

Measuring Water Collection Times in Kenyan Informal Settlements

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ABSTRACT

This paper uses GPS loggers and interviews to measure the time taken to collect water in two Kenyan informal settlements. The time devoted to water collection is widely believed to prevent women and girls, who do most of this work, from undertaking more creative tasks, including income generation and education. We studied collection times in two settlements to compare Nyalenda in Kisumu, where the utility has introduced a new piped water system, with Kibera in Nairobi, where no such improvement has been made. In addition to the primary results of quantitative collections times, we discuss the use of GPS in this context and our findings that the two methods of measurement provide insights which neither would have provided alone.

Categories and Subject Descriptors

J.4 [Social and Behavioral Sciences]; K.4.2 [Computers and Society]: Social Issues

General Terms

Design, Human Factors, Measurement

Keywords

Water collection, GPS, time, Kenya, women's work

1. INTRODUCTION

We want to know how much time is spent collecting water in low income settlements and how that has been changed by the introduction of a new system of water collection. We use GPS to map women's water collection in two Kenyan settlements. We compare water collection times in Kibera in Nairobi, where there is a market system distributing water illegally obtained from the utility mains, with those in Nyalenda in Kisumu, western Kenya, where the utility has introduced a Delegated Management Model with a new piped water distribution system maintained by traders and community groups. We find that there is less time spent in water collection in Nyalenda, with the introduction of this new piped water distribution system. Women continue to use multiple

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sources of water, including springs and unprotected wells.

In addition to measures of water collection time, we report on the introduction of a mature ICT technology, GPS, to measure collection times and distances. Household interviews are the current standard method of collecting this data. We find that GPS provides new insights into the complexity of water collection, but cannot fully replace household interviews.

We are interested in household or domestic water collection because the quality and quantity of household water, and the time devoted to water collection, have wide repercussions on well-being. Water-borne diseases are a significant source of ill-health, in non-industrial countries. Limits on the quantity of water available may also constrain livelihood options and the productivity of domestic work, such as laundry, bathing and washing utensils. In addition, the time devoted to collecting water may crowd out other more creative or rewarding uses of time.

In Sub-Saharan Africa, time devoted to the collection of water is thought to contribute to the over-work or time shortage of women. Thus, Blackden and Wodon [3] write: 'Time poverty has long been recognized as a constraint to development in Sub-Saharan Africa, with women working especially long hours due in part to a lack of access to basic infrastructure services such as water and electricity.' There is evidence that women sleep fewer hours than men in response to the time demands of their various tasks [10].

This paper makes two main contributions: 1) It compares two water supply systems in two low income informal settlements, providing quantitative data which was not previously available. 2) We also compare two methods for measuring the time taken collecting water. We find, on this second point, that neither GPS alone, nor the recall time estimates of water collectors, provide a full picture of the time and place of water collection. In combination, the two may uncover new data about where water is collected, the complex patterns of water collection from several sources, and how long is spent in water collection.

2. RELATED WORK

Measuring water collection: For some decades, the attention of international agencies has been focused primarily on the technology of water collection [8][13]. International statistics on progress in access to water focus on whether or not access is through an 'improved' water source. Improved sources include piped water, boreholes, standpipes and protected springs, a range of technologically improved water sources, in contrast to open ponds, rivers, springs and other easily contaminated sources. These data do not describe the social conditions of water collection, how long it takes, how infrastructure has arisen

historically, and from whom the water is purchased or obtained by other agreement.

There is little systematic collection of data about how long water collection takes. A review of the literature [8] on women's water collection in slums suggests that water availability may be unpredictable on hourly, daily and seasonal time scales, water collection sites may be distant, and public sources may be crowded resulting in long queuing times. In Ghana, water collection times vary from three-quarters of an hour in times of plenty to two and a half hours in times of scarcity, but a significant number of women spent more than four hours collecting water [5]. In the slums of India, women are reported to spend from two to four hours collecting water. Multiple trips may be required, each 15 to 25 minutes long [15].

A review of rural household water access [13] summarized 12 studies of time taken in water collection with average water collection times varying from 17 to 103 minutes per carrier per day, and minimum and maximum collection times vary from 7 to 264 minutes (four and a half hours).

All of the urban data appears to be based on recall estimates made during interviews. In rural areas, some estimates of time taken in water collection have been made by direct observation [6]. This may be a feasible method for collecting reliable data in rural areas where many people use a small number of water sources and seasonal and daily variability of sources is small. For urban areas, with high variability and multiple water sources, it does not seem feasible.

None of this existing research provides quantitative measures of water collection times in Kibera and Nyalenda.

GPS measurement: GPS has been used for tracking a wide array of activities and movements, including busses in a transportation system [1], the movement of livestock [14], flight patterns of albatross [18], pigeons [2], and city pedestrians [16]. GPS has also been used to survey water and locate water points for both livestock [12] and humans [11][17], but not as far as we are aware to map and document household water collection.

We use GPS in approximately the same way as this previous tracking research, to measure water collection times, distances and routes, reporting on the successes and difficulties of its use in this context.

3. RESEARCH SITES

Informal settlements, or slums, in Kenya and much of sub-Saharan Africa suffer several problems of water and sanitation. These settlements arose from the historic rural – urban migration of the last 50 years in which a large part of rural populations have moved to cities in search of jobs and a better life. Services have not kept up with the unprecedented growth of urban areas. As a result both urban utilities and consumers face problems, but of two different types.

Utilities are unable to collect payments for many legal water connections and categorize the majority of their water as 'unaccounted' because it is either withdrawn illegally or lost to leaks and breakages. Utilities' ability to invest in expanded water supply is therefore constrained.

Households, on the other hand, have to seek water where it is available, often from illicit water traders who sell it by the jerry can (20 liters). This water may be expensive, particularly in the

season of shortage, and its availability is uncertain. There is limited storage capacity in the system, partly because it is illicit. Seasonal shortages may lead to rationing by the utility and there may be other shortages as particular sources run out, and water 'cartels' restrict supplies.

We studied water collection in two informal settlements in Kenya, Kibera in the capital Nairobi and Nyalenda in Kisumu on the shores of Lake Victoria (Figure 1).

Kibera in Nairobi is an iconic slum of 170,000 people in the industrial area of Nairobi. It was founded as a settlement at the end of World War II for Sudanese soldiers who had fought with the British Army. Like many recent settlements in Africa, it has suffered from limited government attention because the post-colonial government tried to restrain rural-urban migration by denying land and other rights to migrant communities. In the late 1990s, the government recognized that this policy was not effective, and threats of bulldozing the slum stopped. The fifty-year absence of land tenure rights, regular policing, and government services, however, contributed to the settlement's character as an ungoverned space. In some Nairobi settlements, like Mathari, organized crime has emerged in place of government.

We chose to contrast water collection conditions in Kibera with those in Nyalenda, Kisumu because the introduction of a 2005 water system in Nyalenda has been lauded as a model for water supply in African cities [7], and the water utility in Nairobi has been experimenting with the introduction of a system modeled on that of Nyalenda in several settlements in Nairobi [9]. Nyalenda is the largest informal settlement in Kisumu with a population of about 50,000.

Both Kibera and Nyalenda have been the subject of innovative water supply systems. In Kibera, an unsuccessful attempt was made to build an association of the existing, illegal water traders called Maji Bora Kibera (better water for Kibera). If it had worked, this system would have addressed the problem of the water utility through the payment of bills, legalization and upgrading of water pipe connections to traders. Water shortages,



Figure 1. Showing the location of informal settlements we studied – Kibera in Nairobi and Nyalenda in Kisumu.

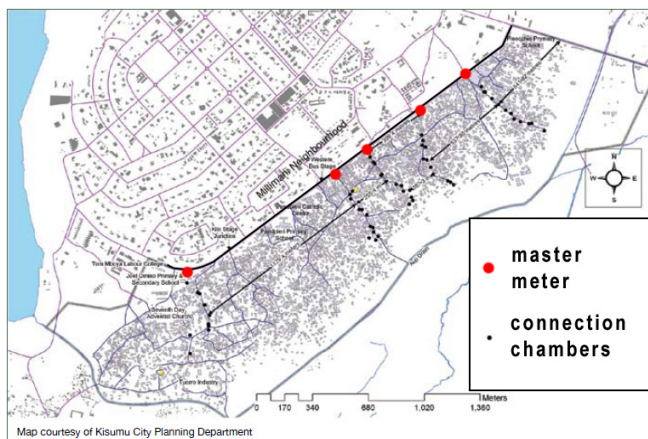


Figure 2. Delegated water management in Nyalenda. Map shows new pipes, master meters, and connection chambers built by utility and managed by community organizations.

high water prices, and uncertainty of supply, experienced by the households, would also have been addressed. But the innovation failed as a result of miscommunication between the water trader association and the utility and, subsequently, police action against organized crime and illegal water and electricity connections [9][4].

In Nyalenda, by contrast, the water supply innovation is believed to have been successful. In this case, the technology preceded new institutions. The system has been dubbed the ‘Delegated Management Model’ and is related to reforms in Mozambique, Malawi, Dhaka and Manila [7]. Prior to the introduction of this new system, Nyalenda was largely supplied by water traders who made illicit connections to a ‘trunk’, water main situated along the North side of the community. This system was comparable to that currently prevailing in Kibera.

The innovation introduced ‘spur’ mains bringing water from the same trunk main into the community. At intervals along these spur mains, concrete meter chambers were constructed (see Figure 2), with the idea that community organizations or water traders would take responsibility for the meters and connections to them. These meter chambers are made with a heavy, padlockable concrete lid to deter theft and interference, and have space for two dozen meters.

Here the story of the Nyalenda innovation gets interesting. The utility and their advisors seem not to have thought through to whom the management of the Delegated Management Model would be delegated. In practice, they were caught by surprise that the new system was strongly opposed by the water traders who were already selling water (albeit from the utility’s trunk main). Interviews with key informants in the community describe a year long program of sabotage, undertaken by community youth in return for payment. The 28 existing water traders held regular Sunday meetings, calling themselves *Waliongoja* (Kiswahili for those that waited), at which acts of theft of meters and pipes would be planned. Young men of the community were employed for K Sh 3-4,000 (\$30-40) per night for these acts of sabotage and traders from *Waliongoja* would go along to supervise.

In response, the utility organized a community meeting of about 1500 people, bringing in senior regional officials and providing a truck load of free soda. Then they built a concerted campaign

with flyers and a ‘task force’ of community volunteers to police each line coming into the community.

Subsequently, some of the young men who had undertaken sabotage were employed in the new water system, and the influence of the water traders comprising *Waliongoja* gradually declined. The utility achieved the goal of having its bills paid and reducing the quantity of water lost to illicit connections and leakage. This transition to a new Delegated Management Model provided the basis for the model of best practice water supply for slums in other parts of Kenya and Africa. We wanted to see if this new system provided more accessible water compared to the situation in Kibera, Nairobi.

4. TWO METHODS

The primary objective of this work is to obtain quantitative measures of water collection times. We initially intended to employ household interviews and surveys to obtain this data. The engineer among our authors joined the project accidentally with the off hand statement, “Why don’t you just use GPS? It’s cheap and specifically designed to measure this sort of thing.” This proved to be correct, but also naïve, a topic which we will address in the discussion in later sections.

Household interviews: A total of 50 households were surveyed, 10 of which also had GPS data collected. To situate these households in the general population of the two settlements, 40 households acted as controls, randomly selected from the communities. This random sample of 40 was chosen by walking several transects through the communities and choosing households at regular intervals along each transect. GPS households were told they would receive a small payment for their participation in the study, and were given K Sh 500 (\$6.70) at the end of the study period. Control households did not receive payment.

The households selected for GPS coverage were not random. In both Kibera and Nyalenda, we chose households known to the program staff of an NGO working in the two settlements, KWAHO (Kenya Water for Health Organization). This provided a basic level of cooperation and mutual trust. We did not know what security and privacy questions might arise for households. This sample was biased toward households concerned about water questions. Many of these households had been involved in activism around water. Some in Kibera were involved with a women’s water committee, and most in both communities had some contact with KWAHO’s solar disinfection of water campaign.

Research assistants, fluent in Kiswahili and Luo, interviewed members of the household, generally the woman collecting water, to explore a range of questions: water storage facilities of the household; where and when they travelled to get water, in the last two days, and who went; how long it took and much they paid for the water; whether they were short of water in the last week; what household activities took the most time; and a series of questions about livelihoods, income and rent.

GPS: The initial plan was to buy GPS units, attach them to the water collection cans of households, and obtain near perfect measurements of the routes and travel times involved in water collection. Data was collected for ten days at each of twenty households, ten in Kibera and ten in Nyalenda.

The households were not paid for participating in surveys, but the GPS households were promised a small gift for agreeing to take care of the units. In practice, they were given K Sh 500 after the experiment.

The ideal GPS unit would be small, inexpensive, and indestructible; provide data in a standard format; have long battery life; run unattended; and provide simple data download. Of course it's not possible to have everything. We purchased a few commercially available units that best matched our requirements, and tested these models against our needs. After testing we bought a batch of 10 units of the Holux M-1000C, which costs US\$69, has battery life of 20 hours, has a swappable rechargeable battery, has only an on/off switch for external interface, and records data to an internal memory chip. Data is retrieved using custom software and a USB connection.

We were initially concerned with making the process as simple as possible for the families, so we obtained GPS units which could simply remain on permanently, and required no direct manipulation by the women collecting water. In practice, the measured data was significantly noisier than we expected. Thus after two days, we decided to train the women to turn the units on when they left home to collect water, and off again upon returning home. A research assistant downloaded the data and replaced the batteries every one or two days.

We encased units in plastic bags to protect them from water, and attached them to the side of one water collection jerry can in each household, as shown in Figure 3. In Nyalenda we changed to having the women carry the unit in a pocket when they went to collect water (turning it on and off at the beginning and end of each trip). With this change we obtained info about many more water collection trips, perhaps because the GPS unit was no longer restricted to one jerry can.

5. RESULTS ABOUT WATER

Interview data: We carried out interviews with 50 households in each community, 10 whose water collection we had tracked with GPS units, and 40 control households selected randomly from the same settlements. Interviews with these households provided estimates of the total time in minutes per day for collecting water. This is the sum of times reported for all people collecting water, usually the woman of the household, sometimes helped by one other person, averaged over two days of reports.



Figure 3. GPS unit attached to jerry can. Study participant is carrying jerry can of water weighing 20kg from a vendor's tap to her home.

Table 1 provides a summary of the data collected. Several preliminary conclusions can be drawn from this data. Water collection times in both communities are highly variable. Collection times in Nyalenda are somewhat less than those in Kibera. This is to be expected because spur pipes and Delegated Meter Management had been introduced to improve water supply in Nyalenda, but not in Kibera. We caution against assuming this is causal and repeatable, since we did not collect pre-condition data in Nyalenda, but at least it matches expectations and shows promise.

Table 1. Water collection times from interviews.

Household	Water collection times (minutes/day)	
	Kibera	Nyalenda
GPS households	105 +/-95	45 +/-27
Control households	64 +/-47	28 +/-18

In both settlements, GPS households estimated they spent more time collecting water than the control households. This also is to be expected because these households were sufficiently concerned about water questions to have contact with the NGO Kenya Water for Health Organization. This relationship is important because it means that our GPS data is likely to be an overestimate of actual average collection times across the entire community.

GPS vs. Interview: For ten households in each community we used GPS to monitor the time, distance, and route of water collection. This data was compared to the interview data collected from the same households. In Kibera we measured few routes per day with GPS partly because narrow lanes generated much noise. In Nyalenda we occasionally had more than ten routes, for households who made many trips to collect water. Figure 4 shows routes taken by two households collecting water in Nyalenda.

Table 2 provides the interview and GPS data collected. The interview data shown is all available quantitative information from the interviews. The GPS and interview data was not necessarily from the same day. Since the GPS data contains thousands of data points along hundreds of routes, the reported quantitative data was averaged across all available days of information on a per household basis. Note that the GPS data is reported on a per-trip basis, rather than as daily totals.

The GPS data confirm the interview data in showing that Nyalenda has shorter water collection times than Kibera. In addition it is interesting to note that the water collection times are relatively short in both communities, less than 10 minutes on average. This contrasts with our expectations that women were spending many hours per day collecting water. Apparently they have access to water points relatively close to home.

Table 2. Daily water collection times and number of trips reported in surveys of GPS households are reported above. Below are average water collection times per trip found via GPS.

	Kibera										Avg	Nyalenda										Avg
	01	02	03	04	05	06	07	08	09	10		01	02	03	04	05	06	07	08	09	10	
Number of trips yesterday	3	4	8	6	4	2	4	4	7	3	4.5	1	13	1	5	8	n/a	n/a	32	1	6	8.4
Minutes collecting yesterday	25	300	20	240	90	30	20	60	180	60	102.5	10	20	5	30	40	n/a	n/a	120	7	30	32.8
Number of trips prior day	2	4	3	8	6	7	6	3	7	1	4.7	1	3	10	5	4	6	5	39	5	0	7.8
Minutes collecting prior day	30	300	25	240	60	60	30	60	180	30	101.5	45	25	45	60	40	30	60	120	25	30	48.0
GPS minutes/trip	11.5	13.5	7.0	12.0		8.5	7.5	8.5	7.0	14.0	9.9	13.2	9.7	8.5	6.9	4.7	7.4	n/a	7.6	4.0	7.0	7.7

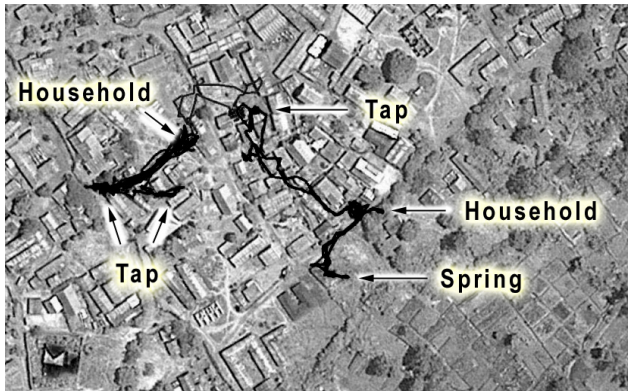


Figure 4. GPS tracks for two households. One household collects water from two different water vendor taps. The other household sometimes collects from a spring.

However, we have consistently been told by women that they frequently must spend a long time obtaining water. We hypothesize that some households in some areas and on some days spend a great deal of time queuing and collecting water. We have not yet sampled this condition in our GPS data.

In order to investigate further the differences between interview and GPS data, we converted the interview data to a per-trip basis by dividing the reported daily totals by the number of reported trips. We plot the household data for all households in Nyalenda

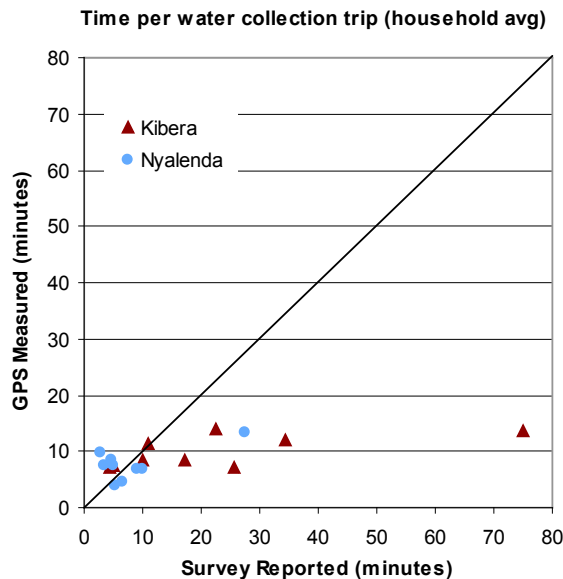


Figure 5. Discrepancy between interview and GPS estimates of collection times. Participant recall of water collection times, during interviews, suggested longer trips, particularly in the case of Kibera, than were recorded by the GPS unit

and Kibera, shown in Figure 5. Notice that as with the aggregate information reported in the tables, it is visually apparent that collection times are shorter for the households in Nyalenda. More striking is that the reported water collection times are much longer than the measured water collection times, especially in Kibera. If the two sources of information agreed, then all data points would lie along the diagonal line.

We are confident that the GPS data represents the true roundtrip travel time, from leaving the house, until returning. There are several possible explanations. The first is that women are reporting time spent on water related activities that is not strictly part of the collection travel time, and therefore does not show up in the GPS data. Another explanation is that women sometimes grossly overestimate the amount of time spent collecting water, when asked to recall what they were doing. Either of these has ramifications for how we should interpret the quantitative data in nearly all water collection research to date, since it has frequently relied on recall based interviews, which appear to inaccurately report collection times.

Distance: GPS data also provided us with estimated distances of travel. We had attempted to collect this information from interviews as well, but our research assistants reported that women were reluctant to even guess, having no idea of the distances traveled.

Figure 6 shows distance vs. time for all round trip routes we observed in our collected data. It has not been aggregated per household, and thus there are many more datapoints available. When analyzing the data we observed that many households used the same one or two water points repeatedly, so many datapoints share a common route distance, but of course the time required for collection might vary from trip to trip. As with collection time, we see that the majority of trips in Nyalenda are of shorter distance than trips in Kibera. We also see that the vast majority of trips in both communities are less than 10 minutes over a distance of less than 400 meters. While this is not nearly as convenient as an in-home tap, it is substantially different from walking for hours per day over many kilometers to collect water.

There were two datapoints in Kibera that were clear outliers from the rest of the data, so we investigated more carefully. In both cases the data really was outlier data, and we discuss both cases later in the paper.

6. DISCUSSION

We employed two different methods for measuring time spent collecting water. Following the conventions of many social sciences, we interviewed people. Following the convention of engineers, we used technology to measure the time and route taken. A priori we assumed that interviews would be better for

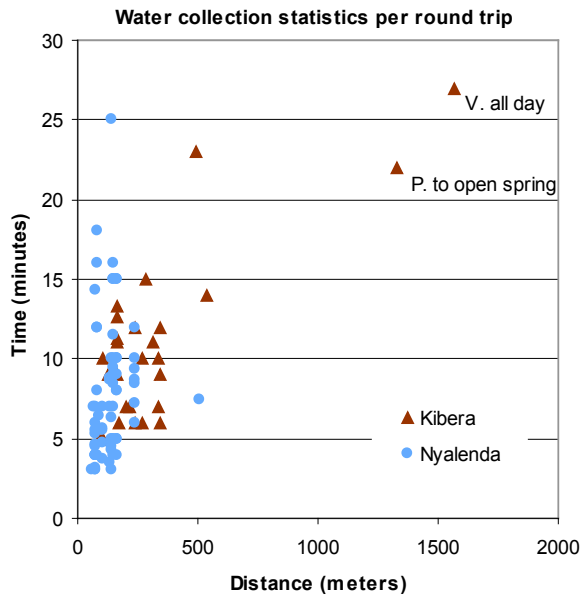


Figure 6. Showing time and distance per trip. The distance estimates would have been difficult to obtain without GPS.

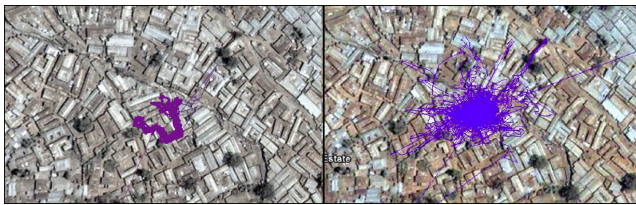


Figure 7. Noisy GPS readings are shown on the right. Note that the noise has magnitude larger than the track distance we were trying to record, shown on the left.

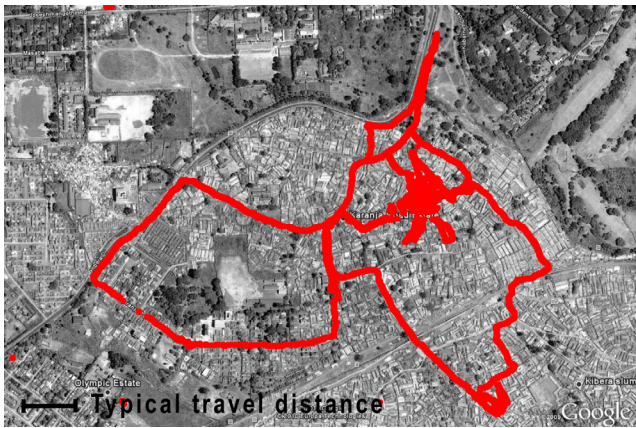


Figure 8. Routes of one study participant taking jerry can with attached GPS unit on distant journey, not just collecting water.

capturing a qualitative understanding of people’s behavior, but would be of low reliability with regard to numerical data. We also assumed that technological measurements would be great for obtaining vast quantities of precise quantitative data, but would not lead to any new qualitative understanding of behavior. These assumptions turned out to be wrong. The GPS data would have

been near useless without the understanding that came from interviewing people. Similarly, the interviews missed important qualitative behaviors that were revealed only because we obtained the quantitative data.

Tin roofs: The first difficulty we encountered was excessively noisy data measured by the GPS unit. One expects datapoints with error of less than 10m. On looking at our tracks from the first couple days of captured data, we found what appeared to be a random cloud of points extending for more than 100m. Figure 7 compares one of these data tracks to an ideal track that we expected to obtain. We hypothesize that this was caused by the jerry can that the GPS unit was attached to being stored indoors under a tin roof for most of the time it was not actively being carried to collect water. In order to reduce the amount of noise, we trained the women collecting water to turn the units on when they left home, and off when they returned. This substantially reduced the number of outlier data points, and made the data usable. Nevertheless a substantial number of outlier measurements remain in the data.

One trip per day: We had hoped to use GPS to measure average time spent collecting water per day. In Kibera, for most households our data provides precise time and distance for one or two trips per day, but does not reliably indicate the number of trips taken. Had we not had interview data indicating the number of trips taken per day to correlate with our technological measurements, we would not have been able to estimate the desired value at all.

Numerical data is subjective: We intended to use GPS with a large number of households, reasoning that it would be easier and faster to aggregate the objective numerical data coming from the GPS units, than it was to understand and process the more subjective interview and survey data. This turned out to be more difficult than we anticipated. The outliers and noise in the raw measurements could certainly have been dealt with automatically since filtering noise in time series data is a staple of engineering work. However, the behavior of the users was not sufficiently consistent to automate the process of interpreting and aggregating the data. Some used the instrumented jerry can for all trips, and some used it for only one trip per day. We also observed that in some cases the GPS did not pickup or was not turned on until halfway to a water point. Some users walked 5 minutes to a water point, stayed there for 2 hours, and then walked 5 minutes home. Should that be counted as 10 minutes to collect water, or 2 hours? Without further field investigation we could not reliably distinguish queuing time from other tasks.

Interpreting the data required all authors to sit together for long hours and make educated guesses about probable water routes. Plausible tracks were separated from noise by speed. Noise tracks often shift rapidly, far faster than walking speed. Plausible water collection routes also follow tracks and alleys between buildings shown on satellite imagery. And it is often possible to identify water tanks in the satellite photos. Even this would have been difficult if one of the authors had not previously walked the physical route with the women as they performed their routine. As such, the precise numerical data is indeed precise, but it is also a function of a lot of qualitative estimation. In order to encourage caution in the treatment of the data, we have left out error bars, standard deviations, and statistical significance measures, which might cause some readers to attribute inappropriate precision to the GPS information.

Routes that should be excluded: One woman recorded a route an order of magnitude longer than other families, apparently walking more than a kilometer and taking several hours to collect water (marked as “V. all day” in Figure6). Figure8 shows her route compared to a typical travel distance. The data was very clean, and we might have been tempted to include this in our average estimates, however the implausible route made us suspicious. We asked one of our field assistants to investigate, and after a couple attempts to understand, at least two stories emerged. This participant may have been concerned to avoid theft of the GPS unit or may have included trips unconnected with water to accentuate water collection time (perhaps expecting greater payment).

Qualitative findings: We would not have expected the GPS data to provide any new qualitative understanding of their behaviors. Nevertheless, we discovered one long GPS trace travelling some distance out of the community. This route turned out, when one author walked with the woman water collector, to lead to a natural spring that was not previously known to us or to the NGO KWAHO. The spring was further from her place of business as a vegetable seller than her other water points, but it was free (marked ‘P. to open spring’ in Figure6) and not subject to the two jerry can per day limit at the school that provided a closer source. In addition, we observed that this spring is at the center of a depression used for open defecation. Water from this source was being used to wash vegetables for sale and thus provided an obvious route of contamination. We were surprised that the numerical data revealed qualitative understanding that was not available from our ethnographic interviews.

7. CONCLUSION

We set out to obtain quantitative data for water collection times of women in two informal communities in Kenya, Nyalenda and Kibera. Water collection work constrains women’s livelihoods, education and leisure. Less time spent collecting water could allow an increase in preferred activities

We measured this data using both interviews and GPS tracking. We believe that this paper is the first to report this information in these communities. In addition, the introduction of GPS tracking allowed us to obtain distances travelled, information that is not normally available from interviews. Importantly, the time and distance data gathered provides some support for the hypothesis that the new water delivery system in Nyalenda is advantageous not only to the water company, but also to women living in the community. The utility loses less water to illicit withdrawals and leaks, and its bills appear to be paid. Households have water sources that are believed safe. They continue to use open water sources, wells and springs, for laundry and house cleaning.

Both GPS and interview data show that water collection times in Nyalenda are less than in Kibera. This probably reflects the introduction of delegated water management in Nyalenda. We do not, however, have data before the introduction of the new system, and there are significant differences between the two communities. We do not, therefore, think this is conclusive evidence that the delegated management system of water distribution reduces the time spent collecting water.

GPS data indicated water collection times and distances were substantially shorter than expected from interview data. It is possible that when asked to recall, women overestimate water collection time. It is possible that the difficulties and labor of

water collection, carrying 44lb jerry cans, contributes to the perception of long duration. We are attempting to explore this question further. If this reporting difference arises in other communities, then care should be taken when interpreting quantitative estimates of water collection time derived from personal recall. In the two communities reported here, the more precise GPS data indicates many short trips under 10 minutes. Further reductions in water collection time are thus not a matter of getting a single water point into the community, but would likely require household connections.

We had originally expected technological measurement to provide accurate quantitative data, and interviews to provide qualitative understanding. In practice we found the methods to be complimentary, with technology providing access to qualitative insights, and interviews being necessary to aggregate the quantitative information. We were surprised not that the methods of different fields have their own disparate strengths, but that strengths were far more coupled than expected.

8. ACKNOWLEDGEMENTS

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