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# AN ASSESSMENT OF WATER SUPPLY AND SANITATION IN TSUMKWE, NAMIBIA

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# **Abstract**

The purpose of this report was to assess the current state of the water supply and sanitation systems in the settlement of Tsumkwe, Namibia. Data collected during fieldwork resulted in a detailed map of the location and condition of these systems, which was not previously available. Information gathered from interviews revealed Tsumkwe residents' perceptions. We have analyzed and compiled this data into a list of recommendations for the DRFN regarding a possible development plan to improve water supply and sanitation.

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# List of Abbreviations

DRFN	Desert Research Foundation of Namibia
HDPE	High Density Polyethylene
IWRM	Integrated Water Resource Management
kVA	kilovolt-ampere
MET	Ministry of Environment and Tourism
MHA	Ministry of Home Affairs
NamWater	Namibia Water Corporation, Ltd.
NGO	Non-governmental organization
uPVC	unplasticized polyvinyl chloride
WDM	Water Demand Management
WHO	World Health Organization
WIMSA	Working Group of Indigenous Minorities in Southern Africa
WPI	Worcester Polytechnic Institute

# Executive Summary

Tsumkwe is an isolated settlement in the northeastern part of the Otjozondjupa region of Namibia. The nearest town is Grootfontein, a four hour drive from the settlement along mostly gravel roads. The water in Tsumkwe is managed by three organizations: NamWater, the Regional Council, and the Local Government. NamWater manages the boreholes and water tower for the settlement, and sells water in bulk to the Regional Council. The Local Government is responsible for collecting water tariffs from residents and paying the Regional Council. Each of these organizations has at least one employee in Tsumkwe.

We were asked to inventory and document the conditions of the existing water and sanitation systems in Tsumkwe. Furthermore, we needed to study how these systems were used by the residents and learn how they cope with the problems they face when using these systems. In addition, we were to develop a list of recommendations for stakeholders to help the settlement of Tsumkwe improve its management systems and consequently the service it provides to residents.

Our team spent two weeks conducting fieldwork in Tsumkwe. We first interviewed local authorities and prominent community members to familiarize ourselves with the situation in the community. We used a global positioning system (GPS) to mark the location of all water and sanitation systems we observed above ground, and we spoke with the local authorities to learn about the water pipes installed below ground. In addition, we attempted to assess the water demand of the settlement by reviewing the government's financial records and recording the amount of water consumed during the day and at night. The data we collected from these studies proved inconclusive, but gave us insight into the management of the water systems. Finally, we conducted 64 surveys with residents to learn about their perceptions of the water and sanitation issues in the settlement and to help us prioritize our recommendations.

Our research determined that much of the water infrastructure in Tsumkwe is in a state of disrepair because of the poor communications between the three organizations that manage the abstraction and distribution scheme. Only a small fraction of the cost of supplying water is recovered, and the Regional Council must pay the difference for what the Local Government cannot recoup from consumers. NamWater has installed borehole pumps that exceed its own suggested abstraction rates. At the time of our field work, most of the septic tanks had not been emptied in four months and were overflowing because the settlement's only septic truck was awaiting repairs in Grootfontein. We also discovered that a majority of Tsumkwe's residents defecate in the bush, a practice that has significantly increased because many of the settlement's septic tanks are overflowing. We observed that a few people were reluctant to use the dry toilets and that some locations refused to have dry toilets installed.

Stakeholders in Tsumkwe should take immediate and decisive action in order to prevent the water supply, distribution, and sanitation situation from deteriorating further. Our prioritized recommendations are as follows:

### **1. Repair the septic truck**

The first priority is an immediate repair of the septic truck to ensure that current sewage pumping demands can be met. This is the most pressing issue as raw sewage is presenting health risks to the community.

### **2. Install a backup generator**

NamWater needs to install a functioning backup engine on BH 16561, the borehole located next to the water tower, in order to provide water in case a catastrophic power failure should occur. The current backup is a diesel engine that will typically need to be run when the settlement generator has exhausted its supply of diesel. A solar generator similar to those found in the surrounding villages would be appropriate for Tsumkwe.

### **3. Keep consistent and complete records**

NamWater and the Local Government need to improve and streamline record keeping. Records should be kept to determine whether the current boreholes are consistently being over-

abstracted or if the abstraction rates are sustainable. The Local Government must document how much water is actually distributed to the users, and how much is lost to leakage. Additionally, the Local Government should conduct an accurate census of human and animal population in Tsumkwe in order to approximately determine the overall water demand. Understanding the potential overall demand versus how much water is sold by NamWater will assist the Local Government in determining how much water is lost to leakage. Moreover, an analysis of the residents' income should be conducted along with the census so that tariffs can be set appropriately.

#### **4. Locate water lines**

The settlement should identify the exact location of water and sewage pipes. A complete survey of the water lines, including informal connections, should be conducted. The precise locations of all lines can then be marked with surface markers to facilitate future repairs to the water lines.

#### **5. Identify and minimize leakages**

The next step for NamWater and the Local Government is to determine where leaks occur and then repair these leakages. For NamWater, this will be namely in fixing leaks in the elevated water reservoir. For the Local Government, this will include replacing and repairing leaky or broken taps and pipes. The oxidation pond should also be repaired, clearly marked, fenced off and locked.

#### **6. Educate the community**

Tsumkwe's residents should be educated that water is a limited resource, and would have to be made aware of how they can store and conserve water. Additionally, the community needs to be educated on alternative sanitation methods, such as the use of Otji toilets and human waste as fertilizer. These measures would ensure that the community is invested in the future of Tsumkwe and the overall well-being of the settlement and the appropriate use of its resources.

#### **7. Enforce cost recovery**

Once the above steps are implemented, the Local Government may begin to enforce cost recovery methods. An equitable tariff should be implemented whereby every resident pays for water. However, low income households should pay proportionally less than higher income households.

Ideally, the Local Government should be able to pay NamWater for all water costs and still profit from the tariff it sets so that it can fund other projects, such as infrastructure maintenance and upgrades.

## **8. Evaluate water demand and increase capacity**

When leakage is fixed and the Local Government enforces cost recovery, NamWater and the Local Government should collaborate to develop a projection of future water demand based on population trends and current water in an effort to determine if additional boreholes are necessary to meet future demand. Additionally, NamWater and the Local Government should work together to determine an appropriate storage capacity as the current capacity of 50 m<sup>3</sup> is unacceptable.

Once these major issues are resolved, another analysis may be conducted to locate smaller-scale problems. It is important to note that the Otjozonzupa Regional Council should allocate the necessary funds to Tsumkwe in order to facilitate these changes. There should also be a system that ensures these funds are spent on appropriate projects (e.g. money allocated for water infrastructure improvement should be spent on replacing and repairing these systems, not installing new septic lines).

To assist future projects, our team has presented the DRFN with an electronic map of the above-ground water and sanitation infrastructure in Tsumkwe. It is in a format that is compatible with a number of mapping programs.

# Chapter 1: Introduction

The scarcity of water is one of the most significant issues that policy makers face in developing countries. The World Health Organization (WHO) estimates that 1.1 billion people do not have access to improved water supply sources, 85% of whom live in rural areas. Namibia is one of the most sparsely populated countries in the world with 67% of the population living in rural areas. In addition, Namibia is the driest country in sub-Saharan Africa, and must obtain most of its water from underground aquifers (Food and Agriculture Organization, 2010). It is therefore paramount for Namibia's policy makers to understand key issues faced by arid and rural countries before developing policies. Issues such as water quality, tariff structure and cost recovery, as well as appropriate sanitation and waste management are all interrelated and must be considered together in order to provide a sustainable society with healthy living conditions.

The mismanagement of water can result in a host of issues for ordinary people. There are a multitude of diseases that can be aggravated by carelessly managed water resources. Diseases such as malaria require waterborne vectors; pathogens and harmful chemicals can enter the human body through contaminated drinking water as well (WHO, 2008). Almost one tenth of the world's disease could be prevented with improved access to clean water, improved sanitation and hygiene, and improved water management as a whole (WHO, 2010b).

Ground contamination poses serious risks to the health of a population. Pollutants can seep into ground sources that provide water to a community. In addition, population growth can significantly strain water resources. If infrastructure does not expand to meet increased demand, the population may be left without adequate supplies or sufficient funds to expand the water infrastructure.

It is difficult for developing countries to recover the money invested in the installation and

maintenance of water infrastructure. In Namibia, much of the current water infrastructure was built during colonial rule, and after independence in 1990 the government had the advantage of not needing to build new systems. However, the country soon realized that it needed to find funding to maintain and improve the water systems. Namibia has elected to commercialize water in order to improve its cost recovery, but this has sometimes resulted in negative consequences for the end-users, and in some areas, costs are still not fully recovered.

The Namibian government has attempted to mitigate problems in the water sector by devising various water policies that outline everything from the proper testing of water supplies to the investigation into new government structures to improve water management. These policies should provide a framework from which water laws and regulations can follow. Unfortunately, there are numerous locations in Namibia where the ideas proposed in water policies are not properly executed and the appropriate management of water seems almost impossible.

Tsumkwe, a remote settlement area in northeastern Namibia, is one such example. The national challenges Namibia faces in managing its water supply are exacerbated in Tsumkwe because it is so isolated. It is time consuming and expensive for the settlement to receive supplies from Grootfontein, the nearest large town, which is more than 300 km away along predominantly unpaved roads. Sometimes, supplies must be shipped from even more distant places like Rundu or Windhoek. In addition, the settlement's small population makes it appear as a low priority to outside organizations. This report investigates water, sanitation and waste management in Tsumkwe, and proposes recommendations that may help improve the state of affairs in the settlement.

# Chapter 2: Background Information

## 2.1 The Tsumkwe settlement

Tsumkwe is a small, isolated settlement located in the northeastern corner of the Otjozondjupa Region, as shown in Figure 2.1. The nearest densely populated area is the city of Grootfontein, which is a four-hour drive away and separated from Tsumkwe by 57 kilometers of paved roads and 220 kilometers of gravel roads.

The NamPower electrical grid does not extend out to Tsumkwe, so electricity is supplied by a diesel generator. Due to limited availability of fuel, the generator only runs from 05:00 to 14:00 and again from 17:00 to 22:00. This generator powers the water supply system. Consequently, water is not available during the afternoon or the night either.



**Figure 2.1:** Tsumkwe is located in the northeastern part of the Otjozondjupa Region  
(courtesy of *Wikimedia Commons*)

The ground is extremely flat in the Tsumkwe District (shown in yellow in Figure 2.1), with a layer of granite close to the surface that prevents water from seeping deep into the ground.



During the rainy months, the low areas flood with standing water. The Tsumkwe District receives an average rainfall of roughly 450 mm between October and April and receives almost no rainfall between May and September (Simmons, Barnes, Jarvis, & Robertson, 1999).

### **2.1.1 Local authorities**

As stated above, Tsumkwe (the settlement) is in the Tsumkwe District (shaded yellow in Figure 2.1) of the Otjozondjupa Region (shaded darker gray in Figure 2.1) of Namibia. This region is governed by the Otjozondjupa Regional Council, which is headquartered in Otjiwarongo. Hon. Moses !Coma represents the Tsumkwe District in the Regional Council, and is a resident of the settlement. Day-to-day administration of the Tsumkwe settlement is the responsibility of the Ministry of Regional and Local Government and Housing, typically referred to as simply “Local Government.” This office consists of three members: Mashesho Likoro, the head of the Local Government, an assistant and an accountant sent by the Regional Council to ensure that records are properly maintained.

### **2.1.2 Population and demographics**

The exact population of Tsumkwe\* is unknown because census data is neither recent nor accurate. An official census conducted by the National Planning Commission in 2001 indicates 700-1000 inhabitants, but local school administrators indicate that they currently have 590 pupils in total. Thus, 1000 people is obviously too low. Tsumkwe locals suggest a population of 2000-3000, which is to us a more plausible number.

The people of Tsumkwe are predominantly San of the Jul’hoansi tribe but many of the residents come from all over Namibia, many with their own language and culture. The most commonly spoken language is Afrikaans, but there are a large number of people who speak only Jul’hoan, the local San language. There are also Damara-, Oshiwambo- and Otjiherero-speaking minorities. According to DRFN field investigator Ian Cook, approximately 200 people speak English fluently, and many more speak only a few words.

A number of houses have a clear European influence, but most homesteads are built in the

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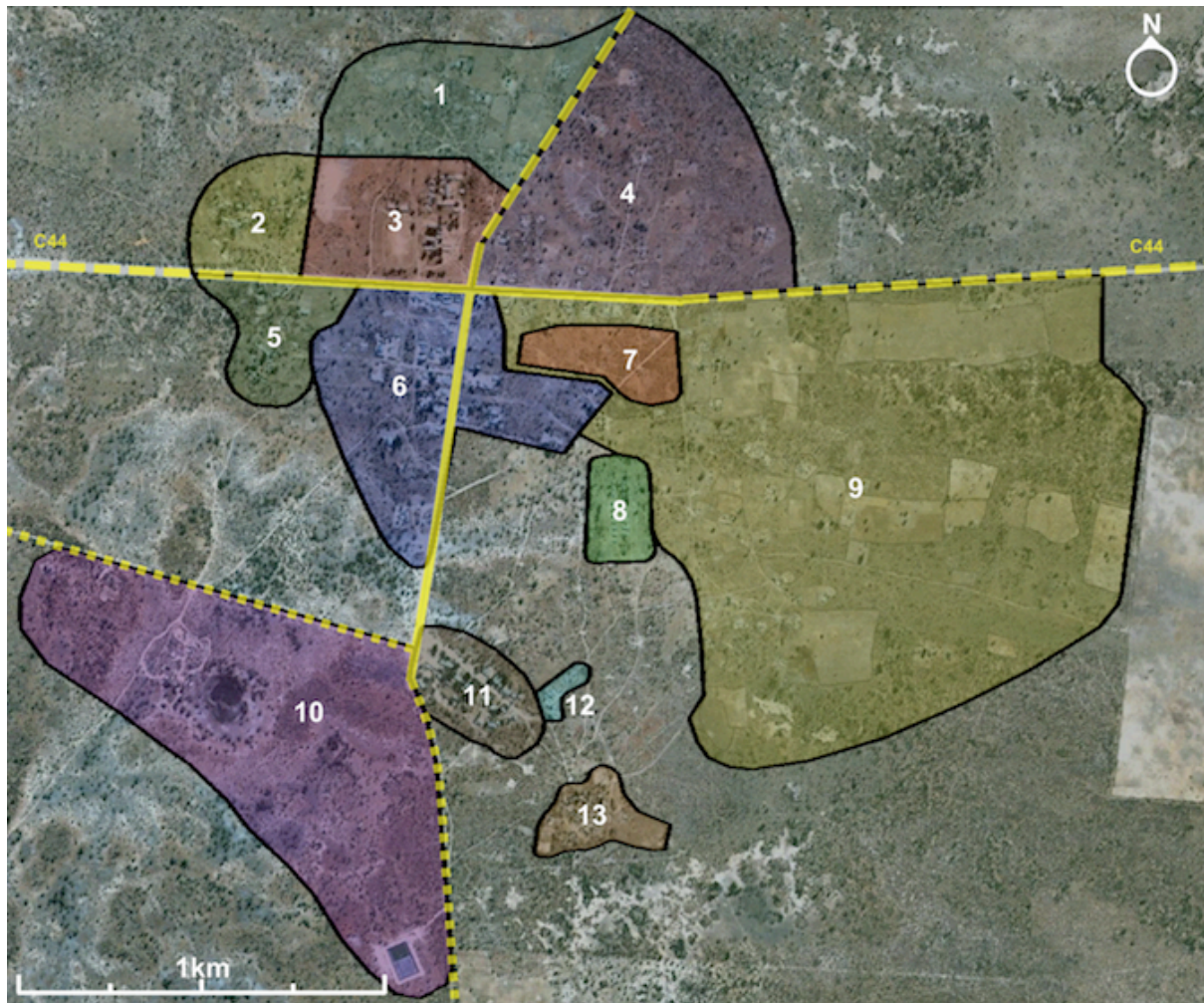
\*In the rest of this report, Tsumkwe will refer to the declared settlement area only, unless specified otherwise.

traditional San or Owambo styles. These traditional homesteads typically consist of a gated area in which there are several huts. Most homesteads are occupied by large extended families of 10 to 20 members.

Within Tsumkwe there are several distinct neighborhoods, referred to colloquially as “locations.” The names of some locations are unofficial but nevertheless widely recognized by the community. The local authorities in Tsumkwe plan to assign official names to each location in the future. Figure 2.2 shows these locations.

The Damara, Gauteng, and ||haras locations each contain roughly seven to thirteen households. These locations are populated primarily by San who live with large extended families. The Seven Houses Location originally contained seven houses that the government built for the San traditional authorities. However, the area now holds nineteen houses, and is populated by a diverse group of people. North, northeast, and central Tsumkwe also contain a wide variety of ethnicities and household types, although central Tsumkwe contains mostly businesses and very few households. The Local Government Location contains all of the Local Government and ministry offices, as well as a large number of homes. In general, the wealthier people of Tsumkwe live in this location. The Ministry of Environment and Tourism (MET) Housing is a cluster of houses that the MET provided for its employees. South Tsumkwe contains the mining camp, the Tsumkwe Lodge and the oxidation pond, which appears as a small green rectangle. Finally, Herero Location is home to immigrant farmers from Gam.

In May 2009, this group of farmers brought their cattle from Gam to Tsumkwe, illegally crossing a veterinary control fence and entering the Nyae Nyae Conservancy, in which livestock are forbidden. When the government learned about the situation, they confiscated the cattle (Shejavali, 2009). The situation is currently being disputed in court, and the farmers are waiting for a verdict. In the meantime, approximately 300 immigrants are squatting in Herero Location, often called by the derogatory name “Gura” which means “those who do not belong here” in Otjiherero. The Red Cross has supplied each household in Herero Location with tarps to waterproof and reinforce their shelters. This has proved to be controversial, since other people in Tsumkwe have never received help from the Red Cross despite living in similar conditions for their whole lives. The immigrants’ presence in Tsumkwe remains highly controversial, and many public organizations do not permit



**Figure 2.2:** The various locations of Tsumkwe are as follows:

- |                      |                                 |                          |
|----------------------|---------------------------------|--------------------------|
| 1. Tsumkwe North     | 6. Central Tsumkwe              | 10. Tsumkwe South        |
| 2. Damara Location   | 7. Herero Location              | 11. Local Govt. Location |
| 3. Schools           | 8. Sewe Huise<br>(Seven Houses) | 12. MET Housing          |
| 4. Tsumkwe Northeast | 9. Owambo Location              | 13.   haras              |
| 5. Gauteng Location  |                                 |                          |

their employees to discuss the issue (Cook, 2010).

### **2.1.3 Known social issues**

The San are known to be very difficult to work with on development projects. In Tsumkwe, many are apathetic to the conditions in which they live and remain skeptical of projects to improve the settlement. Many of them have become accustomed to receiving resources and aid for free from foreign organizations (Pfaffe, 2003).

## **2.2 Water supply policies in Namibia**

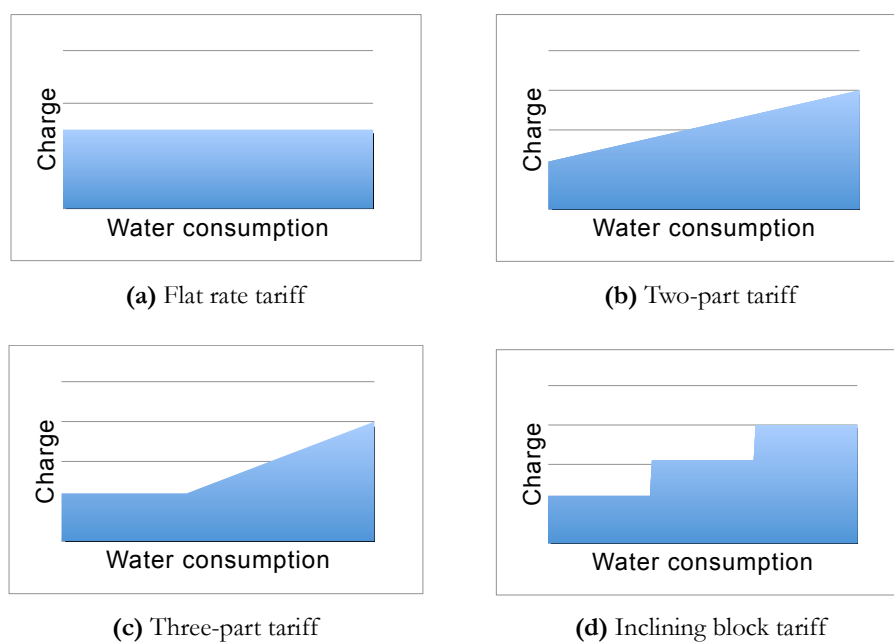
Since its establishment in 1997, the parastatal Namibia Water Corporation (NamWater) has been responsible for bulk water supply in Namibia (Namibia Water Corporation Act, 1997). NamWater recovers costs by collecting tariffs on all water supplied through its water schemes. As the bulk water supplier, NamWater deals directly with the Regional Councils, and they are responsible for recovering their own costs by charging consumers. NamWater's tariff is currently N\$6.75/m<sup>3</sup>, and the Otjozondjupa Regional Council's tariff consists of a basic charge of N\$60/month and a usage tariff of N\$9/m<sup>3</sup> to residential users and N\$12/m<sup>3</sup> to businesses and government institutions. The Regional Council charges a much higher tariff to subsidize the cost of water for those who are simply unable to afford it (Likoro, 2010).

## **2.3 Water Demand Management**

Water Demand Management (WDM) is an approach, popular in southern Africa, to using available water resources as efficiently as possible by changing the habits and water practices of people to limit the demand for water (McKenzie, Wegelin, & Meyer, 2003). WDM emphasizes the importance of water tariffs, leakages, and efficiency factors that must be considered when making water policy decisions.

Consumers must pay for water to ensure the continued maintenance water infrastructure. Without payment, the water systems will fall into disrepair, and the water supplier will require outside investments of capital to continue supplying water (McKenzie et al., 2003). Tariffs must make water affordable, but provide sufficient revenue to fund operations and ensure sustainability. Flat

rate tariffs, in which each consumer pays a fixed rate on the volume of water used, are commonly implemented because they are easy to administer. However, they do not provide users with any incentive to conserve water. Three common types of tariffs serve to decrease water demand while remaining affordable to the consumers: the two part tariff, the three part tariff, and the inclining block tariff. In all three systems the charge increases with water consumption, as shown in Figure 2.3. This provides an incentive to conserve water, but the rates at which prices increase must be set such that sudden, drastic reductions of water consumption are avoided (McKenzie et al., 2003).



**Figure 2.3:** Schematic water tariff structures designed to discourage wastage and subsidize low-volume consumption

In addition to setting tariffs appropriately, the water supplier must minimize water loss due to leakage. Some leakage is inevitable in any water distribution system, but nevertheless losses must be carefully monitored to ensure that they do not exceed acceptable limits (McKenzie et al., 2003). One of the most effective tools for measuring non-revenue water is night flow: the volume of water flowing through the system when most people are asleep and not drawing any water. Since water is not likely being drawn intentionally, the night flow represents the leakage losses. Night flow measurements are typically taken at short intervals between 02:00 and 04:00.

Lastly, numerous water infrastructure improvements can reduce demand for water with min-

imal effects on the consumers. Devices such as the self-closing tap in Figure 2.4 do not allow the consumer to waste excessive amounts of water by accidentally leaving a tap open. Aerators and low-flow shower heads also reduce flow of water from taps with little effect on the consumer (McKenzie et al., 2003).



**Figure 2.4:** This self-closing tap opens only when the button is depressed, preventing it from being left open and forgotten

While the concepts of WDM may seem very basic, the guidelines can improve cost recovery and reduce water consumption when tailored to a selected area. In January 2010, the IWRM Plan Joint Venture Namibia measured the actual water use in Tsumkwe (which stood at 197 L per capita per day) and estimated that applying WDM techniques in Tsumkwe could reduce water consumption by as much as 39% to only 120 L per capita per day (IWRM Plan Joint Venture Namibia no. 3, 2010). This estimate was made using a population projected from the growth in the 1990's.

## Chapter 3: Goals

The primary goal of this study was to evaluate the existing water supply, sanitation and waste management systems of Tsumkwe, Namibia. This allowed us to develop a list of recommendations for stakeholders designed to alleviate water and sanitation related problems in the settlement. Specifically, by directly engaging with the community, we have identified conditions that impact the local residents, and recommend improvements to the settlement's management of water resources in Chapter 7. Our objectives for this project were:

- Document the current conditions of the water supply, sanitation, and waste management systems in Tsumkwe
- Examine how residents cope with issues in the water supply, sanitation, and waste management systems
- Develop a list of recommendations for both government and non-government organizations that may offer improved water supply, sanitation and waste management facilities or practices to the residents of Tsumkwe.

We intended to map public and private water and sanitation systems and analyzed how effectively this infrastructure is used. This required us to work closely with the local authorities in Tsumkwe and to evaluate how well the local authorities understand the installed water and sanitation systems. In addition, we have examined the local authority's financial records to assess how successfully they recover costs and manage their water resources. Furthermore, we have compiled our data into a comprehensive and user-friendly form that will allow future teams to understand the habits, perceptions, and aspirations of Tsumkwe's residents.

In brief, the goal of this study was to motivate future water, sanitation and waste management projects in Tsumkwe by identifying challenges faced in these three sectors. We hope that the data we have collected will aid future teams who plan to address the infrastructural, societal and governmental issues underlying the water supply, sanitation and waste management problems.



# Chapter 4: Methodology

## 4.1 Documenting the current conditions

When we arrived in Tsumkwe, the Local Government did not have up-to-date maps or diagrams of the current structure of the water distribution system. We used the most recent maps (dated 1987) as a guide and began taking an inventory of all taps, water meters, storage tanks, pipes, toilets, septic tanks and other water supply or sanitation infrastructure in the settlement. One member of the group walked through each location inquiring about these items and recorded the latitude and longitude of each using the WGS 84 GPS standard. He meticulously tested and took notes on the condition of each. Every item in this inventory was also photographed to aid his memory while compiling notes.

In order to determine how effectively the costs of supplying water to Tsumkwe were being recovered, we obtained permission from the Local Government to look at the settlement's financial records, keeping any personal information strictly confidential.

Daily measurements of borehole meters are necessary to give a clear picture of the actual pumping capacity of Tsumkwe's water supply system. Tsumkwe has four functioning boreholes, each with an identification number assigned by NamWater. Two team members were each responsible for taking readings at two boreholes at the same time every day during our field work. Flow meter readings for BH 37746 and BH 32655 were taken at 09:00 and 09:05, respectively, while BH 32642 and BH 16561 were recorded at 09:30 and 10:00. This allowed us to obtain a daily record of the volume of water pumped. The generator's hours of operation were also recorded to obtain an accurate hourly abstraction rate. Daily pressure readings were also taken at each borehole with the exception of BH 16561, which does not have a pressure gauge.

Daily meter readings were taken at 10:05 from each of the two meters located at the outlet of

the NamWater tower to track the amount of water flowing into the town each day. The volume of water flowing from the tower after the generator had been turned off was recorded on four days to determine the average amount left in the reservoir when the pumps had stopped. Each meter and pressure gauge was read at five minute intervals from the time when the power was turned off until the water ran out. The time when all water had left the tank was also recorded with the final meter reading.

The most accurate way to measure the leakage of a system is by measuring the water flowing in the middle of the night when most people are asleep and therefore not drawing water. In Tsumkwe, however, there is no night flow because the water stops flowing at approximately 23:00 each night. Thus, we needed to make special arrangements to pump water into the tanks at night after the electricity to the rest of the settlement had been cut. In exchange for compensation for the amount of diesel used to pump the water necessary, we received permission to run the diesel generator from 00:30 to 02:00 to fill the water tower. Initial readings were taken from both flow and pressure meters and the tower's outlet valve was closed. At 02:00 the generator was turned off and the valve was opened. From 02:00 to 04:00 flow and pressure readings were taken at five minute intervals.

## **4.2 Examining how residents cope with water supply issues**

In order to fully understand the challenges faced by the residents of Tsumkwe, we had to conduct a series of interviews with local stakeholders to learn what they regarded as the main water and sanitation obstacles. We also administered a survey to determine how residents use water and how they perceive water and sanitation issues. A copy of the survey can be found in section A.1 of the Appendix. By using a combination of appointments during the work day and door-to-door interviews in the evening, we surveyed more than one fourth of the households in Tsumkwe.

Obtaining a random sample of the population is difficult in a remote settlement like Tsumkwe because some people can be suspicious of outsiders, especially foreigners. To avoid this suspicion, we did not dive right into personal interviews on the first day of field work. Instead, we focused our attention on interviewing Local Government officials and friends of Mr. Ian Cook, the DRFN's field investigator in Tsumkwe. After the local residents became accustomed to seeing us walking around gathering data, buying food from a street vendor, or going out to a shebeen, we began

administering our survey door-to-door. During the second week of field work, we typically arranged to have a translator for one location from 17:00 to about 18:30 and then spent the middle of the day conducting interviews at workplaces or in sparsely populated locations such as Owambo Location and Tsumkwe North.

Most people in Tsumkwe do not speak English very well, if at all. Consequently, it was necessary to bring a translator with us for door-to-door interviews. Mr. Cook made arrangements for translators in each location. During the second week of interviews, DRFN field facilitator Lucky !Ganeb joined us and was able to translate Afrikaans and Damara for us. This gave us more freedom with our schedule, allowing us to conduct interviews during the entire day in Owambo Location and the northern part of town, in which homesteads are farther apart from each other. It was still necessary, however to use a Ju|'hoan translator during some interviews.

We did not conduct any interviews with the residents of the Herero location for two reasons. The Herero immigrants are only temporary residents awaiting a pending court ruling, and we were unable to procure a translator that spoke Otjiherero. We also had difficulty reaching the employees of the Ministry of Environment and Tourism (MET), all of whom live in the housing provided by the MET in the southern end of town. We approached MET employees at their office and scheduled an interview, only to find nobody there at the arranged time. We also attempted multiple times to interview residents of the MET housing, but found only one willing participant.

# Chapter 5: Results and analysis

## 5.1 Inventory of systems

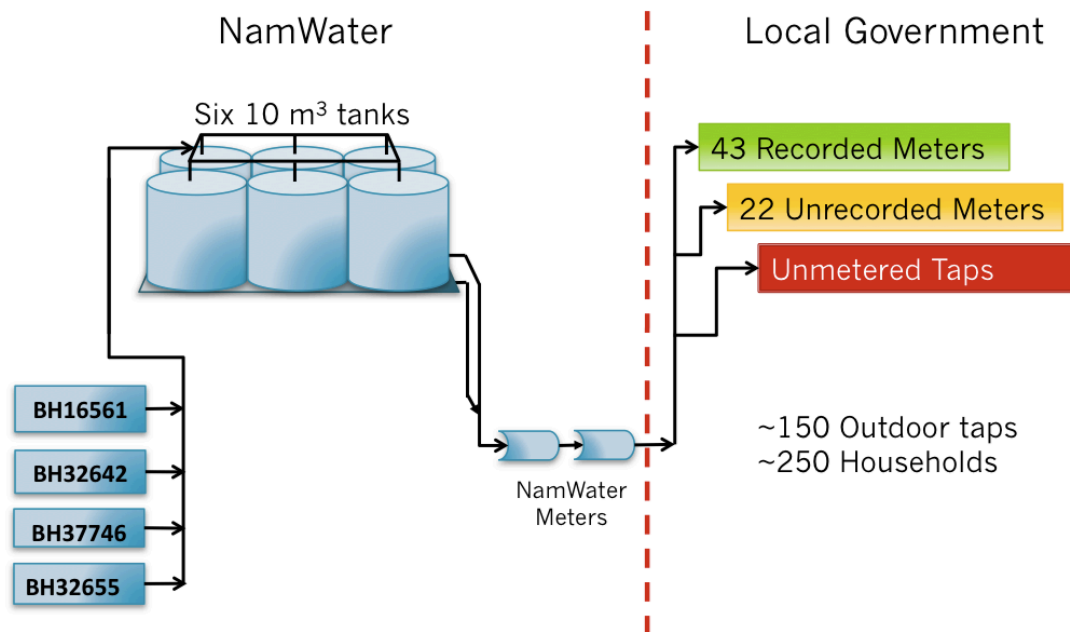
Much of the water and sanitation infrastructure in Tsumkwe appeared in a state of disrepair. In the past, plans had been drafted to perform the necessary repairs, but the municipality lacks the requisite funds and parts to carry them out. The technology used is in many cases outdated or unsuitable.

The water infrastructure can be divided into two parts: supply and distribution, as shown in Figure 5.1. Water is pumped from aquifers deep underground via four boreholes, and then stored in the elevated reservoir near the center of the settlement. Water then passes through a pair of water meters on the outlet of the reservoir. After this point, the water becomes the Regional Council's responsibility and is distributed to the consumers' taps, toilets and storage tanks.

### 5.1.1 Bulk water supply infrastructure

Bulk water supply in Tsumkwe is the responsibility of NamWater, which includes Tsumkwe's four boreholes (BH 32642, BH 16561, BH 37746, and BH 32655), an elevated water tower, and the underground pipes that connect the boreholes to the water tower. On the outlet of the water tower are two water meters that display the volume of water that has flowed out of the tanks. After the water has passed through these meters, it belongs to the Regional Council, which is billed by NamWater for the water supplied. Water distribution after this point is the responsibility of the Local Government and the Regional Council.

All boreholes are enclosed by metal cages, with boreholes BH 37746 and BH 32655 located on the west side of the main road inside stock-proof fences, while BH 16561 is located next to the elevated water tower inside a security fence. BH 32642 is located south of the water tower, and is not



**Figure 5.1:** Water is pumped from four boreholes into an elevated reservoir and then distributed to taps, toilets and personal storage tanks.

enclosed by any type of fence, although it does have a protective enclosure. In the event of a power failure, BH 16561 is supposed to run on a small diesel engine of its own. However, it is unclear if this engine is still operational because it was recently swapped with an older model from Mangetti Dune, a nearby village that depends solely on the diesel engine to abstract water. According to (NamWater, 2010), boreholes BH 32655, BH 37746, and BH 32842 operate with Grundfos SP5A-12 submersible pumps with a delivery capacity of  $5 \text{ m}^3/\text{h}$ , while BH 16561 has a Mono BP6H pump with a Monostroom pump head driven by a Lister ST 1 diesel engine with delivery capacity of  $6.5 \text{ m}^3/\text{h}$ . Each borehole is provided with electricity by a 100 kVA pole mounted transformer and is supposed to switch on automatically when the power comes on. Moreover, boreholes BH 32642 and BH 16561 have a 25A TP circuit breaker next to them.

According to NamWater, boreholes BH 37746 and BH 32655 should not be operated simultaneously due to their close proximity (T'jyahura, 2010). However, during our team's two week stay in Tsumkwe, all four boreholes were operated daily, with three of the four boreholes either over-abstracting or operating very close to the limit recommended by NamWater's Department of Geohydrology. Also, while each borehole is supposed to turn on automatically, poor electronic

equipment at boreholes BH 37746 and BH 16561 require them to be manually turned on as the surge in power often shorts the circuit. Borehole BH 37746 has not yet had an automatic power switch installed and must be turned on twice daily by the NamWater employee.

BH 16561 is equipped with a sensor that will shut off the borehole when the water level in the tower reaches a certain height. Although this sensor works, the water tank never fills up enough to trigger it. Additionally, since BH 16561 no longer has a working diesel engine, there would be no operational boreholes in Tsumkwe in the event of a catastrophic power failure.

According to (NamWater, 2010), a 480 m long, 50 mm diameter HDPE pipeline connects boreholes BH 32642 and BH 16561 with the elevated reservoir, while a 350 m long pipeline connects boreholes BH 32655 and BH 37746 (it is assumed that this is also a 50 mm HDPE pipe). These pipes are estimated to allow a maximum flow rate of 7.5 m<sup>3</sup>/h. No significant leaks or breaks in these pipes have been reported or observed by our team. However, it should be noted that there are no maps at either NamWater or the office of the Local Government showing where these underground pipes are located and no surface markers.

The water abstracted by each borehole is pumped to an elevated water reservoir, which provides water to the settlement via gravity feed. A 12 m steel tower supports six UPVC tanks, each with a 10 m<sup>3</sup> capacity. For the several years, the middle tank on the south side has leaked out of a hole in its side, shown in Figure 5.2. By comparing the volume of water abstracted from the aquifers to the volume sold by NamWater, we determined that each day after about 15 hours of pumping, 170 L were lost through this leak, at an average rate of 12 L per hour. This amount is insignificant compared to the volume of water that passes through these tanks each day, but a NamWater employee stated that this has been a problem for at least a year, which demonstrates a lack of attention that could allow small leaks such as this one to develop into much more serious issues. The south-west tank has not been used since June 2009 due to a crack in its side, bringing the total capacity of the elevated water reservoir to 50 m<sup>3</sup>. However, as stated before, during our stay in Tsumkwe, these tanks never reached their full capacity because of the high demand for water and the short power generation cycle during the day.

Floating capsules inside each tank of the water tower are used to chlorinate the water. NamWater's sole employee in Tsumkwe, Piet Tainqe, tests the water daily for chlorination levels. If the

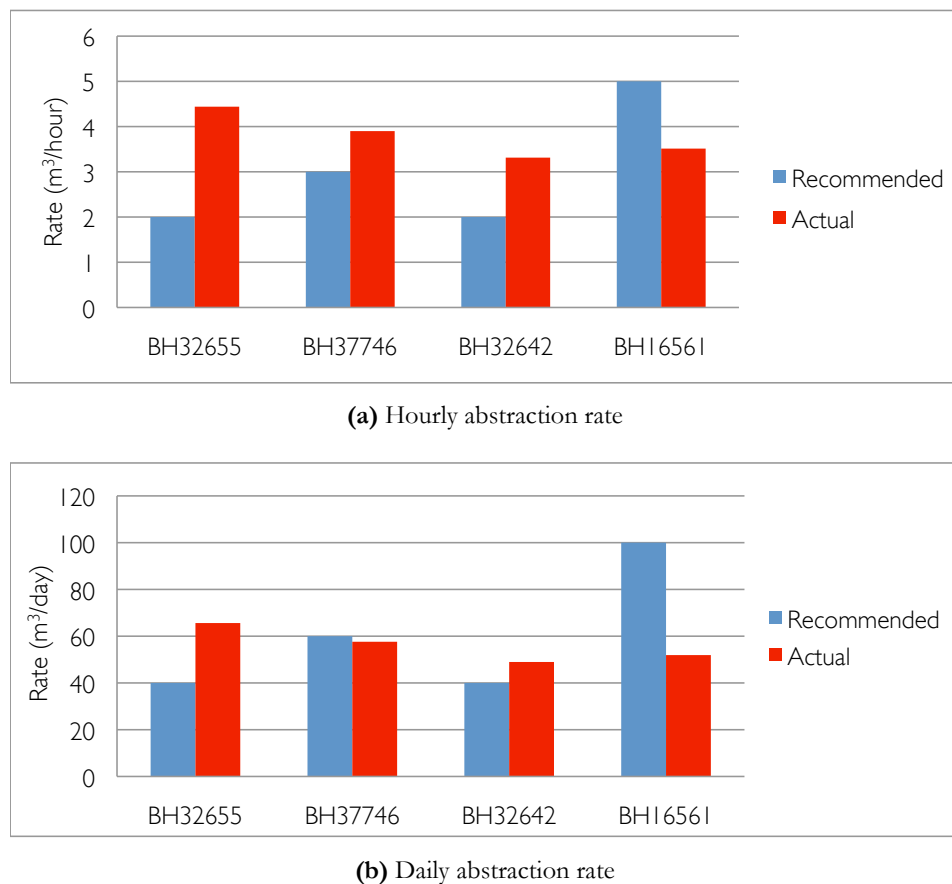


**Figure 5.2:** A leak in one of the NamWater storage tanks

chlorine level falls under 0.3%, Tainqe replaces the tablets in the floating capsules.

During our stay in Tsumkwe, we measured an average daily consumption of  $224 \text{ m}^3$  per day for the entire settlement. This figure is not expected to change throughout the year because each borehole pump has a set, constant abstraction rate. Thus, as long as all four boreholes are operated simultaneously, the same daily abstraction is expected. Three of the four boreholes already abstract more than their recommended hourly rate (Figure 5.3 (a)). In addition, the combined maximum daily abstraction of  $200 \text{ m}^3$  is currently being exceeded by  $25 \text{ m}^3$  (Figure 5.3 (b)). Over-abstracting from the boreholes could lower the water table below the depth of the pumps, greatly reducing the amount of water available. There is also an increased risk of chemical contamination of water sources in the area around an over-abstracted borehole (Foundation for Water Research, 2010).

Given a suggested water demand of 120 L per capita per day in Tsumkwe (IWRM Plan no. 3, 2010), the settlement can support a maximum of 1866 people. However, Tsumkwe's water is not used exclusively for human consumption. The water is used for livestock during the dry season and also used to aid in construction projects. In addition, many people in Tsumkwe seem comfortable using much less than 120L per day. Because of this, it is impossible to calculate the carrying capacity of the settlement without studying water use habits more closely. It is also impossible to determine the average volume of water used per person in the settlement because there is no accurate population data for Tsumkwe at this time. Accurate census data must be obtained before



**Figure 5.3:** NamWater has recommended a maximum abstraction rate for each borehole, but nevertheless has installed pumps that exceed some of these limits.

a proper analysis of water demand can be made.

NamWater has stated that the current number of boreholes is sufficient for all livestock and residents in Tsumkwe (Tjiyahura, 2010), but at the current rate of abstraction, there needs to be at least one additional borehole to meet current demand. Future demand must also be considered, as population growth and the installation of more flush toilets and taps will undoubtedly put a greater strain on the water supply.

### 5.1.2 Water distribution infrastructure

Whereas bulk water supply is NamWater's responsibility, water distribution is the responsibility of the Local Government and the Regional Council. Thus, it is troubling that the Local Government is entirely unaware of the location or condition of a majority of the critical water and



sanitation infrastructure. The Local Government does not know who has access to running water, who has to travel to get it (and how far they travel), or what is the total water demand in Tsumkwe.

The most recent map of the water mains dates from January of 1987, and only shows the original water lines. Moreover, this map was improperly surveyed, as some permanent roads do not line up with those on the satellite imagery from Google Maps. There are a number of markers like those in Figure 5.4 in Tsumkwe, but nobody knows what they represent. Other markers have been stolen, and maintenance workers must use trial and error to locate the pipes when repairs are needed.



**Figure 5.4:** Markers like these can be found in some parts of the settlement

Since 1987, many new water lines have been installed that go to MET Housing, Seven Houses, Tsumkwe North and Owambo Location. However, there are no maps describing these newer water lines, and the size and type of lines installed are entirely unknown. In addition, there is no record of where unauthorized connections have been made, despite the fact that the Local Government has fitted some of these connections with water meters. Informal connections make up a significant portion of the distribution infrastructure in Damara, Gauteng, ||haras and Owambo locations.

Much of the water distribution infrastructure remains in a state of disrepair due to lack of funds, knowledge and/or parts to perform the necessary maintenance. Many taps are old and need to be partially or completely replaced. These broken taps are a major source of leakage in the water distribution system. The gaskets have worn out in some of the taps such that water pressure can force them open, causing water to flow when nobody is around to use it. Other taps do not close completely and constantly leak. Additionally, there are 26 personal water tanks in Tsumkwe, all of

which are prone to overflowing and leakage. These leaks represent widespread losses to the already strained water supply in Tsumkwe. Water meters are generally in better condition, but a few are in need of replacement or repair and have become difficult or impossible to read. In particular, the meters on the outlet of the elevated reservoir are calcified and will need to be replaced in the near future as they are already nearly illegible.

A surface pipe runs through Tsumkwe South, and supplies water to the lodge and the mining camp. This pipe has been cut and patched for a long distance with a smaller diameter pipe, which reduces the pressure and flow of water that would otherwise be measured at the end of the pipe in Tsumkwe South. We have also heard complaints from the owner of the Tsumkwe Lodge that the water pressure from this line is insufficient for his customers' needs. The cut was most likely made by a livestock owner in the dry season to provide his animals with free water, although this assumption is based on anecdotal reports.

The Local Government installed 9 pre-pay water meters around 2005, but their use was discontinued 2 years later because people were circumventing them to receive free water. However, the local authority claims that during their operation the Local Government received excellent cost recovery. These meters are no longer used, but it is important to know where they are located because they now serve as hubs in an extensive network of unauthorized connections. Therefore, while the locations of new pipes are unknown, with the right equipment, one could trace the lines from these prepay meters to the main water supply. Additionally, residents know that the prepay meters are directly above a water pipe, and many informal connections are made either directly below or close to the pre-pay meter.

We determined that our night flow experiment is inconclusive. The amount of water in the towers was far greater than the daily average. This produced an abnormally high pressure that caused the average night flow rate to be significantly greater than the average day flow rate. Even towards the end of the experiment, when pressure levels were similar to those during the day, the night flow rates were around 66% to 89% of the day flow. It is highly unlikely that such a large percentage of loss is due to leakage. There are 19 high-capacity storage tanks in addition to those owned by NamWater. It is possible that these tanks were filled during the night flow experiment. If a similar experiment is to be performed in the future, storage tanks must be disconnected from

the NamWater supply.

### 5.1.3 Sanitation infrastructure

Tsumkwe's residents have three options available for defecation: flush toilets, dry toilets, or using the bush. For those with flush toilets, the Local Government is responsible for collecting and disposing of sewage. Periodically or upon request, the Local Government will send a truck that will pump septic tanks and dump the contents into an oxidation pond located in Tsumkwe South. However, at the time of our field work, the truck had been broken for the past four months and no septic tanks had been pumped in that time. As a result, over 80% of the 41 septic tanks in Tsumkwe are overflowing. This creates obvious health risks, especially to children who play right next to overflowing septic tanks in the schoolyard. Figure 5.5 shows children playing volleyball next to a pool of overflowing sewage. During an interview, an employee at the health clinic indicated that she had seen a recent increase in diarrheal disease and septic infection among children. In addition, the oxidation pond is not labeled or locked and does not yet smell. Children occasionally swim in the pond and many residents, unaware of the pond's purpose, cut pieces of the plastic lining out of the oxidation pond to rainproof their homes. This is clearly unsanitary, and the removal of the lining compromises the oxidation pond's ability to prevent ground contamination.



**Figure 5.5:** Children playing volleyball next to an overflowing septic tank

In the Seven Houses area, sewage lines were installed to bring waste directly to the oxidation



**(a)** Damage to the oxidation pond lining increases the risk of groundwater contamination



**(b)** The owner of this hut has incorporated a piece of the lining as rainproofing

**Figure 5.6:** The oxidation pond normally prevents sewage from seeping into the ground, but the lining has been damaged and no longer prevents ground contamination.

pond. However, no houses are connected to this system, which was installed in 2004 and the system does not even extend all the way to the oxidation pond. Furthermore, the Local Government does not have any maps showing where these unfinished pipes are, and there is no evidence of any analysis being done showing how the installation of flush toilets in the area will affect water demand. The same can be said for the new secondary school currently under construction, where Chinese contractors are installing enough flush toilets and septic tanks to meet the needs of over 260 children and 11 teachers. With an already strained water supply, installing so many flush toilets and spending money on septic lines that do not even connect to homes or the oxidation pond is irresponsible. It is a mismanagement of water resources, and a misallocation of funds and labor.

There are six composting (Otji) toilets in Tsumkwe, which were installed in 2009 by the Clay House Project. Two are in Gauteng Location, two are in the MET housing area, and another pair near the oxidation pond. There were plans to install more dry toilets in ||haras, but construction was halted when the ||haras community decided they did not want them. The Otji toilets that have been installed are working well so far, but many residents are concerned that nobody will want to remove the compost when the toilet is full. Also, two toilets are not sufficient for an entire location, and they may fill up too quickly for the drying process to be completed. Outside of the locations where they have been installed, residents are completely unaware of composting toilet systems and

are resistant to the idea.

In Gauteng Location, 5 of the 7 people surveyed indicated that they use the dry toilets, while the other two use the bush. Those who used the bush expressed odd reasons for not using the toilet. One person claimed that the toilets were too far away when they were actually closer than the nearest bushes. Another person expressed concern after seeing a snake inside one of the toilets. Another person said that she uses the toilet, but also emphasized, “we San are used to the bush.”

The majority of Tsumkwe residents defecate in the bush. This method may work in small villages, but with Tsumkwe’s current population density this could become very unsanitary. Moreover, some residents are concerned for their safety since they are vulnerable to snakes and scorpions while defecating in the bush.

## **5.2 Political and financial analysis**

The Local Government must overcome bureaucratic and logistical challenges before obtaining supplies or materials to repair infrastructure. Several informants stated that Tsumkwe is a relatively low priority for the Otjozondjupa Regional Council due to its small population. Furthermore, the poor condition of the road and remote location of Tsumkwe make it difficult and expensive for supply trucks to reach the settlement.

Repairing the septic truck requires a significant amount of time due to lack of organization of both the local and regional authorities. The Local Government must request funds from the Regional Council to repair the truck. In addition, it is difficult for the Local Government to hire a private sewage truck. Not only is it challenging to find a sewerage company willing to drive the 220 km of hazardous, gravel roads, but the Local Government must present price quotes from three such companies to the Regional Council before the funds are approved. This process is inefficient and time consuming, and has caused some of the sanitation problems we observed.

### **5.2.1 Billing and cost recovery**

We can calculate from the Local Government’s financial records that only 16.9% of the water in Tsumkwe is metered and accounted for.

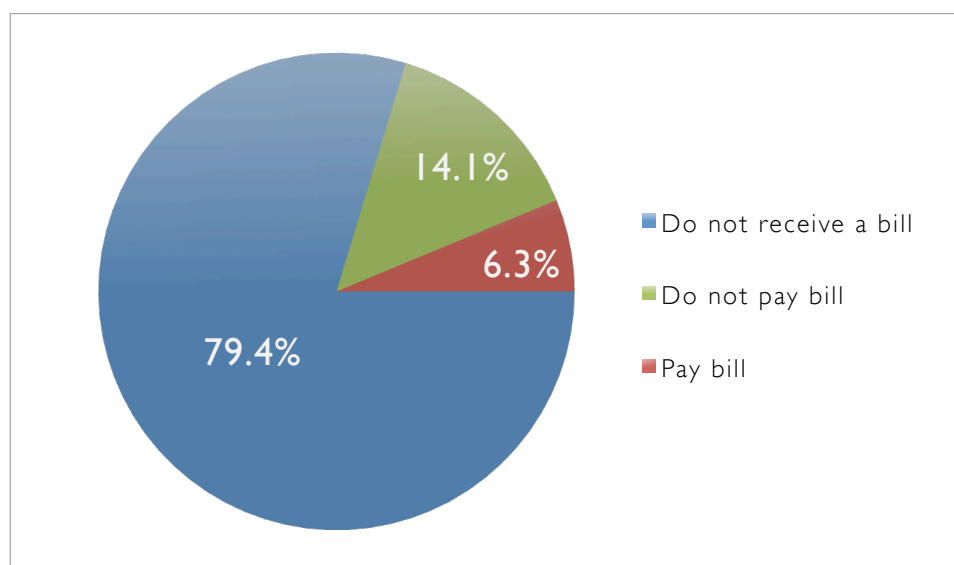
Aside from quantitative data, several observations were made on the quality of the record

keeping system. The records contain many small mistakes and other errors due to carelessness both in recording meter values and not reading certain meters consistently every month. The worst instance of this carelessness occurred from May to August of 2009, when no meters were read at all. Upon inquiry we discovered that the employee of the local authority responsible for reading the meters had quit in May. The current employee was not hired until August and his predecessor had left no record of the meters' locations. Residents were charged a lump sum for all of the water used during the previous three months when meter readings had been neglected. In several instances the Local Government recorded meter values incorrectly. For example, one household was charged a quantity of 20,000 m<sup>3</sup> because the digit in the ten-thousands place was recorded as a "5" rather than a "3". The following month the digit was recorded as a "3" again and no adjustments were made to the previous month's recorded consumption.

Although cost recovery is not actively enforced, the Local Government occasionally sends notices to households with outstanding bills. These warnings threaten to terminate the households water supply, even though the Local Government does not have the technical capability to do so. These ultimatums are not only deceptive, but ineffective. Examples of these notices can be found in section B.2.

### **5.2.2 Water usage trends**

The financial records show no steady trends in water use. This leads us to believe that people generally are not concerned with their personal usage, most likely because most do not pay for their water. Of 64 people surveyed, only 20.4% receive water bills and only 6.3% pay their bills (see Figure 5.7). However, even institutions and businesses that do pay for water have significant and sporadic fluctuations in usage. This observation is in agreement with the financial standing of the wealthy business owners or government bill payers in that consumption is insignificant to their monthly income. Such fluctuations could result from misreadings or otherwise careless record keeping practices similar to those described in the previous section.



**Figure 5.7:** Percentage of households that pay for water usage

### 5.3 Immediate health risks

One of the two head physicians at the Hand in Hand for Children e.V. Clinic commented that there are a minimum of 20 cases of diarrhea diseases every month, which usually account for at least 20% of all cases at the clinic. The physician commented that there has been a recent influx of children with diarrhea and septic wounds on their legs and feet, but she was unaware of the sewage problems at the secondary school. If anyone in Tsumkwe should be informed of the overflowing septic tank at the school, it should be the physician at the clinic.

The inconsistent supply of water jeopardizes the effectiveness and safety of some medical procedures such as child births that require large amounts of water. The Local Government accommodates these special cases to the best of its ability. The clinic also has a rain water collection tank, but the physician notes that it is insufficient for some of their needs. Part of the clinic's safety protocol is to wash hands before examining a patient, even when using latex gloves. This basic task is impossible after water has run out of the NamWater storage, making afternoons especially difficult for the clinic.

## 5.4 Social considerations

The psychology of Tsumkwe residents is perhaps one of the biggest challenges faced by anyone who aims to improve the sustainability of the water and sanitation systems. Many of the people have become accustomed to receiving services, goods and other resources for free from the government or other outside organizations (Pfaffe, 2003). Responses to our surveys suggest that they often are aware of problems, but do not accurately perceive the cause of them. When asked how they would improve the water supply system in Tsumkwe<sup>\*</sup>, several people responded that the town should get a second generator to run when the other one is off. This demonstrates a clear misunderstanding of the real situation, in which the generator is turned off to save fuel. Others were only able to give vague identifications of the problem rather than actually propose solutions. A typical answer was simply “the water must just be there for 24 hours.”

During our interviews with residents, it became clear that some of them simply do not plan for the future. Figure 5.8 shows that a significant number of households store no more than 20 L of water which, according to WHO, is the minimum quantity of water necessary for domestic uses for a single person for one day (Reed, 2002). Moreover, most of the households surveyed store fewer than 60 L, which is only enough for three people for one day. In Tsumkwe, three people is a very modest size for a family. Most homesteads house families of 10, 15, or even more. Our results are clear that most of those families do not have enough stored water to last for even one day during a shortage.

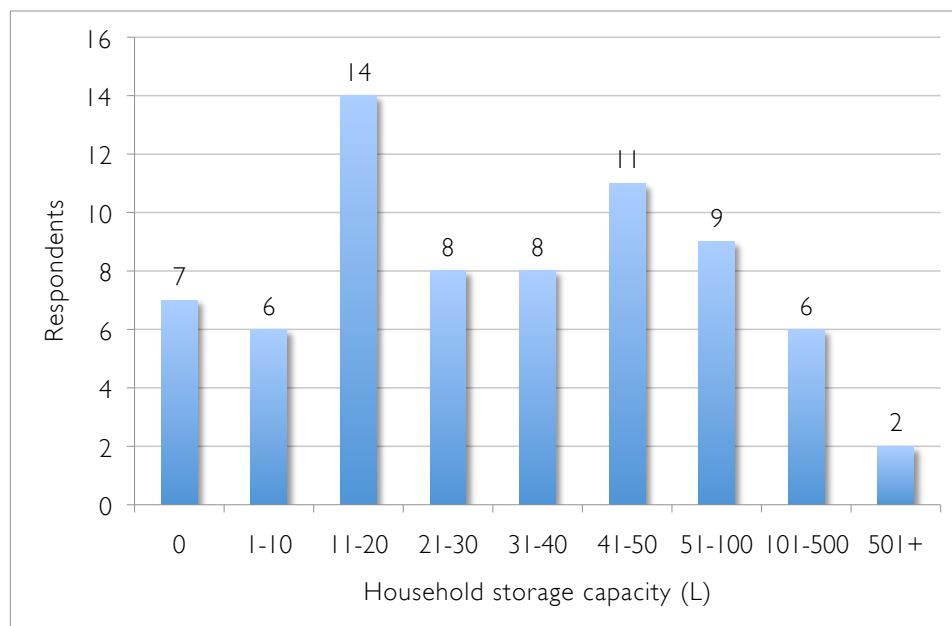
Furthermore, a large number of respondents said that they rely on their personal water storage in the event of a water shortage lasting a day or more. There are also a large number who obtain water from more than 1 km away during such a shortage, which is below the WHO standard for water availability. Very few people said that they ask for water at the lodge, which has its own borehole and generator. During an interview, the owner of the lodge said that he gives water to anyone who asks free of charge, but the data presented in Figure 5.9 makes it clear that very few people do this. There must be a reason that most people are willing to travel more than twice as far as the lodge to obtain water. We can draw three possible conclusions from this result:

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<sup>\*</sup>Question 6 on the residential survey found in section A.1

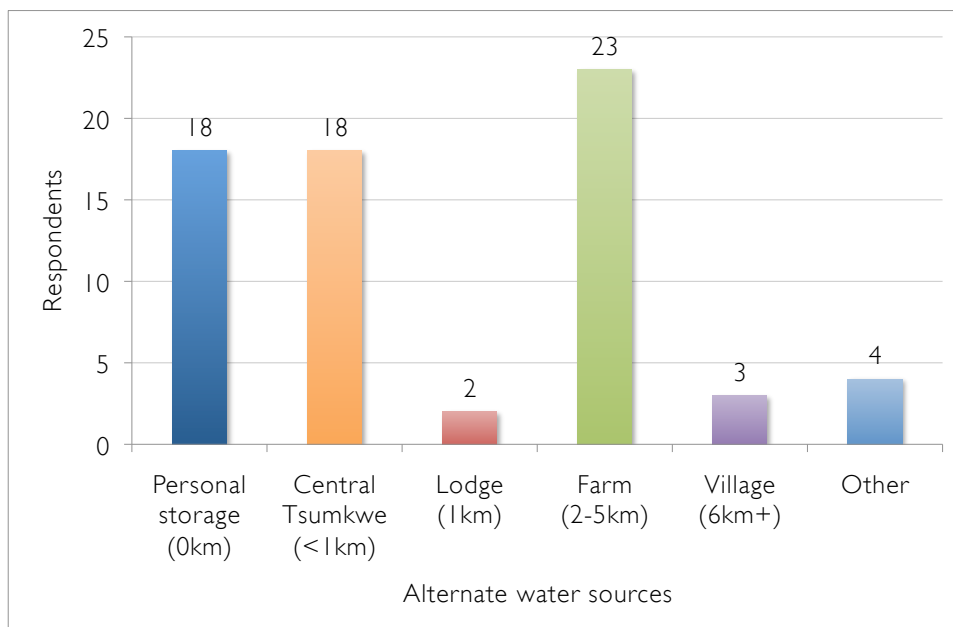


people in Tsumkwe are unaware that the lodge has water when the settlement does not, the lodge owner actually does charge money for his water, or residents are averse to obtaining free water from the lodge for some reason. The first possibility is unlikely because the lodge owner is the largest employer in Tsumkwe and the word that free water was available there could certainly get spread quickly from his employees in a community as small as Tsumkwe. The other two options suggest that there is some underlying tension between the lodge owner and the residents of Tsumkwe.



**Figure 5.8:** Volume of water typically stored each day in 64 households.

People living far from the central part of town, particularly those in Owambo Location, were pessimistic, often responding that nothing could be changed to improve water supply or waste management because nobody cares about the poor. Many interviewees in this location also indicated that the services received from the Local Government are very closely connected to social status. Interview data also support this claim; the only two people who described the Local Government as being both very fast and reliable were both school principals. On the other hand, some people in ||haras and Gauteng report waiting for a year or more for the Local Government to fix water infrastructure.



**Figure 5.9:** Alternate water sources used during a shortage of a day or more, and the distance of each from the center of the settlement

## Chapter 6: Conclusions

The problems with the water supply and sanitation systems in Tsumkwe are primarily caused by lack of maintenance and poor management. Nearly all the taps are in need of repair or replacement and a significant portion of the water distribution system has been installed informally by untrained workers. There are insufficient funds to improve or even maintain the current infrastructure because only a small fraction of the water's cost is recovered. Moreover, the current water abstraction scheme, according to our measurements, is not sustainable and will not be able to meet future demand. In an effort to inventory the existing water distribution system, we have created a map of the above-ground water and sanitation infrastructure. We have also speculated the locations of some of the major water distribution pipes, based on an old infrastructure map and several surface markers. We hope that this will help the Local Government to properly improve and maintain infrastructure and pursue effective cost recovery.

Despite widespread sewage problems, a new septic tank and a number of flush toilets are being installed in the new secondary school. The impact that these will have on oxidation pond and the overall water demand in Tsumkwe was clearly not considered in the planning of the school. Awareness of alternative sanitation systems is very low, and the few dry toilets that have been installed cannot continue to support the current number of users.

# Chapter 7: Recommendations

Stakeholders in Tsumkwe should take immediate and decisive action in order to prevent the water supply, distribution, and sanitation situation from deteriorating further. Our prioritized recommendations are as follows:

## **1. Repair the septic truck**

The first priority is an immediate repair of the septic truck to ensure that current sewage pumping demands can be met. This is the most pressing issue as raw sewage is presenting health risks to the community.

## **2. Install a backup generator**

NamWater needs to install a functioning backup engine on BH 16561, the borehole located next to the water tower, in order to provide water in case a catastrophic power failure should occur. The current backup is a diesel engine that will typically need to be run when the settlement generator has exhausted its supply of diesel. A solar generator similar to those found in the surrounding villages would be appropriate for Tsumkwe.

## **3. Keep consistent and complete records**

NamWater and the Local Government need to improve and streamline record keeping. Records should be kept to determine whether the current boreholes are consistently being over-abstracted or if the abstraction rates are sustainable. The Local Government must document how much water is actually distributed to the users, and how much is lost to leakage. Additionally, the Local Government should conduct an accurate census of human and animal population in Tsumkwe in order to approximately determine the overall water demand. Understanding the potential

overall demand versus how much water is sold by NamWater will assist the Local Government in determining how much water is lost to leakage. Moreover, an analysis of the residents' income should be conducted along with the census so that tariffs can be set appropriately.

#### **4. Locate water lines**

The settlement should identify the exact location of water and sewage pipes. A complete survey of the water lines, including informal connections, should be conducted. The precise locations of all lines can then be marked with surface markers to facilitate future repairs to the water lines.

#### **5. Identify and minimize leakages**

The next step for NamWater and the Local Government is to determine where leaks occur and then repair these leakages. For NamWater, this will be namely in fixing leaks in the elevated water reservoir. For the Local Government, this will include replacing and repairing leaky or broken taps and pipes. The oxidation pond should also be repaired, clearly marked, fenced off and locked.

#### **6. Educate the community**

Tsumkwe's residents should be educated that water is a limited resource, and would have to be made aware of how they can store and conserve water. Additionally, the community needs to be educated on alternative sanitation methods, such as the use of Otji toilets and human waste as fertilizer. These measures would ensure that the community is invested in the future of Tsumkwe and the overall well-being of the settlement and the appropriate use of its resources.

#### **7. Enforce cost recovery**

Once the above steps are implemented, the Local Government may begin to enforce cost recovery methods. An equitable tariff should be implemented whereby every resident pays for water. However, low income households should pay proportionally less than higher income households. Ideally, the Local Government should be able to pay NamWater for all water costs and still profit from the tariff it sets so that it can fund other projects, such as infrastructure maintenance and upgrades.

## **8. Evaluate water demand and increase capacity**

When leakage is fixed and the Local Government enforces cost recovery, NamWater and the Local Government should collaborate to develop a projection of future water demand based on population trends and current water in an effort to determine if additional boreholes are necessary to meet future demand. Additionally, NamWater and the Local Government should work together to determine an appropriate storage capacity as the current capacity of 50 m<sup>3</sup> is unacceptable.

Once these major issues are resolved, another analysis may be conducted to locate smaller-scale problems. It is important to note that the Otjozonjupa Regional Council should allocate the necessary funds to Tsumkwe in order to facilitate these changes. There should also be a system that ensures these funds are spent on appropriate projects (e.g. money allocated for water infrastructure improvement should be spent on replacing and repairing these systems, not installing new septic lines).

To assist future projects, our team has presented the DRFN with an electronic map of the above-ground water and sanitation infrastructure in Tsumkwe, in a format that is compatible with a number of mapping programs.

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# Appendix A: Survey questions and responses

## A.1 Residential survey questions

1. Do you have your own tap?  
  
(if no) (a) Where do you fetch water?  
  
(if yes) (b) Do you have a water meter?  
  
(c) Do you receive a water bill?  
  
(d) Do you pay your water bill?
2. How much water do you store to prepare for the afternoon or night when water is unavailable?
3. Have you ever received a warning before the water was going to be cut off at an unusual time?  
  
(if yes) (a) What type of warning?
4. What is the longest period you have been unable to get water from the tap?  
  
(a) How did you get water during this time?
5. If your tap is broken, who repairs it?  
  
(If self) (a) Why do you repair it yourself?  
  
(If other) (b) How long was it before the tap was repaired?
6. If you could change something about the water supply in Tsumkwe, what would you change first?
7. How do you dispose of rubbish?
8. How could this be improved?
9. In which location do you live?

### **A.1.1 Sanitation questions for teachers**

10. What is your opinion of the sewage system in the secondary school and the hostel?
11. Are you concerned for your own health and/or the learners' health?
12. How could this be improved?

### **A.1.2 Sanitation questions for locations with dry toilets**

13. Do you use the dry toilet system?

**(if no)** (a) Why not?

**(if yes)** (b) Do you have any complaints?

## **A.2 Residential water survey responses**

On the following pages are the responses to the water-related survey questions. The responses to question 6 has been omitted to save space, since it is open-ended and some responses were rather lengthy. The responses to questions 7 and 8 can be found in table B.1 on page 43.

Table A.1: Responses to some water-related questions of the residential survey

		Question #								
		1b	1c	1d	2	3	4	4a	5	9
y	n	50	—	—	17.5 ± 3.5	n	NG church	self	haras	
y	n	0	—	—	7 ± 0	i*	puddles; no plan	local govt	haras	
y	n	0	—	—	7 ± 0	n	village 7km to the south	local govt	haras	
y	n	0	—	—	7 ± 0	n	village 7km to the south	local govt	haras	
y	n	0	—	—	7 ± 0	n	lodge	self	haras	
y	n	0	—	—	7 ± 0	n	Agriculture farm	self	haras	
y	y	0	y	n	1 ± 0	n	church; clinic	local govt	7 Houses	
y	y	50	y	y	0 ± 0	n	no plan	self; local govt	7 Houses	
y	y	60	n	—	14 ± 3	y	NamWater diesel backup	self	7 Houses	
y	y	40	n	—	2 ± 3	y	stored water	self; local govt	7 Houses	
y	y	20	y	n	3 ± 1	n	Agriculture farm	self	Central	
n	—	40	—	—	1 ± 0	n	Church, Clinic, Health Unlimited	others	Central	
y	y	3500	y	y	7 ± 0	n	ADRA	self	Central	
y	n	35	—	y	3 ± 0	i	Farm up road toward Grootfontein	self	Damara	
y	n	50	—	—	2 ± 1	y	no plan	self	Damara	
y	n	25	—	—	2 ± 1	y	no plan	self	Damara	
y	n	50	—	—	1 ± 0	y	Ask neighbors who are driving to farm	self	Damara	
n	n	10	—	—	2 ± 0	y	no plan	self	Damara	
y	n	200	—	—	2 ± 0	y	no plan	local govt	Damara	
y	n	100	—	—	6 ± 1	n	Agriculture farm	self	Damara	
y	n	75	—	—	<1 ± 0	n	NG church; Agriculture farm	self	Gauteng	
y	n	10	—	—	7 ± 1	y	NG church	local govt	Gauteng	
y	n	100	—	—	2 ± 0	y	clinic	self	Gauteng	
y	n	65	—	—	1 ± 1	y	clinic	self	Gauteng	
n	—	10	—	—	3 ± 1	n	ask neighbors	—	Gauteng	
n	—	75	—	—	<1 ± 0	i	no plan	—	Gauteng	
y	n	240	—	—	1 ± 1	n	Agriculture farm	self	Gauteng	
y	n	0	—	—	3 ± 0	y	no plan	ministry of works	Hostel	
y	n	10	—	—	14 ± 0	n	Agriculture farm	ministry of works	Hostel	
n	n	5	—	—	0 ± 0	n	no plan	local govt	Hostel	
y	n	40	—	—	2.5 ± 0.5	y	NG church; Agriculture farm	ministry of works	Hostel	

\*i = inconsistent warnings

Table A.1: (continued)

		Question #								
		1b	1c	1d	2	3	4	4a	5	9
y	y	y	n	n	20	n	1 ±	stored water	local govt	Hostel
n	-	-	-	-	100	n	2 ±	Hostel tank	ministry of works	Hostel
y	n	-	-	n	20	n	2 ±	NG church	ministry of works	Hostel
y	y	n	-	n	35	n	0 ±	no plan	local govt	Near hostel
y	y	n	-	n	65	n	1 ±	stored water	-	Local govt
y	y	y	y	y	125	y	14 ±	Got water from a truck with a tank	local govt	Local govt
y	y	y	y	n	2500	n	5 ±	south farm	self	Local govt
y	y	y	n	y	8	y	2 ±	stored water	local govt	Local govt
y	y	n	-	y	30	y	2 ±	stored water	local govt	Local govt
n	n	-	-	i	40	i	4 ±	Agriculture Farm; Church	local govt	Local govt
n	-	-	-	n	50	n	1 ±	no plan	local govt	NBC
y	y	y	n	y	25	y	2 ±	Hostel tank	self	North
y	y	y	n	n	160	n	10.5 ±	night flow; central Tsumkwe	self	North
n	-	-	-	n	25	n	14 ±	NamWater	self	North
n	-	-	-	n	20	n	14 ±	collected water from bush; drank very little	others	North
n	-	-	-	n	50	n	14 ±	Agriculture farm	self	North
n	-	-	-	n	200	n	5 ±	Agriculture farm	self	North
n	-	-	-	n	20	n	0 ±	no plan	-	North East
n	-	-	-	n	20	y	10.5 ±	Agriculture farm	others	North East
n	-	-	-	n	40	n	14 ±	Agriculture farm	others	North East
n	-	-	-	n	20	n	21 ±	village 7km to the south	self	North East
y	y	n	-	i	50	i	1 ±	Agriculture farm; Lodge	self	North East
n	-	-	-	n	25	n	2 ±	Agriculture farm	self	Owambo
y	y	n	-	n	50	n	3.5 ±	Agriculture farm	self; others; local govt	Owambo
y	y	y	n	n	100	y	1.5 ±	Agriculture farm	local govt	Owambo
y	y	y	-	y	50	y	3 ±	clinic; neighbors	self	Owambo
y	n	-	-	y	25	y	2 ±	Agriculture farm	self	Owambo
y	y	y	n	n	25	n	3 ±	clinic; Agriculture farm	local govt	Owambo
y	y	y	-	n	50	n	1 ±	clinic	local govt	Owambo
n	-	-	-	n	40	n	2 ±	no plan	self	Owambo
n	-	-	-	y	125	y	1 ±	Agriculture farm	self	Owambo
n	-	-	-	n	50	n	14 ±	Agriculture farm	self	Owambo
y	y	n	-	n	30	n	1 ±	stored water	self	Owambo
										MEI

### A.3 Business/community center survey questions

1. How many taps does this business/community center have?
  - (a) How many are functional?
2. How many toilets does this business/community center have?
  - (a) How many are functional?
3. How many customers come here on a typical day?
4. How many employees/volunteers work here on a typical day?
5. What is water used for (i.e. flushing toilets, drinking, cleaning windows, etc.)?
6. Who pays the water bill for this business/community center?
  - (a) Is the bill paid?

### A.4 Business/community center survey responses

**Table A.2:** Responses to the business/community center water and sanitation survey

Name	1	1a	2	2a	3	4	Question # 5	6	6a
Savannah II Supermarket	1	1	1	n	0	2	drinking, washing hands, cleaning	Store Owner	y
Community Learning and Development Center	2	y	2	n	50	4	drinking, washing hands, gardening, mostly cleaning	Swedish NGO	y
Police Station	8	y	8	y	8	20	washing, drinking, cleaning, gardening	Police	n
General Dealer	1	y	2	y	0	4	washing, drinking, cleaning	Lodge Owner	y
Ministry of Home Affairs and Immigration	3	y	3	y	10	3	cleaning, toilet, drinking, gardening	MHA	y

## Appendix B: Waste management

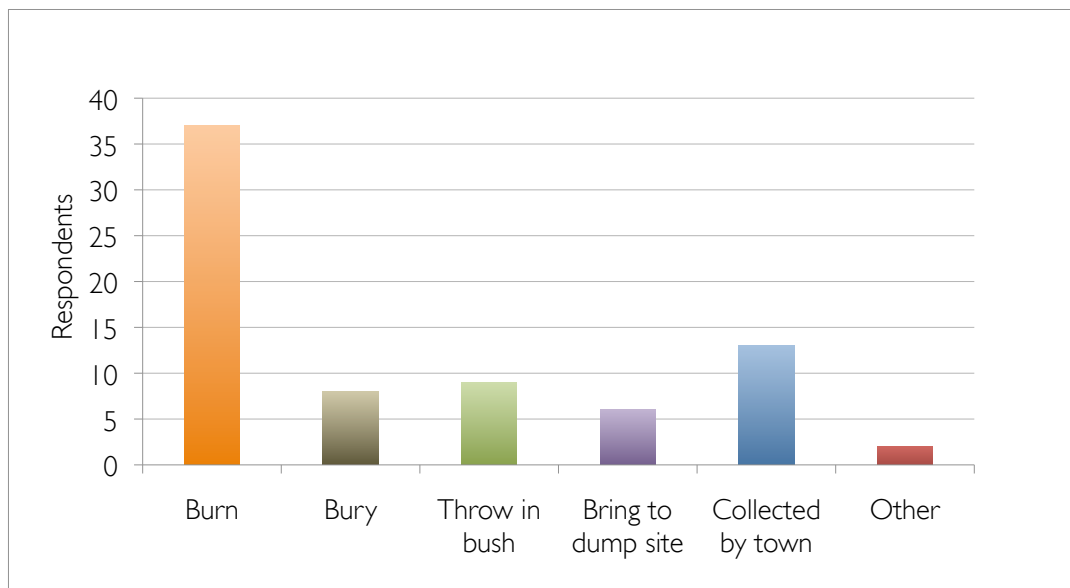
Waste management is a problem related to public health and safety in Tsumkwe. Nearly everywhere in the town, there is some type of garbage that has been left on the ground. The settlement does have a designated dumping site about 3 km to the east, but this is too far for people without cars to carry their garbage. The Local Government pays a tender to a man with a truck who is supposed to collect garbage and bring it to the dump site every Wednesday. However, during our survey many people claimed that the garbage was not collected reliably every week. Others indicated that only certain locations, such as the Local Government location, receive weekly garbage collection services.

The dump site is not used by most of the population, and regardless it has no containment mechanism as is evident in Figure B.1. Any papers or plastic bags that are brought there dry out and are carried off into the bush by wind. This pollutes the Nyae Nyae Conservancy, which is home to a diverse range of wildlife.



**Figure B.1:** The waste dump site has no means of containing garbage

It is clear from Figure B.2 that burning is by far the preferred method of waste disposal. Furthermore, several respondents said that they burn any combustible material, including plastics. Even when asked directly, few people said that they burn only paper. This poses several health risks, especially to the San who are very susceptible to tuberculosis (Jenkins, Lehmann, & Nurse, 1974). Burning plastics can release carcinogenic chemicals that damage the immune, nervous, endocrine,



**Figure B.2:** Waste disposal methods in Tsumkwe (some respondents employed multiple methods)

and reproductive systems (WHO, 2010a). Moreover, the presence of broken glass bottles and metal cans combined with the current prevalence of overflowing septic tanks increases the risk of septic wounds, especially among children who frequently play outside unshod.

## B.1 Recycling in Tsumkwe

The owner of the Tsumkwe Lodge has begun implementing a recycling program in Tsumkwe to alleviate some of the settlement's waste management problems. During our stay in the settlement, the Tsumkwe General Dealer offered to buy back empty Namibian beer bottles, and send them back to *Namibia Breweries* to be recycled. The lodge owner explained during an interview with our team that he plans to develop this program even further, hiring Tsumkwe residents to gather and sort recyclables. He intends to build shelter at the dump site to protect the sorters from the sun and rain. He will make a profit by selling the sorted recyclables to Collect-a-Can, a South African recycling company.

## B.2 Waste management survey responses

**Table B.1:** Responses to questions 7, 8 and 9 of the survey found in section A.1

Question #		
7	8	9
burn	recycling	haras
bush	would like to see the old system brought back	haras
bush	would like to see the old system brought back; garbage should be collected every day	haras
bush	would like to see the old system brought back; the rubbish bins should be collected	haras
bush	everyone should have a dustbin	haras
bush	would like to see the old system brought back	haras
collection; bush	local govt should provide containers for trash	7 Houses
collection	–	7 Houses
burn	collection services	7 Houses
collection	collection services	7 Houses
bury	dustbins	Central
bush; burn paper	collection	Central
bring to dump	collect litter	Central
bury; burn paper	bigger dustbins; collection services	Damara
burn	collection services	Damara
burn	collection services	Damara
burn paper and plastic	collection services	Damara
burn paper and plastic	NG church program	Damara
burn	collection services	Damara
bury; burn	collection services	Gauteng
burn; bury; bring to dump	recycling	Gauteng
kids clean it	collect litter	Gauteng
bury	dustbins	Gauteng
bring to dump	collection services	Gauteng
collection	burning is better	Gauteng
burn	burning is fine	Gauteng
burn	collect litter	Gauteng
collection; burn	–	Hostel
collection	bins for garbage	Hostel
burn	–	Hostel
collection; burn paper	more reliable garbage pickup; need a schedule so we know when its going to be picked up	Hostel
burn	more reliable garbage pickup	Hostel
collection; burn	more reliable garbage pickup	Hostel
kids clean it	clean schoolyards	Hostel
collection	–	Across street from hostel
collection	collect every 2 days	Local govt
collection	The waste dump is not good because it is open to the air and paper can fly everywhere. Medical rubbish can cause diseases.	Local govt
bring to dump	dump site should be cleaned up	Local govt



APPENDIX B. WASTE MANAGEMENT

**Table B.1:** (continued)

7	Question # 8	9
collection	waste dump	Local govt
collection	collection services	Local govt
burn	Local govt should buy a truck to collect rubbish	NBC
burn	burning is the best way	NBC
burn	collect litter	North
burn; bury	collection services	North
burn	collection services	North
burn; bury	collection services	North
burn	collection services	North
burn	dustbins or bags; collection services	North East
burn	collection services	North East
burn	WIMSA program	North East
burn	collection services	North East
burn	collection services	North East
bury; burn	would like to see proper garbage collection	Owambo
burn	collection services	Owambo
burn	collection services	Owambo
burn	collection services	Owambo
burn	dustbins; collection services	Owambo
–	–	Owambo
bring to dump	collection services	Owambo
bring to dump	–	Owambo
burn	central place for garbage	Owambo
bush	collection services	Owambo
bush	collect litter	Owambo
burn	not a problem	MET

## Appendix C: Night flow measurements

We recorded night flow measurements on 15 April, 2010, in an attempt to measure leakage. The readings can be found in Table C.1, and summary data can be found in Table C.2. Mr. Likoro also presented us with night flow data from 2008 (Table C.3).

**Table C.1:** Night flow measurements taken on 15 April, 2010, from the outlet of the NamWater reservoir in Tsumkwe

Time	Meter 1 (m <sup>3</sup> )	Meter 2 (m <sup>3</sup> )	Pressure 1 (mWh)	Pressure 2 (mWh)
1:55	627525.76	620235.76	0.5	2.5
2:00	627525.76	620235.76	13.0	2.0
2:05	627527.40	620236.50	13.0	4.0
2:10	627529.12	620239.16	14.0	6.0
2:15	627531.06	620241.10	14.5	7.0
2:20	627532.73	620242.56	15.0	8.5
2:25	627534.21	620244.20	15.0	9.5
2:30	627535.61	620245.60	15.0	10.0
2:35	627536.96	620246.93	15.0	10.5
2:40	627538.28	620248.23	15.0	10.5
2:45	627539.58	620249.52	15.0	10.5
2:50	627540.86	620250.79	15.0	10.5
2:55	627542.14	620252.05	14.5	10.5
3:00	627542.94	620252.84	10.0	8.5
3:05	627543.03	620252.93	8.5	7.5
3:10	627543.50	620253.41	7.5	5.5
3:15	627543.73	620253.64	6.5	5.0
3:20	627543.89	620253.79	6.5	5.0
3:25	627543.97	620253.86	6.0	4.5
3:30	627544.01	620253.91	5.5	4.0
3:35	627544.04	620253.95	5.0	3.5
3:40	627544.06	620253.97	3.5	2.0
3:45	627544.06	620253.97	3.0	1.5
3:50	627544.06	620253.97	2.5	1.5
3:55	627544.06	620253.97	2.5	1.0
4:00	627544.06	620253.97	2.0	1.0

**Table C.2:** Additional night flow data

**(a)** Total flow through reservoir outlet

	Meter 1 (m <sup>3</sup> )	Meter 2 (m <sup>3</sup> )	Average (m <sup>3</sup> )
Water Pumped (m <sup>3</sup> )	19.61	19.61	19.61
Water Metered	18.3	18.21	18.25
Difference	1.31	1.4	1.36

**(b)** Flow through borehole pumps

	BH 16561	BH 32642	BH 32655	BH 37746
Initial (m <sup>3</sup> )	197889.88	14128.8	119694.3	148044.02
Final (m <sup>3</sup> )	197893.74	14133.5	119700.9	148048.47
Initial (mWh)	NA	32	66	13
Final (mWh)	NA	30	65	12
Power ON	0:55	0:43	0:43	0:52
Power OFF	2:00	2:00	2:00	2:00
Time Pumped (min)	65	77	77	68
Water Pumped (m <sup>3</sup> ) (m <sup>3</sup> )	3.86	4.7	6.6	4.45
Total (m <sup>3</sup> )	19.61			

**Table C.3:** Night flow measurements taken on 20 November, 2008

Time	Meter 1 (m <sup>3</sup> )	Meter 2 (m <sup>3</sup> )
02:00	530590	523273
02:05	530591	523273
02:10	530592	523274
02:15	530593	523275
02:20	530594	523276
02:25	530596	523278
02:30	530597	523280
02:35	530598	523281
02:40	530600	523282
02:45	530601	523283
02:50	530602	523285
02:55	530603	523286
03:00	530605	523287
03:05	530606	523288
03:10	530607	523290
03:15	530608	523291
03:20	530610	523292
03:25	530611	523293
03:30	530612	523294
03:35	530613	523296
03:40	530614	523297
03:45	530615	523298
03:50	530616	523298
03:55	530616	523298
04:00	530616	523298

# Appendix D: Daily pressure and flow rate measurements

**Table D.1:** Daily readings of the pressure at the outlet of the elevated reservoir immediately after the electricity has been turned off in the afternoon

(a) Day 1

Time	Interval (min)	Pressure 1 (mWH)	Pressure 2 (mWH)	Rate 1(mWH/min)	Rate 2 (mWH/min)
14:07	not taken	12.0	11.0	not taken	not taken
14:15	8	11.0	10.0	0.125	0.125
14:21	6	7.0	9.0	0.667	0.167
14:24	3	6.0	7.0	0.333	0.667
14:33	9	5.0	5.5	0.111	0.167
14:40	7	4.5	5.0	0.071	0.071
14:52	12	3.0	3.5	0.125	0.125
15:00	8	2.5	3.0	0.063	0.063
15:03	3	0.5	2.5	0.667	0.167

(b) Day 2

Time	Interval (min)	Pressure 1 (mWH)	Pressure 2 (mWH)	Rate 1(mWH/min)	Rate 2 (mWH/min)
14:25	3	8.0	8.0	0.667	0.000
14:30	5	6.0	6.5	0.400	0.300
14:35	5	4.5	5.0	0.300	0.300
14:40	5	4.5	5.0	0.000	0.000
14:45	5	4.0	4.5	0.100	0.100
14:50	5	2.5	3.0	0.300	0.300

(c) Day 3

Time	Interval (min)	Pressure 1 (mWH)	Pressure 2 (mWH)	Rate 1(mWH/min)	Rate 2 (mWH/min)
14:05	3	12.0	9.5	0.333	0.167
14:10	5	9.0	8.5	0.600	0.200
14:15	5	6.0	6.0	0.600	0.500
14:20	5	5.0	5.0	0.200	0.200
14:25	5	4.5	4.5	0.100	0.100
14:30	5	3.5	4.0	0.200	0.100
14:35	5	3.0	3.5	0.100	0.100
14:40	5	1.5	1.5	0.300	0.400

**Table D.2:** Daily readings of the water meters on the outlet of elevated reservoir immediately after the electricity has been turned off in the afternoon

<b>(a) Day 1 (only one meter was recorded)</b>					
Time	Interval (min)	Reading (m <sup>3</sup> )	Rate (m <sup>3</sup> /min)		
14:07	—	619940.20	—		
14:31	24	619940.51	0.0141		
14:36	5	619940.59	0.0160		
14:41	5	619940.69	0.0200		
14:46	5	619940.75	0.0120		
14:51	5	619940.80	0.0100		
14:56	5	619940.85	0.0100		
15:01	5	619940.88	0.0060		
15:03	2	619940.90	0.0075		

<b>(b) Day 2</b>					
Time	Interval (min)	Reading 1 (m <sup>3</sup> )	Reading 2 (m <sup>3</sup> )	Rate 1 (m <sup>3</sup> /min)	Rate 2 (m <sup>3</sup> /min)
14:22	—	627446.65	620157.00	—	—
14:25	3	627447.01	620157.36	0.1200	0.1200
14:30	5	627447.28	620157.64	0.0540	0.0560
14:35	5	627447.50	620157.86	0.0440	0.0440
14:40	5	627447.57	620157.93	0.0140	0.0140
14:45	5	627447.61	620157.97	0.0080	0.0080
14:50	5	627447.63	620158.00	0.0040	0.0060

<b>(c) Day 3</b>					
Time	Interval (min)	Reading 1 (m <sup>3</sup> )	Reading 2 (m <sup>3</sup> )	Rate 1 (m <sup>3</sup> /min)	Rate 2 (m <sup>3</sup> /min)
14:02	—	627674.40	620383.50	—	—
14:05	3	627674.94	620384.07	0.1800	0.1900
14:10	5	627675.88	620385.01	0.1880	0.1880
14:15	5	627676.44	620385.58	0.1120	0.1140
14:20	5	627676.68	620385.82	0.0480	0.0480
14:25	5	627676.89	620386.02	0.0420	0.0400
14:30	5	627676.93	620386.07	0.0080	0.0100
14:35	5	627676.97	620386.11	0.0070	0.0080
14:40	5	627676.98	620386.14	0.0038	0.0052
14:45	5	627676.98	620386.14	0.0000	0.0000

**Table D.3:** Daily flow measurements taken from each borehole and the meters at the outlet of the elevated reservoir

	Borehole #				Reservoir outlet		<b>Total</b>	<b>Average</b>
	BH 32655	BH 37746	BH 32642	BH 16561	Meter 1	Meter 2		
<b>Day 1</b>								
Water Pumped (m <sup>3</sup> )	66.8	60.15	50.00	52.74	230.04	229.03	<b>229.54</b>	
Hours Pumped (m <sup>3</sup> )	14.45							
Rate (m <sup>3</sup> /h)	4.62	4.16	3.46	3.65	15.92	15.85	<b>15.89</b>	
Amount Lost (m <sup>3</sup> )	0.15							
<b>Day 2</b>								
Water Pumped (m <sup>3</sup> )	61.8	53.61	46.00	49.1	210.83	209.84	<b>210.33</b>	
Hours Pumped (m <sup>3</sup> )	14.09							
Rate (m <sup>3</sup> /h)	4.39	3.80	3.26	3.48	14.96	14.89	<b>14.93</b>	
Amount Lost (m <sup>3</sup> )	0.18							
<b>Day 3</b>								
Water Pumped (m <sup>3</sup> )	68.25	59.09	50.90	53.9	232.3	231.61	<b>231.96</b>	
Hours Pumped (m <sup>3</sup> )	15.83							
Rate (m <sup>3</sup> /h)	4.31	3.73	3.21	3.40	14.67	14.63	<b>14.65</b>	
Amount Lost (m <sup>3</sup> )	0.19							