Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Washington, DC Professional Chapter
COUNTRY: Cameroon
COMMUNITY: Mbokop
PROJECT: Water Supply and Health
TRAVEL DATES: Dec. 1 – Dec. 15, 2014

Prepared By:
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September 14, 2014

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Table of Contents

Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
March 8-23, 2013	Assessment	EWB-DC's first trip to Mbokop established the needs and priorities of the community. We collected data on the existing water infrastructure and qualitative information on the health conditions in Mbokop.
November 17-December 1, 2013	Assessment	The EWB-DC team gathered data required to design a water catchment and distribution system in Mangi, one of the settlements in Mbokop. We gathered quantitative health data throughout the community to set project metrics. We met with local leaders and established a health education plan.

3.0 Travel Team:

4.0 Health and Safety

The travel team will follow the site-specific HASP that has been prepared for this specific trip and has been submitted as a standalone document along with this pre-trip report.

5.0 Planning, Monitoring, Evaluation and Learning

3.1 The travel team has reviewed the 901B – Program Impact Monitoring Report template and has assigned travel team members to complete this report during the upcoming trip. We acknowledge that the completed 901B is required with the eventual submittal of the 526 – Post-Implementation Trip Report. _X_Yes ___No

6.0 Budget

6.1 Project Budget
Project ID:
Type of Trip: I

Trip type: A= Assessment; I= Implement & Evaluation		
Trip Expense Category	**Estimated Expenses**	**Comments**
Direct Costs		
Travel		
Airfare	$18,000	$1000 per flight, 18 travelers, 3 trips ($6000 per trip)
Gas	-	
Rental Vehicle	-	
Taxis/Drivers	$3,000	Extrapolated from Assessment II Costs (x3) = $955 per trip
Misc.		
Travel Sub-Total	$21,000	
Travel Logistics		
Exit Fees/ Visas	$2,610	$145 per person (x18) = $870 per trip
Inoculations	$3,600	Extrapolated from Assessment II ($200 per person, 18 travelers, 3 trips) = $1200 per trip
Insurance	$900	Extrapolated from Assessment II (x3) = $300 per trip
Licenses & Fees	-	
Medical Exams	-	
Passport Issuance	-	
CPR & Wilderness First Aid Trainings	$1,200	$200 each for 2 travelers (x3) = $400 per trip
Travel Logistics Sub-Total	$8,310	
Food & Lodging		
Lodging	$1,800	Extrapolated from Assessment II (x3) = $600 per trip
Food & Beverage (Non-alcoholic)	$3,000	Extrapolated from Assessment II (x3) = $1000 per trip
Misc. (Water Treatment Pens/Bottles)	$600	$200 per trip (x3)
Food & Lodging Sub-Total	$5,400	
Labor		
In-Country logistical support	$1,500	Extrapolated from Assessment II - translators ($500 per trip)
Local Skilled labor	$5,400	Extrapolated from Assessment II - assuming four skilled laborers (Farmer Tantoh at $20-40/day, $80/day for Divine + 2 skilled) is $120/day. Assuming 15 days labor. = $1800 per trip

Misc.		
Labor Sub-Total	$6,900	
EWB-USA		
Program QA/QC **(1)** See below	$3,700	
EWB-USA Sub-Total	$3,700	
Project Materials & Equipment (Major Category Summary*)* add rows if needed		
Spring Collection	$1,800	
Spring Box	$1,600	
Pipeline	$6,400	
Break Pressure Tanks	$3,100	
Tank	$2,700	
Tap Stands	$2,100	
Catchment Protection	$400	
Tools & Misc. Supplies	$800	
Material Transport	$1,000	
Skilled Labor (2 people; $40/day; 45 days)	$3,600	
Contingency (10%)	$2,350	
Project Materials & Equipment Sub-Total	$28,850	See Section 7 for detailed costs.
Misc. *(Major Category Summary)*		
Report Preparation	-	
Advertising & Marketing	-	
Postage & Delivery	-	
Misc. Other	-	
Misc. Sub-Total	$0	
TOTAL	$71,160	
a. (1) Program QA/QC (EWB-USA Headquarters Project Managers and Chapter Relations Managers) Assessment = $1,500 Implementation = $3,700 Monitoring = $1,150		
EWB-USA Headquarters use:		
Indirect Costs		
EWB-USA		
Program Infrastructure **(2)** See Below	$1,200	
Sub-Total	$1,200	
TRIP GRAND TOTAL (Does not include Non-Budget Items)	$72,360	
a. (2) Program Infrastructure (EWB-USA Headquarters accounting, administration and fundraising) Assessment = $500 Implementation = $1,200		

Monitoring = $350		
Non-Budget Items:		
Additional Contributions to Project Costs		
Community		
Labor	$747	Minimum wage in Cameroon is 783.8 CFA per day. Assuming CFA 1000 as per day labor cost.
Materials	$1,000	Estimate cost of sand, wood and other materials we hope Mangi will contribute.
Logistics	$4,800	
Cash	$1,292.50	Assumed 5% of total construction materials.
Other		
Community Sub-Total	$7,840	
EWB-USA Professional Service In-Kind		
Professional Service Hours	500	
Hours converted to $ *(1 hour = $100)*	$50,000	
Professional Service In-Kind Sub-Total	$50,000	
TRIP GRAND TOTAL (Includes Non-Budget Items)	$130,200	
Chapter Revenue		
Funds Raised for Project by Source	**Actual Raised to Date**	
Source and Amount *(Expand as Needed)*		
Engineering Societies		
Corporations	$5,000	CH2M HILL
University		
Rotary		
Grants - Government		
Grants - Foundation/Trusts		
Grants - EWB-USA program	$5,000	
Other Nonprofits		
Individuals	$15,000	Colesvile Presbyterian
Special Events		
Online Fundraising Campaign	$4,677	
EWB-USA Program QA/QC Subsidy **(3)** See below	$3,800	
Total	$24,677	
Remaining Funds Needed	**$47,683**	

a. (3) Program QA/QC & Infrastructure Subsidy:
Assessment = $1450
Implementation = $3,800
Monitoring = $950

7.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply __X_ Source Development __X_ Water Storage __X_ Water Distribution ____ Water Treatment ____ Water Pump **Sanitation** ____ Latrine ____ Gray Water System ____ Black Water System **Structures** ____ Bridge ____ Building	**Civil Works** ____ Roads ____ Drainage ____ Dams **Energy** ____ Fuel ____ Electricity **Agriculture** ____ Irrigation Pump ____ Irrigation Line ____ Water Storage ____ Soil Improvement ____ Fish Farm ____ Crop Processing Equipment **Information Systems** ____ Computer Service

8.0 Project Location
Longitude: *10°51’46”*
Latitude: *6°32’59”*

9.0 Project Impact
Number of persons directly affected: 225
Number of persons indirectly affected: 2,200
Mbokop has 2,200 residents, the first project is a water supply project for the settlement of Mangi (with approximately 225 residents).

10.0 Professional Mentor Resume(s) - Please see document *405 - Mentor Qualifications* for the requirements of the Responsible Engineer in Charge (REIC) and the overall Professional Mentor Team. This can be found in the Sourcebook Downloads on the Member Pages of the website.

See Appendix A for Stephen Clark’s resume.

Pre-implementation Report Part 2 – Technical Information

1.0 EXECUTIVE SUMMARY

This water supply and health project, in Mbokop, Cameroon (Project 9791), is being carried out by the Engineers Without Borders Washington, DC, Professional Chapter (EWB-DC). This project consists of design and construction of a gravity-fed water supply system in the settlement of Mangi, training community members in skills needed to maintain the water system, capacity building of community water and health committees, and public health education in the community. The water supply project implementation activities discussed in this report will be phased and implemented over three trips.

EWB-DC is seeking TAC approval for the finalized design for the construction of a spring box and gravity-fed distribution network that will include piping, break pressure tanks, storage tanks, and communal taps.

The goal of this project is to deliver a sustainable solution for improved drinking water to the settlement of Mangi within Mbokop. Drinking water was identified as the priority for EWB-DC's partnership with Mbokop, both in Mbokop's initial application to EWB-USA, and in subsequent data collection and meetings between EWB-DC, the community of Mbokop, and partner nongovernmental organizations (NGOs). The community of Mbokop decided that the first drinking water solution implemented in Mbokop should be within the settlement of Mangi.

The community of Mbokop is a remote, impoverished village in the Northwest Region of Cameroon that lacks several basic services. Mbokop's five settlements -- Ntayi, Mbutung, Njapnjang, Mangi, and Mbotop - are home to three different tribes, the Mbum, Fulbe (Mbororo), and Yamba. These tribes speak different tribal languages, but most people are fluent in Pidgin English, Limbum, or Fulfulde. The community members are predominantly farmers and vendors, with some herders, teachers, and religious leaders/teachers. Because of the layout of the community, EWB-DC will have to implement multiple water systems to provide improved access to improved quality drinking water to all 2,200 residents of Mbokop spread throughout the five settlements.

EWB-DC is partnering with the Health Development Consultancy Services (HEDECS) and the Society for Initiatives in Rural Development and Environmental Protection (SIRDEP), both of whom are in-country NGOs headquartered in Bamenda in Northwest Cameroon. HEDECS strives for socio-economic empowerment of marginalized and other community member groups through improved health (http://hedecs.wordpress.com). SIRDEP seeks to "improve the standard of living of the poor and needy in Cameroon by building on their potentials through innovative strategies and efficient management of resources" (http://sirdep.wordpress.com). SIRDEP facilitated the signing of land-rights agreements for this project between landowners, the local mayor, and the Mbokop Water Committee, which will allow Mbokop to utilize spring sources in Mbongong (the community adjacent to Mbokop). SIRDEP provided a Project Partnership Agreement (PPA), which EWB-DC has signed, along with SIRDEP and representatives of the Mbokop Water Management Committee. In September 2014, an Implementation Agreement was signed by the community of Mbokop, and subsequently signed by SIRDEP and EWB-DC.

In early 2012, Mbokop community members contacted EWB-USA requesting help in the design and implementation of sustainable and durable infrastructure to meet the needs of current and future generations. EWB and the community determined that the most crucial need in the community was the construction of an improved drinking water system. In June 2012, this project was awarded to EWB-DC. In December 2012, the community of Mbokop elected a water committee to serve as a liaison to EWB-DC. EWB-DC conducted assessment trips to the community in March 2013 and November 2013. Based on data collected during Assessment Trip I and subsequent meetings within the community and with NGOs, a water supply project for the Mangi settlement was prioritized as the first project in this program. EWB-DC focused the majority of data collection activities during Assessment Trip II on information that will be used to plan construction of a water supply project in Mangi.

The Manning's equation was used to calculate the flow through the collection pipe into the spring box. The Hazen-Williams equation was used to calculate head loss in the pipe. Refer to Section 4.2 for a summary of full calculations and Appendix B for pipeline hydraulic calculations. Structural design was completed in accordance with EWB Guidelines and the 2009 International Building Code, including reference standards. Structural calculations are provided in Appendix J.

Refer to Appendix C, which contains drawings for the pipe plan, pipe profile, spring box and collection system, storage tank, break pressure tanks, tap stand, air release box and clean out box, trench and backfill details, and civil details.

Prior to the arrival of the EWB team, the community is expected to prepare the construction site with guidance from the local construction manager, collect any locally available materials and raise at least 5% of the construction cost (per the signed PPA and IA). The local construction manager will procure materials prior to the EWB team arrival, store, and transport the materials. Upon arrival, the first EWB team will procure any additional construction material with SIRDEP and organize transportation to Mangi. The construction will be carried out in three phases each corresponding to an EWB implementation trip – first the construction of the spring box and collection system, second the construction of the storage tank, and third the construction of the break pressure tanks and tap stands. The pipeline will be installed over the entire duration of these three phases. The EWB team will be present in the community for all crucial construction activity, although some activities such as trenching, curing tank walls and foundation, etc. will be expected to be carried out by the community in the absence of an EWB team with help and guidance from the local construction manager. While EWB-DC will provide the technical oversight, the community will provide the required manual labor. A construction manager familiar with spring box construction in this region of Cameroon will oversee the construction activities. SIRDEP will provide training and follow-up support to the community.

Long-term sustainability is critical for project survival. The system will need to be inspected regularly and issues will need to be fixed as they are identified. It is estimated that the annual operations and maintenance (O&M) cost will be around $245. The Mbokop Water Committee has been established to ensure continuity in maintenance and provide financial stability to the project. EWB-DC will facilitate training the community on water system maintenance that will help to ensure ongoing functioning of the facilities. Through follow-up trips, post-implementation, EWB-DC will measure progress of community led maintenance based on visual inspections of the system and review of maintenance logs kept by the Water Committee.

2.0 INTRODUCTION

This report outlines the design plan for the implementation of a spring box and collection system for the Mangi settlement within Mbokop. The community identified the settlement of Mangi within Mbokop as the location for the project. Based on findings from two assessment trips, subsequent partner NGO community visits, and an alternatives analysis, the spring box has the potential to meet the demand of the community. In addition, it allows for a gravity-based system, which both simplifies design and eliminates potentially complex and expensive pumps and power costs. This report includes design plans, calculations, drawings, descriptions of project ownership and other pertinent information related to the construction of a spring box and distribution network that will include capture at the source, piping, break pressure tanks, storage tanks, and communal taps. As described in Section 1.0, a land use agreement has been established. At this time, this project is the only planned project for the team's Mbokop project, however the overall program goal is to improve access to improved quality drinking water for the entire Mbokop community. Therefore, future projects under the EWB-DC program within Mbokop may include the design of additional water systems.

3.0 PROGRAM BACKGROUND

In early 2012, the rural community of Mbokop in the Northwest Region of Cameroon contacted Engineers Without Borders-USA requesting the help of EWB to provide expertise in the design and implementation of sustainable and durable infrastructure to meet the needs of current and future generations. The most crucial need in the community, as expressed in the Project Application Form 501, was the construction of an improved drinking water system. In June 2012, this project was awarded to EWB-DC. In December 2012, the community of Mbokop elected a water committee to serve as a liaison to EWB-DC.

Mbokop is northeast of the town of Ndu and is a diverse community with five settlements (Ntayi, Mbutung, Njapnjang, Mangi, and Mbotop), three tribes (Mbum, Fulbe (Mbororo) and Yamba), and two primary religions (Islam and Christianity). Based on the focus groups and interviews from the first assessment trip, the community members' major concerns for Mbokop are the lack of safe drinking water, lack of a health center, poorly maintained roads, and lack of electricity. The community hopes to gradually address infrastructure needs in order to improve their quality of life beginning with the most basic services such as improved quality drinking water, hygiene and sanitation, and electricity.

Since March 2013, the EWB-DC team has conducted two assessment trips to assess the needs of Mbokop, establish a partnership with the community and in-country NGOs, conduct topographical surveying, and collect water quality and flow data. The team's two 522 post-trip reports contain detailed assessment findings and were published May 19, 2013 and February 16, 2014. Through a community meeting in Mbokop, facilitated by a partner NGO, the community prioritized a water supply project for the settlement of Mangi as the first construction project within the EWB-DC Cameroon Program (see Appendix D for meeting report).

The residents of all five Mbokop settlements collect water from a number of surface water sources. The residents of Mangi use nearby streams to collect water, which EWB-DC tested during both assessment trips and identified as contaminated with elevated levels of total coliform and *E. coli*. In the past, an earthen channel was used to provide Mangi with water from a spring at the head of the Mbokop River, but it is not currently in use (the channel presumably filled in with silt due to a lack of maintenance). The catchment areas that feed water sources throughout Mbokop are not sufficiently protected. Cattle drink from streams that provide water for the residents and often roam free through the water sources. Open grazing of cattle and other animals (e.g., goats, chickens) is common and catchment protection is generally not implemented to protect drinking water from animals. Moreover, eucalyptus and other water-intensive species of trees grow throughout Mbokop, further depleting water sources.

On June 14, 2014 the EWB team submitted the 523 - Alternatives Analysis report. A brief summary is listed below and the full 523 is attached as Appendix E.

Alternatives Analysis Summary:
Based on the needs of the community and the data collected during the assessment trips, EWB-DC determined that the following four options were worth further consideration and evaluation as the most viable alternatives to provide Mangi with improved drinking water: (1) Capturing a new spring source in Mbongong, (2) Collecting rainwater, (3) Pumping water from wells, or (4) Pumping and treating water from existing surface water sources in Mangi.

After meeting with the community, a project to produce more water was identified as a priority over a project that would address water quality alone (such as point of use treatment). Estimated demand was a minimum of 20 liters per person per day, and an ideal supply of 100 liters per person per day. Geographic constraints, including elevation differences and distances, were another consideration. The lack of a readily available and reliable electricity supply further limited the viable water supply alternatives. Raising cattle is important to the livelihood of many Mangi residents, so the drinking water needs of the cattle were considered if the chosen design solution might reduce or eliminate access to an existing livestock surface water source. Lastly, the construction, operation, and maintenance of the system must be affordable to Mbokop. Based on the assessment, Alternative 1 (Spring Box and Collection System) was the most desirable. The spring box has the potential to meet the demand of the community now and in the future; and allows for a gravity-based system, which both simplifies design and eliminates potentially complex and expensive pumps and power costs. Additionally it is not expected to affect the water supply for the community’s livestock and may potentially be able to supply troughs for livestock needs.

4.0 FACILITY DESIGN

4.1 Description of the Proposed Facilities

This project proposes to build a spring box and distribution network that will include capture at the source, piping, break pressure tanks, storage tanks, and communal taps. There is an untapped spring source in the neighboring community of Mbongong, which lies to the south of Mangi (close to the border). The Mbongong spring source is located approximately 2,250 meters away from and 135 meters above the Mangi town center. A land use agreement has been established between the Mbokop Water Committee, the Mbongong landowner (where the spring source is located), and the Mayor of Ndu. The agreement turns the spring source and land surrounding the spring source over to Mbokop for use for a drinking water supply. The agreement includes the land surrounding the spring to provide for protection of the catchment area, which is described as having a radius of 40m surrounding the source.

Groundwater from the diffuse (or seepage) spring source will be collected using two (2) 90mm perforated collection pipes laid in parallel arrayed in a 10m wide “V” pattern behind a subsurface poured concrete wall. The drain pipe will discharge into the spring box. The spring box will feed the collected water to a gravity-fed, 90mm water pipe and will discharge excess flow via an overflow to prevent back pressure on the spring. The water pipe will carry flow down from the spring source towards Mangi. Prior to reaching Mangi, the water pipe will discharge flow into two (2) concrete break pressure tanks in order to prevent over-pressurization of the pipe due to the large change in elevation. The break pressure tanks will also serve as sediment traps for the pipeline and will provide vacuum relief. Approximately 721m from the Mangi town center, the pipe will discharge the collected spring water into a storage tank near Mangi with a usable capacity of approximately 8,600L. From the storage tank, a water pipe will distribute the collected water to one (1) tap stand with a pair of taps in Mangi town center and a second tap stand with a pair of taps at the Mangi Government School where residents can retrieve the water.

4.2 Description of Design and Design Calculations

Further details regarding the design components for this project can be found in Appendix C, which includes the following drawings:

- Pipe plan
- Pipe profile
- Spring box and collection system
- Storage tank
- Break pressure tanks
- Tap stand
- Air release box and clean out box
- Trench and backfill details
- Civil details

4.2.1 Water Quality and Water Quantity

EWB-DC performed water quality testing and water quantity flow measurements during Assessment Trips I and II.

The water that originates from the spring source was sampled from an area where it reaches the surface. Samples taken in both March and November 2013 tested negative for E. coli bacteria. However the laboratory analysis of a sample from November 2013 showed the presence of aluminum (1.6 mg/L) and turbidity (11 NTU). Because the sample was taken at the surface there was a significant amount of suspended solids within the water, which contributed to a high turbidity. It is anticipated that turbidity will be significantly lower once underground water is channeled directly to the spring box. There are no health-based standards for aluminum in drinking water set by the U.S. Environmental Protection Agency (EPA) or the World Health Organization (WHO). Aluminum is an aesthetic consideration because the presence of aluminum at concentrations in excess of 0.1-0.2 mg/L may result in floc formation and may contribute to discoloration in the drinking water. The U.S. EPA has set a non-mandatory water quality standard, SMCL, of 0.05 to 0.2 mg/L. Once the spring is captured in the spring box another round of water tests will be run to determine if aluminum is still present and turbidity is still elevated.

Quantitative public health surveys conducted by EWB-DC on Assessment Trip II estimated actual water usage within the community. Estimates ranged from four to 60 liters per person per day, with a mean of 17.5 liters per person per day in the dry season and 16.5 liters per person per day in the wet season. Based on the data collected during the assessment trips, published standards, and the team's best professional judgment, the following demand estimates will be applied and targeted in the design of the Mangi water system:

- Minimum condition: 20 liters per person per day
- Ideal condition: 100 liters per person per day

Table 4-1 below summarizes both the minimum and ideal condition values that can serve as targets for water supply to be delivered to the community under various population scenarios. It should be noted that actual water delivery may be constrained by the available sources, fluctuating rainfall, and corresponding spring and groundwater supply levels.

Table 4-1. Minimum and Ideal Water Demand Estimates Under Various Population Scenarios

Population Scenario	Minimum Condition (at 20 L/day/person)**: Water needed per day per population (L/day)**	Ideal Condition (at 100 L/day/person)**: Water needed per day per population (L/day)**
226 (current)	4,520	22,600
270 (20% growth)	5,400	27,000
400 (80% growth)	8,000	40,000

This water source has been monitored for flow in both the dry and the rainy seasons (see Table 4-2). Two rainy season measurements were taken. Based on the flow measurements, the spring source will provide sufficient flow during the rainy season to meet both the minimum and ideal water needs of even the highest future population estimate for all of Mangi. Two dry season measurements were taken and the estimated dry season supply based on these values suggest that minimum supply may be met for all three population scenarios; however, the supply will be below the ideal supply volume of 100 liters per day for all population scenarios (see Table 4-2).

Based on the available flow data, it is estimated that approximately 35 liters per person per day could be supplied to the current Mangi population during the dry season under the lowest flow conditions the team has observed (5.6 liters/min) via field observations.

Table 4-2. Summary of Flow Measurements Taken at the Spring Source

Time of Year	**liters/min**	**liters/day**	**Is minimum condition supply need mett[le]**	**Is ideal condition supply need met?[f]**
Dry season estimated flow 1[a]	5.6	8,120	Yes (all scenarios)	No (all scenarios)
Dry season estimated flow 2[b]	7.6	11,000	Yes (all scenarios)	No (all scenarios)
Rainy season estimated flow[c]	109	156,430	Yes (all scenarios)	Yes (all scenarios)

Rainy season estimated flow[d]	322	463,104	Yes (all scenarios)	Yes (all scenarios)

Table Notes:
a. Flow data collected on Assessment I – March 2013
b. Flow data collected by in-country partner, Julius – April 2014
c. Flow data collected on Assessment II – November 2013
d. Flow data collected by Rahul Mitra – July 2014
e, f. Compared to data in Table 4-1, (e) minimum and (f) ideal condition for population scenarios of: current, 20% population growth and 80% population growth.
Note: data collection points varied, all were downstream of source and therefore may under-estimate actual source flow rates.

4.2.2 Spring Collection System (Collection Dam, Collection Pipe, and Spring Box)

The water source to be captured is a diffuse (or seepage) spring. To collect water across a wide area of seepage, a subsurface dam will be constructed on the impervious layer underlying the water-bearing layer in conjunction with two (2) parallel collection pipes running behind it (uphill). The collection pipes will collect and convey the spring flow to a spring box, where it will either enter the pipeline or discharge to the surface as overflow. Refer to the Spring Box Detail in Appendix C for drawings of the design components mentioned in this section.

The overall design is based on Jennings (1996), which is the sole citation for seepage spring capture in EWB's Water Resources Guidelines (2005). Other sources consulted include a widely cited technical note from Water for the World (n.d.), a fact sheet from Pennsylvania State University (Clemons, et al., 2007), EWB-DC's assessment of the spring boxes in the nearby community of Ntayi (Clark, 2013), and a presentation from David Sacco at EWB's 2012 Northeast Region Conference.

Collection Dam

The collection dam will divert spring flow into two collection pipes that lay uphill from it (towards the water source). The dam will be constructed on the impervious ground layer underlying the water-bearing layer of the spring. This will require excavation of the spring to a point where the impervious layer is more than 1m beneath the ground surface. The dam will be constructed in a wide-angle (approximately 140-degree) "V" shape to direct water to a collection pipe at the center of the "V." The exact width of the diffuse source is not known, so onsite construction will need to be responsive to the conditions encountered. Jennings (1996) recommends that the collection dam wall extend at least 1.2m beyond the seep area. Conservatively, this design calls for the wall to cover a horizontal range of 10m (perpendicular to the seep flow), resulting in 10.6 linear meters of wall due to its "V" shape. The wall is designed to be 1m high, but field conditions will determine its exact height. The wall will cover most of the vertical cross-section of the water-bearing layer, but will not break the plane of the ground surface, so as to not divert surface runoff into the collection pipe. After construction is complete, the collection dam will be covered in at least 0.3m of soil to restore the original surface topology.

The collection dam wall will be 15cm thick and constructed of cast-in-place concrete (see *Concrete and Stone Masonry* section for further specifications). The material and thickness are taken from Jennings (1996), Clemons, et al. (2007), and Water for the World (n.d.). A spring box located in the nearby settlement of Ntayi also employs a subsurface collection wall made of concrete (Clark, 2013).

Collection Pipes

The two parallel collection pipes will capture and divert water flowing from the seep area. They will be located in a 0.6m-wide gravel-lined trench dug up to 15cm into the impervious layer (but not puncturing it), just behind (uphill from) the collection dam wall. The trench and collection pipes will follow the same "V" shape and cover the same horizontal range (10m) as the collection dam wall. The trench and collection pipes will have a 0.5% slope downward from both ends towards the center of the "V," and capped vertical solid pipe sections extending 0.5m above ground level will be connected to both ends via wyes (or equivalent) for clean-out purposes (both according to specifications in Water for the World, n.d.). The collection pipes will be covered in gravel after installation. Plastic sheeting will be used to cover the gravel and at least 0.3m of displaced soil will be backfilled on top of the sheeting to restore the original surface topology. The plastic barrier combined with the termination of the collection wall below ground level should prevent surface water runoff from entering the collection system.

The preferred collection pipe material is 90mm perforated PVC pipe, as this will allow for the most reliable connection to the spring box. If only solid PVC pipe can be obtained, numerous 3mm-diameter perforations will be drilled into the pipe (Water for the World, n.d.), consuming a significant amount of labor.

The two sides of each collection pipe "V" join at the center in a wye. Two solid 90mm PVC pipes extending from the downhill side of the wyes pass through the collection wall near its base. They are joined by a wye or tee at a point between the collection dam and the spring box. A solid 90mm PVC pipe runs downhill from the pipe intersection at a 2% slope and serves as the influent pipe to the spring box.

All references used for the system design (Jennings, 1996; Clemons, et al. 2007, and Water for the World, n.d) specified 100mm pipe for collection and influent to the spring box. The one spring box in neighboring Ntayi that uses a pipe for influent also conforms to this specification (Clark, 2013). We are using two 90mm PVC pipes because the size is readily available in the area.

The highest observed flow observed by EWB-DC near the spring source was 321.6 L/min, or 0.00536m^3/s. To validate the selection of a 90mm pipe for collection, Manning's equation was applied to describe the flow assuming a 0.5% slope when the 90mm PVC pipe flows full. A Manning's coefficient of n=0.01 was used as it is typical for PVC.

$$Q=A*(Kn/n)*(R^{2/3})*(S^{1/2})$$

The flow through the 90mm collection pipe flowing full would be 0.0036m^3/s. EWB-DC will install two parallel 90mm collection pipes to ensure adequate capacity from the collection dam. Therefore, the total full pipe flow at 0.5% slope would be 0.0072m^3/s, or 34% higher than the maximum observed flow. The single section of collection pipe, serving as the influent pipe for the spring box will also carry 0.0072m^3/s at 2% slope. If field conditions permit steeper pipe slopes, additional collection capacity can be expected.

Spring Box

The spring box will serve as a means to connect flow from the collection pipes to the distribution pipeline. It will also enable the discharge of overflow from the collection pipes to the surface, thus preventing backpressure on the spring. The spring box will not provide storage. There is disagreement in the literature on the appropriateness of using a spring box for storage (both Jennings, 1996 and Clemons, et al., 2007 assume that the spring box can be sized for moderate storage, but others warn against it). We bypass this issue by installing a storage tank downslope along the distribution pipeline. Therefore, the spring box is sized only to reach the needed depth and to allow for human access for cleaning and maintenance. The dimensions were modeled on the existing local spring boxes in Ntayi, but are also within the general guidelines of all of our primary references. Our design baseline of a 2m interior height allows for the base of the spring box to be low enough that water can flow downslope into it from the collection area and the top to be high enough above ground level to prevent surface water intrusion around the lid. If sufficient downhill grade between the collection dam and spring box is found, the height of the spring box may be reduced.

Water will enter the spring box through the 90mm collection pipe, which will penetrate the spring box wall on the uphill side at a minimum center-pipe height of 0.4m above the interior bottom. Two PVC pipes will exit the spring box on the downhill side: 1) the overflow pipe and 2) the effluent pipe. The 90mm PVC overflow pipe will discharge any water above a height of 0.3m from the interior bottom of the tank, thus preventing backpressure on the influent pipe and, by connection, the spring. The overflow pipe will be vertical inside the spring box and will penetrate the base slab before turning 90 degrees and running horizontally at a 3% slope until it daylights at the existing surface streambed. The 90 degree elbow will be cast into the base slab with the bell flush with the top of the slab. PVC cement will not be used when installing the vertical segment inside the spring box, this will allow for the vertical segment to be removed to drain the spring box for cleaning. After cleaning, the vertical segment can be reinserted to place the spring box back into service. At a 3% slope, the overflow pipe will flow full at $0.0088m^3/s$, which is larger than the influent capacity, preventing overfilling of the spring box and backpressure on the spring. Rip-rap will be provided at the discharge to prevent soil erosion. As a possible future add-on, a cattle trough or other facility may be constructed to utilize the overflow.

The second pipe exiting the spring box on the downhill side, the effluent pipe, will penetrate the spring box wall at a centerline height of 0.2m above the interior bottom of the tank. The effluent pipe is horizontal and does not have a vertical bend like the overflow pipe. The effluent pipe will have the same specifications as the distribution pipeline (90mm PVC) and will connect directly to it. While significant sediment has not been observed, and is thus not expected, from this spring, the 0.2m height of the effluent outlet above the bottom of the tank will provide some space for sedimentation.

The structural design of the spring box will follow the same basis as the two functioning Ntayi spring boxes. The base and first 0.6m of the sides of the box will be reinforced CIP concrete. This will provide a one-piece bathtub-like basin for the functional part of the spring box (all pipe penetrations will occur through this portion. Above 0.6m, the walls will be constructed of stone masonry. Both the concrete and masonry portions of the walls will be 0.3m thick (Cook, 2013). The top of the tank will again be formed of reinforced CIP concrete. A 0.6m by 0.6m hole will remain in the top for access. A 0.025m-thick, 0.6m by 0.6m precast reinforced concrete lid will fit tightly over this opening. The *Construction Plan* and *Concrete and Stone Masonry* sections contain further specifications on the structural design of the spring box.

4.2.3 <u>Pipeline</u>

The pipeline will transmit water collected at the spring box down to taps at the Mangi town center and school for use by residents. Refer to the Pipeline Profile and Pipeline Plan in Appendix C for drawings of the design components mentioned in this section. A single 90mm pipe will be capable of meeting the water distribution needs for the project. The design assumes that 90mm PVC pipe will be used. The size of the pipeline was determined based on the volume of water that will be flowing through it. This is based on the current population of Mangi plus future growth for a total of 400 residents. Hydraulic designs were based on a maximum demand of 100L/day per person during the rainy season. Therefore, 40,000 L/day is the maximum Mangi demand. Design calculations were performed using a spreadsheet model to calculate head loss in each pipe segment as surveyed by the EWB-DC teams during Assessment Trip II. The hydraulics were later validated using Bentley WaterCAD. A summary table of hydraulic calculations is provided in Appendix B.

Water flowing through a pipe loses energy due to friction with the pipe wall. The head loss due to friction can be determined using the Hazen-Williams equation:

$$\text{Head loss} = 10.67 * Q^{1.85} / C^{1.85} * d^{4.87}$$

Where head loss is measured in meters of water per meter of pipe length, Q is the flow rate in m^3/s, C is the Hazen-Williams friction factor, and d is the inside pipe diameter in meters. PVC pipe, which is the most readily available material to the community, has a C-factor of 140-150. This analysis used a C-factor of 145. The head loss is multiplied by the length of the pipeline to determine the head loss for the entire system.

The best readily available pipe size for the Mangi system is 90mm. A pipe this size carrying the maximum Mangi demand of 27.8L/min (based on a demand of 100L/day for a population of 400 people) loses 0.0086 meters of head per 100 meters of length. At a peak flow of 48L/min (4 taps operating concurrently at 0.2L/s), the pipeline loses 0.0236 meters of head per 100 meters of length. A 0.2L/s flow at the taps is recommended by EWB-USA's "Water Resources Guidelines."

The Mangi pipeline was sized large enough to maintain at least 20psi at the tap locations at all times while maintaining an appropriate pipeline velocity. The EWB-USA Water Resources Guidelines (2005) suggests the pipeline should be sized so water velocities are between 0.7 m/s and 2.0 m/s. The velocity in a 90mm pipe at the average flow rate of 27.8L/min is 0.07m/s; the peak velocity (when all taps are opened) is 0.13m/s.

It is noted that the average flow rate will result in velocities lower than EWB-USA's recommendation. The primary concern for low velocities is the risk of sedimentation within the pipeline. The velocity of water in the Mangi pipeline will often drop below the average flow rate when the taps are closed, and at times see no flow at all. To attempt to control sedimentation problems, EWB-DC plans to provide clean-out connections along the pipeline and sediment weirs in the break pressure tanks.

The Mangi route has an abundance of system head during static conditions (i.e., when the taps are not being used). The pressure could be controlled by balancing pressure lost due to moving water, but since the velocity of water flow will vary greatly and drop to zero at times, this is not a viable option. EWB-DC preferred to maintain tighter control over system pressure using break-pressure tanks. The discussion on pressure follows this section.

Hydraulic grade lines were calculated during the peak flow of 48L/min (when all taps are in use) for the main pipeline and the school branch and overlaid on the ground profile to ensure sufficient positive pressure is available at all points along the line. The hydraulic profiles under peak flow conditions and the calculations for each pipe segment are provided in Appendix B. Note that the sharp changes in the hydraulic grade line are caused by break-pressure tanks, which reduce pressure in the pipeline to atmosphere. More discussion on break-pressure tanks follows in the next section.

The pipeline generally will be installed at a consistent depth below the ground surface. Per the EWB-USA Water Resources Guidelines (2005), at least 0.6m of ground cover will be required to protect the pipe from weather and exposure. During installation of the pipe, a trench will be hand-dug. A trenching detail is provided in Appendix C. The Standard Practice for Underground Installation of Thermoplastic Pipe, ASTM D2321, recommends trench widths be the greater of either the pipe diameter plus 400mm or 1.25 times the pipe diameter plus 300mm. The laborious process of hand-digging a trench may limit the practical width of the trench.

Because motorized vehicles are not readily available, it is not feasible to use well-graded bedding and backfill material. The soil removed during trench digging will be used to backfill on top of the pipe. Large rocks and boulders will be removed to protect the pipeline and minimize damage following installation. Chicken wire mesh will be brought to the site with 2x4 boards to construct a makeshift sieve, in the event that the soil needs to be separated from small stones.

Galvanized pipe will be used as a protective sleeve for better protection when the pipe crosses under roads, including the Mangi town center. Galvanized pipe will also be used for places where the pipe is above the ground surface, such as at the tap stands. In the event that 90mm galvanized steel pipe is not available, two parallel 65mm pipes will be used at a tee connection to provide sufficient capacity.

Air release valves are important to prevent air lock and maintain full flow through the pipeline. The Mangi design uses two air release valves at local high points along the pipeline. The valves will be manually operated to reduce cost and complexity of the design. Periodically the Water Committee Caretaker(s) will be required to open the valves to purge any air that becomes entrapped. Refer to Appendix C for air release valve details.

Clean-outs are also important to maintain the optimal operating conditions of the pipeline. The Mangi system will include three flushing connections so the pipe can be cleared of settled sediment and debris that may accumulate in the line. The clean-outs will be located at local low points. Refer to Appendix C for clean out details.

Resultant forces on pipe bends were calculated. Based on an estimated soil bearing capacity of 140 kPa, thrust blocks will not be needed. The area of the pipe bend will be sufficient to prevent pipe movement once the trench is backfilled.

4.2.4 Break-Pressure Tanks

Based on surveying data obtained during EWB-DC's Assessment Trip II to Mangi, the ground elevation at the proposed spring box location is approximately 1,799m above mean sea level (MSL). The proposed points of use will be in the town center and at the school. The elevation at these locations is 1,674m above MSL and 1,662m above MSL, respectively. Therefore, the system head is between 125 and 137 meters. This is approximately 1,300 kPa, or 3 times greater than typical distribution system pressures in the United States.

The working pressure of PVC pipe varies based on several factors. Some of the most important are wall thickness, operating temperature, and manufacturing standards. Though PVC pipe can be specified in the United States to withstand the pressures of the proposed Mangi system, the availability of such materials local to the community is largely unknown. EWB-DC has consulted with other engineers during the Mangi design. Some sources claim the standard for PVC working pressure in Cameroon is 100m of head (about 980 kPa), but this is unconfirmed. It is EWB-DC's opinion that this is an unsafe working pressure and would lead to extensive breaks and leaks.

Limiting the maximum design pressure of this system will be beneficial for several reasons. For many who will help assemble the pipeline, this will be the first experience working with PVC primers and solvents to join segments together. The quality of the PVC bonds cannot be assured as they could be with a qualified contractor. Additionally, the temperature in the region is about 24-30 degrees Celsius. The EWB-USA Water Resources Guidelines (2005) recommends using de-rating factors for quoted working pressures of PVC pipe. When pipelines operate at higher pressures, they are more susceptible to leaks, breaks, and the effects of water hammer. Lower pressure pipelines are easier and safer to maintain.

EWB-DC plans to use float valves to control flow into the storage devices in the system. According to other EWB chapters, these have been known to reliably operate at pressures below 415 kPa. Therefore, the maximum design pressure for the Mangi line will be 415 kPa, or about 42.3 meters of water.

The Mangi system will require three pressure-reducing stations between the spring box and the tap to maintain a maximum of 415 kPa of pressure. Specialized pressure-reducing valves are capable of modulating downstream pressure using hydraulic energy, but are prohibitively expensive and require trained professionals to service them. A simple and reliable alternative is the break-pressure tank. These devices work by restoring the pipeline pressure to atmosphere (0 kPa gauge pressure) at the location of the tank.

Break-pressure tanks are relatively small and essentially provide a basin so the upstream pipe may discharge freely. The downstream pipe continues out under gravity flow. Refer to the Break-pressure Tank Detail in Appendix C for design specifics. The design for the break-pressure tanks based on the SANAA design. The tanks need to be placed along the pipeline route such that the maximum pressure downstream is not violated, while enough hydraulic head remains to maintain flow over any local crests. The location of the tanks must also be practical for construction. It is noted that the primary storage tank also serves as a break-pressure tank. Therefore, two (2) dedicated break-pressure tanks will be needed. The third pressure-reducing station will be the storage tank.

The profile of the Mangi system was digitized and imported into AutoCAD to graphically determine the best locations for the break-pressure tanks (see the Pipeline Profile drawing in Appendix C). A vertical line 42.3 meters tall was drawn, indicating the maximum head for the PVC pipe. The locations were selected so positive pressure will be maintained at all points along the route under static and flow conditions. The proposed break-pressure tank locations were verified with the EWB-DC members who performed the survey during Assessment II to ensure constructability. The first break-pressure tank is located near the change in ground profile close to the spring. This will have the benefit of relieving any back-pressure at the spring box to ensure unimpeded flow into the device.

The break-pressure tanks hold a relatively small volume of water because storage is not a primary function. The tanks only hold enough volume to effectively balance water flowing in with water flowing out. The water that flows out of the tank through the downstream pipe can be described using the orifice equation:

$$Q = C_d*A*\sqrt{(2*g*h)}$$

Where Q is the flow rate through the orifice in m^3/s, C_d is the orifice coefficient (a value of 0.6 is typical for sharp-edged transitions), g is the acceleration of gravity, and h is the height of water above the orifice.

The level of water in the break-pressure tanks will be controlled using float valves. According to other EWB chapters, these devices generally operate properly and reliably when the incoming pressure is lower than 415 kPa. As the taps are opened, the storage tank will drain and the receding water level will open the valve. Consequently, the water level in the break-pressure tanks will recede and each float valve will open in turn. These valves are necessary to keep the entire pipeline pressurized without exceeding the limits of the pipe wall strength. It is noted that the use of float valves in rural water systems is sometimes discouraged because they rely on a mechanical function that has the ability to fail. In order to ensure that they function as designed they will require inspection and as-needed maintenance. Refer to the O&M Manual for further details about O&M of the break pressure tanks and associated float valves.

4.2.5 Storage Tanks

Sizing

The water storage tank sizing was based on the daily water supply requirement for the potential future population of Mangi. With a future population of 400 people and a minimum supply requirement of 20 liters/person/day, the minimum water supply required is 8,000 liters per day. The sizing would need to factor in this requirement in order to meet the minimum water supply requirements from the World Health Organization and allow for population growth.

When sizing the tank, it was decided that one tank could be sized to meet the minimum requirements while keeping the tank size manageable for construction. Refer to the Tank Plan and Section drawing in Appendix C. The tank was sized for a three hour peak usage time frame where all four taps in the system are constantly open (supplying a total of 48L/min). In that three-hour period, 8,640L would be delivered to the community, more than what would be required for the entire day. Assuming an input flow rate (the dry season flow rate measured during Assessment Trip I) of 5.6L/min and an output flow rate of 48L/min, there is a need to have an additional 7,625L of water available in order to meet the demand (48L/min-5.6L/min*180 min). This volume is the minimum tank capacity storage capacity in order to provide water for 3 hours to all taps when fully open.

Design

The tank will be cylindrical with a 1.5m internal height to limit the complexity of construction and reduce the stress on the walls. The tank has an internal diameter of 2.7m. Total tank capacity is 8,588L. Refer to the tank drawing in Appendix C. The outlet and overflow pipe locations were selected to maximize the amount of usable volume and minimize the total tank size. With an overflow pipe inlet 10cm below the tank ceiling and the outlet to the tap 3cm above the tank foundation, only 7,844L of the total 8,588L volume will be usable, which meets the required volume of 7,625L.

The tank will include a drain line at the bottom to allow for maintenance. The overflow pipe will connect to the drain line downstream of the drain valve to reduce piping. The overflow piping and drain line will be configured so that the water is discharged away from the foundation to prevent the integrity of the tank foundation from being compromised. A bypass line will be included between the tank inlet and outlet lines to allow for maintenance of the tank. The bypass line will provide water to the taps directly from the spring source when the tank is unavailable. The line will be located upstream of the inlet valve and downstream of the outlet valve. A vacuum breaker will be added to the outlet line. A vent will be added to the top of the tank to prevent the storage tank from becoming pressurized.

A valve box will be required to both protect the valves and to allow access for maintenance. All of the piping will penetrate the same side of the tank so that only one valve box is required. The valve box foundation will be offset from the tank foundation to accommodate the drain line. The inlet, outlet, and drain lines will be stacked in a vertical row with a 15cm separation for each. The resulting valve box will be a 75cm^3 (internal) stone masonry cube connected to the tank. The size will provide enough space to operate the valve and perform maintenance. Since the valve box does not hold any water, it will not need to be reinforced.

Materials

EWB-DC consulted with a local expert who has constructed tanks and spring boxes before, as well as a structural engineer in the US. The local expertise can support both reinforced concrete and stone masonry, although there is more local experience with stone masonry. A stone masonry tank currently exists in the neighboring settlement of Ntayi, so the materials required have been proven available in the area and the community is familiar with that type of tank. It also shows that the skilled labor required to build such a tank is available. Additionally, there are rock formations in the area that can be used as a material source to reduce cost. The US structural engineer ran calculations using only unreinforced stone masonry and determined that the wall thickness would be too great to reasonably construct. The Ntayi tank has had some cracking issues which supports this assessment.

The proposed tank design for this project is to build a three-layer wall with the outer walls being stone masonry and the interior wall being reinforced concrete. Refer to the tank detail in Appendix C. The stone masonry walls would avoid using complex formwork and instead use a medium with which the local experts have the most experience. This configuration was used by the University of Illinois at Urbana-Champaign EWB project in Cameroon.

The typical concrete thickness was designed to be 150 mm to allow for adequate concrete cover. The rebar size and spacing was calculated in accordance with the International Building Code and all referenced standards. The concrete was assumed to have a compressive strength of 2,000 PSI. The steel rebar was assumed to have a yield strength of 40 KSI. This resulted in a typical configuration of 10mm bars spaced 200 mm on center, each way.

Reinforced concrete slabs are proposed for the tank and valve box foundations and lids. The same material assumptions used for the concrete wall were used to calculate the thickness and rebar placement for the slabs and lids. For the tank lid, the live load was assumed to be 20 PSF. This resulted in a lid thickness of 150mm with 10mm bars spaced 200 mm on center, each way.

An opening will be included in both the tank lid and valve box lid to provide access. The reinforcement configuration for the access opening can be found in Appendix C. A pre-cast concrete cover will be provided to cover the opening. The cover will be 25mm thick to allow it to be handled by one person.

The calculations for the foundation resulted in a 200mm thickness with 10mm bars spaced 150 mm on center, each way. Detailed calculations can be found in Appendix J.

The inside of the tank will be sealed with a waterproof coating. There are three options available in the region: zoom cement, Panticolt, and Sikalite. The team plans on using Sikalite, which is the most commonly used and is mixed with concrete to make waterproof coating. If Sikalite is not available one of the other alternatives will be used.

EWB-USA Concrete Mixes Guideline (2005) were used for the stone masonry and concrete design standards. A structural engineer was consulted for the specifics of the design. The structural design calculations for the tank can be found in Appendix J.

4.2.6 <u>Tap Stands</u>

The tap stands are perhaps the most visible and therefore the most symbolically important design component (Jordan, 1980). They will become a new gathering place in Mangi and it is very important that they are constructed and maintained properly to ensure the system is perceived in the best light and supported by the community. It is very important that proper drainage is used so that unsanitary conditions and mosquito breeding is avoided at these important points in the community.

The tap stand designs will generally be based on the existing tap stands in Ntayi to maximize on the knowledge transfer of construction practices and regarding maintenance between the Ntayi caretakers and the Mangi caretakers. See example of Ntayi tap stand in Figure 4-1. In addition, the Handbook for Gravity-Flow Water Systems (Jordan, 1980); EWB-USA Water Resources Guidelines (2005); Water Aid Technology Notes; and tap stand designs from other EWB projects in Cameroon (University of Illinois, Urbana-Champaign, 2010; Georgia Tech, 2011) were consulted to develop the Mangi tap stand design. This section outlines the design considerations from these sources and Table 4-4 summarizes the design that will be specified for the Tap Stands in Mangi. Refer to the Tap Stand Detail in Appendix C for design specifics.

Ntayi Tap Stands

EWB-DC evaluated the Ntayi tap stand construction during Assessment Trip I. Based on the Condition Assessment of these existing taps and the knowledge transfer benefit that could be realized by the caretakers, we have determined that replicating the same basic design (with improvements, as identified below) is optimal. Overall the condition of the concrete stands and basins in Ntayi was acceptable, however the condition assessment identified some problem areas that shall be improved upon in the Mangi tap stand designs. A summary of the observed conditions in the Ntayi Taps and the improvements that will be added to the Mangi tap designs is provided in Table 4-3.

Table 4-3. Ntayi Tap Assessment and Mangi Tap Improvements

Design Parameter	Ntayi Observations	Mangi Improvements
Drain pipe	The drainpipes of all the Ntayi tap stands were all broken and did not properly drain. The proximity of the drainage points were typically too close to the tap stand. Because of these issues, many of the standpipes had pooling water nearby.	Drain pipes will be extended to a nearby ditch, swale, or natural water way. The drain pipe will be extended away from the tap stand in order to ensure the proper drainage area is reached (we are budgeting for as much as 10m of drain pipe per tap stand). In addition the concrete within the basin will be sloped to the drain and a metal drain cap will be provided to prevent debris from entering the plastic drain pipe.
Spigot	Three of the five standpipes in Ntayi had broken spigots. The broken spigots were all the same type however a heavier duty spigot was used for the other two, which were working at the time of the assessment.	The heavier duty spigots used on the two taps that were not leaking will be specified for construction. See Figure 4-2.
Connections	The connection from the PVC distribution pipe to the galvanized steel pipe of the standpipes in Ntayi were all leaking and wrapped in rubber.	Proper fittings will be specified and used to ensure the connections between different materials do not leak. The fittings will be properly supported as well.
Shutoff valves	The Ntayi taps were not designed with shutoff valves.	Each tap stand will have a gate valve so that flow to the tap can be shut off for maintenance at the tap.

Figure 4-1. Ntayi Tap #3 (in Ntayi Square).

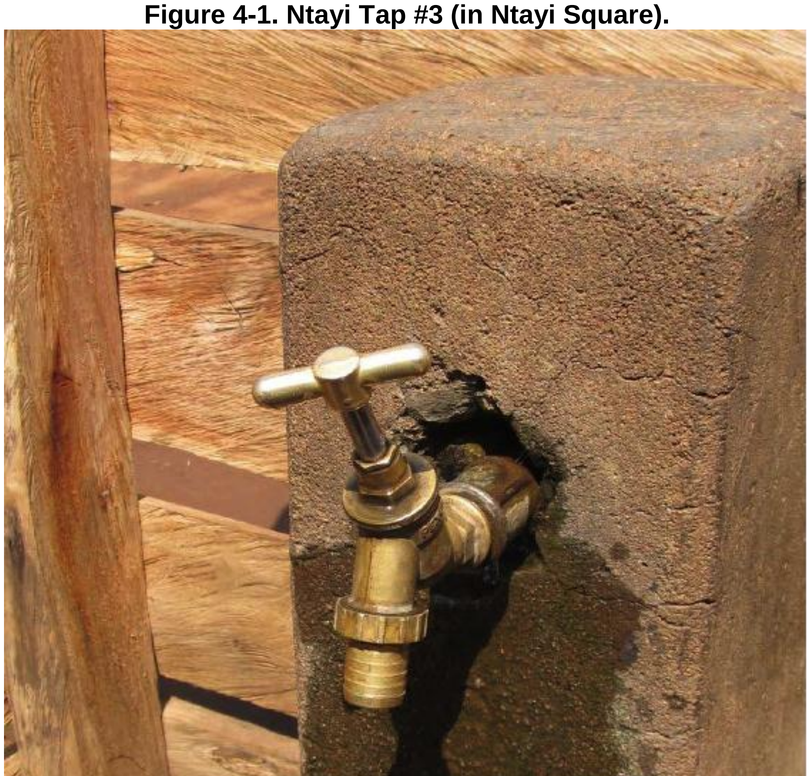


Figure 4-2. Ntayi tap example, preferred spigot.

Design References and Considerations

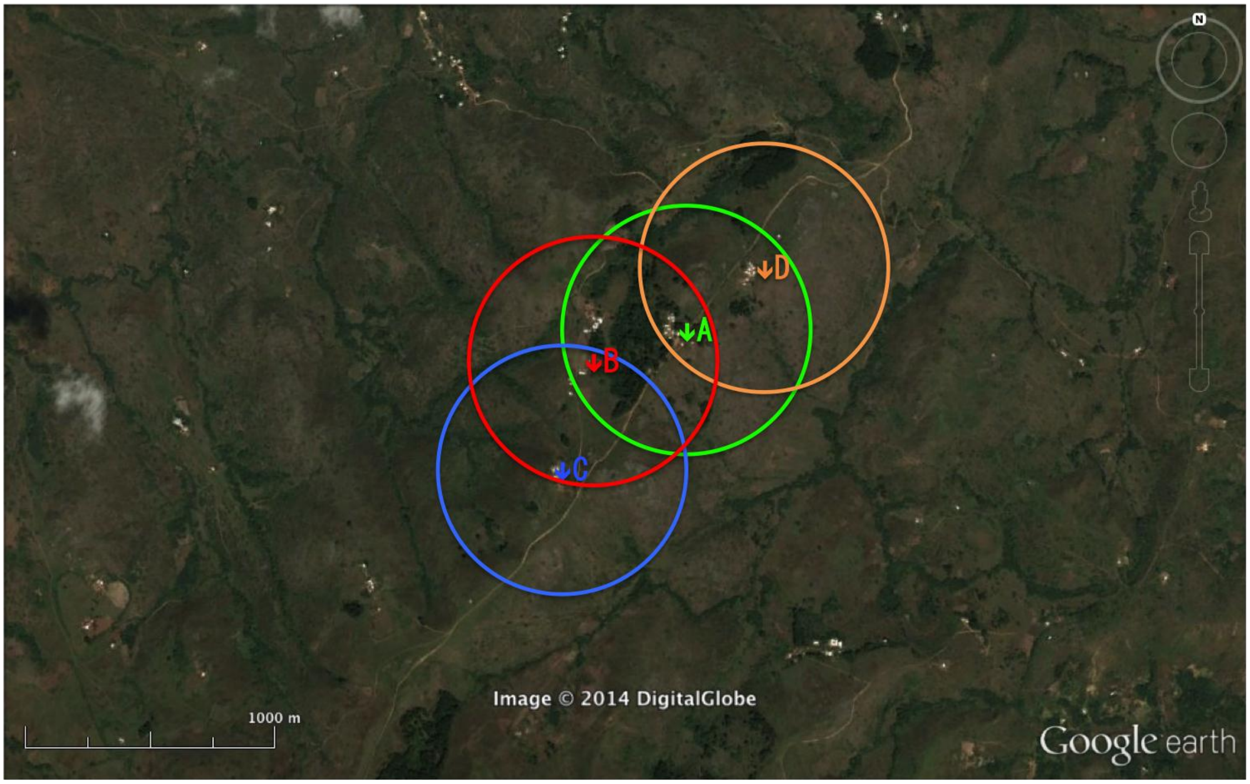
According to the EWB-USA Water Resources Guidelines (2005), the following design considerations should be included in tap stand design:

- The number of taps and distance from dwellings on a water system should use minimums of 200 people per tap at 0.2L/s (SPHERE recommends 250 people per tap at 0.125L/s) and that no dwelling is located greater than 500m from a tap.
- The tap stand should be designed with positive drainage away from the tap to prevent standing water. The drainage should be directed towards a trough for livestock, a garden, or soak pit (if the soils have a percolation rate faster than 25 minutes per cm). Without such measures in place, the standing water will quickly create unsanitary conditions and an environment suitable for insects.

EWB-DC also consulted the Water Aid Technology Notes (which EWB USA recommended as a reference), which provides the following recommendations regarding tap stands:

- Each tap stand should serve about 150 people and should be positioned so as to reduce uniformly the maximum distance people have to carry water.
- Tap stands have several components: a concrete post supporting a 15mm mild steel riser pipe from the pipeline up to a bib-cock which should discharge at least 0.1L/s; a concrete stand on which to place a bucket; a concrete apron to collect spillage; and a gutter and drainage to a soak away, in order to prevent the breeding of mosquitoes and the development of a muddy mess.
- Tap stands should have a fence around them to keep animals away and each one should have a nominated person, or caretaker, to keep the area clean and tidy.

Based on data collected in the quantitative public health survey on Assessment Trip II, EWB-DC estimates the current population of Mangi to be between 226 and 370 people. As mentioned previously, to allow for growth the system is being sized for a population of 400 therefore, at least two tap stands should be installed in Mangi. To evaluate the distance from each dwelling to the proposed tap location, EWB-DC reviewed mapping data in GoogleEarth (See Figure 4-3) to determine if the homes in Mangi fall within a 500m radius of the proposed tap locations (at the school and in the town center). Figure 4-3 shows the recommended tap locations, which are marked with an arrow at the center of circles A (green) and B (red). The majority of dwellings in Mangi are within circles A and B, therefore two tap stands may be sufficient. Circles C and D mark EWB-DC's secondary tap location recommendations, should the Water Committee choose to increase the number of locations and decrease walking distance. EWB-DC will recommend these more remote locations as system expansion options.



A: Mangi Town Square; B: Government School – Mangi; C: Remote Location #1; D: Remote Location #2

Figure 4-3. Map of Potential Locations Considered for Mangi Tap Stands

Since the Water Aid Technology Notes recommend that each tap should serve 150 people or less, EWB is recommending a two spigot design for each tap for a total of four spigots. Although the low estimate of the current population of 226 is sufficiently served by just two spigots in the two locations, the additional spigots allow for population growth while streamlining maintenance and construction costs by consolidating two spigots at one general location and valve box.

The Tap Stand Detail in Appendix C contains the design drawings for the Mangi tap stand design. Table 4-4 summarizes the final tap stand design recommendations based on the literature and considerations discussed above.

Table 4-4. Summary of Mangi Tap Stand Design

Design Parameter	Literature Design Recommendation[1]	Mangi Design Description
Number of Tap Stands	Where population density warrants it (e.g., when more than 200 persons will be using a tap, water demand schedules are unusual, a great number of persons trying to use the tap at once), it is possible to economize on the number of tap stands by constructing tap stands	Based on the evaluation presented above two spigots will be installed at the two tap stands (locations A and B in Figure 4-3), with the possibility of future tap stand construction at locations C and D.

	with two or three faucets. In this case one faucet would be set 30cm lower and the control valve adjusted so that not less than 0.2 L/s flows from each tap when all taps are on.	
Vertical concrete supports	Construction material should be brick, stone, or wood, using dry-stone masonry. A masonry tapstand of cement mortar should have a supporting column 50cm by 50cm around the galvanized pipe, and should be on a footing imbedded 30cm below ground level. Mortar should be 1:4 and the exterior can be plastered if desired. The height of the faucet should be between 120cm and 150cm above the apron (a smaller height is recommended near a school yard).	Two (2) 1m tall, 20cm by 20cm reinforced concrete supports Note: The Ntayi tap stands were approximately 20cm by 20cm concrete Each support has a horizontal opening for the galvanized pipe to pass, consisting of a 50mm diameter, 20cm long PVC pipe cast into the support. The opening invert elevation is at 90cm from the base of the support Note: The Ntayi taps were approximately 90cm above the ground surface. This was sufficient given the container sizes used in Mbokop.
Concrete splash basins	N/A	A rectangular reinforced concrete basin with splash area sloped toward drain. Outside diameter approximately 1.4m wide (away from vertical tap support) by 2.6m long on the edges opposite the taps. Basin walls are 20cm thick with an interior height of 20cm and exterior height of 30 cm (i.e., the basin base is approximately 10cm thick)
Drain pipe	A non-erodible drain channel or a 90mm drain pipe should carry the excess water to a suitable drainage point.	One (1) 90mm PVC drain pipe will carry water from the splash basin at least 3m away from the tap stand (exact discharge point will be decided during construction and will ensure drainage to a ditch or stream that carries water away from the tap stand). Note: A 40mm drain pipe was used in the Ntayi system. However, the drainage at the Ntayi taps was overall performing poorly. A 90mm drain pipe will be specified.
Connection	N/A	A 90 mm to 25 mm PVC reducer is used to connect the incoming supply pipe to the tapstand scheme; following that reducer connection, a 25 mm adapter is used to transition to galvanized pipe. At the location of the tap stand a 25 mm to 20 mm galvanized pipe 90 degree reducing bend is used to direct the flow vertically.
Tap stand	For the vertical pipe to the tap, a	After the vertical galvanized pipe emerges

piping	galvanized steel pipe should be used (with a diameter of 0.5 inches). The faucet should protrude far enough so that the water vessels can be easily filled (no more than 30cm from the vertical support)	at the surface (approximately 0.2m above the ground surface), a 20mm galvanized side outlet 90 degree bend connection splits the flow to serve the two taps. The horizontal flow from that split connection travels through 1m of 20mm galvanized pipe to a 90 degree galvanized bend, where it is transitioned to a vertical 20mm galvanized pipe (“riser A”). On each galvanized pipe riser there will be a gate valve to allow flow to each tap to be shut off. At the top of each riser a 20mm galvanized 90 degree bend directs flow to the spigot. A 70cm long galvanized pipe will transport water to the 25mm galvanized pipe gate valve. Note: Most of Ntayi taps used 0.75 inch galvanized pipe, however one used 0.5 inch. At both spigots, the 20mm diameter galvanized pipe will extend out from the concrete support 20cm, at which point the spigot is connected. Teflon tape will be used at all threaded connections to ensure a proper seal. Note: The Ntayi taps protruded between 8cm and 21cm.
Spigot	N/A	For each tap ¾” (approximately 20mm diameter) brass spigots will be installed.
Control Valve	The control valve should be located in a securely locking valve box that prevents tampering.	Gate valves will be installed at all taps and major structures (see pipeline section) in Mangi. The Water Committee can also decide to lock the taps themselves in order to prevent tampering. Note: One of the findings in EWB-DC’s condition assessment of the Ntayi system was that it should have valve boxes or shutoff valves.
Bench	A low bench added near the tap (either cement, mud mortar, or dry-stone masonry) will be helpful to facilitate lifting the vessel to the head to carry.	This is a recommendation that will be made to the Water Committee, it will not be part of the EWB design and/or cost estimate.

Protection from Animals	Animals should be prevented from walking through the tap stand area, therefore some fencing may be needed.	EWB will recommend the water committee build protective fencing or wall around the taps in Mangi, utilizing locally available wood or clay block. Note: Fencing existed at some taps in Ntayi but was later removed. Fencing will be specified for the Mangi taps.

1. Design recommendations are from the Handbook for Gravity-Flow Water Systems (Jordan, 1980)

4.2.7 Catchment Area

This section gives a summary of the design for protection of the catchment area. The complete Catchment Protection Manual is in Appendix F and includes more detailed information on design decisions.

Water catchment protection includes precautionary actions, procedures or installations undertaken to prevent or reduce harm to the environmental integrity of drainage areas used to catch water, such as reservoirs or basin. It is an important component to any water system design because simple steps taken to fence off a water catchment area minimizes contamination from animals and other sources. This improves overall water quality and reduces or eliminates the need for water treatment at the source.

The catchment protection system for Mangi includes the following components:

- Fire barrier
- Drainage ditch
- Dead fence
- Life fence
- Vegetation within catchment

These components along with an installation timeline are described in more detail in the Catchment Protection Manual located in Appendix F.

4.3 Drawings

The drawing index in Table 4-5 lists the various engineering drawings found in Appendix C that support the design.

Table 4-5. Drawing Index

Design Element	Drawing Title.	Description
Title Sheet	Cover Page	List of all design drawings provided
Site Layout and Location	Pipe Route	Location of the project and route of the proposed pipeline (plan view) and project design elements
Pipeline	Pipe Profile	Profile view of the entire proposed pipeline and station location of project design elements
Collection System	Spring Box	Plan and section view of the spring box, collection dam wall, and piping
Storage Tank	Tank	Plan and section view of the storage tank
Break-pressure Tanks	Break Pressure	Plan and section view of a typical break-pressure

	Tank	tank
Tap Stand	Tap Stand Detail	Plan and section view of a typical tap stand
Pipeline high and low points	Air Release Box and Clean-out Box	Plan view of typical air-release box and plan and section view of typical clean-out box
Pipeline trenching	Trench and Backfill Details	Section view of typical pipeline trench and backfill
Civil Details	Civil Details	Section view details of stream crossing and road crossing, spring collection pipe, and plan view of opening reinforcement details for structure openings.

4.4 Names and Qualifications of Designers

Name	Student or Professional	Qualifications	Work Done
Robert Horner & Lauren Scott	Professional	Robert: B.S. Industrial and Systems Engineering; B.A. Science, Technology, and Society; M.S. Sustainability; 5 years of work experience Lauren: B.S. Civil Engineering; M.S. Environmental Science and Policy, 7 years of work experience	Spring box design and drawings
Eric Hirschmann	Professional	B.S. Biological Engineering; 4 years professional work experience in water and wastewater system design	Pipeline design calculations and drawings
Kim Fellenz	Professional	B.E. Mechanical Engineering; 6 years of work experience in project engineering	Tank design calculations and drawings
Lisa Biddle & Eric Hirschmann	Professional	Lisa: P.E.; BS Civil Engineering; MS Environmental Engineering; 10 years professional work experience in water resources and policy Eric: (see above)	Tapstand design calculations and drawings
Matt Drury	Professional	BS and MS. Civil and Environmental Engineering. 5 years professional work experience.	Catchment protection design calculations and drawings
Stephen Clark, P.E. (REIC)	Professional	P.E., BS in Civil Engineering, MS in Environmental Engineering, 7 years of professional work experience in water and wastewater process and mechanical design.	Supervised, provided technical review, and QA/QC of design calculations and drawings for: spring box, pipeline and associated components, tanks, tap stands, and catchment

Lauren Wingo	Professional	BS Civil Engineering; MS Structural Engineering; E.I.T; 2 years work experience	Structural engineering technical support and review; Reinforced concrete and masonry design specifications
Jonathan Doane, David Hill, Elizabeth Blair	Professional	Practicing design engineers at Black & Veatch, all at or above the project manager level	Supplemental mentors providing technical advice and third party review of draft design plans

4.5 524 - Draft Final Design Report Comments

EWB-DC has addressed to the best of its knowledge all comments that were provided to the chapter during the review of the 524. Refer to Appendix G for a list of the EWB-USA Project Manager's review comments and EWB-DC responses.

5.0 PROJECT OWNERSHIP

EWB-DC, the community of Mbokop, partner NGOs and our primary liaison Pastor Julius all recognize the importance of having clearly defined ownership, responsibilities and community investment in any EWB project within this program. To determine what project to prioritize first the community organized itself for a meeting with a partner NGO and voted to select the Mangi settlement. This shows that the community holds a vested interest in the EWB program, an understanding of the EWB process, and their roles in decision-making.

Through the PPA and IA, the community has acknowledged that they will contribute the required 5% to the project costs. As it currently stands, this will consist primarily of financial payments through a water tax implemented by the Mbokop Water Committee. The Water Committee has established a bank account for financing the water system implementation and future maintenance. The money the community raises towards the 5% contribution will be spent on material costs. During both assessment trips, the Water Committee and Health Committee members, along with other community members at-large, provided in-kind labor to assist the EWB-DC team with topographic and public health surveys, translations, public health education in schools, and other support.

The Water Committee had three leaders sign the land rights agreement. As stated in the land agreement, the community of Mbokop is the owner of the acquired land for the proposed spring box and catchment area. The public taps will be located on public land near Mangi's town square, technically owned by the community Subchief. While ownership of all EWB-implemented infrastructure lies with the community, the Water Committee will be in charge of overseeing the operation and maintenance of the system. They will be responsible for the collection of a water tax, making decisions on system changes and upgrades, use of revenues, resolving any disputes that might arise, etc. The Water Committee oversees a Water Maintenance Subcommittee that is responsible for the technical aspects of maintaining and repairing the future water system. The Water Maintenance Subcommittee members will be involved in the construction and implementation process so as they understand how the system was designed and built to improve their knowledge and capacity for future work on the system. Members of the Water Maintenance Subcommittee have already worked along-side EWB-DC team members during the first two assessment trips.

The EWB-DC team is working with the community and partner NGOs on capacity building for the Water Committee, the Water Maintenance Subcommittee, and the Health Committee. These capacity building efforts will help ensure sustainability and independent ownership of the water system once it is complete.

6.0 CONSTRUCTION PLAN

EWB-DC will provide construction oversight, labor, and construction management while in Mangi. EWB-DC will coordinate with local experts, procure materials, provide technical guidance, and convey expectations to the community and those involved in construction. A local expert, Divine Kanjo, who has built spring boxes before will support EWB-DC on each implementation trip and act as construction manager while EWB-DC is not in the community. The community members will primarily be responsible for providing unskilled labor and will receive task direction from EWB-DC either directly or through Divine Kanjo. In addition to the labor support, the community will provide 5% of the construction costs.

Construction trainings have been scheduled to allow team members to gain practical experience in the construction activities that will be occurring in the implementation of the Mangi system. These trainings will include instruction by construction professionals with expertise in components of the water system design. The materials utilized in the trainings will simulate the expected resources and conditions within Mbokop.

Subjects in the trainings include: general construction safety and first aid, pipe assembly and installation, pressure testing, basic repairs, trenching and excavation, foundation preparation, leveling, cement and concrete mixing, formwork, bending reinforced steel, rebar tying, tank penetrations, stone masonry, making mortar, and waterproofing. All of the EWB-DC travelers will attend at least one day-long construction training hosted by EWB-DC.

The major construction activities anticipated for the water system construction are outlined in three (3) illustrative Gantt charts in Appendix H covering the proposed implementation activities for three (3) separate trips. The first trip will be to build the spring box, the second trip will be to build the storage tank, and the third trip will be to build the break pressure tanks and the taps.

The pipeline route will be staked by the EWB-DC team with the Construction Manager during the first and second trip. The EWB-DC team will describe and demonstrate expectations for trench depth, pipe bedding, pipeline testing, and valve/valve box installation during the first trip. After the EWB-DC team leaves, the Construction Manager will oversee the construction of the pipeline and installation of air release valves and cleanout valves and valve boxes. The EWB-DC team will inspect installed valve boxes and review testing logs from the local foreman for installation of buried pipe upon subsequent trips.

Skilled laborers with local knowledge in the following areas are required for successful construction:

- Stone masonry
- Concrete form work (skilled carpenter)
- Concrete mix design
- Structural concrete implementation

The chosen Construction Manager, Divine Kanjo, either possess expertise in the these areas or will be able to identify local laborers to provide the necessary expertise.

Some activities can be accomplished simultaneously, while others will have to occur in series. These relationships are illustrated in the Gantt Charts (Appendix H). In the event that some activities take longer or are not able to be accomplished during the allocated time in the construction schedule, we have included contingency days for each construction activity. This time will allow the team to have a buffer to finish up any activities that take longer than planned per the schedule.

Steps for constructing some of the design elements are outlined below.

Collection Dam Construction

1. Dig down to impermeable layer (taking care not to puncture it) and back to source of spring, or to an acceptably narrow collection point (less than 10m across).
2. Dig test hole/core at least 10m off to side to determine thickness of impermeable layer.
3. Install both perforated collection pipe assemblies in parallel with each other and on top of impermeable layer (if thin) or in 6-in deep trench in impermeable layer (if thick) at back of excavation, against seeping soil. Line trenches with round gravel. Slope pipes at 0.5% in direction of flow. Mound soil to 6-inch height immediately below lower perforated collection pipe.
4. Run solid pipes from collection pipe wyes at 0.5% slope downhill through collection dam construction area, per design specifications.
5. Connect both solid collection pipes with elbow and tee at a point between the collection dam and the spring box. Install another tee and then a valve immediately below the connection.
6. Slope single resulting collection pipe below valve downhill at 2% slope. End pipe before spring box construction area.
7. Run second pipe branch off of tee above valve, forming a diversion branch that runs to the side of the spring box construction area. Close valve so that collected water drains to side of spring box construction area.
8. Allow excavated ground downhill from the perforated collection pipe assemblies to dry.
9. Construct wooden forms for concrete collection dam immediately below mounded soil in 6-inch trenches, making sure that the solid collection pipe penetrates the dam
10. Fill bottom 3 inches of forms with gravel prior to pouring concrete, to isolate concrete from ground if ground not fully dry
11. Pour concrete into forms
12. Follow curing procedures
13. Remove forms
14. Backfill area between back of excavation and collection dam (over perforated collection pipe) with gravel and cap with plastic sheeting, according to design specifications
15. Backfill on top of plastic and in front of collection dam with previously excavated soil to restore ground to original topography

Spring Box Construction

1. Excavate to necessary depth to provide for specified slope of collection pipe and to meet spring box design specifications.
2. Excavate trench for overflow pipe (same as trench for effluent pipe, to be installed above it), including under base of spring box.
3. Allow ground to dry.
4. Install first few meters of overflow pipe, including elbow joint.

5. Place layer of gravel in bottom of spring box excavation.
6. Build and install forms for spring box base, incorporating elbow for overflow, and influent and effluent pipe sections for penetrations. Place rebar.
7. Mix and pour concrete into forms.
8. Follow curing procedures.
9. Remove forms.
10. Build masonry walls.
11. Build forms for concrete top and lid, incorporating lid handles formed from small diameter rebar. Place rebar and wire mesh reinforcement.
12. Mix and pour concrete into forms.
13. Follow curing procedures.
14. Remove forms.
15. Complete overflow pipe trenching and installation, maintaining 3% downhill slope until pipe is daylighted.
16. Backfill over overflow pipe and install first segment of effluent pipeline and cap (to be completed later). Backfill over effluent pipe.

Collection Dam and Spring Box Finishing

1. Connect influent pipe section of spring box to solid collection pipe below valve, maintaining 2% slope.
2. After bond is cured, open valve.
3. Remove diversion branch piping.
4. Cap diversion branch of tee.
5. Backfill over all exposed pipe to restore original topography

Pipeline Trenching, Installation, and Testing

- EWB-DC members along with the water committee and Construction Manager will mark the entire route of pipeline and instruct the community laborers on trenching and pipelaying.
- During this survey, the locations of the following will be clearly marked:
  - branches
  - changes in pipe size
  - changes in direction
  - pressure release valves
  - clean-outs
- The pipeline will be installed at a consistent depth of 0.6m below the ground surface. The trench will be dug with a minimum width of 0.69m.
- The trench will be hand-dug using shovels and pick axes
- No more than 100m of trench will be dug ahead of pipeline being installed.
- Sections of pipe will be laid carefully in the trench so as not to introduce dirt into the pipe or damage it.
- Following is the procedure for connecting sections of pipe:
  - Section of pipe will be cut to the size of the trench (if necessary).
  - The inside of the pipe will be de-burred
  - Ends of pipe will be cleaned using a cloth and then an alcohol-based solution.
  - PVC glue will then applied uniformly to the end using the solution applier. The use of a simple mask will be encouraged in order to avoid inhaling toxic fumes
  - The two sections of pipe will then be connected, quarter-turning the downhill pipe into the other pipe.
  - The pipe connection will be held in place applying pressure for about a minute

before laying into the trench.

- Soil removed during trenching will be used for backfill, making sure that large rocks are removed during the process.
    - Soil will be laid in 0.3m lifts with compaction following each lift.
- Since some settling will occur, the trench will be made into a mound large enough to avoid it becoming a conduit for rainwater or surface run off.
- The minimum pipe working pressure is 14.7psi
- The maximum pipe working pressure is of 415 kPa (42.3m of water)
- Test for pipe leaks every 100m using the following method:
    - Install tee at downstream section of pipe after a 100m section of pipe
        - Air release valves and cleanouts can be used.
    - Connect valve and pressure gauge to tee
    - Run system, building up water pressure; use a manual pump to build pressure if needed
    - Cracks in pipe can be identified by any drop in pressure noticed using the gauge or visual inspection of exposed joints
    - Process will be repeated for each 100m section of pipe

Stone Masonry and Concrete Work During Implementation

Additional construction considerations for stone masonry include:

- Stones will have to be carefully selected for each element.
- Large stone will have to be broken into smaller pieces to stay within wall design dimensions, which are 30cm for the spring box and storage tanks.
- Stone needs to be angular with rough faces to ensure a strong bond with the mortar and other stones. Stones that are rounded and smooth should not be used.
- Stones will need to be positioned for as tight a fit as possible to avoid large pockets that have to be filled with mortar since the wall strength is a result of how well the stone faces interlock.
- Stone faces need to be cleaned of dust and loose fragments and should be dampened before mortar is applied to form a strong bond.

Mortar is the binder that will be used to hold the stones in place permanently. It consists of a calculated mixture of cement, sand, and water. In general, only enough mortar should be mixed as can be used within about 30 minutes to prevent to cement from starting to set before placement. It should also be continuously stirred in place to prevent segregation and hardening. Sand may either be from a natural source or manufactured from crushed rock, and will need to be run through sieves to ensure that excessively large grains are kept out of the mixture. Table 6-1 below lists sand gradations from the Portland Cement Association (1992). Specific gradations will likely not be possible on site, but the table above should be used as a loose guide when adding sand.

Table 6-1. Limit of Allowable Sand Gradation

Sieve Size	**Percentage Passing***	**Percentage Passing***
	Natural Sand	Manufactured Sand
No. 4	100	100
No. 8	95 to 100	95 to 100
No. 16	70 to 100	70 to 100

No. 30	40 to 75	40 to 75
No. 50	10 to 35	20 to 40
No. 100	2 to 15	10 to 25
No. 200	--	0 to 10

*Additional requirements: Not more than 50 percent shall be retained between and two sieve sizes nor more than 25 percent between the No. 50 and No. 100.

Typical cement to sand ratios are 1:4 or 1:3. Water should be slowly added to the mixture while stirring continuously until the mortar achieves a thick paste-like consistency. Mortar should be able to hold its shape when wet, but be soft and workable. Too much water has been added if the mixture starts to bleed cement slurry or if it appears shiny. Water for mortar should be taken from the cleanest source possible and be free of organics and contaminants that could inhibit strength. The spring that this project intends to capture will be a good water source. If available, a pH meter should be used to make sure that water pH is between 4.5 and 8.0. Given the unknown sand and cement quality, a cement to sand ratio closer to 1:3 is recommended, but the local mason will be consulted for specific details. The local mason will need to ensure that stones do not get shifted or disturbed once they are set, otherwise the bond between the mortar and stone will be broken before the mortar has cured. This will result in a leaky wall with weak joints.

Joint location is also important when constructing a stone wall. Joint placement should be varied both horizontally and vertically by using adjacent stones of different sizes to create strong interaction between stone faces. Allowing a continuous joint will create a potential weak plane where stones could shift and cause cracks in the mortar. Over time this will develop into a crack and could lead to failure. This is critical for the tanks given their size and the volume of water they must contain.

Concrete has four primary components that form a durable finished material when carefully combined: coarse aggregate (graded gravel), fine aggregate (graded sand), cement (the binder), and water. Coarse aggregate dimensions are between 3/8” and 1.5” diameter. Stones larger than 1.5” become difficult to manage. Aggregate size also depends on the application and should not be greater than 1/5th of the distance between form faces, 1/3rd of slab depth, or 3/4th of the clearance between reinforcement bars. This is to ensure that the concrete mixture can be worked around all surfaces. Coarse aggregate needs to be strong. Stone that is weak or brittle must be avoided, otherwise the resultant concrete will be equally weak and brittle. A suggested field test is to strike potential aggregate with a hammer to see how easily it breaks. Fine aggregate consists of sand and smaller stones no greater than 3/8” diameter. Non-organic dust is also acceptable as part of the mixture in small amounts. All aggregates should be evenly graded.

Additional construction considerations for concrete include:
There are several required steps prior to placing concrete for slabs. For structural slabs, a 6” aggregate base should be placed, leveled, and compacted. The coarse aggregate for the concrete mix makes a good base material. Prior to placing concrete, forms should be built on the base material or other level surface (for various other concrete elements) using 3/4” plywood and 2”x4” lumber spaced no more than 2’ apart. The forms must be staked into the ground to prevent them from shifting. Plywood surfaces that will contact concrete need to be coated with vegetable oil (or equivalent), which will serve as a release agent for stripping formwork. Diesel fuel is also an acceptable release agent if the concrete surface will not touch drinking water.

Formwork:

Next, reinforcing steel needs to be carefully measured and cut so that 2" clearance is provided between steel bars and the formwork. Reinforcement bars should be 10mm diameter, known as #3 bars. Reinforcement should be spaced on 20cm centers in both directions and tied together to form a grid. The grid will need to be elevated off of the base so that it is within the bottom third of the slab and has 2" of clearance from the base aggregate. This will be done by using manufactured chairs if available, or by making them on site out of concrete. If concrete is used, this will need to be done in advance to allow it to cure.

Cast-in-place Concrete:
A 3,000 psi mix design will be targeted in the field. It is assumed the concrete will be mixed in the field, therefore, the concrete strength was derated to 2,000 psi strength for structural calculations. The mix design was based on EWB Structural Guidelines. Below is the proposed mix design in lbs. per cubic yard of concrete and # of shovels per 3.5ft3 of concrete. Using the shovel method will allow for simple volumetric mixing in the field.

Table 6-2. Proposed Mix Design for Cast-in-Place Concrete in Lbs. Per Cubic Yard of Concrete and # of Shovels per 3.5ft3 of concrete

Water:Cement	**f'c, psi**	**Max Size of Aggregate, in**	**Water (lb per cu yd of concrete) (gallons)**	**Cement (lb per cu yd of concrete)**	**Fine Aggregate (lb per cu yd of concrete)**	**Coarse Aggregate (lb per cu yd of concrete)**
0.60	3,000	¾"	340 (40.8)	565	1,260	1,740
Water:Cement	**f'c, psi**	**Max Size of Aggregate, in**	**Water (lb per 3.5 ft3 of concrete) (gallons)**	**Cement Approx No. of Shovels per 3.5 ft3 of concrete**	**Fine Aggregate Approx No. of Shovels per 3.5 ft3 of concrete**	**Coarse Aggregate Approx No. of Shovels per 3.5 ft3 of concrete**
0.6	3,000	¾"	44.1 (5.29)	8.5	24	26

Coarse aggregate needs to be wetted prior to mixing because dry stone will absorb water from the concrete mix and reduce workability and ultimate strength. Concrete is also highly temperature sensitive. If mixed at the ideal 21 degree Celsius temperature (70 degrees Fahrenheit), concrete will set in about 6 hours, but this decreases significantly as the mix warms. Cool water and cool aggregate are important. Concrete should be placed within 30 minutes of mixing for best workability and integrity.

When the slab is ready to be poured, the stone base needs to be wetted to prime it. Concrete placement should start at one side of the form and gradually work toward the opposite side, reaching full slab depth completely before moving on so that it eventually forms one monolithic slab. It needs to be agitated by prodding it with a shovel or by gently stomping on the mixture to force out any air pockets and to work the mix around all surfaces; however, if water starts to collect on the surface that is a sign of over agitating. As the placement advances across the form, a straight edge that spans the form from edge to edge should be worked across the fresh concrete to screed off any excess and create a uniform surface. It will then need to be finished with a float and trowel. The local concrete expert will be consulted for all concrete mixing, placing, and finishing.

Once placed, concrete needs to be kept wet to hydrate properly. This can be accomplished by placing plastic sheeting over it to keep moisture from evaporating, or by covering it with 2-3 layers of wet burlap. If burlap is used, it needs to be re-wet every few hours. Forms can be stripped 24 hours after placement. Any exposed surfaces will need to be kept wet once forms are removed. Concrete should be allowed to cure for 7 days before work continues; however, 3 days is adequate for less critical (non-structural) items if 7 days is not possible.

There are several concrete safety practices that must be followed. Gloves, safety glasses, and long pants must always be used. Concrete is caustic and hydroscopic and will cause skin burns if handled without skin protection. Clean water should be available for flushing eyes. Dust from sand and cement should not be inhaled. See the Health and Safety Plan (HASP) for full construction safety plans.

Slump Test:
A slump test will be performed for each mix. A 30cm tall cone with 10cm and 20cm openings will be used. If a cone is not available a plastic cup will be used. The cone will be filled with concrete in three lifts compacted with 25 strikes of a tamping rod. The cone is removed and the slump is measured by taking difference between the cone height and concrete. The target is a slump of 25% to 50% of the original height. If the slump is less than the target, water can be added and the slump will be performed again. If the slump is greater than target the concrete will not be used for structural purposes.

7.0 MATERIALS LIST AND COST ESTIMATE

Refer to Appendix I for the detailed cost estimate. Table 7-1 below summarizes the costs that are detailed in the Appendix. The estimate for construction costs of this project is $25,850.

Table 7-1. Summary of Cost Estimate for Construction of the Mangi Water System

Construction Component	Cost
Material costs subtotals by design component:	
Spring Collection	$1,800
Spring Box	$1,600
Pipeline	$6,400
Break Pressure Tank	$3,100
Tank	$2,700
Tap Stands	$2,100
Catchment protection	$400
Tools	$800
Total (materials)	**$18,900**
Material Transport	**$1,000.00**
Skilled Labor	**$3,600.00**
Contingency (10%)	**$2,350**

Total Preliminary Construction Cost Estimate	**$25,850**

8.0 SUSTAINABILITY

8.1 Background

Sustainability of the water system is of the utmost importance. The previous water system implemented in the community, in the Ntayi settlement, has fallen into disrepair. EWB-DC hopes to eliminate the likelihood of maintenance pitfalls by implementing a sound education plan, rooted in educational best practices. Furthermore, EWB-DC hopes to adequately train community members on the basics of routine maintenance and provide them with the necessary skills to diagnose commonly identified issues related to spring boxes, pipe management and other system components.

To ensure technical sustainability, EWB-DC will only source locally available materials and utilize construction practices that are widely used in the area. Necessary skilled labor required for the construction and operation of the system will come from the community or this region of Cameroon. Gravity-fed water distribution systems are common in this region of Cameroon, and the neighboring settlement of Ntayi already has such a system. Thus, the community already has a good understanding of the operation and maintenance of the proposed system. Moreover, the community has been involved throughout the planning of the project, from assessment to alternatives analysis, and will play a crucial role in the construction. EWB-DC will work alongside the water committee to train community members on construction practices and on the operation and maintenance of the implemented infrastructure. This will ensure that the community has the skills and capacity to sustain the system without EWB involvement.

EWB-DC is compiling a thorough operation and maintenance manual for the residents of Mangi. This manual with detail basic troubleshooting activities and directions to perform maintenance tasks such as fixing pipes and cleaning storage tanks. Through training sessions, the water committee is expected to disseminate any required information to all households using the system. In partnership with our primary NGO (SIRDEP), EWB-DC will also train the community on catchment protection and sustainable environmental practices. This will include information on plant species that are good and bad for the catchment area, suggested locations for cattle grazing, water conservation, etc. These efforts will ensure environmental sustainability of the project.

The community has agreed to a water-tax system. The water committee will determine the amount and frequency of the tax, while taking into account the capacity to pay and the estimated life-cycle cost of the system. These funds will be managed by the water committee, and used for any operation and maintenance purposes, including system expansion and improvements. A bank account has already been established to collect these funds. This system will encourage community ownership of the project and establish financial sustainability.

The tank design is scalable by adding additional storage tanks if the needs of the community grow. Once the initial system is installed, more flow measurements can be taken from the source and the usage rates monitored to determine if additional storage capacity is warranted. The selected tank area will have enough level terrain to accommodate a level foundation for a second tank.

Another Mbokop settlement, Mbutung, is located northwest and generally downhill from Mangi. It may be feasible to connect this settlement to the Mangi system by extending the branch north of the school for approximately 1,500 meters. However, the measured flow rates at the spring during the dry season would not provide a sufficient volume of water for both Mangi and the additional residents in Mbutung. Though EWB-DC speculates that the flow rate from the spring box (once constructed) will be higher than the flow rates measured at the surface, this is not guaranteed. There are approximately 150-200 residents of Mbutung and if additional taps were built for that community, a larger pipeline would be required to provide adequate water pressure to all users during all conditions. EWB-DC prefers not to install a larger pipeline (with greater cost and complexity) under speculations that the spring will provide enough water for Mangi and Mbutung; therefore, the pipeline will be sized only for the residents of Mangi.

8.2 Operation and Maintenance

The Water Committee and Maintenance Subcommittee will be in charge of operation and maintenance (O&M) of the implemented water system. The water committee members were elected by the community and will involve the community in any maintenance tasks as needed. Some of the current water committee members already have an understanding of gravity-fed water system maintenance, due to the existence of a similar system in the settlement of Ntayi. EWB-DC will encourage cooperation and knowledge sharing among the members of the water committee and the community members. Moreover, EWB-DC will train the water committee on key O&M tasks and relevant construction practices, which will be documented in detail in the Operation and Maintenance Manual.

The Maintenance Subcommittee is a group of individuals within the Water Committee, who have been tasked with the day-to-day O&M tasks of the system. They will be involved in the oversight of the following infrastructure implemented by EWB-DC: catchment area, tap stands, storage tanks, break-pressure tanks, pipeline, and collection system (collection dam, collection pipe and spring box). They will also perform any tasks associated with water catchment protection, including the regulation of planting and grazing in the watershed and maintaining fences. EWB-DC will equip this subcommittee with a complete toolbox required for overseeing O&M activities. They will be trained on the use of each tool and maintenance material such as wrenches, water sealants, plumbers tape, etc. The Subcommittee will ensure that this toolbox is well stocked.

The Water Committee will be in charge of the collection and use of a water tax from the beneficiaries of the system. The amount and frequency of this tax will be decided by the water committee, while keeping in mind the financial capacity of the community and the lifecycle costs of the system infrastructure. Consideration will be made to ensure that a surplus of money is available for unexpected costs, in addition to annual repairs. The Committee will dedicate a portion of the water tax to cover the eventual overhaul of some or all of system. Future option to consider in the event the water system requires major overhaul, the Committee will explore additional options to finance the repairs through the local or national government. The Committee will be encouraged to keep reserve funds in case of a major repair. The Water Committee will accompany the EWB-DC team during the purchase of the construction material from the nearby city of Bamenda. In the future, the Committee will be expected to directly contact hardware stores in Bamenda and travel there to collect any parts required for O&M. Funds required for the purchase of materials will come from the Water Committee’s bank account after approval from the entire committee. The Committee itself will decide on the process for the approval of use of funds and other decisions associated with water system O&M. However, EWB-DC encourages transparency, inclusiveness (of tribe, settlement, religion, age, and gender), and overall accountability.

The ongoing O&M cost was one of the criteria for evaluating various design alternatives. The gravity-fed spring collection system that was chosen by EWB-DC and the residents of Mangi has very minimal ongoing O&M cost associated with it. The quantities of materials needed for annual maintenance were estimated using the O&M costs of previous EWB projects in Cameroon, and material cost data collected during our two assessment trips. These quantities are estimates of the consumables that the community should be prepared to purchase annually for operation and maintenance of the spring box, tank and distribution system. After the first year of operation, EWB-DC will reassess these values based on the community's experience with system maintenance. Based on our current estimates, the cost of the materials totals to approximately USD $245 as itemized in the table below. This assumes that labor will be free. This will be reassessed with the community to determine if and how caretakers should be compensated.

Table 8-1. Operations and Maintenance Costs

Item	Unit Cost (CFA)	Unit Cost (USD)	Units	Quantity	Total Price (CFA)	Total Price (USD)
90 mm PVC Pipe	3857.04	8	6m sections	5	19285.2	40
Valves	7231.95	15	Each	1	7231.95	15
Elbows, unions, etc.	1928.52	4	average	5	9642.6	20
Cement	5399.856	11.2	50 kg bag	1	5399.856	11.2
Chlorine	14463.90	30	5 lbs.	1	14463.90	30
Catchment Vegetation	24106.50	50	Lump sum	1	24106.50	50
Tap Spigot	3857.04	8	each	1	3857.04	8
Miscellaneous tools	9642.60	20	Lump sum	1	9642.60	20
Miscellaneous materials	24106.50	50	Lump sum	1	24106.50	50
Total						244.2

A thorough Operation and Maintenance manual will be provided to the Water Committee and will explain in detail the procedures for troubleshooting problems. This document will be created after consultation with the committee, in order to ensure the proper level of detail and visual content. The O&M manual will also list where parts can be obtained in hardware stores in the nearby cities, any safety precaution needed during the maintenance activity and a guide to conducting periodic water quality tests. This manual will be mostly pictorial, to account for variable levels of literacy in the community. The O&M Manual is still being developed by EWB-DC and will be finalized prior to the first implementation trip. A draft copy of the O&M manual will be sent to the Water Committee through our in-country NGO, SIRDEP. The manual will then be modified based on feedback from the water committee. The outline for this manual is provided below. The O&M Manual will use simplified language and visuals to describe the steps.

Operation & Maintenance Manual

Part 1: Operations Guide

Part 1 of the manual will detail information needed by the community to operate various components of the system. This section will detail the pre-operational checklist community members should adhere to prior to operations, as well as provide direction for the initiation and shutdown of the system. This section will additionally detail the targeted quality and performance metrics for the system components and potential indicators of any system issues. The following sections will be addressed:

1. System Overview
    a. Conducting a System Visual Inspection
2. Component Baseline Operations Requirements
    a. Spring Box
    b. Tank
    c. Break-Pressure Tanks
    d. Tap Stands
3. System Start Up
4. Desired Baseline Quality and Performance
5. System Shut Down

Part 2: Maintenance Guide

Part 2 of the manual will detail the construction techniques for system components, troubleshooting procedures for system issues, and a schedule for routine maintenance activities to be performed by the system caretakers.

1. Construction Techniques
    a. Connecting PVC and metal pipes
    b. Mixing concrete
    c. Basic reinforced concrete construction
    d. Stone masonry construction
2. General System Testing and Troubleshooting
    a. System Quality Testing Schedule and Procedure
    b. System Issue Troubleshooting
3. System Components

    Each system component section will contain the following: purpose, safety notes, materials needed, expected materials lifetime and potential repairs needed, cost and availability of replacement items, and schedule of maintenance,

    a. Catchment Area
    b. Springbox
    c. Tap Stand
    d. Tank
    e. Pipeline
    f. Pressure Tanks and Valves
4. Summary Table of Maintenance Schedule

Table 8-2. Schedule of Operation and Maintenance Tasks

Weekly	Visually inspect catchment area including dead/live fence, spring box, tank and tap stands for functionality and any leaks or damage
	Check tank and spring box for cracks or leakage
	Check tank and spring box for insects, rodents, and accumulated leaves.
	Walk entire pipeline to detect leaks
Monthly	Clear vegetation around spring box and tank
	Clear any sediment that has collected in the bottom of the spring box
	Ensure proper grazing rules are being enforced
	Check water quality at tap stand
Every Year	Clear fire barrier and drainage ditch at catchment area. Ensure live fence and vegetation are operating sufficiently.
	Disinfect tank, spring box and pipeline with chlorine
	Flow rate test for entire distribution system
	Check pipe leakage using water pressure test

8.3 Education

In the hopes of creating a very strategic education curriculum with ownership from the Water and Health committees, EWB-DC worked with SIRDEP to facilitate strategic planning meetings during SIRDEP's September trip to Mbokop. SIRDEP solicited feedback from the Health Committee to determine the priority target audiences for health education messaging. SIRDEP will also be able to provide EWB with a better picture of the current capacity of both the Water and Health Committees, both of whom will be key drivers of the two-pronged education plan to address the water system and community health.

With limited time in the community, education will focus on the water system (construction, maintenance, and water quality) and health (WASH—water, sanitation, and hygiene). Both the Water and Health Committees will receive education on capacity building.

Utilizing the engineering experience of the EWB team and its partners, this educational plan hopes to disseminate information in a way that water committee members as well as maintenance sub-committee members will feel equipped to teach others in the community as well. This starts with a strategic hands-on approach, in which the EWB team will include the water committee in the actual construction of the new water system.

The water operations and maintenance plan detailed in section 8.2 will be the main resource for the community. While the majority of the time will be spent on construction, the EWB team will hold workshops with the water committee and maintenance sub-committee in conjunction with in-country NGO partners. As EWB cannot always be accessible, it will be important to have in-country NGOs closely involved, especially since the partner NGOs, HEDECS and SIRDEP, have complementary expertise to EWB. SIRDEP has expertise with catchment protection and has catchment protection materials that will be an important resource for Mbokop.

EWB hopes to strategically initiate an education plan that is grounded in the notion of capacity building to ensure sustainability of the actual water system as well as proper and correct knowledge of the system's operation and maintenance. Management education has been requested by the community to help give them the skills needed to maintain the project and ensure its sustainability.

In parallel with the water system education plans for the Water Committee and Maintenance Subcommittee, health education is critical to the sustainability of the water system and improving access for the community to improved quality drinking water. Health is intrinsically tied to the deliverables of this water project and education specific to diarrhea prevention through proper hygiene behaviors, water storage, and water use will be included in the curriculum. There are behavioral changes that the community can make and improve their health before the completion of the water system.

Using the baseline data collected on the assessment trips, SIRDEP met with the Health Committee in September to present the findings from the November 2013 quantitative health survey and present areas that EWB recommends addressing. SIRDEP provided the information from EWB and guided the Health Committee through a discussion to decide on the priority target areas and the corresponding priority populations for each target area for education activities on the first implementation trip in December.

Through the meeting with SIRDEP, the Health Committee selected the following target areas and populations to be addressed on the first implementation trip in December:

Table 8-3. Target Areas for Health Education Activities

Target Area	Target Population
Hand washing method	Children and women
Knowledge of critical instances of hand washing	Children and women
Reduce open defecation	Women

These topic and population areas were agreed to by the Health Committee as appropriate and feasible.

The Health Committee provided additional, valuable information for shaping the health education curriculum. They suggested the best times for reaching children were during the school hours and that women can be best reached at the vaccination sessions with the local registered nurse (these sessions have been observed on both EWB assessment trips to Mbokop) and during church group meetings. The EWB team is taking this information into account, but also recognizes that these venues will not reach all of the critical populations. For instance, Muslim women will not be in attendance at the church group meetings. Therefore the plan will be extended and flexible to accommodate the various populations. The Health Committee also referenced that the best methods for teaching will be through practical demonstrations and group activities, so individuals can learn through doing. The Health Committee requested that additional areas be considered as potential education curricula.

These suggestions (washing of fruits, handling of drinking water containers, and construction of latrines) will be integrated into the Implementation I education curricula and/or included in future education curricula.

Based on the feedback from the Health Committee, the Implementation I education plan is as follows:

Table 8-4. Education Plan for Implementation

Target Area	Target Population	Activities (sample)	Place of Education
Hand washing method	Children	"Don't Pass It Along" (Project Wet) "Shake my hand!" (UNICEF) "Count to 5, Count to 10" (UNICEF)	School
Hand washing method	Women	"Hand Washing for Health" (Project Wet)	Church group, vaccination sessions, additional sessions geared to Muslim women
Knowledge of critical instances of hand washing	Children	"Hand Washing for Health" (Project Wet)	School
Knowledge of critical instances of hand washing	Women	"Break the Chains" (Project Wet)	Church group, vaccination sessions, additional sessions geared to Muslim women
Reduce open defecation	Women	"Open defecation does not happen here!" (UNICEF)	Church group, vaccination sessions, additional sessions geared to Muslim women

A variety of education activities will be used to conduct these lessons. Sample education lessons for each target area can be found in Appendix O. The education activities will be conducted in partnership with the Health Committee, support from local NGOs, and translators. Any written materials will be translated into local languages, Limbum and Arabic.

EWB hopes to liaise messaging on proper water operation and maintenance with the added health benefits by establishing conversations and partnerships between the water committee and health committee. With both committees working together, disseminating parallel messaging, correct knowledge can be more efficiently delivered to the community.

9.0 SIGNED IMPLEMENTATION AGREEMENT

The Implementation Agreement is being drafted. SIRDEP will work with the community in August to sign this agreement and it will be included in the 525 report.

10.0 SITE ASSESSMENT ACTIVITIES

Two assessment activities are planned during this trip to gather additional information for future phases of implementation.

The first assessment activity is an assessment of an additional cluster of houses in Mangi that was identified in July. It was relayed to EWB-DC that this additional cluster of houses is part of Mangi and far from the proposed tap stands. Before a pipeline branch is added to the proposed system, additional information is needed. The additional information that will be collected includes the number of houses and estimated population, distance to the currently planned tap stands, elevation, and where these cluster of compounds currently accesses their water.

The second assessment activity is planning for the pipeline road crossings. The pipeline will be crossing the main road through Mbokop in at least two places. This is the main road that connects multiple Mbokop settlements to Ndu, the closest city, and is a trade road through to Nigeria. Each road crossing has the potential to create a road closure for several days. EWB-DC understands the importance of coordinating this with the Mbokop leadership and leadership in Ndu. The mayor of Ndu has been supportive of this project and we will work with his office to begin planning for the road closures. We will plan for trenching across the full road or half at a time, doing multiple road closures at one time, safety, and communications. There are safety concerns with a trench across the road for these few days. Without electricity, these crossings will not be noticeable once the sun sets. The road closures will need to be communicated to the appropriate parties. We will work with the local government in Ndu and in Mbokop to ensure the road crossings are well planned and all of their concerns and needs are addressed.

11.0 PROFESSIONAL MENTOR ASSESSMENT

11.1 Professional Mentor Name and Role

Stephen Clark, PE is the professional mentor writing this assessment and is the REIC and will be the traveling Professional Mentor.

11.2 Professional Mentor Assessment

The report was prepared by members of EWB-DC. Each section had a designated lead that was responsible for completing the section on schedule. The report was reviewed by outside professionals, the Program Leads, and the RIEC. Recommendations made during the review process were incorporated to finalize the report.

Design has progressed since submission of the 524. Calculations and drawings have been completed and local construction expertise has been identified. The local Construction Manager has been engaged in the design process and has provided recommendations for construction of the water system. He has completed similar projects in the past and will be instrumental during implementation.

The storage tank material was selected through discussions with the local Construction Manager and the EWB-DC structural engineer. It was determined that a cast-in-place concrete core with inner and outer stone masonry rings is the best option. The existing stone masonry tank in Ntayi (another settlement in Mbokop) is leaking in several locations. The team hopes the addition of a concrete core will prevent leakage and increase the usable life of the tank. The team has decided to avoid stone masonry for water bearing surfaces. The spring box and break pressure tanks will include cast in place concrete below the water surface and stone masonry to grade. This should reduce construction cost and prevent leakage from the system.

The community has been engaged throughout design and will continue to be updated on events. The team will need to work with our local contacts to ensure they know when we will arrive, how long we will stay, and what we expect from them. These details have been conveyed to the community already but the team will need to maintain communication with the community between now and the travel date.

The local Construction Manager has agreed to assist prior to the team's arrival by purchasing construction materials, storing materials, and preparing the site to begin construction. He will coordinate delivery of materials and can oversee implementation of the pipeline and completion of the spring box while the team is not on site. The team will continue coordinating with the local Construction Manager between now and the travel date to identify which materials need to be purchased before the team arrives and where those materials will be stored, identify a source(s) for purchasing materials by the team after they arrive, identify how materials will be transported to the site, and discuss site preparation and construction planning.

I am confident the team will be ready for implementation prior to the proposed travel date.

11.3 Professional Mentor Affirmation

I have been involved throughout the design development phase and accept responsibility for the course the project is taking.

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List of Appendices

Appendix A –Professional Mentor Resume
Appendix B – Pipeline Hydraulic Calculations and Profiles
Appendix C – Design Drawings
Appendix D –Report: Assessment Meetings with the Mbokop Community for the EWB-DC/HEDECS Water Project
Appendix E – 523 Alternatives Analysis Report
Appendix F – Catchment Protection Manual
Appendix G – EWB-USA 524 Comments and Responses
Appendix H – Construction Plan Gantt Chart
Appendix I – Cost Estimate
Appendix J – Structural Calculations
Appendix K – Signed PPA
Appendix L – Report: SIRDEP Visit to Community September 2014
Appendix M – Signed Implementation Agreement
Appendix N - Ntayi Water System Condition Assessment
Appendix O – Sample Public Health Education Activities