Vehicles	$20,000			

Table 6-2 Estimated Capital Costs for Alternative #2

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Current Population to be Served	Cost per Person Served
2	Gravity Feed with Storage	Restore Intake Road	600	meter road	$36,000	$1,907,000	2,915	$654
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Construct Chlorination System	3	- inline chlorinators	$12,000			
		Construct Storage Facility	1	Facility	$35,000			
		Restore 8" DICL Gravity Main to WTP	2,600	LF	$260,000			
		Construct Gravity 8" PVC Main to Area #1	2,700	LF	$216,000			
		Construct Gravity 6" PVC Main to Area #1	8,800	LF	$528,000			
		Construct Gravity 6" PVC Main to Area #2	10,400	LF	$624,000			
		Construct Metered Dispensing Locations	18	each	$36,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	2	Vehicles	$20,000			

Table 6-3 Estimated Capital Costs for Alternative #3

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Current Population to be Served	Cost per Person Served
3	Gravity Feed with Storage and Improved Ground Water Supply	Restore Intake Road	600	meter road	$36,000	$2,279,000	3,251	$701
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Construct Chlorination System	3	- inline chlorinators	$12,000			
		Construct Storage Facility	1	Facility	$35,000			
		Restore 8" DICL Gravity Main to WTP	2,600	LF	$260,000			
		Construct Gravity 8" PVC Main to Area #1	2,700	LF	$216,000			
		Construct Gravity 6" PVC Main to Area #1	8,800	LF	$528,000			
		Construct Gravity 6" PVC Main to Area #2	10,400	LF	$624,000			
		Construct Metered Dispensing Locations	24	each	$48,000			
		Improve Groundwater Supply	1	per site	$25,000			
		Install Pump	1	Subm. Pump	$2,000			
		Install Solar Panel and generator	1	Power Set	$20,000			
		Construct distribution system to Area #3 Lower	5,100	LF	$306,000			
		Construct storage facility	1	Facility	$35,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	2	Vehicles	$20,000			

Table 6-4 Estimated Capital Cost for Alternative #4

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Current Population to be Served	Cost per Person Served
4	Gravity Feed with Storage and Improved Ground Water Supply	Restore Intake Road	600	meter road	$36,000	$2,280,000	3,252	$701
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Construct Chlorination System	3	- inline chlorinators	$12,000			
		Construct Storage Facility	1	Facility	$35,000			
		Restore 8" DICL Gravity Main to WTP	2,600	LF	$260,000			
		Construct Gravity 8" PVC Main to Area #1	2,700	LF	$216,000			
		Construct Gravity 6" PVC Main to Area #1	8,800	LF	$528,000			
		Construct Gravity 6" PVC Main to Area #2	10,400	LF	$624,000			
		Construct Metered Dispensing Locations	24	each	$48,000			
		Improve Groundwater Supply	1	per site	$25,000			
		Install Pump	1	Subm. Pump	$2,000			
		Install Solar Panel and generator	1	Power Set	$20,000			
		Construct distribution system to Area #3 Lower	2,500	LF	$306,000			
		Restore Upper Reservoir	1	Facility	$8,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	2	Vehicles	$20,000			

Table 6-5 Estimated Capital Cost for Alternative #5

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Population to be Served	Cost per Person Served
5	Restore WTP and Water System	Restore Intake Road	600	meter road	$36,000	$2,939,000	3,515	$836
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Restore 8" DICL Gravity Main to WTP	2,600	- inline chlorinators	$260,000			
		Restore Slow Sand Filter	1	Facility	$35,000			
		Restore Balancing Tank	1	Facility	$15,000			
		Restore large scale chlorination system	1	Facility	$10,000			
		Restore High Lift Pumps	3	Pumps	$24,000			
		Construct Generator Facility	1	LF	$25,000			
		Install Instrumentation and Controls	1	LF	$10,000			
		Restore Transmission Main	2,200	LF	$220,000			
		Restore Lower Reservoir	1	Facility	$14,000			
		Restore Lift Station	2	Pumps	$12,000			
		Restore Upper Reservoir	1	Facility	$8,000			
		Construct Lower Zone Distribution System	27,000	LF	$1,890,000			
		Construct Upper Zone Distribution System	2,500	LF	$150,000			
		Construct Metered Dispensing Locations	30	each	$60,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	3	Vehicles	$30,000			

Table 6-6 Estimated Capital Cost for Alternative #6

#	Alternative	Components	Quantity	Description	Cost	Alternative Cost Estimate	Estimated Current Population to be Served	Cost per Person Served
6	Package WTPs	Restore Intake Road	600	meter road	$36,000	$4,520,000	3,515	$1,286
		Restore Culverts	14	- 2 m culverts, 10 m long	$112,000			
		Restore Intake Structure	1	Facility	$20,000			
		Restore 8" DICL Gravity Main to WTP	2,600	- inline chlorinators	$260,000			
		RO Package WTPs	10	Package WTPs	$1,700,000			
		Restore Transmission Main	2,200	LF	$220,000			
		Restore Lower Reservoir	1	Facility	$14,000			
		Restore Lift Station	2	Pumps	$12,000			
		Restore Upper Reservoir	1	Facility	$8,000			
		Construct Lower Zone Distribution System	27,000	LF	$1,890,000			
		Construct Upper Zone Distribution System	2,500	LF	$150,000			
		Construct Metered Dispensing Locations	30	each	$60,000			
		Restore Offices	1	Facility	$8,000			
		Work Vehicles	3	Vehicles	$30,000			

Table 6-7 Estimated Labor Cost per Alternative

		Estimated Labor Cost							
		Staffed Positions							
#	Alternative	Superintendent	WTP Operators	Chemist	Maintenance	Distribution Operator	Accountant	Billing	Costs
0	No Action	0	0	0	0	0	0	0	$0
1	Gravity Feed	1	1.5	0.5	0.5	2	0.5	2	$39,240
2	Gravity Feed with Storage	1	1.5	0.5	0.5	2	0.5	2	$39,240
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	1	2	1	1	3	1	3	$58,800
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	1	2	1	1	3	1	3	$58,800
5	Restore WTP and Water System	1	4	1	2	4	1	3	$76,320
6	Package WTPs	1	10	2	4	5	1	3	$121,200
	Daily Rate	$30.00	$16.00	$25.00	$25.00	$16.00	$25.00	$20.00	

Table 6-8 Estimated Chemical Cost per Alternative

		Estimated Chemical Cost						
		Population Served	Residential Demand	Total Daily Flow	Chlorine	Hypochlorinte Required	Hypochlorite Cost	
		Person	gpcd	gpd	mg/l	lb/d	$/lb	
0	No Action	0	10	-	10	0	$12.00	$0
1	Gravity Feed	1866		24,258		3		$13,140
2	Gravity Feed with Storage	2915		37,895		5		$21,900
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	3251		42,263		6		$26,280
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	3184		41,392		5		$21,900
5	Restore WTP and Water System	3515		45,695		6		$26,280
6	Package WTPs	3515		45,695		6		$26,280

Table 6-9 Estimated Fuel Cost per Alternative

		Estimated Fuel Cost							
		Flow Pumped	Hours Operating	Rate	Head	Required Power	Fuel Demand	Cost of Diesel	
		gpd		gpm	feet	KW	gph	$/gal	
0	No Action	0	0	0	0			$6.00	$0
1	Gravity Feed	0	0	0	0				$0
2	Gravity Feed with Storage	0	0	0	0				$0
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	5000	8	10	150	2	0.4		$7,100
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	5000	8	10	240	3	0.6		$10,600
5	Restore WTP and Water System	35,150	12	49	200	10	1.2		$31,600
6	Package WTPs	35,150	12	49	multiple	multiple	4		$105,200

Table 6-10 Estimated Cost of Supplies

		Estimated Cost of Supplies					
		Office Supplies	Spare Parts	Tools	Pipe and Fitting	Vehicular	Costs
0	No Action	$0	$0	$0	$0	$0	$0
1	Gravity Feed	$8,000	$4,800	$600	$3,000	$4,000	$20,400
2	Gravity Feed with Storage	$9,000	$6,000	$900	$5,000	$4,000	$24,900
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	$10,000	$12,000	$2,000	$8,000	$4,000	$36,000
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	$10,000	$15,000	$2,000	$8,000	$4,000	$39,000
5	Restore WTP and Water System	$12,000	$25,000	$6,000	$12,000	$4,000	$59,000
6	Package WTPs	$12,000	$85,000	$15,000	$15,000	$4,000.00	$131,000

Table 6-11 Summary of Operating Costs per Alternative

#	Alternative	Operating Costs
0	No Action	$0
1	Gravity Feed	$72,780
2	Gravity Feed with Storage	$86,040
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	$128,180
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	$130,300
5	Restore WTP and Water System	$193,200
6	Package WTPs	$383,680

6.1 COST-BENEFIT ANALYSIS

The cost-benefit analysis is used to evaluate and rank the financial value of various solutions. A properly conducted and accurate cost-benefit analysis is capable of assessing alternatives and scenarios with respect to the increase in the public's welfare from a financial perspective. The financial perspective is on the key factors in selecting and developing a sustainable water system. The Robertsport cost-benefit analysis was developed based on the estimated value of an effective water system, and the present worth of the estimated capital and operational costs for the various alternatives being considered.

The benefit of a water system is primarily based on the anticipated improvements provided by a safe and protected source. The primary advantage is anticipated to be the improvement to the public health especially that associated with the impacts of diarrheal diseases. This is calculated through the decrease in: direct health care costs; miscellaneous expenditure associated with health care issues; loss of income by the household providers; loss of education value for sick children; loss of income associated with parents who care for sick children in lieu of work;; the loss of time spent fetching water; and the loss associated with decreased life expectancy. The value of the Robertsport Hospital being served by a water system is included at the bottom of the table. This benefit only applies to alternatives that include the restoration of the previous high service zone, in which the hospital complex is located. The below table lists the parameters and assumptions used to estimate and summarize these costs.

Table 6-12 Summary of Benefit Costs/Values

Parameter	Value	
Demographics		
City Projected Population	3,515	persons
Average Household Size	5.0	persons per household
Estimated Number of Households	700	households
Health Care Cost - associated with diarrheal disease		
Unit Cost - per visit	5	visit per case
Unit Cost - per day	15	per day of hospitalization
Time -	1	outpatient visit per episode
Time -	5	days for hospitalization cases
Distribution of Treatment-	1	outpatient visit
Distribution of Treatment-	0	hospitalization cases
Estimated Occurrence	2	times per person per year
Estimated Outpatient Medical Cost	$31,635	per year
Estimated Hospitalization Cost	$10,545	per year
Other Direct Expenditures Cost		
Transportation Cost per visit	1	per visit

Estimated percent of patients using transportation	1	
Estimated Transportation Costs	$5,624	per year
Lost Income due Illness		
Days out of work due to Outpatient episode	3	days per episode
Days out of work due to Hospitalization episode	7	days per episode
Percent of Population in Work Force	0	
Estimated Daily Income	7	per day
Income Lost due to Outpatient episode	$53,147	per year
Income Lost due to Hospitalization episode	$13,779	per year
Loss of Education Value		
Percent of Population in Schooling	0	
Estimated Value of Education (minimum wage)	4	per day
Ed. Value Lost due to Outpatient episode	$26,573	per year
Ed. value Lost due to Hospitalization episode	$6,889	per year
Lost Income from Parent due to Child Illness		
Percent of Population in Child Age	0	
Estimated Loss of Parent Income (minimum wage)	4	per day
Ed. Value Lost due to Outpatient episode	$22,777	per year
Ed. value Lost due to Hospitalization episode	$5,905	per year
Lost Convenience Time spent Collecting Water		
Time lost per household	1	hours per day
Time lost per person	0	hours per day
Value of Conv. Time (minimum wage)	4	per day
Estimated value of Lost Conv. Time/household	$340,670	per year
Estimated value of Lost Conv. Time/person	$171,070	per year
Cost Summary		
Sum of Losses per year	$688,615	per year
Value of Loss of Life		
Estimated Current Life Expectancy	55	Years
Estimated Projected Life Expectancy	65	Years
Estimated Increase to Years of Income Production	5	Years
Estimated Productive Days per Year	200	days per year
Estimated Loss Income	$9,842,000	
Project term and cost		
Life of Project	20	Years
Estimated Cost associated with lack of water system (Present Worth, 20 years, 2%)	21,100,852	
Option Benefits -depending on Alternative Coverage		
Value of Serving Robertsport Hospital		
Visits per Year per Resident	0.33	visit per resident per year

Increase to Value to Hospital with Water Service	$50	per visit
Estimated Value of Hospital with Water Service	$57,998	per year

The costs to construct and to operate the various alternatives have also been estimated. These costs were summarized and calculated using present value (based on a 20 year term and 2% interest rate).

The below table adjusts the benefit value of the improved water system based on the population to be served. The table also indicates if the proposed alternative complies with the project goal of 90% access to an improved water supply access . Alternatives that do not comply with this project goal are still presented because certain alternative may be considered as part of a phased construction approach.

Table 6-13 Benefit: Cost Ratio and Alternative Rankings

#	Alternative	Population Served	Benefit Cost	Alternative PW Cost	Benefit: Cost Ratio	Rank	Meets 90% Coverage
0	No Action	-	$0	$0	-	-	No
1	Gravity Feed	1,866	$10,483,700	$2,370,000	4.42	2	No
2	Gravity Feed with Storage	2,915	$16,377,300	$3,249,800	5.04	1	No
3	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Lower	3,251	$18,265,000	$4,374,700	4.18	4	Yes
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	3,184	$18,747,500	$4,381,400	4.28	3	Yes
5	Restore WTP and Water System	3,515	$19,748,200	$5,999,800	3.29	5	Yes
6	Package WTPs	3,515	$19,748,200	$10,793,200	1.83	6	Yes

The benefit values and the alternative cost are directly compared to each other and ratio is determined (Benefit Value / Alternative Cost). Based on the input into the benefit values, the alternative's benefit : cost ratios can be compared and ranked.

The top-ranked option (with no consideration to project goal compliance) is Alternative #2, the gravity feed with storage option. The low capital and operational costs are the primary reason for the high rating. This option also addresses any concern or commitment to supply the planned Fish Project in Robertsport.

The highest-ranked options that are anticipated to be in compliance with the project goals are Alternatives #3 and #4, the Gravity Feed with Storage and Improved Groundwater Supplies to either Area #3 Lower or Upper. Both Alternative #3 and #4 have nearly identical ratios. The low operating cost is again the primary factor for the high rating.

The other alternatives that would comply with the project goals, Alternative # 4, Restore WTP and Water System, and Alternative #5, Package Treatment Plants were not rated as highly due to their higher capital and operating costs. However, both alternatives provide water treatment and improve drinking water quality; therefore they have higher benefit value compared to the other alternatives.

As previously noted, the beneficial value of a new water system was based on the general town wide impact to residents related to the elimination of using unsafe water supplies. There is one specific benefit associated exclusively with Alternatives #4, #5 and #6, because these options include the restoration of the high service zone. The existing hospital that serves the City of Robertsport is located and operating in the high service zone.

7. RECOMMENDATIONS OF SELECTED ALTERNATIVES

Outlined below are the recommendations for the planned improvements to the City of Robertsport's water supply access needs.

The sequence recommendations prioritizes the supply of water to residents and the proposed Fish Project and high density areas (Area #1 and #2) (Alternative #2), followed by serving the Robertsport Hospital complex (Alternative #4). The implementation of these alternatives is anticipated to achieve the 90% access to an improved water supply source.

The ability to concentrate on the supply of water is possible due to the water quality present in Fasa Creek, but an important short-term recommendation is the establishment of regulations and administration to protect the source quality of the surface water supply, i.e., to protect the Fasa Creek watershed area.

7.1 SHORT-TERM PROJECT – PHASED CONSTRUCTION SEQUENCE

7.1.1 Phase 1-Alternative #2- Construction of Raw Gravity Main Extension with Storage Facility

The components of Alternative #2 include:

- Intake structure with storage facility and chlorination system
- Restored gravity raw main to previous WTP (with road and culverts)
- New gravity distribution system to Area 1 and Area 2 (with public dispensing stations)

Focusing on these components will allow for a quicker construction period that will lead to an earlier implementation of a water service. The initial water supply system will rely essentially on no power demand. Any water utility office building will require a private generator to supply power for the office to properly function.

This initial step will require a limited amount of chemical to operate. The only chemical anticipated is chlorine for disinfection. The use of any chemical, but especially chlorine, will require that the operators of the water utility receive adequate training. The use of chemical represents a potential danger to the operators and the consumers if not handled and applied properly.

With the exception of the application of chlorine, the proposed alternative can be characterized as a flow-through water system from source to customer. The water is withdrawn from Fasa Creek at the previous intake structure. A storage facility is proposed to meet the peak demand when it exceeds the constant withdrawal rate from Fasa Creek. Depending on the design of the storage facility, an overflow pipe would return any excess water from the storage tank to the creek. The limiting factor concerning the water conveyance ability of this type of flow-through gravity system is the elevation difference between the source (intake structure) and to the proposed service area (generally near sea level). .Therefore, a key design factor to be established is the elevation of the intake and storage facility.

7.1.2 Phase 2 - Alternative #4 - Gravity Feed with Storage To Area #1 and Area #2, and Improved Groundwater Supply to Area #3 Upper

To achieve the project goal of 90% access to an improved water supply, pumping will be required to reach certain areas. In addition, pumping is required to serve the Robertsport Hospital, which is located in the Upper area with a relatively-high elevation. The first phase of the project recommendation is limited by the vertical constraints of the gravity supply. Since the surface supply source is remotely located from the previous high service zone (Area #3 Upper), high-yielding wells adjacent to this area were identified as a potential source to supply the population and the hospital in Area #3 Upper. The implementation of the additional components of Alternative #4 would include:

- An improved groundwater supply with pumping and chlorination system
- Solar panel and backup generator for well pumping
- Restored upper reservoir
- New distribution system to Area #3 upper (with public dispensing stations) and service connection to the hospital

Design provisions and modifications could also be taken to address water quality issues associated with the groundwater supply be feeding Area #3 upper from the gravity feed water distribution system (part of Alternative #2). This modification would include the relocation of pumping system from the high yielding well to the main transmission main from Fasa Creek.

7.2 SHORT TERM PROJECT - ESTABLISH PROTECTION OF FASA CREEK WATERSHED

The degradation of natural resources and the resultant in the loss of soil fertility, deforestation and other environmental changes can contribute to the declining capacity of water resource that represent drinking water supplies. Portion of Liberia, such as Grand Cape Mount in Robertsport, contain valuable forest resources. While forests can represent a cultural to the residents of the area, this resource areas also provide forest-dependent residents with the capacity to harvest edible and medicinal plants, wild meat, fruits, honey, shelter, firewood and many other goods.

On a global scale, all forests play a crucial role in climate regulation and constitute one of the major carbon sinks on earth. But on a local level the natural forest that makes up the watershed above the Fasa Creek intake structure is critical component to both the quantity of water available and just as importantly the quality of the surface water.

The protection of the forest that makes up the limited watershed of the surface streams and creeks in Robertsport should be valued as a resource in the control of stream flow and water quality. The current

sources of drinking water would be significantly and adversely impacted if the current watershed is altered. Alteration of the watershed area would decrease the quantity of water that is available and degrade the quality of the water.

Along with the administration and institutional establishment of the water utility in Robertsport, the protection of the Fasa Creek watershed should be prioritized.

7.3 MEDIUM-TERM PROJECTS

7.3.1 Alternative #5- Restore WTP and Water System

The Medium-Term Recommendation is to improve the water quality and to expand the service area to cover the majority of the City of Robertsport to serve a minimum of 90% of the population) through the restoration of the previous water treatment plant and water system. The slow sand filtration process with chlorination would be restored to improve the quality of the water supplied.

The previous process represents a solution that relies on minimal power requirements. The primary demand for power (either generator or solar) is associated with the effluent supply pumps which lift and transport the treated water to the customers. The slow sand filtration process requires less operation, maintenance, and control than other treatment process. Restoration of the process would also reduce the dependency on groundwater supplies.

Due to the simple operational skills and capacity required to operate the slow sand filter, and the lower power and chemical cost, the re-establishment of the previous system is considered to be a solution that can be made to be sustainable.

7.4 LONG-TERM PROJECTS

Assuming the Short-Term and Medium-Term recommendations are adopted, the Long-Term recommendations include:

- Further improvements to Operational and Institutional Capacity to improve sustainability
- Improved delivery of water by converting from public dispensing locations (kiosks and public stand pipes) to more private connections (private stand pipes and house connections)
- Re-visiting and updating of the Master Plan for Robertsport (recommended every 5 years)
- Implementation and advancement of an Asset Management Plan
- Continuous updating of the O&M manuals for the water system, its components, and its operational staff
- Continuous training for the water system staff
- Development of a training program to assist other water utilities being developed in Liberia
- Promotion of rainwater harvesting

8. IMPLEMENTATION

8.1 ORGANIZATIONAL

The various parties anticipated to be involved in the efforts to improve the access to water for the City of Robertsport, as outline in this report could those in the below table. Also presented in the table are the roles, tasks and responsibilities of those parties.

Table 8-1 Implementation Roles and Responsibilities

Role	Part	Tasks and Responsibility

Technical and Institutional Support	Tetra Tech through its Liberia Municipal Water Project (LMWP)	• Prepare Master Plan
		• Prepare Construction Documents
		• Presentations of Master Plan and Documents to
		  ○ Steering Committee
		  ○ USAID
		  ○ LWSC
		• Revise Report and Bid Documents to address comments from Stakeholders
		• Assist in tendering for construction services
		• Provide engineering service during construction
		• Provide Institutional development support and guidance, develop MOU regarding operational and regulatory responsibility
		• Provide engineering support regarding startup operations

Donor and Financial	United States Agency for International Development (USAID)	• Review Master Plan and Bid Documents • Obtain capital cost financing
Local Entities	City of Robertsport & Steering Committee	• Review Master Plan and Bid Documents

Operator	Liberia Water and Sewer Corporation (LWSC)	• Review Master Plan and Bid Documents • Enter MOU regarding operation and oversight responsibility • Implement Institutional changes • Tender bid documents • Take over operation of new water utility

8.2 STAKEHOLDER INPUT AND PUBLIC INVOLVEMENT

A driving principle in the LMWP and in this Master Plan is collaboration and integration with, local parties, local government, and stakeholders in the Liberia water sector (LWSC, MOH, and MPW). Some of the important components of this document are derived from collaboration with these parties. Additional comments, discussions and input from the interested parties and stakeholders are anticipated to be received during the review and comment period.

8.3 FUNDING

The cost associated with the Robertsport recommendation outlined in this master plan can be categorized as either capital costs or operation and maintenance cost. Capital costs for infrastructure projects, such as this water system, are generally one time large costs. Capital costs are typically associated with the construction of new water system components or the restoration of aging water system components. Restoration capital cost should not be mischaracterized with typical repair and small rehabilitation efforts by a water utility. Capital costs are generally covered by the water utility borrowing monies from lenders.

Operation and maintenance costs are associated with the daily, monthly and annual operation of the water utility. Some of the large O&M costs are associated with labor, chemicals and fuel/power. Other O&M cost can be associated with computer and office supplies, insurance, tools and equipment, and the procurement of specialized services by outside contractors.

It is intended that the capital cost associated with the proposed water system improvements will be covered by the USAID, but ongoing operation and maintenance costs should be fully recovered through user tariff charges.

8.4 PROCUREMENT

The procurement for the project is presently anticipated to be conducted by the Liberia Water and Sewer Corporation (LWSC) with technical and additional support provided by Tetra Tech's Liberia Municipal Water Project (LMWP) team or another GoL entity agreed to with USAID . It is anticipated that the project will be solicited and awarded by the LWSC or any other entity agreed to with USAID. The LMWP team will assist LWSC or the selected entity, since they have not presently had significant procurement experience with construction projects of this scale relative to water supply, treatment and distribution projects. The LMWP is expected to assisted in the following tasks:

- Distribution of bid documents

- Attend pre bid meetings
- Respond to questions submitted by potential bidders
- Receipt of bid proposals
- Review of bid proposals and cost
- Review of References
- Execution of contract

USAID's preference is to utilize host country procurement mechanisms for construction of works under LMWP. Significant capacity building is needed before LWSC is capable of procuring major capital works itself. However, procurement policies promulgated by the Government of Liberia do have strong implementation requirements and are being supported by the Infrastructure Implementation Unit (IIU) within the Ministry of Public Works, which provides procurement support to other agencies of the government.

LMWP conducted an assessment to determine the feasibility of using host country contracting mechanisms for procurement of construction services under LMWP. The assessment developed the findings and recommendations that have been reported to USAID in separate documents.

Progress is being made to bring about improvement through implementation of some of these recommendations, including the LWSC recruitment of a Procurement Manager and provision of better accommodation and equipment for the LWSC Procurement Unit. With these expected improvements within LWSC, the support offered by PPCC and the help that the Project's procurement expert will provide, it should be possible to bring procurement practices of LWSC into compliance with the law by the end of the present calendar year.

The suggested capacity building measures and any involvement by the LMWP in these measures have not been provided for in the Project's budget and additional help from USAID may be needed.

8.5 ASSET MANAGEMENT

Asset management is the framework widely being used to pursue and achieve sustainable infrastructure. An asset management process is the practice of managing infrastructure capital assets (inventory) to lessen the expense of being responsible for and operating and maintaining the water system components including source, treatment, storage, distribution, and administration.

Asset management is a developing practice with the goal of maintaining a desired level of service that the management, operators, and customers should expect from their assets. The future Robertsport water utility customers should expect the lowest possiblelife-cycle cost for the operation, maintenance, rehabilitation, repair, or replacement of a component of the water system. An asset management system will help ensure life-cycle costs are kept to a minimum and funds available for the water system are used efficiently.

Many proponents consider the four fundamentals of a sustainable water system to be better management, full cost pricing, water conservation, and watershed awareness. Better management at the local or facility level involves asset management, environmental management systems, and capacity development. Full Cost Pricing is needed to reliably recover all of the costs of construction, operations, and maintenance from water price. Water Conservation, water quantity, and water quality issues are inextricably linked to

sustainability the level service provided. Watershed Awareness is an approach that focuses on stakeholders and activities located within hydraulic boundaries as a means to address water quality and quantity concerns. Asset Management programs are not intended to be developed to address all four fundamentals, but can be an important tool in supporting better management and full cost pricing.

Asset management programs require good data collection and maintenance on the age, condition and criticality, and life-cycle costs of system components. The program also requires operations and maintenance (O&M) and capital replacement plans based on cost-benefit analyses. While the planning is the most effective tool, the gathering and inputting of all the data can be done best when a new water system is created.

The benefits of asset management include:

- Extended asset life and avoidance of premature loss of capital purchases
- Reduction in operational and capital expenditure costs
- Meet consumer demands with a focus on system sustainability
- Establishment of water tariffs based on sound operational and financial planning that are justifiable to the customer base
- Budgeting focused on activities critical to sustained performance
- Improved responses to complaints from customers
- Preparation for emergencies

Asset management is focused on maintaining continuous awareness of five fundamental conditions of the water system as listed below. These conditions should periodically be assessed as part of the administration of the asset management program.

- Which assets or components of the system are critical to sustained performance?
- What is the current condition of the critical components of the water system?
- What is the expected "sustainable" level of service required from the water system?
- What are the minimum and expected life-cycle costs?
- What are the utility's long-term funding options and strategy?

An asset management program can be developed for a new municipal water system such as Robertsport, a rural water system, or an existing larger water system such as Monrovia. There are distinct advantages to starting an asset management program with a new water system, one of which is the collection of operational data over the life of the equipment.

It is recommended that the establishment of any new water system in Robertsport include the establishment and practice of an asset management program. The US EPA offers free asset management software, known as "Check Up Program for Small Systems (CUPSS)." It is available for download and with supporting information at the following internet address:

http://water.epa.gov/infrastructure/drinkingwater/pws/cupss/index.cfm

The website notes that

> *"CUPSS is a free, easy-to-use, asset management tool for small drinking water and wastewater utilities. CUPSS provides a simple, comprehensive approach based on EPA's highly successful Simple Tools for Effective Performance (STEP) Guide series. Use CUPSS to help you develop:*
> - *A record of your assets*

- *A schedule of required tasks*
- *An understanding of your financial situation*
- *A tailored asset management plan"*

An alternative free program is the"Total Electronic Asset Management System (TEAMS)" developed by the Maryland Center for Environmental Training (MCET). Asset management software is available for purchase as well.

8.6 OPERATIONS AND MAINTENANCE MANUAL

The operations and maintenance (O&M) manual is a documents that contains references and record information regarding the details of the water system constructed. The O&M manual describes the general mechanical operation and chemical functions of a water treatment facility, along with the necessary manufacturer materials for maintenance and repair of equipment. The manual also clearly outlines the responsibilities of the various staff members of the water utility. The manual is meant to be periodically updated as the staff structure and the water system each evolves over time

The operations manual can be used as a guidance document for the water system staff and personnel during training sessions. The manual will provide specific instructions as to the daily testing and operation of the facility and day-to-day tasks, which must be accomplished to meet the operational objectives.

O&M manual typically contains the following information:

- Introduction to water system, source watersheds, and facilities(s).
- Water Quality Standards
- Responsibilities of operations and supervision personnel
- Description of facility operations and hydraulics
- Description of facility equipment and relationships
- Common operating problems and solutions
- Chemical applications
- Laboratory testing and operator responsibility
- Power conditions, sequencing and general operation
- Shut-down procedures
- Records and daily logs to be completed
- Calculations for chemical usages and dosages
- Schematic diagrams of flow within the facility
- System maintenance requirements and instructions

An O&M manual should be prepared after each major improvement or institutional change in the water system. A draft sample copy of an O&M Manual is presented in the Appendix. This will constitute the basis for the capacity building documents and other materials to be developed for LWSC.

8.7 ECONOMIC SUSTAINABILITY

The supply of an improved source of water can be inadequate or restricted due to challenges such as power outages, source depletion, and delay in receiving chemicals for treatment or spare parts and

replacement equipment. A water system must support its customers and provide services and a product that is both affordable and reliable. The planned approach within the improved Robertsport water system must balance the need to provide water services with the local ability and willingness to pay for services, which is critical to ensuring that such systems are sustainable. Without ensuring full cost recovery or adequate subsidies, the systems put in place are likely to enter into a spiral of poor maintenance leading to equipment and system failure. While tariff structures must ensure full cost recovery, they also must ensure that the poorest customers have access to a basic level of service via a "lifeline" tariff. It is expected that the tariff structure will include cross-subsidies where the larger water users pay more per volume than low-volume users.

The construction of the distribution system to provide the conveyance of water from the source or treatment to the customer is typically substantial capital cost of system. Therefore, the cost effectiveness of extending the distribution system is typically reduced as the distribution network extends into less densely developed areas where it costs more to extend service on a per capita basis.

In order to reduce costs and barriers to access, the initial supply of water in the short term is expected to be solely via public kiosks located throughout the city with locations to be determined during design. The medium and longer term goal is to transition from kiosks to private yard taps and private house connections.

LMWP will provide a detailed analysis on sustainability once the options have been finalized. The will include detailed financial analysis based on system cost, customer base and revenues and operation and maintenance costs projections. However, an initial analysis regarding the financial feasibility as currently outlined is presented below.

In order for the proposed systems to be sustainable without external subsidies, then at a minimum the cost of operation and maintenance must be recovered via water tariffs. It is important to compare expected tariffs with the prices currently being paid to water vendors, from whom about one fifth of Robertsport residents get their drinking water. The expected average tariff associated with the proposed new water system per jerrican volume equivalent (approximately $0.08/jerrican) is less than one-third of the current rate being paid to water vendors in Robertsport (about $0.25/jerrican). According to the household survey, the reported average household expenditure on water is around $10/month, although this figure includes residents who only obtain water from free sources. Only 56% of survey respondents reported paying for water from their main source.

Table 8-2 presents a preliminary analysis which demonstrates that given currently estimated annual operating costs and water demand, the requisite average cost recovery tariffs are generally within the range of affordability in Robertsport when examined using several different metrics. First, the estimated monthly water cost per household for water from the proposed systems can be expected to vary from approximately $12/month/household initially (after implementing Alternative #2) to approximately $23/month/household after completion of all recommended Medium Term Improvements. This cost represents between 7 and 12 percent of median household income as reported during the household survey. The estimated household monthly net (surplus) income in Robertsport is $35, as calculated based on results of the household survey.

It is important to compare expected tariffs with the prices currently being paid to water vendors, from whom about one fifth of Robertsport residents get their drinking water. The expected average tariff associated with the proposed new water system per jerrican volume equivalent (approximately $0.08/jerrican) is less than one-third of the current rate being paid to water vendors in Robertsport (about $0.25/jerrican). According to the household survey, the reported average household expenditure on water is around $10/month, although this figure includes residents who only obtain water from free sources. Only 56% of survey respondents reported paying for water from their main source.

Table 8-2. Robertsport Water System Initial Affordability Analysis

#	Alternative	Annual Operating Costs (USD)	Estimated Population Served	Expected Volume Sold (gpd)[1]	Expected Per Capita Demand (gpcd)	Estimated Monthly Water Cost per Household (USD)	Monthly Water Cost as Percentage of Median Household Income (%)[2]	Household Monthly Net (Surplus) Income (USD)[3]	Estimated Avg. Tariff per Jerrican volume equivalent (USD / jerrican)[4]	Current Robertsport Vendor Rate per Jerrican (USD / jerrican)[5]
2	Supply Area#1 and #2 Via Gravity from Fasa Creek, with Storage	$86,040	2,915	16,200	6	$12	7%	$35	$0.08	$0.25
4	Supply Area#1 and #2 Via Gravity from Fasa Creek, with Storage, plus Groundwater Supply to Area #3 Upper	$130,300	3,252	32,600	10	$17	9%	$35	$0.06	$0.25
5	Restore WTP and Water System to serve all areas	$193,200	3,515	37,200	11	$23	12%	$35	$0.08	$0.25

[1]Assumes Option 2 completed in 2013, Option 4 completed in 2014, and Option 5 completed in 2015. For conservatism, assumes only residential flow is sold and ignores expected commercial and institutional flows such as Fish Landing Site and Hospital, which will increase demands and revenues and be incorporated into analysis subsequently.

[2]Per Situational Analysis, total reported median monthly gross household income in Robertsport was $187.50.

[2]Per Situational Analysis, total reported median monthly household expenses were $123.61, including groceries ($24.31), water ($4.86), and medical expenses ($2.78). Other costs include telephone, electricity, clothing, and transport. These figures yielded a median net household income (surplus) after expenses of $35.42.

[3]Per Situational Analysis, survey respondents indicated they would be willing to pay a median of LD 5 ($ 0.07) per jerican from stand posts and water kiosks within 100 meters of their home.

[4] Per Situational Analysis, current vendor rates in Robertsport are 20 LD ($0.30) per jerrican sold in Fanti Town neighborhood and 15 LD ($0.20) per jerrican in Grassfield. Assume an average rate of $0.25 USD/jerrican.

8.8 LAND OWNERSHIP

The implementation of some the recommendation is this Master Plan will require that land ownership be determined and the consideration of real estate needs. The local government officials, LWSC, and the steering committee for the LMWP should be engaged in land ownership and real estate needs early in the implementation phase of this plan.

The layout of much of the raw water main, WTP improvements and storage reservoirs are located on the previous sites. This should reduce the need to address land ownership or rights issues as it is understood that the former facilities are under public ownership. The layout of the distribution network is anticipated to follow the shoulders of existing roadways. Access to certain lands may be needed in perpetuity to support the operations and maintenance of the water system.

8.9 SANITATION PLANNING

There has never been and there are no current plans for a sanitary sewage collection system in Robertsport. There is also no solid waste collection and disposal system in place. The solid waste is either cast out as littered to be washed away during the periods of heavy rain, or accumulated into piles for burning.

The majority of residential human waste is discharged to either to latrines or openly cast to the ground. When a sanitation master plan is developed it is recommended that the sanitary waste collection system should initially be situated in decentralized locations throughout the city. Latrines should be located to protect to water sources, by providing provide horizontal offsets and properly designed and constructed. Latrine areas or other properly sited facilities should also include exterior facilities to wash clothing. It is anticipated that any future developed sanitary collection system in Robertsport would increase the water usage.

8.10 SCHEDULE

In order to implement the master plan, the table below was developed to sequence and list the major steps required.

In the near-term, the schedule shows the completion of the ongoing planning stage of the LMWP. The subsequent short term project phase includes the construction of the raw water main with chlorination and distribution systems to Area #1 and #2, followed by the addition of service to #3 Upper including the Robertsport Hospital. The supply of water to these areas is projected to be done by constructing public stand posts. The later stage of the project is to restore the water treatment plant and begin the transition to private house connections and yard taps.

A key benefit of this approach is that a large portion of the distribution system can be quickly restored to improve access to the majority of Robertsport. This initial water system is considered to be simple to operate and does not require a large amount of chemicals or fuel. Since the short term water system is simple to operate it is also anticipated that the initial cost of operation will be low.

Table 8-3 Recommended Robertsport Master Plan Implementation Schedule

Stage	Date	Liberia Municipal Water Project	City of Robertsport and Steering Committee	USAID	Liberia Water & Sewer Corp.
Planning Stage	Sept 2012	Submit Master Plan to • City of Robertsport Steering Committee • LWSC • USAID			
	Oct 2012	Conduct presentation of Master Plan Report to Steering Committee and LWSC	Steering Committee to attend presentation of Master Plan Report	Review Process	LWSC to attend presentation of Master Plan Report
	Nov 2012		Provide Comments	Provide Comments	Provide Comments
	Jan 2013	Respond to comments and Finalize Report	Acceptance of Report	Acceptance of Report	Acceptance of Report
Short Term Project Stage	Feb 2013	• Finalize Phase I (Alt #2) and II (Alt #4) Construction Bid Documents (plans, specs and estimate) and submit for review • Assist Robertsport and LWSC with Institutional development process and implementation	Begin institutional development process		Review and comment on Construction Bid Documents Begin institutional development process
	Mar 2013	Revise Bid Documents based on comments	Implement Watershed Protection Program for Fasa Creek		
	Mar 2013	Assist LWSC to Tender Bid Documents to solicit construction services		Secure capital funding	Tender Bid Documents to solicit construction services
	May 2013	Start Construction of Phase 1 to Serve Areas #1 and #2			
	Feb 2014	Complete Construction of Phase I and II			
	March 2014	Operational Start Up of Phase I and II water system	Begin obtaining water from new water distribution system		Start Operation of new water distribution system

Stage	Date	Liberia Municipal Water Project	City of Robertsport and Steering Committee	USAID	Liberia Water & Sewer Corp.
Medium Term Project Stage	May – June 2014	Finalize Phase III (Alt #5) Construction Bid Documents (plans, specifications and estimate			Review and comment on Construction Bid Documents
	Aug - Sept 2014	Revise Bid Documents based on comments			
	Oct – Nov 2014	Assist LWSC to Tender Bid Documents to solicit construction services		Secure capital funding	Tender Bid Documents to solicit construction services
	Dec 2013 to Jan 2014	Start Construction of Phase III			
	April to May 2015	Complete Construction of Phase III			
	May - June 2015	Operational Start Up of Phase III water system	Begin obtaining water from new water treatment plant		Start Operation of new water treatment plant.
Long Term Projects	2016+				Convert from public to private connections
	2017		Review planning efforts		Update of the Master Plan every 5 years
	2017				Asset Management Plan
	2017				Develop training program to assist other water utilities
	Ongoing				Promotion of rainwater harvesting

8.11 COST OF OPERATION

This section **is not** being presented to suggest or recommend the tariffs or water rates and charges that should be paid by the future water customers of Robertsport. The means to determine the proposed rates and the tariff system should be developed after additional evaluation and collaboration with the various parties.

This section is simply indicating the overall cost of operation as present projected based on the alternatives recommended and the preliminary plans and estimated. As noted above the final distribution of cost to user will be determined at a later date.

The below table simple presents the estimated operational costs, the anticipated average water use, and from that determine the cost per volume of water.

Table 8-4 Preliminary Estimate for Cost of Operation

#	Alternative	Population Served	Estimated Annual Operating Cost	Estimated Average Daily Flow	Estimated Average Daily Flow	Operational Rate in US Dollars
			(US$)	(liters per day)	(liters per day)	(US$/liter)
0	No Action	-	$0	0	$0.0000	$0.000
4	Gravity Feed with Storage and Improved Groundwater Supply - Area #3 Upper	3,184	$130,300	159,200.00	$0.0022	$0.168
5	Restore WTP and Water System	3,515	$193,200	175,750.00	$0.0030	$0.226

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