Pre-feasibility study for a potential piped water system

Kabende subcounty, Kabarole district, Uganda

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Abstract

Findings from a pre-feasibility study of water point sources across Kabende subcounty at the northernmost end of Kabarole District, Western Uganda. The findings of this 2018 study can hopefully lead to further steps in creating a proposal for a piped water system to serve the communities of Burungu, Kabende Trading Center, Masongora, Rwengyeyo, and Rwensenene.

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Executive summary

Kabende subcounty is a recently annexed county at the northern end of Kabarole District in Western Uganda. As part of a district-wide initiative, in the summer of 2017, IRC-Uganda assisted the district government with mapping existing water points across Kabarole. The scope of that study covered 26 of these recorded sites which are located within Kabende subcounty. In summer 2018, IRC returned to Kabende subcounty to study the potential for a gravity pipe system. The results of this study are the premise of this report. The investigation is a form of a pre-feasibility study which can be followed up with further field investigations.

Uganda's Ministry of Water and Environment is scaling up piped water supply across the country. However, it should be recognised that a piped water system is only as good as its source. Thus an investigation around water sources is the primary objective of this field study. In summary, many water points throughout the subcounty either have poor yield, poor quality, or both. The greatest challenge therefore is not in deciding how to convey water but how to supply adequate supplies of clean wate to meet the water demand of the community.

Following the field study and analysis of the results, a few recommendations are provided on how to proceed. If surface water is chosen to provide the bulk of water supplies, the most feasible in terms of water quantity would be the Nyakibuguta and Sogahi Rivers which flow along the subcounty border to the southeast. Ultimately, significant treatment and training are required in order to treat and convey the highly contaminated water from this local river system. If groundwater is selected as the primary source, a fully hydrogeological survey of the region is necessary to determine the source yield of a given aquifer. Often multiple springs will flow from the same aquifer. Thus, to determine the yield and recharge rate of an aquifer, a number of pilot holes must be drilled and monitored for a specified period of time.

At the end of this report are a few rough design drawings, a list of select water points visited with notes on each, and a literature review on piped water systems. All of these resources are available to use in the process of drafting a more detailed feasibility study in the future. This report provides field observations and initial recommendations only and should not be used as a feasibility study or proposal.

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Terminology

Aquifer = a body of permeable rock that can contain or transmit groundwater

River Gauge = a monitoring point that hydrologists or environmental scientists can routinely monitor the depth and flow of a river

Water Table = the level below which the ground is saturated with water.

Water Point Abbreviations

BH = Borehole

L = Lake

OWP = Open Well or Pond

PS = Protected Spring

R = River

RH = Rainwater Harvesting Source

SH = Scoop Hole

SW = Shallow Well

TS = Tap Stand (implies some pipe network or gravity flow scheme)

Introduction and purpose

The purpose of this report is to inform local leaders at the subcounty and district levels of the findings of a recent field study of Kabende village conducted in the summer of 2018. In the previous year, IRC conducted an extensive survey of nearly 1,100 water points across Kabarole District in Western Uganda. In Kabende subcounty specifically, a recently annexed subcounty within the district, approximately half of the 26 documented water points are functional and only one of these functional sources can adequately supply a reasonable population. Additionally, Kabende receives a variable annual rainfall - between 0-2 mm/day in the dry season to upwards of 6 mm/day during rainy seasons according to the most recent meteorological data released by Uganda's Meteorological Authority[1]. Compared to the rest of the country, the level of rainfall in this region of interest is low, posing a significant challenge to water availability. Between the months of May and August,2018, IRC sought to investigate the feasibility of providing water to Kabende village and surrounding communities with a piped water system. Assisting with this study, two University of Colorado students from the U.S. helped IRC assess the water supply situation. This report presents the findings and recommended next steps. The report is not a proposal or a complete feasibility study. However, it is possible that these findings can better direct any future feasibility study in the region.

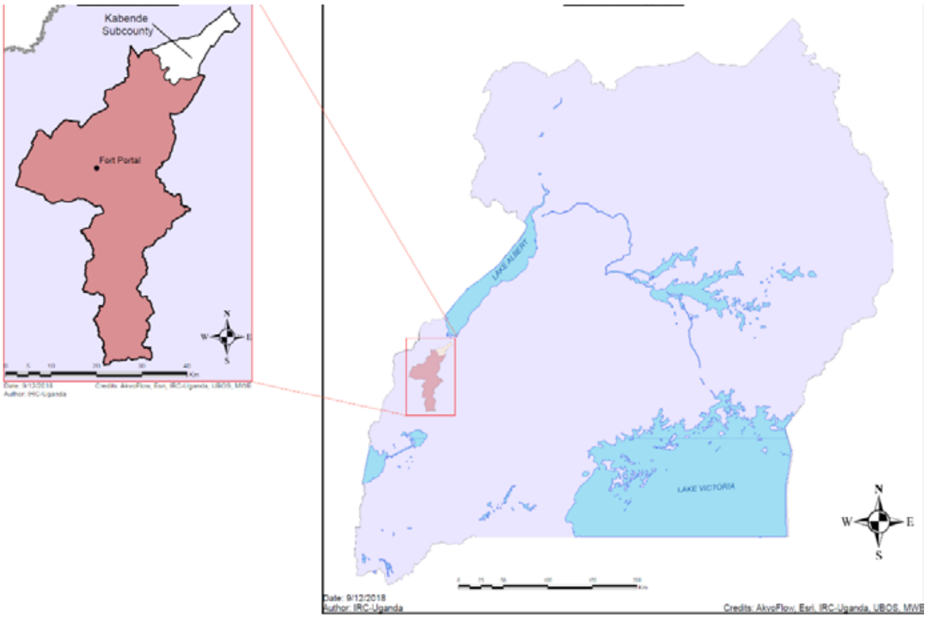

Figure 1: Kabende subcounty reference map in relation to Uganda

Kabende subcounty is an administrative region annexed from the former Hakibaale Parish in 2015[2]. Situated at the northernmost end of Kabarole District in western Uganda, the subcounty is surrounded by Lake Albert to the north, Semuliki National Park to the west, and Itwara National Forest in the southeast. Although the region is not considered arid, sources of safe water are severely limited due to recent human activity among other factors. As mentioned above, of the 26 groundwater sources in the subcounty identified in 2017 by IRC, 15 are functional, but nearly all of these have inadequate yields to serve the residents of the region, estimated to be nearly 12,000[3]. Fourteen of these 15 functional sources take longer than 60 seconds to fill a 20 litre jerrycan, and can realistically only serve 800 people if the per capita usage is taken to be 20 litres/person/day.

Unfortunately, the solution to water access is not as simple as drilling more wells in Kabende or pumping water directly from the Sogahi River flowing along the southeastern border. Further investigation is required to obtain necessary hydrogeological information and/or surface water treatment options before any plans are made to act on any point-source water system design.

1 Uganda National Meteorological Authority, UNMA (2018). UNMA Dekadals. Uganda. Retrieved August 3, 2018 from http://www.unma.go.ug/index.php/dekadals
2 Atuhaire, Scovia. Tusiime, Francis (2015, August 12) 14 sub-counties annexed to form city. Daily Monitor. Uganda. Retrieved from http://www.monitor.co.ug/News/National/14-sub-counties-annexed-to-form-city/688334-2828470-mil3bbz/index.html
3 Kabende Subcounty Local Government (2018)

Fieldwork data collection

Field observations and collected data

Water source availability

This section includes the data that was collected during the students' trips to Kabende subcounty. Included are also some rough calculations based on the data that was collected, including calculations for required yields for various populations to be served (based on 20 L/day), and numbers of people that could be served based on yield measurements which were collected from the sites which were visited. The findings are summarised in Table 1 below. A key point is that although the Sogahi river and its tributaries offer considerable yield, the water quality is very dangerous – seen in Table 2 and summrised in the water quality subsection below. The map of all known water points in Kabende can be found in Appendix A.

Table 1: Flow rates and population that could be served per day, with stated assumptions of flow percentage to be used

Code	Name	Comments	Measured Total Yield (L/s)	Total Yield (L/day)	Maximum population served[1]	Target design population[2]	Estimated number of households in village
PS79	Kanyabuhuka mwambabazi PS	dried up	0.228	19700	985	591	300
PS82	Late Patric		0.1	8600	432	259	6000
SW222	Twesge m sw	no good in dry season	0.26	22000	1123	674	300
PS253	Kabende Center PS		0.287	24800	1240	744	
SW501	Kyanga SW (new)	Poor quality	0.246	21200	1063	638	
R14	Sogahi River	Poor quality	1980	171072000	8553600	5132160	
R17	Nyakibuguta tributary	Poor quality	128	11059200	552960	331776	
PS256	Rwengyeyo PS	Low flow	too low		0	0	
PS255	Protected spring north of Kabende Center	Poor quality	too low		0	0	

[1] Number of people served per day at 20 L each and 100% of total yield

[2] Number of people served per day at 20 L each and 60% of total yield

**Rows highlighted red indicated sources that either have too low yield or poor water quality.*

On water usage rates, the design yield is not the same as the yield of the source on a given day. According to the Rural Water Design Manual, the usable yield for design is 2/3 of the dry season yield of the spring source. Assuming 20 L/person/day, a design yield (i.e. usable yield) serving 5,000 – 15,000 people would need to be 1.2 L/s to 3.5 L/s, respectively. As a word of caution, the number of springs cannot be simply summed up to equal a total yield because many of the springs and shallow wells in a given area can flow from the same aquifer source. Therefore, further investigation on the aquifer is advised and listed in the recommendations of this report.

Similarly for rivers and streams, hydrological information for gauged rivers (rivers with measured flow data) must be taken into account and have been monitored for a number of dry seasons prior to determining a design yield for water usage from the given river. For ungauged rivers, as in the case of the Sogahi and Nyakibuguta Rivers in Kabende on the Kabarole/Kyenjojo border, hydrological and river flow data from similar gauged rivers in the nearby area will suffice.

All in all, negligible impact on surface river flows and groundwater tables is desirable. If not, there is risk of groundwater sources (i.e. shallow wells, springs, deep boreholes), and surface water sources (i.e. open wells, ponds, lakes, rivers streams) all drying up during the dry seasons. An example of such a case is Kanyabuhuka Mwambabazi Protected Spring (PS79 on the map in Figure 2) in Masongora parish. The reason for this spring drying up is unknown and it cannot be confirmed whether it is due to human activity or geological activity near the rift valley, thus further investigation is needed to determine why the water table in this location is dropping. A map of the relevant villages within Kabende subcounty is depicted below in Figure 2, and additional water points across the subcounty are included in Appendix 1.

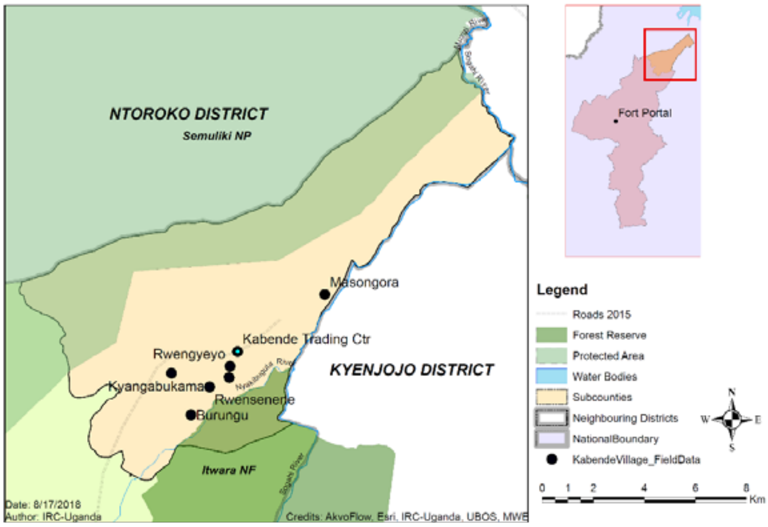

Figure 2: Kabende subcounty villages and various communities

Tables 2,3, and 4 depict relevant end user data. Population, household, and institution usage data were provided by Kabende subcounty local government officials. Approximate GPS points of communities and institutions were collected by the two University of Colorado students assisting with the study.

In short, a system that would serve the nearly 6,200 residents at 20 litres per daily capita would need to be 124,000 L / day and higher to serve the institutions. This is the water availability challenge that was mentioned at the beginning of this report. And it should be noted that this is the usable yield which is a fraction of the dry season yield of a given source.

Table 2: General data on relevant communities in Kabende subcounty

Location	Population	Households	Latitude (UTM 36N)	Longitude (UTM 36N)	Elevation (m)
Burungu	734	148	93564.38	216054.68	1324
Karokarungi	N/A*	N/A	95033.67	217549.87	1318
Kabende Trading Centre	1,944	369	96055.13	217882.39	1360
Kibiso	695	144	N/A	N/A	N/A
Kyangabukama	751	160	95199.48	215287.13	1490
Masongora	811	188	98212.71	220985.72	1230
Rwengyeyo	524	122	95473.04	217587.05	1332
Rwensenene	714	171	94667.86	216773.45	1306

Sources: Population & Household data from Kabende SC local government 2018, GPS from Android Kyocera phone collected by Caleb Cord and Ken Wallace

**N/A = data unavailable*

Table 3: General data on relevant institutions in Kabende Subcounty

Location	Number of Users	Latitude (UTM 36N)	Longitude (UTM 36N)	Elevation (m)
St. Felix School	400	95847.56	217558.16	1365.1
Kabende Primary School	862	N/A*	N/A	N/A
Kabende Health Center 3	600/mo	95986.51	217829.21	1357

Sources: Population & Household data from Kabende SC local government 2018, GPS from Android Kyocera phone collected by Caleb Cord and Ken Wallace

**N/A = data unavailable*

Table 4: Tap stands requested per location by community members

Name of Village	How many public tap stands should your village have?
Rwengyeyo, SW222	3 public taps
Kanyabuhuka, PS79	4 public taps, plus 1 primary school 150
Burungu, SW208	6 public taps, plus 3 churches
SW Kyanga Zone	6 public taps
Kabende Centre, PS86	5 public taps
Kabende Trading Centre, PS253	5 public taps (Tumusume Justus, Benon Rwegyers, Doviko Rwomushana, Awjujuna Herbet, Kyamukama Robert); 5 institutions (PS 845, St F 400, HC 596 p/mo, Mosque 200 p/mo, SC Office 100)
Kibiso - Kyakarakita PS, PS3	4 public taps (Atukoase Robert, Kaboroga Samuel, Kalid, Kibiso TC)

Table 5: Water quality sample results: physical and bacteriological parameters

Point	Name	District	Sub-county	Temp (°C)	EC (µS/cm)	pH	Turbidity (NTU)	Total Coli-form	E. Coli (CFU/100)
R14	R.Sogahi	Kabarole	Kabende	22.3	242	7.2	10.1	TNTC	TNTC
PS80	Kyakarakata protected spring	Kabarole	Kabende	24.8	282	7.8	1.8	12	<1
PS253	Kabende centre protected spring	Kabarole	Kabende	24.1	192	6.9	1.1	20	<1
PS82	Late Patrick protected spring	Kabarole	Kabende	23.5	133	6.2	1.4	<1	<1
SW501	Kyanga shallow well	Kabarole	Kabende	23.9	174	5.9	3.2	TNTC	53
R17	R. Nyakibuguta	Kabarole	Kabende	21.7	269	6	33	TNTC	TNTC
Potable Water Standards				-	1000	6.5-8.5	10	0	0

**Parameters exceeding potable water standards are highlighted in red; please not that many of these are extremely high, some TNTC (too numerous to count)*

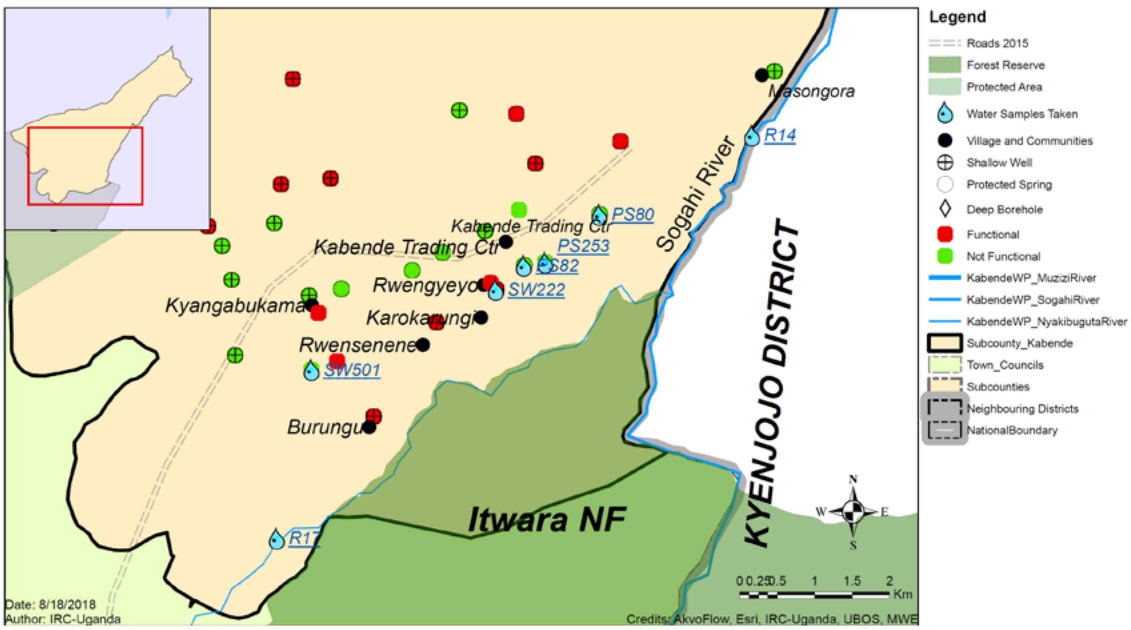

Figure 3: Water Quality Sample Point

Fieldwork data analysis and discussion

As can be seen in Table 5 of the Fieldwork data collection section, water quality is a significant issue in the surface waters that were tested in Kabende subcounty – both the Nyakibuguta (R17) and Sogahi (R14) rivers. This indicates that significant treatment would be required, especially because total coliforms and E. Coli, indicators of faecal contamination in the water, were measured to be "too numerous to count." This is especially concerning and must be properly dealt with. For potential treatment options, please see the "Recommendations and next steps" section of this report.

The poor water quality in the rivers of this area (and in a hand pump near Burungu and Kyanga) may be attributed to the possibility of poor sanitation practices in the area, and possibly open defecation. During visits to the Burungu community, it was indicated by the subcounty health inspector that open defecation is a major issue in the community. A person had reportedly died of typhoid from the water at the village's only "improved" source - a shallow well with a hand pump.

While the spring sources which were tested generally had positive water quality results, they all produced very low yields for the populations to be served. In Table 1 it can be seen that there are very few good options (from the sources explored) for providing water to a piped system. Many sources either have very poor water quality, too low of yields, or both. While it is true that several sources can be used together to increase the yield provided to the community, it's important to remember the nature of groundwater sources such as springs. When pulling water from one spring, water is being extracted from the groundwater table. This means that if a spring nearby is also being used, the water comes from the same source. Because of this , yields from springs cannot simply be added together for the total amount of water they can provide as in many cases water is being pulled from the same source.

Lessons learned and good practices for piped system design

Understanding factors that contribute to success or failure of piped water supply systems in developing countries can help to prevent failure and improve the likelihood of success when a system is being designed. It also can help to improve the continuous operation and maintenance of existing systems, based on evidence and lessons learned from other systems around the world. For the specific sources used here, please see Appendix C (full desktop study that was conducted on piped systems in developing communities).

Based on the desktop review mentioned above, the following were identified as factors leading to success or failure in piped systems:

Factors leading to **success** in piped systems primarily include

- cash contributions from consumers including capital and equity
- small scheme size with ideally less than 10 kilometers of pipe in total
- community involvement at all stages in project design and construction
- tariffs capable of covering costs of major repairs, rather than just minor operation and maintenance
- strong leadership and high levels of transparency, especially with the community
- provision of materials and sustained financial support for the system
- institutional framework in place that facilitates alternative sources of financing, such as private-sector lending
- using gravity whenever possible and minimising use of pumps
- proper water treatment and disinfectant use within the system.

Factors leading to **failure** in piped systems primarily include

- poor construction and protection techniques for pipes and infrastructure
- lack of water availability from sources, especially during dry seasons
- inadequate operation and maintenance of systems, especially intake structures
- poor location design for piped infrastructure
- construction of large schemes, especially more than 30 km of pipe
- difficulty in tariff setting and collection
- lack of long-term institutional and financial support

These factors should be addressed in practical ways when designing new systems, or when operating and maintaining existing systems. For example, constructing smaller systems (30 km of pipe or less, ideally less than 10 km) and using cash contributions from consumers for capital can help improve the likelihood of the system's success and sustainability. Based on this literature review and those factors which lead to success and/or failure, the following conclusions and recommendations are drawn:

- In general, smaller systems are a better option than larger systems: less than 30 km of pipe (total) is good, and 10 km or less of pipe is ideal. Large systems are much more difficult to monitor and routinely maintain.
- From the project's inception and initial design selection to lifetime operation and maintenance, the community should be involved in decision-making and implementation of the project's various stages. Multi-stakeholder committees, such as steering and management committees, are potential ways to do this.
- It is generally considered good practice for communities to contribute capital to the system from its very inception to foster ownership. This capital can be in the form of money and/or labour for families who may not be able to afford monetary contribution.
- When a system is being constructed, it should be built so that pipelines can be walked with ease, rather than through dense bush. Gully or river crossings should also be avoided when possible to avoid pipe washout and breakages. If they must be built over a crossing like this, considerations can be made for increased resilience and stability.
- Other important considerations for facilitating successful routine maintenance include access to adequate long-term financial and institutional support; access to spare parts and provision of materials; and proper training for technicians to carry out both minor and major repairs and rehabilitation.
- Proper attention should be given to intake structures, as these are essential components of the system that can cause system-wide failure when not properly built and maintained.
- Tariffs should be set to be able to cover long-term expenses and community members should be meaningfully involved in the process of setting tariffs for water. Community members may use less water than what is planned for in the design, causing a gap between anticipated and generated income from the system.

Recommendations and next steps

According to the Ministry of Water and Environment, the national government is pushing for improved water sources, and achieving the ultimate goal of supplying piped water to communities (4). This objective determines which implemented systems will receive government funding and which will not. This report is not a proposal although the study findings may lead to additional data collection and further analysis to propose a water system for the village of Kabende and surrounding communities.

Potential distribution routes

As mentioned in the above "Lessons Learned" section, distribution routes should not be made too long. Ideally, less than 30 total kilometers of pipe should be used. Distribution routes should avoid gullies and river crossings whenever possible, as laying pipelines in these areas increase the likelihood of system failure. In addition, pipelines should not be laid in areas of dense brush, as this makes it difficult to walk along the distribution lines for maintenance purposes, which should be done frequently. For this reason, it is recommended to run distribution lines along main roads as much as possible.

With these recommendations in mind, potential distribution routes are shown below in Figure 4. The solid line represents a distribution line serving Rwengyeyo, Karokarungi, Rwensenene, and Burungu with an approximate length of 3.1 kilometers. Another distribution line running from the same storage tank on top of Kabende Hill (represented by dots and dashes) can then serve Kabende Center and run along the road to Masongora. This second line is approximately 5.0 kilometers long.

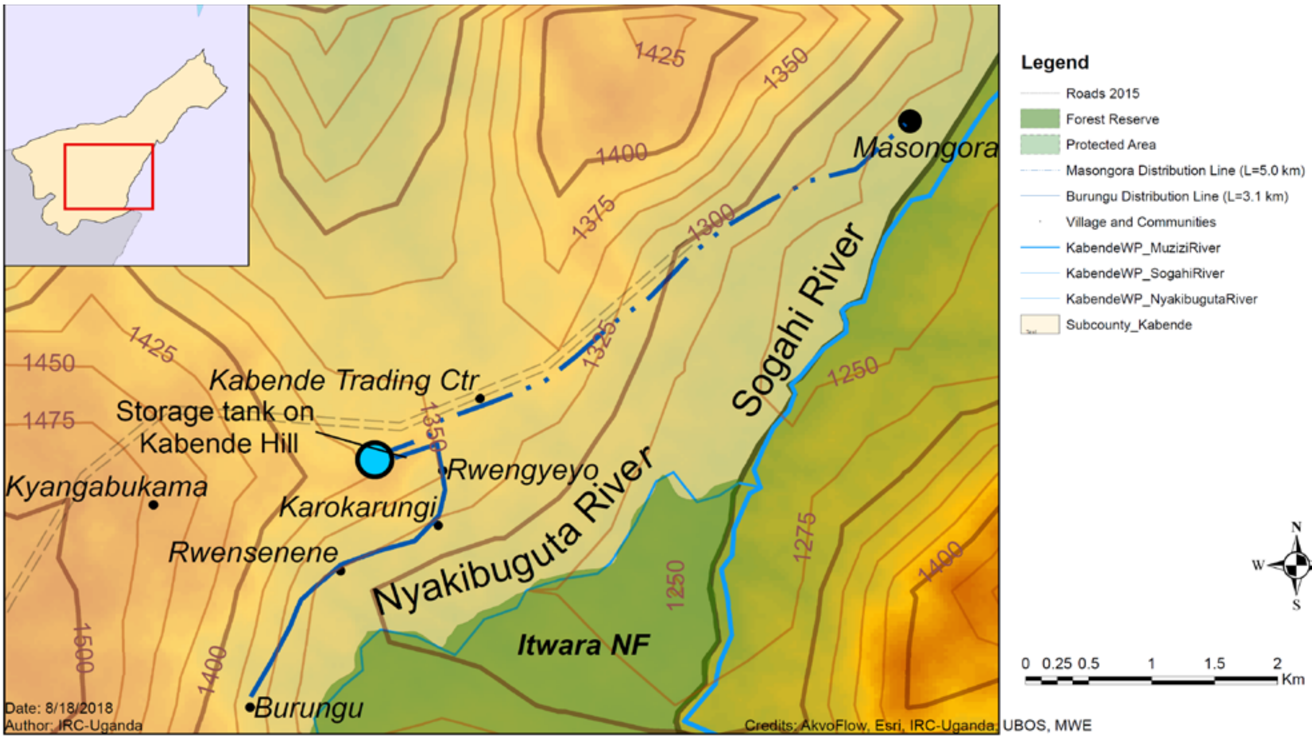

Figure 4: Potential distribution routes

Treatment recommendations

Based on the data collected from this field investigation, robust treatment of the Sogahi river (if used) is strongly advised prior to any distribution of such water for drinking. With very high biological contamination, it is recommended that there is slow sand filtration and disinfection of the water prior to storage. To maximise the life expectancy of slow sand filters, the extracted river water should be thickened with coagulant to ensure sedimentation. Following disinfection, the water can be pumped up to a storage reservoir at the top of Kabende Hill or any other high point to provide adequate head pressure to supply the selected communities.

Such robust systems are expensive. Pumps require adequate power. Coagulant and disinfection dosing require trained technicians to monitor and know the dosing amounts to add to the water. Additionally, the logistics, construction, and maintenance costs could be extremely challenging for this remote region. Although this may be the ultimate solution, the communities that make up Kabende village are currently a long way from being able to maintain such a treatment scheme.

Groundwater is the other option. This would require minimal treatment since most of the bedrock acts as a natural filter. Disinfection is still recommended, but the removal of biological contaminants can be greatly reduced if the spring source or borehole are at an adequate depth.

Future field measurements

In future it would be good to continue searching for potential water sources to be used for this system. While the rivers can be used, treatment will be required, which could be costly. One option would be the drilling of boreholes to be pumped for the system (as used for the Rweyhamba system in Kasenda subcounty), which would require some additional fieldwork and efforts. For guidelines on using boreholes for groundwater sources, refer to the Water

Supply Design Manual (Second Edition) on the Ministry of Water and Environment's website. Permit applications for groundwater sourcing, drilling, and construction can also be obtained on the Ministry's website under **Manuals, Guidelines, and Forms.**

Dry season yields are critical for design, as they are the only yield measurements from water sources that can truly capture how much water a source would be able to provide at a minimum. For this reason, surface and ground water source yields must be measured during the dry season. However, only a fraction of this yield should be used as not all water can be taken from the environment as per Ugandan law. For more information, see the Ministry's Water Supply Design Manual.

Additional recommendations

Based on the concerning findings in the Burungu community, a sanitation/hygiene intervention is recommended for this community, and potentially for many of the surrounding villages. There is reason to believe, based on the data collected during this study, that poor sanitation and potentially open defecation are issues in the area. Water quality results could be shared with the community, but it should be noted that, based on WASH sector principles, without improved sanitation and hygiene practices, improved drinking water is not likely to lead to better health outcomes.

From the project's inception and initial design selection to lifetime operation and maintenance, the community should be involved in decision-making and implementation of the project's various stages. Multi-stakeholder committees, such as steering and management committees, are potential ways to do this. This is an essential part of designing such a system. In addition, consumers should contribute capital prior to the system's construction, based on good practice from other interventions mentioned in the "Lessons learned" section.

Operation and maintenance of systems are vital for sustainable service delivery of piped systems, as with any water distribution system. Important considerations for facilitating successful routine maintenance include access to adequate long-term financial and institutional support; access to spare parts and provision of materials, and proper training for technicians to carry out both minor and major repairs and rehabilitation. Proper attention should be given to regular maintenance and upkeep of intake structures, as these are essential components of the system that can cause system-wide failure when not properly built and maintained.

Next steps

Once it is determined which communities will be served by this system, suitable water sources will need to be identified based on what has been discussed in this report, and based on the Ministry's Water Supply Design Manual. The manual gives a robust description on the process for source selection, but in general, sufficient yield and water quality are critical.

As mentioned earlier, groundwater sources can be combined, but care must be taken when adding the yields of groundwater sources. This must involve an in-depth study of existing hydrogeological maps; installation of test wells at a sufficient distance from the actual well to be drilled; and routine monitoring of these wells to ensure that the water table is not depleted.

Rivers and other surface water are possible alternatives to groundwater for system sources. However, though the yield may be adequate, the quality is not and will likely require much more robust treatment, which is likely to add significant cost to the system.

It cannot be emphasised enough that water quality is of great importance. Supplying a large community with water of poor quality on the scale of a piped distribution system would be dangerous and irresponsible: access to **safe** water is essential.

Appendix A: Maps and tables of Kabende subcounty water sources

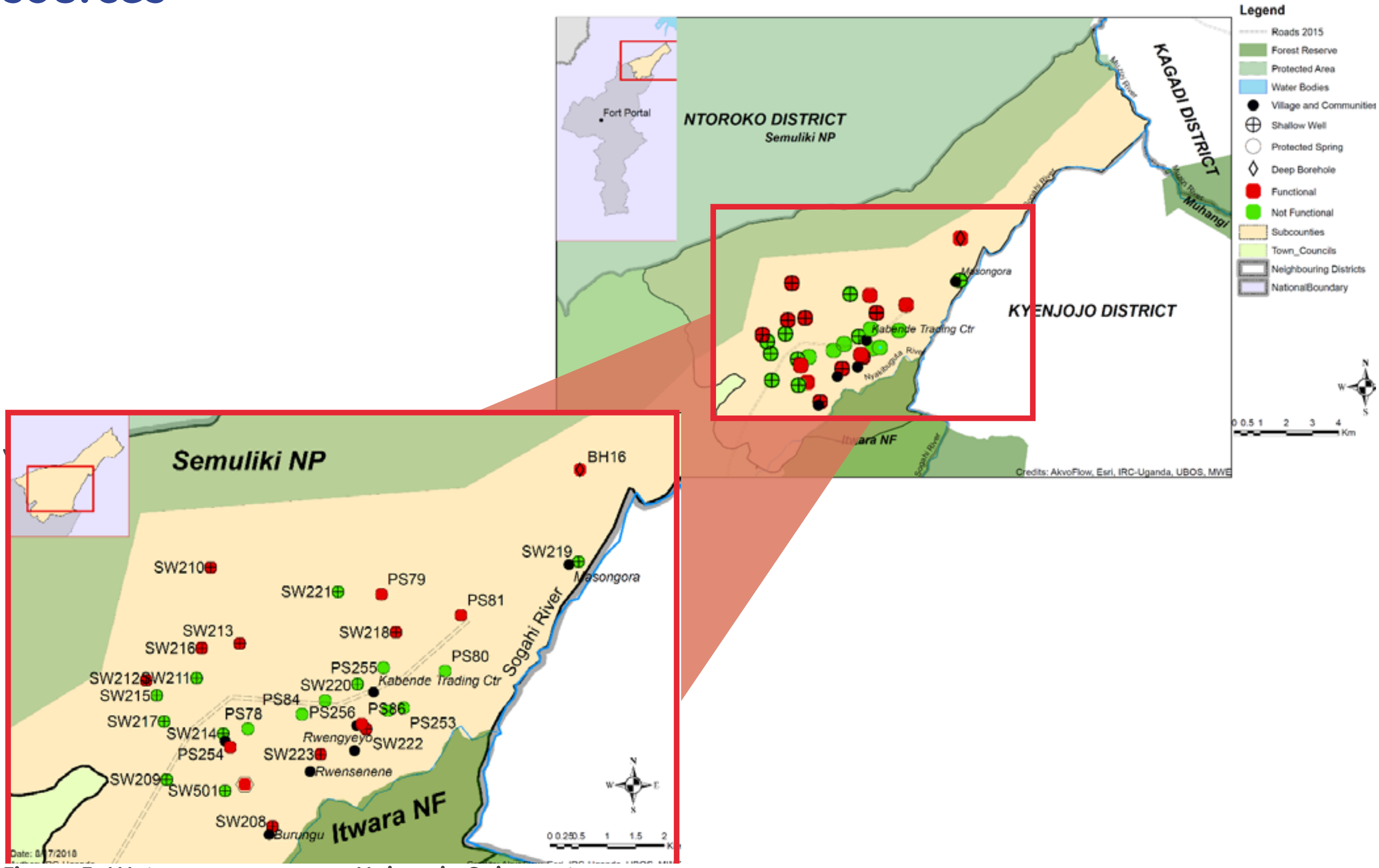

Figure 5: Water sources across Kabende Subcounty

Appendix B: General field notes on select sites

PS = protected spring
SW -shallow well
BH - borehole

PS 79

- Name: Kanyabuhuka mwambabazi PS
- Village: Kanyabuhuka
- Parish: Masongora
- PS 5 is north of Kabende Center
- Original PS5 Coordinates (WGS 1984):
    - Lat=0.883617 N
    - Lon=30.466417 E
    - EL= 1333.0 m
- New PS5 Coordinates (WGS 1984):
    - Lat=0.883663 N
    - Lon=30.466293 E
    - EL= 1331.0 m
- Coordinates (UTM):
    - Original PS5: 36N 218016 97763
    - Relocated PS5: 36N 218003 97768
- Site Visits:
    - 6/1/2018, Weather = clear, sunny
- **Calculated yield (1/6/2018)**: 0.23 L/s

Water Quality: (5/6/2018): MARGINAL

PS 80

- Name: Kyakarakata protected spring
- Village: Kibiso / Kyakarakata
- Parish: Masongora
- Coordinates (WGS 1984):
    - Lat=0.87149296 N
    - Lon=30.47643669 E
    - EL= 1275.5 m

- Coordinates (UTM): 36N 21931 96419
- Construction Date: 4/18/2018
- Rehab Date: N/A
- Site Visits:
    - 6/1/2018, Weather = clear, sunny
    - 6/5/2018, Weather = overcast & rainy (received much rain 2 days prior)
- **Calculated Yield (1/6/2018):** 0.31 L/s (reported as normal)
- **Water Quality (5/6/2018)**: **MARGINAL**

PS 82

- Name: Late Patric
- Village: Kabende Center
- Parish: Ndaiga
- Coordinates (WGS 1984):
    - Lat = 0.86531776 N
    - Lon = 30.46736486 E
    - EL = 1298.3 m
- Coordinates (UTM):
    - 36N 218121 95738
- Site Visits:
    - 1/6/2018, Weather = clear, sunny
    - 5/6/2018, Weather = overcast & rainy (received much rain 2 days prior)
- **Calculated yield (1/6/2018):** 0.10 L/s (reported as normal)
- **Water Quality (5/6/2018): GOOD**

PS 253

- Name: **Previously unmarked protected spring south of Kabende Center (between PS7 and PS3)**
- Village: Kabende Center
- Parish: Ndaiga
- Coordinates (WGS 1984):
    - Lat=0.865723 N
    - Lon=30.469923 E
    - EL= 1292.0 m
    - **Near Kabende center, situated between PS 7 and PS 3**

- Coordinates (UTM):
    * 36N 218406 95782
- Site visits:
    * 1/6/2018, Weather = clear, sunny
    * 5/6/2018, Weather = overcast & rainy (received much rain 2 days prior)
- Calculated yield (1/6/2018): 0.29 L/s (reported as normal)
    * Has not dried up (according to local report of villager);
    * Same flowrate even during dry season
- **Water Quality (5/6/2018): POOR**

PS254

- Name: **Previously unmarked protected spring in Kyanga**
- Village: Kyagabukama
- Parish: Kyamwirukya
- Coordinates (WGS 1984):
    * Lat = 0.85949 N
    * Lon = 30.442715 E
    * EL = 1472 m
- Coordinates (UTM): 36N 215375 95095
- **NOT FUNCTIONING**
    * No visible flow observed from spring

PS 255

- Name: Protected spring north of Kabende Trading Center **(Previously unmarked)**
- Village: Kabende Trading Center
- Parish: Ndaiga
- Coordinates (WGS 1984):
    * Lat=0.872063 N
    * Lon=30.466772 E
    * EL= 1318.0 m
- Coordinates (UTM):
    * 36N 218055 96484
- Site visits:
    * 1/6/2018, Weather = clear, sunny

* **Calculated yield (1/6/2018): Yield too low**

- Recently constructed by FBO as a donation

PS 256

- Name: **Previously unmarked protected spring serving as alternative source to SW 16 (Rwengyeyo)**
- Village: Rwengyeyo
- Parish: Ndaiga
- Coordinates (WGS 1984):
  * Lat = 0.86320299 N
  * Lon = 30.4633802 E
  * EL= 1309.6 m
- Coordinates (UTM):
  * 36N 217677 95504
- North of SW 16 (northeast of Rwengyeyo)
- Site visits:
  * 5/6/2018, Weather = overcast & rainy (received much rain 2 days prior)
- Calculated yield (5/6/2018): YIELD TOO LOW
  * Spring is seasonal
  * Poor drainage from the pool below spring outlet
- **Water Quality (5/6/2018): WATER IS NOT SAFE, no samples taken**
  * Protected spring is poorly built
    - No drainage outlet from pool of water
    - No channel to divert surface runoff around the spring
    - Silt and debris present around the spring

R14

- Name: Sogahi River @ Bridge northeast of Kabende Center
- Village: Masongora
- Parish: Masongora
- Coordinates (WGS 1984):
  * Lat = 0.88114243 N
  * Lon = 30.4947393 E
  * EL = 1201.9 m
- Coordinates (UTM): 36N 221171 97487

- Site visits:
  - 5/6/2018, Weather = overcast & rainy (received much rain 2 days prior)
- Measured depth: 1.2 m (single measurement in center of river)
- Measured Width (5/6/2018) = 7.50 m (single cross-section)
- Measured surface velocity (5/6/2018): 13.7 m / 28 s = **0.489 m/s** (measured velocity; single measurement in center of river)
- **Calculated Yield (5/6/2018): 1,980 L/s** (yield including 0.9 correction factor for silty/sand bottom with grass; trianglular cross-section)
- **Water Quality: POOR**
- Bed material: river bed and banks mostly tall grass and silt
- **CAUTION:** Sogahi River is downstream of a lot of communities (O.D. contamination), and tea farms (pesticide runoff?)

R17

- Name: Nyakibuguta River upstream of Burungu
- Village: Karuteete
- Parish: Kyakabaseke
- Coordinates (WGS 1984):
  - Lat = 0.83215552 N
  - Lon = 30.43774431 E
  - EL = 1403.8 m
- Coordinates (UTM): 36N 214819 92071
- Site visits:
  - 5/6/2018, Weather = overcast & rainy (received much rain 2 days prior)
- Measured river depth: 0.40 m (single measurement in center of river)
- Measured Width (5/6/2018) = 7.50 m
- Measured surface velocity (5/6/2018) = 0.32 m/s (measured velocity; 3 measurements in center of river)
- **Calculated Yield (5/6/2018): 128 L/s** (yield including 0.8 correction factor for silty bottom and heavy vegetation; trianglular cross-section)
- **Water Quality: POOR**
- Bed material: heavy vegetation, silt, weeds, and submerged branches

SH7

- Name: **Alternative source to SW17 near Kyagabukama**
- Village: Kyagabukama
- Parish: Kyamwirukya

- Coordinates (WGS 1984):
    - Lat = 0.85360625 N
    - Lon = 30.44500509 E
    - EL = 1447.9 m
- Coordinates (UTM): 36N 215630 94444
- Previously unmarked
- **Calculated Yield (1/6/2018): YIELD TOO LOW**
- **Quality (1/6/2018): UNSAFE TO DRINK**
- Many neary Kyagabukama gather water from here rather than from SW17
- Scoophole - unprotected and downstream of a latrine

SW 208

- Name: Lauransiyo tibesigwa sw
- Village: Burungu
- Parish: Kyakabaseke
- Coordinates (WGS 1984):
    - Lat: 0.846861 N
    - Lon: 30.449308 E
    - EL: 1310 m
- Coordinates (UTM): 36N 216108 93697
- Calculated yield: DID NOT MEASURE
- Water Quality (6/1/2018): Likely very poor, see below (from community people)
    - Water smells like rotten eggs (High Sulfur?)
    - Water changes color at times (yellowish)
    - One person reportedly died of typhoid
    - Community generally fetches water from open dug wells

SW 214

- Name: Kyanga sw
- Village: Kyanga bukama
- Parish: Kyamwirukya
- Coordinates (WGS 1984):
    - Lat = 0.86160497 N
    - Lon = 30.44153873 E

* EL = 1472.6 m

- Coordinates (UTM): 36N 215244 95329
- **Calculated Yield: Yield is too low**
- Located in the middle of tea fields, seems to be either new or newly renovated
- Everything on this side of the ridge (essentially this side of the highway) appears to have the issue of the water table lowering - low flows, low yields, etc.
    * Is quality being impacted by this? Will be interesting to see in the results from the tests

<u>SW 222</u>

- Name: Twesge m sw
- Village: Rwengyeyo
- Parish: Ndaiga
- Coordinates (WGS 1984):
    * Lat=0.86237 N
    * Lon=30.464001 E
    * EL= 1303.2 m
- Coordinates (UTM):
    * 36N 217746 95412
- Site Visits:
    * 1/6/2018, Weather = clear, sunny
- Calculated yield: 0.26 L/s (84 strokes of handpump lever)
    * Conservative calculation using the longest time measured to fill the basin
- Dries up seasonally
- Unprotected alternative sources utilized by community
    * Very low yields at these alternative sources
    * Alternative 1 (R3)
        - Very far downhill - is this an indication of how low the water table is in this area, in general? Would deep boreholes possibly work for this area?
- Difficulty measuring flow with hand pumps, so we need to determine exactly how we want to determine how these shallow wells will be used in our design (especially with regard to their capacity)
- Jerry cans used to collect water observed to be dirty

<u>SW 223</u>

- Name: Herbert k sw

- Village: Rwensenene
- Parish: Ndaiga
- Coordinates (WGS 1984):
    - Lat = 0.8583643848 N
    - Lon = 30.45689739 E
    - EL = 1305.45 m
- Coordinates (UTM): 36N 216954 94969
- **Not functioning** (as recorded by a local)
    - Site not visited for confirmation

SW 501

- Name: **Not previously recorded in Akvoflow**
- Village: Kyanga bukama
- Parish: Kyamwirukye
- Coordinates (WGS 1984):
    - Lat = 0.85261095 N
    - Lon = 30.4419029 E
    - EL = 1441.3 m
- Coordinates (UTM): 36N 215284 94334
- Site visits:
    - 6/1/2018, Weather = clear, sunny
    - 6/5/2018, Weather = overcast & rainy (received much rain 2 days prior)
- Calculated yield: 0.25 L/s (100 handpump lever strokes calculated)
    - Conservative calculation using the longest time measured to fill the basin
- Water quality (6/5/2018):
    - Samples collected on 6/5 by Maurine (Albert Water Mgmt Zone)
    - Unmarked shallow well that could potentially support Burungu
- Currently serves Kyanga, Karutete, and Burungu (HH served roughly = roughly 150)
- Needs to be added to IRC's spreadsheet of all Kabarole water points
- Community disagreement on water quality? Claims of water smelling?
    - No odor detected during visit on 6/1

Appendix C: Piped system desktop review

Desktop review: factors leading to success or failure in rural piped water systems in developing countries

Executive Summary

Piped water supply is the subject of a large push in Uganda from the Ministry of Water and Environment. Understanding factors that contribute to success or failure of piped water supply systems in developing countries can help to prevent failure and improve the likelihood of success when a system is being designed. It also can help to improve the continuous operation and maintenance of existing systems, based on evidence and lessons learned from other systems around the world. The purpose of this desktop review is to provide this high-level understanding, based on a review of relevant literature sources and case studies. This review includes sources of information from developing communities around the world (but with a focus on African nations). The following were identified as factors leading to success or failure in piped systems:

Factors leading to success primarily include

- cash contributions from consumers, including capital and equity
- small scheme size, with ideally less than 10 total kilometers of pipe
- involvement of the community at all stages of the project and its construction
- tariffs capable of covering costs of major repairs, rather than just minor operation and maintenance
- strong leadership and high levels of transparency, especially with the community
- provision of materials and sustained financial support for the system
- institutional framework in place that helps facilitate alternate sources of financing, such as private-sector lending
- utilising gravity whenever possible and minimising use of pumps
- proper water treatment and disinfectant use within the system.

Factors leading to failure primarily include

- poor construction and protection techniques for pipes and infrastructure
- water availability from sources, especially during dry seasons
- inadequate operation and maintenance of systems, especially intake structures
- poor location design for piped infrastructure
- construction of large schemes, especially larger than 30 km of pipe
- difficulty in tariff setting and collection
- lack of long-term institutional and financial support

These factors should be considered in practical ways when designing new systems, or when operating and maintaining existing systems. For example, constructing systems in a smaller size (30 km of pipe or less, ideally less than 10 km) and using cash contributions from consumers for capital can help improve the likelihood of the system's success and sustainability. Failure rates in piped systems in developing countries are high; learning lessons from mistakes made and successes achieved in years past is important and helpful for sustainable progress.

Introduction

The purpose of this desktop review is to provide an understanding of factors that influence the success and/or failure of piped water supply systems, and the types of failure and/or success observed. This understanding is hoped to influence design and management of piped water systems. This desktop study was conducted on piped systems in developing communities around the world with a focus on Africa, but systems in Latin America were considered also. Most of the studies summarised here include large sample sizes of piped systems for better generalised understanding.

While success is defined differently from one literature source to another within this review, for the purpose of this document, success is defined as functional and sustainable water service delivery, with failure being defined as system breakdown or water service delivery inadequacy. Specific types of successes and failures seen are mentioned here as well as the factors influencing them, as previously described.

Factors leading to success

One factor contributing to success is having consumers contribute financially to the system - ideally through regular maintenance payments and upfront capital. It is dangerous to assume that community members will provide unskilled labour for maintenance purposes, as demonstrated in the many case studies performed on the Malawi Piped Scheme Program (Kleemeier, 2000). However, it is also good for communities to contribute capital to the system from its inception, as demonstrated by several successful systems in East Africa. In Kenya, 20% equity was provided by the community under a programme for financing investment in community-managed piped water (Advani, 2011). In Ethiopia, 20% capital was provided by community members in the Oromia Region in forms of cash and/or labour for piped systems to be constructed (Njonjo & Lane, n.d.).

Involvement of the community in all stages of the project was found to be another key factor for system success (Mesa, Tamekawa, Ezbakhe, Cuadrado, & Chan, 2014; Nanjowe, 2016). In Ethiopia, project steering committees were appointed for many schemes that were developed, including community members, central and local government staff, and staff from the implementing NGO. This steering committee was responsible for planning the overall project; supervising construction; monitoring activities against plans; and resolving problems (Njonjo & Lane, n.d.). Management committees were also formed which continue to manage and monitor the schemes today. This was cited as a large factor contributing to the success of these systems.

A project called "Community Water Plus," funded in part by Australian Aid, broke success factors, or "plus factors," down in to those that are most relevant in the short-term, short- and long-term, and long-term. Short-term factors leading to success can include advice on management and finance; access to loans and microfinance (when needed); access to spare parts and services; and capacity building on technical skills. In both the short-term and long-term, financial support, provision of materials, and management capacity-building were found to be critical. In the long-term, having a decentralised system under a regulatory framework is a critical factor to sustained success (Mesa et al., 2014).

System size has a huge impact on long-term sustainability, as referenced by many studies in this desktop review. Based on case studies of built systems from around the world funded by multiple bilateral and multilateral donors, small systems nearly always provide better service delivery long-term than large systems. Regular maintenance is much more difficult to perform on large systems, making failure much more difficult to diagnose and act on (Mesa et al., 2014). Size also increases the burden on leaders and system managers, as well as community members who provide unskilled labour. Systems in Malawi with over 30 km of laid pipe suffered disproportionally due to their large size. Systems with 10 km of pipe or less should be targeted (Kleemeier, 2000). A study conducted in Latin America also found that systems serving the largest populations were much less likely to provide continuous service delivery than those serving the smallest populations (Cronk & Bartram, 2018).

If community-based organisations are to ultimately be responsible for operating and maintaining the system, adequate long-term support and backstopping are required from the implementing agency (Mesa et al., 2014). This could be a good place for KAHASA to step in – with the builtt capacity the organisation could take charge of this long-term support for communities, and systems may be more sustainable in the long run. Several common difficulties related to operation and maintenance should also be addressed, including availability of materials and adequate repair processes (Kleemeier, 2000; Mesa et al., 2014). This includes access to spare parts for minor repairs.

Transparency is an important part of system sustainability, especially when a private operator such as KAHASA is involved. Regular meetings should be held with the community, as well as within the organisation. This is especially important regarding the use of funds raised through water tariffs. Lack of transparency can lead to higher unwillingness to pay, ultimately resulting in a lack of proper operation and maintenance and system failure (Mesa et al., 2014). In this sense, transparency, or a lack thereof, can be either a factor leading to success or failure.

Finally, the use of a disinfectant is a success factor for drinking water distribution systems (Lee & Schwab, 2005). Health benefits are huge from improved drinking water sources in the home, as well, without much need for secondary storage (Cronk & Bartram, 2018). Secondary storage increases the likelihood of secondary contamination, which mitigates the benefits of treating water in the first place. If quality water service delivery is to be considered as the definition of success for these systems, then the water arriving at consumers' taps must be safe for consumption. This is an important and often overlooked component of success.

Factors leading to failure

A common type of failure seen in piped systems in Malawi was breaks/blockages in pipes. This was largely caused by exposed PVC pipe; poor previous repairs or use of inadequate materials; tanks not cleaned; lines not having enough scour points/air valves; debris and dirt introduced to the system during repairs; and failure to respond to customer complaints. Inaction on the part of consumers is also a factor leading to failure, such as failing to report problems or refusing to provide unskilled labour to assist repair teams (Kleemeier, 2000).

Infrastructure condition and water availability from sources, during both wet and dry seasons, are incredibly significant factors contributing to continuous flow of water in piped distribution systems (Cronk & Bartram, 2018). Special care must be taken for proper maintenance of these systems, but also for determining the sources that will feed in to them. Gravity flow schemes are also cheaper and easier to maintain than pumped systems, which can lead to significantly increased likelihood of long-term sustainability (Nanjowe, 2016). However, location design must be considered when choosing the system type. Poor location design is a large factor contributing to failure of piped systems. This was especially cited for systems in Malawi. Placing pipes in dense bush or difficult terrain can cause difficulty walking the lines for monitoring (Kleemeier, 2000); pipes placed over rivers or streams experience increased likelihood of being washed away during the rainy season (Kleemeier, 2000; Njonjo & Lane, n.d.).

Routine maintenance and necessary rehabilitation of system components are important for piped systems, in order to mitigate gradual deterioration, a factor leading to failure. This is especially true for intake structures. During the rainy season, intake structures frequently become blocked and are especially important to maintain (Kleemeier, 2000). In Panama, it was discovered that intake structures in need of rehabilitation were significantly associated with non-continuous service delivery. An overall lack of institutional capacity (at all levels) to manage and maintain the system, including a lack of long-term financial and institutional support, is another related factor leading to failure (Kleemeier, 2000; Mesa et al., 2014).

Whereas the construction of small systems generally leads to greater likelihood of sustainability, construction of large systems does the opposite. In Malawi, systems with more than 30 km of pipe suffered disproportionally due to their large size (Kleemeier, 2000). On the whole, large systems are incredibly difficult to maintain (Mesa et al., 2014). In Nicaragua and Honduras, systems serving the largest populations were much less likely to provide continuous service delivery than those serving the smallest populations (Cronk & Bartram, 2018). In general, it appears that designing systems to be smaller, closer to 30 km or less (and ideally 10 km or less) significantly increases the likelihood of long-term sustainability.

Another factor leading to failure is difficulty in tariff setting and collection. This can be made more problematic by neglecting to involve communities during the planning, designing, and implementation phases – including the tariff setting process (Mesa et al., 2014). A factor that builds on this is that of community members using less water than projected for in the design, and therefore not generating the anticipated income through water tariffs for upkeep of the system (Njonjo & Lane, n.d.). In general, a lack of funds for necessary rehabilitation is a huge contributor to service delivery discontinuity, indicating that this is a factor leading to failure (Cronk & Bartram, 2018).

Many systems operate at only a fraction of the capacity they were designed and built for (Lee & Schwab, 2005). Developing countries experience higher failure rates of piped distribution systems than developed countries do, and infrastructure deteriorates more quickly in developing countries also (Lee & Schwab, 2005). In general, the concept of routine maintenance and upkeep is a very important one in the context of piped systems in developing communities. Overall lack of institutional capacity (at all levels) to manage and maintain the system, including a lack of long-term financial and institutional support, is a significant factor attributed to failure (Kleemeier, 2000; Mesa et al., 2014).

Conclusions and Recommendations

Water system size

In general, smaller systems are a better option than larger systems. There are many reasons for this but operation and maintenance of the system is the primary driver. Large systems are much more difficult to monitor and routinely maintain, and often experience breakdowns and system failure that can go undiagnosed for long periods. The time, effort, and finances required from stakeholders are much larger in magnitude for a large system. The recommendation for systems to be built smaller when possible, ideally with less than 30 km of pipe, is based on solid evidence from lessons learned within this desktop review.

Community and stakeholder engagement

Community involvement at all stages of the project is an essential component of success. From the project's inception and initial design selection to lifetime operation and maintenance, the community should be involved in decision-making and implementation of the project's various stages. Multi-stakeholder committees, such as those demonstrated by the steering and management committee examples, are potential ways to do this, with a lot of demonstrated success in African countries. These should involve community members, as well as other relevant stakeholders such as government officials and members of the implementing agency (NGO, private service provider, etc.). It is generally considered good practice for communities to contribute capital to the system in order to promote ownership. This can be in the form of money and/or labour for families who may not be able to afford monetary contribution

Design and maintenance

Time must be invested in the regular maintenance of these systems, with financial contributions coming from the community. There are certain things that can help facilitate successful routine maintenance and monitoring of a piped system, and part of this is related to geography. When a system is being constructed, it should be built such that pipelines can be walked with ease, rather than through dense bush. Gully or river crossings should be avoided when possible, to avoid pipe washout and breakages. If they must be built over a crossing like this, considerations can be made for increased resilience and stability. Other important considerations for facilitating successful routine maintenance include access to adequate long-term financial and institutional support, access to spare parts and provision of materials, and proper training for technicians to carry out both minor and major repairs and rehabilitation. Proper attention should be given to intake structures, as these are essential components of the system that can cause system-wide failure when not properly maintained. Infrastructure deterioration is a large problem in developing countries, and carrying out routine maintenance is extremely important for system sustainability.

Tariff setting

Tariffs should be set to be able to cover long-term expenses, and community members should be very involved in the process of setting tariffs for water. Care should also be taken when planning financially for tariffs to be a primary/necessary source of income for the system: community members may use less water than what is planned for in the design, causing a gap between the projected and generated income. This is important to consider for system sustainability, as adequate funds must be available for routine operation and maintenance, as emphasszed by many different studies referenced here. This is where access to long-term financing is important, in addition to proper long-term support and backstopping from the implementing agency.

There are many steps that can and should be taken when planning for water distribution systems in developing countries, and many of these are unique to specific contexts. However, a broad understanding of previous successes and failures and the factors influencing them around the world is helpful for identifying methods to prevent failure and promote success. Sustainable service delivery is a tricky topic, but an essential goal for achieving Sustainable Development Goal 6 (SDG6) and eventual universal access and safe management of water for all.

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