TOOLS TO MEASURE IMPACTS AND OPERATIONS OF RURAL SMALL-COMMUNITY WATER SUPPLIES IN RURAL SOUTH AFRICA

Report to the

Water Research Commission

by

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This report supplements WRC Report 1700/1/12: *The Impacts of Rural Small-Community Water Supply Interventions in Rural South Africa.*

Executive summary

This report contains descriptions and contents of two rapid assessment tools. Tool 1 is a tool to measure impacts of rural small-community water supply interventions in rural South Africa. Tool 2 is a tool for Rapid technical assessment of rural water supply systems.

Tool 1: THE IMPACT MEASUREMENT TOOL

Introduction

Chapters 1-4 in WRC report 1700/1/12 on the *Impacts of rural small-community water supply interventions in rural South Africa* (Jagals, 2012 – and referred to herein as the *main report*) has shown the health, sociological and economic impacts on rural households of improved access to, as well as availability and potability of water from small community water supply systems. This simple tool was based on measuring only the impacts of changes in the service functions since these have been shown (in Chapter 2) to be relatively easy to assess and its output parameters (the impact values) could be modelled.

These impact values were derived from the *function changes* and *effect values* in the report and used in the tool under the assumption that these are sufficiently generic realistically reflect what could be expected in rural small-community water supply interventions.

Water service providers as well as other interest groups can use for themselves this tool – which is essentially a single monitoring instrument – to evaluate whether the small-community water supply systems that they are providing, are beneficial for their recipients and if not, where there will be areas that require improvement.

Piloting the tool

The tool was applied to the data of several of the communities using a range of interventions from the ones that showed the most consistent performance as data from villages that had no service. In all instances, the tool could fit the impact based on the function performances with the impact found in the study.

Tool 2: THE RAPID ASSESSMENT TOOL

Introduction

This tool was developed as a precursor to the impact assessment tool (Tool 1) and in several of the technical aspects formed the basis of Tool 1. The assumption was that the primary reason for an impact, be it on health, the social aspects or the economics in a small rural community that has been provided with a small water supply system would be the overall functioning of the system.

Assessment criteria

General requirements

Three general requirements drove the development of the tool methodology ❶ consistency and comparability; ❷ practicality and ❸ rapidity. As a rapid assessment tool would have a limited scope and its primary power of the methodology lies in its ability to rank and compare the results from a number of different systems, to alert the responsible authorities to those systems that require more urgent attention than others. Moreover, it is meant to guide authorities to those aspects of the systems which are performing poorly (e.g. water quality, or systems where the growth had outstripped the capacity of the system), but does not provide detailed solutions.

Assessment criteria

A thorough review of the literature revealed a host of different criteria pertaining to water supply and distribution systems. In the main, two criteria were found to be relevant, namely *reliability* and *durability*. These were further split into more narrowly defined criteria, namely *availability*, *capacity, continuity (reliability)* and *condition (durability)*.

- *Availability* pertains to the adequacy of the *source* in terms of *quantity* and *quality* of the water that can be obtained from it. Availability starts to drop when either the required quantity cannot be drawn from the source, or the water quality drops below the required standard for drinking water supply:
    - Water quantity is the ratio of the water volume that can be *supplied* to the water volume *demand* in the community that was provided with the system;
    - Water quality which were measured by pH (to detect a lack of chemical stability), electrical conductivity (to detect excessive brackishness), turbidity (NTU to detect aesthetic problems) and total coliforms (TC) to signal system hygiene problems.

For the purposes of this tool, purposes, water quality at or better than the *ideal* limit would score 1 and quality worse than the *absolute* limit would score 0. Water quality results between ideal and absolute were interpolated between 1 and 0.

- *Capacity* is the adequacy of the *water supply system* (including transport, storage and distribution) to supply water to the community. The capacity index is based on four sub-indices, each dealing with a part of the water path from water source to the consumers' homes:
    - From source to storage (bulk supply capacity);
    - The storage itself (storage capacity);
    - From storage to standpipe (distribution capacity);
    - From the standpipe to the home (human carrying capacity);

- *Continuity* is the consistency whereby water is conveyed from the source to the consumer. System failure measured as short interruptions (measured in hours) to prolonged periods (measured in days or even weeks).

- *Condition* is the current status of the system in terms of its serviceability. For a water supply system, all the components (i.e. pipes, pumps, reservoir, standpipes, hand pumps) must ideally be assessed to give an overall picture of the system condition. Four readily observable indicators were identified:
    - Condition of the tap(s) connected to the standpipe;
    - Condition of the standpipe platform;
    - Condition of the tap support;
    - Presence and condition of secondary water connections.

Comparative evaluation

A comparison was made of the findings of this method and one used for a similar project conducted on a much grander scale, by the Department of Water Affairs and Forestry to develop a system for spot check assessments of water and sanitation projects constructed under the Municipal Infrastructural Grant programme of the national government (DWAF/CSIR 2007). There are marked similarities between the DWAF and our approaches. Observations were based on what could be determined during a site visit, without any external data sources. All data had to be collected during a single visit, thus providing a snap-shot only. As DWAF worked with larger projects, they devised a transect sampling strategy to include only a sample of households. The DWAF project considered both sanitation and water supply, both at bulk and household level. The overlap between the DWAF project and our project is thus only the bulk water supply system.

It was clear that the two independent projects came up with similar approaches, which strengthens the credibility of both. The scope of the DWAF project was much broader and directed its primary attention at *finding* problems. Our rapid assessment tool, more modest, directed its primary attention to finding indicators which were not only easily measurable, but would also suggest the logical means of fixing the problem.

The findings of the DWAF project were in several critical aspects similar to those found in the case studies of this project. Their *reliability* component for water supply systems was found to score the lowest, corresponding to our finding of *continuity* being unacceptably poor.

Table of contents

Tool 1
A tool to measure impacts of rural small-community water supply interventions in rural South Africa
(By Paul Jagals and Luuk Rietveld)

1 Introduction

Chapters 1-4 Chapters 1-4 in the WRC report 1700/12/1 on the Impacts of rural small-community water supply interventions in rural South Africa (Jagals, 2012), have shown the health, sociological and economic impacts on rural households of improved access to, as well as availability and potability of water from small community water supply systems. It would be ideal if programmes of similar extent of assessments could be rolled out to as many as is feasible other areas of South Africa. However this would require water service providers and other associated users to invest in exhaustive and costly research.

The research in this report has shown that a well maintained basic water supply service, even with the practice of fetching water from communal taps in heavy (when filled) and poorly sanitised containers still very much in place, would mostly have a beneficial impact on health, social satisfaction and economic values to the households in the community.

The HSE impact categories indicated the extent to which the intervention, consisting of the system and its continual service functions, impacted on very small and rural recipient communities of limited socio-economic status. It could therefore be argued that although the research reported here reflected only a very limited sample of the small-community water supply service scenario in South Africa, it provides sufficient information for a generic and simple tool to monitor small community water supply services.

Therefore, a simple tool could be based on measuring only the impacts of changes in the service functions. These have been shown in Chapter 2 to be relatively easy to assess and from there describe the impact of the water supply service intervention. By adding a limited suite of effects measurements, the resolution for assessing the impacts is increased.

A simplified tool will have a two-fold advantage. Firstly it will avoid costly rolling out the full research package used in this study and reflected in this report – to a more representative sample of communities across South Africa. The functions, their related criteria and the methods used for this research are quite simply too broad to use as actual measuring instruments for a routine monitoring programme aimed at tracking impact of small community water supply schemes roll-outs, maintenance and operations over time. Most importantly however, a simpler tool will avoid the complexity of monitoring these services. It offers a simpler way to collect and synthesize new data and – based on the parameters derived and tested in this research, measure the impact of the system and its functions.

The impact values derived from the research as reported in Chapters 1-4 are not advocated to be an exact answer from what was research into rather non-exact science. Nevertheless, based on the findings of the research as well as reports and literature from similar studies and related research activities elsewhere in the world, the function changes and effect values used in the tool are assumed sufficiently generic to be a realistic reflection of what could be expected in small-community water supply interventions.

The researcher community can still use the methodologies for the various research components to pursue some research of their own, hopefully thereby refining the methods and sharpening the results so that it can continue to improve the use of the monitoring tool should a central repository and data custodian assume this responsibility.

More generally though, water service providers as well as other interest groups can use the single monitoring instrument discussed reported on in this report to evaluate for themselves whether the small-community water supply systems that they are providing, are beneficial for their recipients and if not, where there will be areas that require improvement.

2 Layout

Of the four <u>*effect*</u> components, two were excluded because they require more research to clearly account for these effects in impact analyses. These were:

- The risk of contracting a *musculo-skeletal disorder.* As shown in Chapter 3, while this risk was indicated in this study it was not sufficient to account for it in in terms of health, sociologic or economic impact.
- The risk of *bacterial infection.* This was indicated for the exposed communities but could not be directly accounted for in the health impact or economic impact analyses.

The actual tool is in Excel spread sheet format obtainable as part of this tool pack. The tool was tested using the data provided in the case study described at the end of this report. The data was obtained from the actual intervention communities from the research area described in Chapter 1.

The layout of this report is related to the parameters, structure and data requirements of the tool. It includes descriptions of the formulae, fixed parameter values derived from the research, the inputs required from the user as well as the very basic types of data that have to be measured to populated the toll field and derive an impact value as final outcome.

3 TOOL COMPONENTS, FUNCTION PARAMETERS, DATA INPUTS AND CALCULATIONS

The components ultimately used in the tool are shown in Table 1 and the reasons for their inclusion discussed briefly in sections to follow.

Table 1: The monitoring tool components

Function	Indicator	Tool criteria	Source of data
Access	Distance	Distance in metres from home to water source point	Calculation function in tool
	Capita per standpipe	Persons (capita) per water point	Calculation based on number of people in community reliant on communal taps and number of standpipes
	Sourcing point condition	Tap and platform condition	Onsite technical assessment based on tap condition, flow, and supports as well as platform condition
Availability	Capacity of system / source	Meeting demand including loss factor	Desktop, design and onsite technical assessment of system capacity to meet planned / expected water demand based on policy level water supply quantities
	Continuity	Long and short interruptions	Calculated from community survey and service records
	Flow rate	Flow rate of taps / fill rate of containers in ℓ / min	Calculated from onsite tap flow measurements and tap numbers
Potability	Supply hazard	Source point *E. coli*: Org / 100 mℓ at the 95th %ile	*E. coli* numbers measured in tap water samples and reported at the 95th %ile
	Supply hygiene	Source point Total coliforms: Org / 100 mℓ	As for *E. coli*
		Source point Turbidity NTU/ℓ	Onsite measurement at source point
	Supply stability	pH scale	Onsite measurement at source point
	Supply aesthetic quality	Conductivity mS / m	at source point
Effect			
Time	Individual collection time (minutes) per 20-ℓ container	Minutes (based on 5 mins walking to source, 5 mins fill time and 16 mins extra time)	From the research reported in Chapter 2
Water use	Daily water quantity collected per household member	Litres per person per day at the 10th %ile	From the research reported in Chapter 2
Domestic water safety	*E. coli* in containers (container effect factor)	Org / 100 mℓ – fixed value factor at 1.8 at the 90th %ile	Measured *E. coli* numbers multiplied by the container effect (from research)

4 ACCESS

Access to an improved water supply is a widely used expression to indicate the mode of improvement. It is often not clearly defined (Refer to review Section 2.3.1, Chapter 2) but can be best described as a function of ❶ distance, ❷ number of people per communal tap in the serviced community, and finally, ❸ the condition of the communal taps (Section 3.2, Chapter 2).

4.1 Distance

Distance is best described by meters between source and the home if the tap is not on site. In this case on-site taps and in-house connections were not included in the calculations as these were not deemed significant in the quest to collect water. However, to measure all actual distances in a community can be tedious, cumbersome and often quite inaccurate because community water carrying patterns change as soon as measurements commence.

There is a more practical way to measure distance as is shown below. The research reported in Chapter 2 showed that the distance can be calculated from the water point density (number of communal taps) in the area receiving the service (yard taps and in house connections are not considered in this equation).

Distance (D_{av}) in metres was therefore derived from:

$$D_{av} = \left(\frac{1}{\pi * wp_{dens}} \right)^{0.5}$$

Where wp_{dens} = water point density in #/ $m^{2.}$

Water point numbers can be derived from the design planning of the system and the area (usually in hectares) from surveyor mapping of the area – quite often also included in the design planning.

4.2 Taps for people

The *number of communal taps available* for the number of people in a service community plays a major role in how long a household member collecting water has to wait (queue) at the tap – often accounting as part of the 16 minutes extra time derived from this research (Section 3.1, Chapter 3).

The *persons (capita) per communal tap* (C_{tap}) is defined by # persons / # taps.

This is easily calculated from counting the taps and obtaining people numbers from the latest census data.

4.3 Water point condition

The communal tap and its structure also played a major role in the accessibility of communal tap water (Section3.2, Chapter 2).

The *water point condition* index (I_{cond}) is defined by:

$$I_{\text{tap}} = \frac{N_{\text{tap,good}}}{N_{wp,total}}$$

$$I_{\text{platform}} = \frac{N_{\text{platform,good}}}{N_{wp,total}}$$

$$I_{\text{support}} = \frac{N_{\text{support,good}}}{N_{wp,total}}$$

$$I_{\text{sec}} = \frac{(1 - N_{\text{sec,connect}})}{N_{wp,total}}$$

$$I_{cond} = \delta_1 I_{\text{tap}} + \delta_2 I_{\text{platform}} + \delta_3 I_{\text{support}} + \delta_4 I_{\text{sec}}$$

Where $N_{wp,total}$ is the total number of water points in the community, $N_{tap,good}$, $N_{platform,good}$, $N_{support,good}$ the number of taps, platforms and supports, respectively, that are in good state, $N_{sec,connect}$ the number of standpipes with secondary connections, and δ_i are weighing factors, where $\Sigma\delta_i = 1$.

These data bits are obtainable by assessing the actual water point infrastructure as described in Section 3.2, Chapter 2.

5 Availability

Access to a water source has little meaning if water is not available at that point. The indicators for availability we have derived from the research to best fit this tools were the ❶ capacity of the system to deliver the quantity of water required by the community, ❷ continuity of the supply and ❸ the rate of water flow at the taps, more in particular, the ratio of taps in the monitored area that have the required flow rate.

5.1 Capacity

The *capacity of the system* to deliver the required quantity of water:

$$I_{pump} = \frac{Q_{pump}}{Q_{demand}} \leq 1$$

$$I_{res} = \frac{V_{res}}{Q_{demand} * T_{res}} \leq 1$$

$$I_{cap} = \beta_1 I_{pump} + \beta_2 I_{res}$$

Where Q_{pump} is the actual pumping capacity (in m^3/h), Q_{demand} is the required water flow for distribution, including losses in the system (in m^3/h), V_{res} is the installed reservoir volume (in m^3), T_{res} is the required minimum storage time (in h), , and β_i are weighting factors, where $\Sigma\beta_i = 1$.

Data for tis component will be obtainable from design planning documents as well as operational records.

5.2 Continuity

The availability of water at the water points was based on interruptions both planned and breakdown-related. The *continuity* index (I_{cont}) is defined by (Sections 3.1 and 3.2, Chapter 2):

$$I_{day,month} = e^{-\lambda*(N_d - N_{d,\max})} \leq 1$$

$$I_{hours,day} = \frac{T_{\sup}}{T_{\sup,\min}} \leq 1$$

$$I_{cont} = \gamma_1 I_{day,month} + \gamma_2 I_{hours,day}$$

Where T_{sup} is the supply time per day (in h), $T_{sup,min}$ is the minimum, predetermined supply time per day (in h), N_d is the number of days per month without water, while water was available, $N_{d,max}$ is the maximum allowable number of days per month without water, and γ_i are weighting factors, where $\Sigma\gamma_i = 1$. South African guidelines are very conservative in the allowable number of days per month without water i.e. a very small number, a linear relation cannot be used. An exponential relation is therefore adopted, where the factor λ depends on local circumstances and insights.

Data for these components are obtainable from operational records.

5.3 Ratio of taps with sufficient flow

Flow rate was determined by the ratio of taps with adequate flow:

$$I_{wp,funct} = \frac{N_{wp,good}}{N_{wp,total}} \leq 1$$

Where $N_{wp,good}$ is water point with a sufficient flow rate, $N_{wp,total}$ is the total number of water points

Data are usually obtainable by measurement of flows at the tap.

6 Potability

Potability measurement is structured according to the approach described in Chapter 2, namely ❶ the hazard factor, ❷ the supply hygiene and the ❸ aesthetic quality of the water provided by the new system.

Data for all these parameters will have to be obtained according to measurements as prescribed in the SABS National Standards for Drinking Water (SANS 241: 2006).

6.1 The hazard factor

The determining factor here was the numbers of *E. coli* measured in water sampled at the communal taps, which could be expected to be monitored frequently. The tool at this point reflects the *E. coli* as measured at the taps and the results entered at compliance level required by the water quality standard.

6.2 The supply hygiene

The determining factor here was the numbers of total coliforms measured at the tap, which should be monitored frequently.

6.3 The aesthetic quality

The aesthetic water quality indices are calculated as follows:

$$I_{pH} = e^{\mu 1(pH-7)}$$

$$I_{EC} = e^{-\mu 2 * EC}$$

$$I_{NTU} = e^{-\mu 3 * NTU}$$

μ_i are constants depending on the allowable values in the drinking water.

7 Effect parameters, equations and data requirements

Chapter 3 in the main report (WRC K5 1700/1) discusses effects that were measured as outcomes of the changes in water service functions. The effects selected here were ❶ water collection time, ❷ actual daily water use per person and ❸ the container effect in the context of the health-related microbial quality of water sampled in domestic water storage containers.

The numbers for these effect parameters are fixed in the tools as were derived from the research reported in Chapter 3. These values can of course be changed as new research shows the need. It is not intended for monitoring agencies to do such research, but it is also not excluded – the full methodologies are described in the main report.

7.1 Water collection time

The calculation for *time* was as follows:

$Time = Time_{filling} + Time_{walking} + Time_{extra} = Time_{filling} + D_{av}/v_{av}*2 + (16-50*(1/HHwp))$

Where v_{av} is average walking speed in m/min and HHwp is Households per waterpoint.

The input data will already have been obtained from the households per water point measurements described in 3.1.1.2 above. The other values are fixed values derived from the research.

7.2 Actual daily water use per person

The *actual daily water* collected by members of the households were reported in the research and are used as fixed values here. Table 2 in Section 4 below shows these values.

7.3 The container effect

As long as containers are used to collect and store water at communal taps, an increase in the number of *E. coli* in the containers would be a given. The container effect for this work is set at numbers of *E. coli* per 100 mℓ * 1.8 (the latter is the container effect). In case of 0 (zero) *E. coli*, it was still assumed that the consumer would be exposed to at least 8 *E. coli* per 100 mℓ as our research have shown.

8 FIXED INPUT PARAMETERS AND WEIGHTING FACTORS

The research reported in the previous chapters has shown that where the function measurements return a "good" or "compliant" performance outcome, the HSE impacts were beneficial (Appendix A). The "Impact" statement that is reflected by the tool (Excel spread sheets) once applied to the data from a particular community is based on the function performances and the selected effect values as supported by the HSE outcomes in Chapter 4 of the main report. Calibration of the toll therefore was done but using fixed input parameters (Table 2) derived from the research and weighting factors (Table 3) judged by the research group to be most appropriate. All these values can of course be changed should a larger stakeholder group consider these and conclude on the necessity for the changes.

Table 2: Fixed input parameters

			Actual	Ideal		
Water demand	Litres per capita use for:	Standpipes	15	25	The *actual values* showed here were derived from the research and are given at the 10th %ile as this is a minimum compliance we sought. It is used as a fixed value in the calculation of impact.	
		Yard connections	25	60		
		House connections	60	120	The *ideal values* were derived from South African guidelines and other literature	
	Water loss factor	Based on research	1.25		This value was derived from the research. It is a value most likely to be changed as other measurements shows different values	
		Comply	**Ideal**	**Limit**		
Access	Distance	200.0	10.0	1000.0	metres	The *compliance* distance of 200 m max is taken from South African guidelines. The 10m *ideal* and 1000m *limit* is from literature.
	Capita per standpost	100.0	6.0	250.0	#/#	From literature
	Collection time of 20 ℓ	15.0	5.0	25.0	min	Actual measurements from the research
	Walking speed	1.0			m/s	
	Filling time of 20 ℓ container	1.5			min	
	Maximum extra time	16.0			min	
Availability	Lcd	25.0	50.0	5.0	litres	The required quantities are taken from South African guidelines and from literature
	Filling rate	10	20	5	l/min	Actual measurements from the research
Potability						
Hazard	*E. coli*	0.1	0	1	org/100ml	SABS National Standards for Drinking Water (SANS 241: 2006)
System hygiene	Total coliforms	1	0.1	10	org/100ml	
	Turbidity	0.1	1	20	NTU	
Aesthetics	pH (low)	5.0	4.5	4.0	-	
	pH (high)	9.5	10.0	10.5	-	
	Conductivity	70	150	370	mS/m	
Hazard Effect	*E. coli* container effect factor	1.8	Actual measurements from the research			
Capacity parameters						
Required storage for:	Gravity systems	1.0	days		From South African guidelines and from literature	
	Pumped systems	2.0	days			
	Minimum flow rate at taps	10	litre/minute			
	Minimum water point density	15	#/km2			
Continuity parameters	Normal daily operating hours	10	h/day		Actual measurements from the research and values from literature	
	Allowable days of non-supply	7	days/year		From South African guidelines and from literature	
	Lambda factor	0.5	-		Fixed mathematical value	

Table 3: Fixed input parameters

Compliance	Percentile	0.9	This percentile is key to what the assessor wants to monitor – for instance set at the 90th %ile (as we did for the case study), indicates that there should be 09% compliance before the system is accepted to be beneficial
Capacity	Mass delivery / pump capacity	0.75	These weightings are in terms of the importance of the factor – we deemed delivery more important than storage as it certainly appeared to be so in the research area
	Storage – Reservoir capacity	0.25	
Continuity	Short interruptions	0.50	Both these types of interruptions have their own level of impact and were seen to be equally detrimental.
	Long interruptions	0.50	
Condition (communal taps)	Taps	0.30	Taps and platforms were for various reasons shown in the research, the more important factors here
	Platforms	0.30	
	Supports	0.20	
	Secondary connections	0.20	

9 Piloting the Tool

The tool was applied to the data of several of the communities using a range of interventions from the ones that showed the most consistent performance as data from villages that had no service. In all instances, the tool could fit the impact based on the function performances with the impact found in the study.

10 Case Studies

In the case of one of the upgraded communities – receiving communal taps and some households paying for yard tap connections (Table 4), the impact was beneficial (Table 5). In the case of the communities not receiving any service (Table 6), the impact was quite detrimental (Table 7).

10.1 Upgrade community

Table 4: The measurements used for the intervention community – using ground water fed to communal taps

Community level data		
Household size (median people numbers)	5.4	Used to calculate actual water use and official water demand
Community location footprint	20ha	Used to calculate the average distance between households and water point
Service level data		
Number of water points (communal taps)	16	Used to calculate the average distance between households and water point
Households per water point / tap	140	Used to calculate the collection time
Households on private connections	9	Used to calculate actual water use and official water demand
Short / managed interruptions	16 hpd	Community makes water available for 8 hours due to lower pumping capacity – i.e. pump does not pump for at least two days per month because of diesel shortages
Longer interruptions	2 dpm	Causes lower shorter pumping capacity
System level hardware		
Gravity fed system	No	This means water is pumped from the source to the higher level reservoir
Pumping delivery capacity	15 Kℓ	Calculated from design capacity and hours pumping
Storage capacity	20 Kℓ	Design capacity of high level drinking water reservoir
Standpipes with: Adequate flow	16	Measured to gauge ease of access – the taps had good flow – fast filling
Good taps	8	Poor quality taps wore out easily – making access difficult
Good platforms	9	Platforms poorly constructed – breaking up – making access difficult
Good supports	16	All the tap supports were still good – assists with lifting heavy containers
Unsolicited connections	4	Excessive use by owners of these collections deny equitable share of water
Water Quality Data		
pH	7	Good pH
Conductivity	250	Slightly elevated salts
Turbidity	2.5	Reasonably clear
Total coliforms	25	Some coliforms can be found in un-chlorinated tap water 90th %ile of several lab results
E coli	0	Good microbial quality tap water – 90th %ile of several lab results

Table 5: Impact measurement in the upgrade community (ground water fed to communal taps)

Comunity	Upgraded		
Date	2009		
Community level data			
Household size serviced by standpipes	5.4	#	Census data
Community location footprint	35	ha	Survey records
Service level data			
Actual demand (Litres Capita Day)			
Standpipe	11,340		*Calculate*
Yard connection	1,215		*Calculate*
House connection	0		*Calculate*
Number water points	16	#	Design records
# households served by communal tap	140	#	Community records
# household members served by communal tap	756	litre/day	*Calculate*
Daily water demand (litres) by communal tap	23,625		*Calculate*
# households served by yard tap	9	#	Community records
# household members served by yard tap	49	litre/day	*Calculate*
Water demand (litres) by yard tap	3,645		*Calculate*
households served by house connection	0	#	Community records
# household members served by house connection	0	litre/day	*Calculate*
Water demand by house connection	0		*Calculate*
Daily total community water demand	27,270	litre/day	*Calculate*
System level hardware data			
Short / managed interruptions	16	h/24 hrs	Service records / community survey
Long interruptions	2	days/month	Service records / community survey
Gravity system	NO		
Pump / delivery capacity	25,000	litre/day	Design records
Storage capacity	15,000	litre	Design records
Standpipes with:		#	
Adequate flow	16	#	Onsite assessment
Good taps	8	#	Onsite assessment
Good platforms	9	#	Onsite assessment
Good supports	16	#	Onsite assessment
Unsolicited connections	4	-	Onsite assessment
Water quality data measured at tap (90th %tile of total number of samples)			
pH	7.0		Laboratory / Onsite assessment
Conductivity	250	NTU	Laboratory / Onsite assessment
Turbidity	2.5	mS/m	Laboratory / Onsite assessment
Total coliforms	25.00	#/100 ml	Laboratory assessment
E-coli	0.00	#/100 ml	Laboratory assessment

Outcome	*Good*	0
	Compliant	1
	Poor	2
	Critical	3
Functions		
Access		**2**
Availability		**2**
Potability:	**Hazard**	**0**
	System hygiene	**3**
	Aesthetics	**3**
Effects		
Collection time		**1**
Water lcd		**1**
Container effect		**2**
Total impact		**2**

The results in Table 4 show that the system performed poorly, despite good performance for collection time and water available in good quantity to the household. This is mainly because the access to and the interruptions of the pump availability compelled the community to time-manage the availability of water at the tap. It is also quite a hypothetical value in the sense that the community used less than the 25 litre per person per day – which should have eased on the performance. However, should the community use 25 ℓcd at the 10^{th} %ile, this particular system would be totally under-designed both in what the pumping system could deliver as well as storage. This does not bode well for the days to come if the community starts using more house connections.

The performances were interpreted at the 60^{th} percentile – 0.1 percentile point more than the median as one would expect a new system to perform optimally for more than the average time. If the tool is asked to calculate the system performance at the 90^{th} percentile (Table 3), the system would return a "critical" (red) performance result.

The lesson here is that the system was probably under designed in the first place, or that the community has simply outgrown the original design capacity in a very short time – something to consider when designing future systems.

10.2 The no-service community

Table 6: The measurements used for the no-service community (using untreated river water)

Community level data		
Household size (median people numbers)	6	Used to calculate actual water use and official water demand
Community location footprint	20	Used to calculate the average distance between households and water point at the river
Service level data		
Number of water points	1	Used to calculate the average distance between households and water point
Households per water point / tap	70	Used to calculate the collection time
Households on private connections	0	NA
Short / managed interruptions	0 hpd	River water always available – much higher availability
Longer interruptions	0 dpm	Always available – river never dries up
System level hardware		
Gravity fed system	No	This means water is fetched at the river – no tap system
Pumping delivery capacity	0	
Storage capacity	0	
Standpipes with: Adequate flow	0	
Good taps	0	
Good platforms	0	
Good supports	0	
Unsolicited connections	0	
Water Quality Data		
pH	7	Good pH
Conductivity	90	River water is sweeter than the ground water of the upgrade community
Turbidity	10	Reasonably clear
Total coliforms	500	Total coliforms abound in untreated river water
E coli	50	Poor microbial quality tap water high hazard in *E. coli* contamination

The results in Table 7 show that the impact was critical in terms of the water supply performance as one would expect from these conditions. The community did have uninterrupted access to their water, which holds the potential for them to use as much as they wanted to. Despite their water being always available, access was a problem as the point by the river did not lend itself to the ease of access that a properly constructed water point (tap) would offer.

The performances were also interpreted at the 60^{th} percentile – 0.1 percentile point more than the median as one would expect a new system to perform optimally for more than the average time.

Table 7: Impact measurement in the reference community (no service – using untreated river water)

Community	Upgraded		
Date	2009		
Community level data			
Household size serviced by standpipes	6	#	Census data
Community location footprint	20	ha	Survey records
Service level data			
Actual demand (Litres Capita Day)			
Standpipe	6,300		*Calculate*
Yard connection	0		*Calculate*
House connection	0		*Calculate*
Number water points	1	#	Design records
# households served by communal tap	70	#	Community records
# household members served by communal tap	420	litre/day	*Calculate*
Daily water demand (litres) by communal tap	13,125		*Calculate*
# households served by yard tap	0	#	Community records
# household members served by yard tap	0	litre/day	*Calculate*
Water demand (litres) by yard tap	0		*Calculate*
# households served by house connection	0	#	Community records
# household members served by house connection	0	litre/day	*Calculate*
Water demand by house connection	0		*Calculate*
Daily total community water demand	13,125	litre/day	*Calculate*
System level hardware data			
Short / managed interruptions	0	h/24 hrs	Service records / community survey
Long interruptions	0	days/month	Service records / community survey
Gravity system	NO		
Pump / delivery capacity	0	litre/day	Design records
Storage capacity	0	litre	Design records
Standpipes with:		#	
Adequate flow	0	#	Onsite assessment
Good taps	0	#	Onsite assessment
Good platforms	0	#	Onsite assessment
Good supports	0	#	Onsite assessment
Unsolicited connections	0	-	Onsite assessment
Water quality data measured at tap (90th %tile of total number of samples)			
pH	7.0		Laboratory / Onsite assessment
Conductivity	90	NTU	Laboratory / Onsite assessment
Turbidity	10	mS/m	Laboratory / Onsite assessment
Total coliforms	500.00	#/100 ml	Laboratory assessment
E-coli	50.00	#/100 ml	Laboratory assessment

Outcome	*Good*	0
	Compliant	1
	Poor	2
	Critical	3
Functions		
Access		**3**
Availability		**3**
Potability:	**Hazard**	**3**
	System hygiene	**3**
	Aesthetics	**3**
Effects		
Collection time		**2**
Water lcd		**1**
Container effect		**3**
Total impact		**3**

11 CONCLUSION

To obtain a rapid indication for the performance of a small water supply system, criteria were sought that are well defined, but are easily measurable. These were derived from the research work and used in the development of the tool. The tool can be successfully applied to give a broad assessment of the impact of a small water supply intervention in rural areas. However, there is a note of caution.

The proposed tool was developed to provide a "snapshot" of a system at the time of the assessment. Some of the indicators will require that consumers be interviewed about the some of the aspects. For this tool to work well, a higher frequency of assessments will necessarily require reflection over a period longer than a "snapshot". Experience, the research as well as the literature have shown that consumers cannot reliably recall such frequencies more than a month in the past. We therefore assumed that the "snapshot" would reflect the performance of the system over the month preceding the assessment. To make the tool work effective to obtain a more comprehensive picture of a particular system's performance and its predicted impact over time, multiple assessments would have to be carried out, say monthly for twelve months to represent a full year.

For instance in the research area, there would be no option but to conduct multiple site visits to capture extreme events such as the dry winter months when groundwater tables drop somewhat, or the summer vacation period when many migrant workers return to their home villages.

This means that the tool should ideally be used frequently by water utilities and service providers and the data collected over time will continue to question the on-going validity of the tool. It is therefore important to note that the various assumptions we have made in parameterising the tool, will have to be revised. The tool makes provision for that in the calibration page where these changes can be affected.

Tool 2
Rapid technical assessment of rural water supply systems
(By Johannes Haarhoff)

List of Symbols

Alphabetic

D	per capita daily demand for each type of connection (ℓ/capita/day)
e	natural logarithm base (2.71828)
I	index, sub-index or sub-sub index
N	number of people having access to the supply
N_d	number of days without water when source was available
V_{month}	monthly water production of the source (m^3/month)
Q_{demand}	daily water demand (m^3/day)
Q_{pump}	pumping capacity from source to storage (m^3/day)
T_{sup}	supply time (h)

Greek

η	factor to account for system losses
μ	calibration factors derived from allowable water quality parameters
ε	weighting factors for water quality sub-index
α	weighting factors for availability index
β	weighting factors for capacity index
γ	weighting factors for continuity index
δ	weighting factors for condition index
ρ	water point density
λ	factor to penalise longer term interruptions

Subscripts

actual	as measured/calculated
av	availability
av,qual	the quality aspect of availability
av,quant	the quantity aspect of availability
cont	continuity
cond	condition
hc	house connection
min	minimum allowable
max	maximum allowable
platform	concrete base of standpipe
pump	pumping capacity from source to storage
sec	secondary, unauthorised connections at standpipes
sp	standpipe connection
support	vertical support of tap at standpipe
tap	the tap at a standpipe
wp,dens	water point density
wp,func	water point functionality
yc	yard connection

1 Background and introduction

A typical rural water supply system, as considered in this report, is supplied from a river, spring or a borehole, supplying water to a central elevated tank, from where a simple distribution system is fed. The system terminates in a series of public standpipes.

The development of the technical procedure presented started early in 2006 with a first reconnaissance visit to the Vhembe District study area, followed by study periods during July 2006 (first survey), September/October 2007 (detailed survey) and September/October 2008 (final survey to verify the proposed procedure). Significant contributions were made by Gerdien Sterk (MEng student at TU Delft), Luuk Rietveld (professor at TU Delft), Paul Jagals (professor at Tshwane University of Technology) and Mike Mokoena (student at Tshwane University of Technology).

A peer-reviewed paper covering the surveys up to the end of 2007 was published in 2009 in the Journal of the Chemistry and Physics of the Earth, 34 (2009) 43-49. An oral presentation of the proposed method was made at the 10th International Water Distribution System Analysis Conference held during August 2008 in the Kruger National Park, which was favourably received.

2 Assessment criteria

2.1 General requirements

Three general requirements drove the development of the proposed methodology:

- *Consistency and comparability*. To make comparable assessments between many different systems scattered throughout a large and diverse country, it is important to eliminate subjectivity of the assessors as far as possible. All observations, readings and impressions thus have to be quantitative and algorithmic for reduction to a set of comparable numbers.
- *Practicality*. The assessments must only rely on what can be measured on site. In practice, it is notoriously difficult to find, for example, reliable as-built drawings from regional offices, or historical sequences of water quality measurements from some remote central laboratory. Also, there is an almost complete lack of on-line data for flows and pressures.
- *Rapidity*. A field assessment must done as rapidly as possible, to allow an observer to collect all the required field data in a single site visit.

It is obvious that an assessment will only provide a “snapshot” of the system at the time of the assessment. To assess the frequency and duration of supply failures, however, consumers have to be briefly interviewed. This information will reflect a situation covering the previous two weeks. Multiple assessments would therefore have to be carried out if a more comprehensive picture is required of the system performance, say twelve months to represent a full year. There would be no other option but to conduct multiple site visits to capture extreme events such as the dry winter months when groundwater tables are likely to drop, or the summer vacation period when many migrant workers return to their home villages to put the water supply systems under additional strain. It is furthermore assumed that the supply area of a water supply system is homogeneous – if not, it will be necessary to split the supply area into subsections where land use, customer profiles and water point density, for example, are about the same.

The limited scope of the proposed assessment method prohibits a detailed assessment in absolute terms. The primary power of the methodology lies in its ability to rank and compare the results from a number of different systems, to alert the responsible authorities to those systems that require more urgent attention than others. Moreover, it can guide authorities to those aspects of the systems which are performing poorly (e.g. water quality, or systems where the growth had outstripped the capacity of the system), but does not provide detailed solutions.

2.2 Selection of assessment criteria

A thorough review of the literature revealed a host of different criteria pertaining to water supply and distribution systems. Many of these criteria rely heavily on detailed hydraulic analyses and are framed in such specific terms as the percentage of time that threshold pressure can be maintained, the number of nodes not reaching specified flows, etc. These criteria obviously do not apply to simple systems with only a few standpipes. In the main, two criteria were found to be relevant, namely *reliability* and *durability*. Reliability of an urban water system generally encompasses the availability and distribution of water supplied, water usage restriction and pressure in the water main, as well as system failure in providing these services. A common measure of reliability is the probability of system failure, which could result due to failure at source, failure during distribution, insufficient pressure, or failure of outlet hardware. Reliability as a single criterion was found to be too broad for the assessment of rural water supply systems. In these cases, it is important to also determine where along the supply chain the failure occurred, and how the reliability could be improved. It was necessary to split the broader concept of reliability into three more narrowly defined criteria, namely *availability*, *capacity* and *continuity*. The concept of durability was captured as the better defined criterion of *condition*. The proposed method, described in more detail in the sub-sections below, thus hinges upon four criteria:

- The *availability* of a water source in terms of quality as well as quantity;
- The *capacity* to distribute the water from the source to the consumer;
- The *continuity* of the system over time as measure of distribution reliability;
- The *condition* of the system in terms of diligent maintenance and repair.

2.2.1 Selection and weighting of indicators

For each of the criteria, practical indicators had to be found which are quantifiable during a short site visit, requiring a minimum of prior knowledge. There is more than one indicator for each criterion, which requires weighting to combine them into a single index for each criterion. The ability to adjust the relative weight in this process is a feature which could make this method useful to any other authority, who could express their own performance priorities through appropriate weighting.

The indicators for each criterion, and their numerical manipulation, are covered further on when the criteria are discussed in more detail.

2.2.2 Water demand and losses

A key parameter underpinning the entire assessment procedure is the total water demand to be delivered by the system. It is necessary to identify the main components of water demand in rural context:

- Water losses from the distribution system, between the source and standpipes. This loss is relatively small, as network topologies in small rural systems are simple with little interlinking, pipe lengths are short, pipe diameters are small, and systems are built with robust pipe materials;
- Water leaks from the standpipe while it is not used;
- Water consumed at the standpipe. This consists of some direct drinking (a small component) and water used for washing laundry at the tap (a larger component). Many households rather carry the laundry for washing to the standpipe, rather than carrying the wash water to the home;
- Water spilled during the filling of containers due to the narrow opening of the plastic containers now almost in universal use, and spilling of the water while the container is carried or carted to the home;
- Water consumed from the containers in the home.

It should be noted that metering errors, an important consideration with conventional systems, are not relevant in rural water systems as water is free and unmetered. Almost all the rural systems in SA start as a system with standpipes only. When individual households later pay an extra fee, these households are provided with a yard tap for their exclusive use. The usual design approach is to allow for a per capita water demand of 25 litre / capita / day for standpipes, and 60 litre / capita / day for yard connections. The bulk water system components are sized for eventually supplying all the inhabitants with 60 litre / capita / day.

It is a common feature of most rural water supply systems to provide intermittent supply. Storage tanks are filled during the night, with the water supply to the households cut off. (This is to prevent the surreptitious use of water during the night for the watering of gardens, or leakage.) During the day, the water is turned on for a number of hours. Where capacity is adequate, the water is available during daylight hours, but where capacity is limited, the use is further restricted by only turning the water on for a few hours per day. In some cases, where communities have to pay for the diesel required for pumping, the hours are also restricted as a water, and thus diesel saving measure. Different communities have different arrangements. In a case where capacity was severely limiting, water was only turned on every second day, with the alternating day used for filling the storage tanks. Another community chose not to have water on Sundays at all, to allow their pump operator to have a day off.

A reasonable approach for estimating the total water demand is to use the design guidelines quoted above, and to use a single loss factor to account for all the loss components enumerated above. The estimate is thus given by:

$$Q_{demand} \quad = \quad \left[(N\,.\,D)_{sp} + (N\,.\,D)_{yc} + (N\,.\,D)_{hc} \right] . \,\eta$$

During this investigation, no serious effort was made to obtain reliable estimates for the loss factor, as the emphasis was on developing a framework rather than the detailed calibration of the method. For Folovhodwe, the largest cluster of five villages, a volumetric measurement of the daily water demand was made in the storage tank and compared with the previously measured per capita demand, which suggested a value of approximately 1.25 – a value used throughout this report.

3 AVAILABILITY

3.1 Indicators

Does the water supply system depend on an adequate water source? Availability pertains to the adequacy of the *source* in terms of *quantity* and *quality* of the water that can be obtained from it. Availability starts to drop when either the required quantity cannot be drawn from the source, or the water quality drops below the required standard for drinking water supply. The source can be a borehole, a spring or local storage dam, a treatment plant or a connection to a larger regional network. The availability index is thus made up as a weighted average of quantity and quality sub-indices:

$$I_{av} \quad = \quad \alpha_1\,.\,I_{av,quant} \quad + \quad \alpha_2\,.\,I_{av,qual}$$

3.1.1 Water quantity

The sub-index for water quantity is merely the ratio of the water volume that can be *supplied* to the water volume *demand*, with a maximum value of 1:

$$I_{av,quant} \quad = \quad \frac{V_{month}\,.\,1000}{30\,.\,Q_{demand}} \quad \leq \quad 1$$

3.1.2 Water quality

Comprehensive water quality assessment in remote rural areas is not possible due to the absence of reliable water quality records. Four readily measurable parameters were therefore selected for the sub-index for water quality:

- pH to detect a lack of chemical stability;
- Electrical conductivity to detect excessive brackishness;
- Turbidity (NTU) to detect aesthetic problems;
- Total coliforms (TC) to signal microbiological problems.

The first three can be rapidly measured on site, while the fourth requires a laboratory procedure. During this project, TC were measured with the *Quantitray* procedure which provided results after 24 hours.

For water quality variables, authorities usually recognise two (sometimes three) limits. For our purposes, water quality at or better than the *ideal* limit would score 1. Water quality worse than the *absolute* limit would score 0. Water quality between ideal and absolute would require interpolation between 1 and 0. Where an intermediate *suggested* limit is used, an appropriate index value has to be assigned to this limit. In this report, intermediate limits were used in all cases and the index values at the intermediate value were assumed to be 0.5 for pH and EC, and 0.8 for TC and turbidity. Table 1 shows the values for the water quality variables upon which the sub-indices were based in this report.

Table 1: Guidelines for rural water quality assessment (adapted from Water Research Commission *et al*, 1998)

Parameter	Electrical conductivity	pH	Total coliforms	Turbidity
Unit	**(mS/m)**	**(-)**	**(#/100ml)**	**(NTU)**
Absolute lower limit	-	4.0	-	-
Suggested lower limit	-	4.5	-	-
Ideal lower limit	-	5.0	-	-
Ideal upper limit	70	9.5	0	0.1
Suggested upper limit	150	10.0	10	1
Absolute upper limit	370	10.5	100	20

The indices are thus calculated according to the following algorithm:

variable ≥ absolute upper limit:	index = 0.0
variable ≤ ideal upper limit:	index = 1.0
variable = suggested upper limit	index = 0.5
ideal < variable < suggested	interpolate between 1.0 and 0.5
suggested < variable < absolute	interpolate between 0.5 and 0.0

For pH, there are two sets of limits, both on the high and the low side. This requires interpolation when the variable pH exceeds either the higher or lower ideal limit.

For pH and electrical conductivity, *linear* interpolation is suggested, with the general form:

$$y \quad = \quad y_1 + \left(\frac{x - x_1}{x_2 - x_1}\right).(y_2 - y_1)$$

For total coliforms and turbidity, the limits follow an approximately exponential trend. In these cases, *logarithmic* interpolation is suggested, with the general form:

$$y \quad = \quad y_1 + \left(\frac{\ln x - \ln x_1}{\ln x_2 - \ln x_1}\right).(y_2 - y_1)$$

Once a sub-index for each water quality variable had been determined, they are weighted to obtain an overall quality sub-index:

$$I_{av,qual} \quad = \quad \varepsilon_1 . I_{pH} + \varepsilon_2 . I_{EC} + \varepsilon_3 . I_{NTU} + \varepsilon_4 . I_{TC}$$

3.2 Example 1

A village of 450 inhabitants is served by a borehole pump with pumping capacity of 24 m^3/day. A total of 65 of the inhabitants stay in households with access to a yard connections; the others fetch their water from public standpipes. A water sample taken at the borehole pump has turbidity of 1.1 NTU, pH of 6.3, conductivity of 57 mS/m and a total coliform count of 230 /millilitre. The borehole is shallow with a reputation of poor microbiological quality in the past.

The sub-index for water quantity:

Public standpipe use	(450 – 65) * 25	=	9 625 litre/day
House connection use	65 * 60	=	3 900 litre/day
Home connections			none
Loss factor		=	1.25
Water demand	(9625 + 3900)*1.25	=	16 906 litre/day
Pump capacity		=	24 m^3/day
V_{month}		=	720 m^3/month
$I_{av,quant}$	(720*1000) / (30*16906)	=	1.42
	therefore	=	1.00

The sub-indices for water quality are calculated from the values in Table 1. For electrical conductivity, the index is 1.0 as the value of 57 mS/m is less than the ideal limit of 70 mS/m. For pH, the index is 1.0 as pH 6.3 lies between the ideal limits of pH5.0 and pH9.5.

For turbidity, the value of 1.1 NTU lies between the suggested maximum of 1 NTU and the absolute maximum of 20 NTU. The index thus has to be logarithmically interpolated between 0.50 and 0.00:

$$y \quad = \quad 0.5 + \left(\frac{\ln 1.1 - \ln 1.0}{\ln 20 - \ln 1.0}\right).(0.0 - 0.5) \quad = \quad 0.48$$

For total coliforms, the value of 230/100ml lies above the absolute maximum of 100/100ml. The index is thus 0.0

Knowing that the borehole has a reputation of being microbiologically compromised at times, the water supply authority wishes to place a heavier weighting on the total coliforms than on the other parameters. The weighting is thus slanted in favour of the TC:

$I_{av,qual}$	=	0.2 * I_{EC} + 0.2 * I_{pH} + 0.4 * I_{TC} + 0.2 * I_{NTU}
	=	0.2 * 1.00 + 0.2 * 1.00 + 0.4 * 0.00 + 0.2 * 0.48

= 0.59

The availability index is made up, in this example, by equally weighting of quality and quantity:

I_{av} = $0.5 * I_{av, quan} + 0.5 * I_{av,qual}$
= $0.5 * 1.00 + 0.5 * 0.59$
= 0.80

4 CAPACITY

4.1 Indicators

Can enough water be transported from the source to the consumers? Capacity is the adequacy of the *water supply system* (including transport, storage and distribution) to supply water to the community. Inadequate capacity will typically arise when a village grows in size, per capita demand and population to the point where a previously large enough system will begin to fall behind the water demand. The capacity index is based on four sub-indices, each dealing with a part of the water path from water source to the consumers' homes:

- From source to storage (bulk supply capacity);
- The storage itself (storage capacity);
- From storage to standpipe (distribution capacity);
- From the standpipe to the home (human carrying capacity);

Once these four sub-indices have been quantified, they are combined by weighting to form the overall capacity index:

$$I_{cap} = \beta_1 . I_{pump} + \beta_2 . I_{res} + \beta_3 . I_{wp, func} + \beta_4 . I_{wp,dens}$$

4.1.1 Bulk water supply capacity

Can enough water be transported from the source to the storage tank? This is quantified by comparing the pumping capacity to the average water demand:

$$I_{pump} = \frac{Q_{pump}}{Q_{demand}} \leq 1$$

4.1.2 Storage capacity

Is there adequate storage to balance differences between demand and pumping capacity, and to provide adequate reserve during interruptions in supply? This is quantified by comparing the actual storage capacity to a generally accepted design standard:

$$I_{res} = \frac{V_{res}}{Q_{demand} . T_{res}} \leq 1$$

The usual requirement for T_{res} in South Africa is 1 day for storage reservoirs fed by gravity, and 2 days for tanks supplied by pumping. For the borehole-supplied systems used in most parts of rural South Africa, the requirement is therefore 2 days.

4.1.3 Distribution capacity

Can enough water be transported from the storage tank to the standpipes? This is quantified as the fraction of the standpipes which meet a generally accepted minimum flow rate:

$$I_{wp, func} = \frac{N_{wp,good}}{N_{wp,total}} \leq 1$$

The guideline used in South Africa is a minimum standpipe flow rate of 10 litre/minute (DWAF, 2004). This is rapidly measured at each standpipe by timing the filling of a calibrated container.

4.1.4 Human carrying capacity

Are the standpipes close enough to the homes to allow sufficient water to be carried from the standpipe? The most exemplary water supply system would be of little benefit if the standpipes are too far away from some homes. The distance of water points from consumers is indirectly approximated by calculating an average water point density and relating that to what is minimally required:

$$I_{wp,dens} = \frac{\rho_{actual}}{\rho_{\min}} \leq 1$$

The South African guideline is phrased in terms of the maximum distance between a home and a public standpipe, set at 200 metre (DWAF, 2004). The best theoretical coverage is obtained if the standpipes are arranged in a hexagonal pattern. For an infinitely large supply area, the required water point density to limit the maximum distance to 200 metre, is 9.6 standpipes/km^2. For the more usual case where the standpipes are arranged in a square pattern, the theoretically required density is 12.5 standpipes/km^2. Given that many local constraints and finite village sizes make optimal coverage impossible, a minimum density of 15 standpipes/km^2 was assumed.

To calculate the water point density, the limits of each village are readily delineated from aerial photographs or Google Earth. By approximating the boundaries with straight lines, the area is quickly determined. The number of water points is easily counted during the site visit.

4.2 Example 2

Using the same village as Example 1, it known that the borehole pumping capacity is 24 m^3/day and the average daily demand is 16906 litre/day. The storage facility consists of two tanks of 10 000 litres each. The village has a footprint of 34 hectare, and there are 6 standpipes of which 5 exceeded the minimum flow rate.

The sub-index for bulk transfer capacity:

Water demand	(9625 + 3900)*1.25	=	16 906 litre/day
Pump capacity		=	24 m^3/day
V_{month}		=	720 m^3/month
I_{pump}	(720*1000) / (30*16906)	=	1.42
	therefore	=	1.00

It will be noted that I_{pump} above is identical to $I_{av,quant}$ in Example 1. This is due to the fact that the same borehole pump provides the measure of the source capacity as well as the bulk transport capacity. In other cases, where transfer of water from the source is independent of the source itself (e.g. a water treatment plant as source, followed by a pump station to transfer the water), these two indices will be different.

The sub-index for storage capacity:

For a tank fed by pumping, the required volume is 2 days at average demand. The actual storage is 20,000 litre or 20 m^3.

I_{res}	20 / (24 * 2)	=	0.42

The sub-index for distribution capacity:

A total of five out of six standpipes delivered more than the required minimum flow rate.

$I_{wp,func}$	5 / 6	=	0.83

The sub-index for human carrying capacity:

The village footprint of 34 hectare is equal to 0.34 km^2, served by 6 standpipes. The population is 450, thus there are 75 people/standpipe, within another guideline that no single standpipe should serve more than 100 people.

Standpipe density	6 / 0.34	=	17.6 standpipes / km^2
$I_{wp,dens}$	17.6 / 15	=	1.18
		=	1.00

The overall capacity index is made up, in this example, by equally weighing the four capacity components:

$$\begin{aligned} I_{cap} &= 0.25 * I_{pump} + 0.25 * I_{res} + 0.25 * I_{wp,func} + 0.25 * I_{wp,dens} \\ &= 0.25 * 1.00 + 0.25 * 0.42 + 0.25 * 0.83 + 0.25 * 1.00 \\ &= 0.81 \end{aligned}$$

5 Continuity

5.1 Indicators

To what extent is the water supply periodically interrupted? Continuity is the consistency whereby water is conveyed from the source to the consumer. System failure can result from short interruptions (measured in hours) to prolonged periods (measured in days or even weeks). Both types lead to different types of undesirable effects. The South African national guidelines implicitly recognise this distinction by stating a limit of 7 days of total interruption per year, with no single interruption exceeding 48 hours (DWAF, 2003). An interruption of more than 48 hours is a serious event which will force consumers to other, less suitable supplies. A short interruption was thus defined as one having a duration of less than 48 hours, while a long duration will exceed 48 hours. The continuity index has to take both short and long interruptions into account:

$$I_{cont} \quad = \quad \gamma_1 . I_{short} + \gamma_2 . I_{long}$$

5.1.1 Short interruptions

Short interruptions typically occur during power outages, pipe bursts or broken taps. When villages have the ability to make their own repairs, these problems are reported and often fixed within a few hours. During the site surveys, however, even these relatively small problems were found to drag on for days due to a lack of spares, or lack of response from remote, centralised maintenance personnel.

If the interruptions continue for only a few hours, households could ride out the interruption by using the water they have already stored in the home and no serious effects follow. What should the minimum period of supply be for any given day? This question depends heavily on the local water supply arrangements of each village, of which some examples were earlier noted in the section on “water demand and losses”. One solution is to estimate the number of hours per day with no supply when supply was expected by the consumers. The sub-index for short interruptions is thus quantified as:

$$I_{short} \quad = \quad \frac{T_{normal} - T_{non-\sup ply}}{T_{normal}} \quad \leq \quad 1$$

The required data has to be obtained by randomly interviewing some villagers. When the first three interviewees provide about the same information, it is accepted. If there are serious discrepancies, then more villagers have to be interviewed.

5.1.2 Long interruptions

Long interruptions of more than 48 hours typically follow from larger infrastructural failures, for example when pipeline crossings through rivers are washed away, boreholes dry up, fuel deliveries are disrupted, or when smaller problems escalate into long interruptions due to inefficient repair and maintenance procedures.

The effects of long interruptions are more serious. Households have to search for alternative sources mostly questionable in terms of their quality, or wait on water tankers to provide an intermittent, often unpredictable supply. Because the national guideline (no more than seven days of non-supply per year or 0.58 days/month) is a small number, an exponential relation has to be adopted, where the factor λ depends on the level of performance indication required. For this report, a value of $\lambda = 0.5$ was found to provide realistic values. The longer term interruptions are expressed as:

$$I_{long} \quad = \quad e^{-\lambda .(N_d - N_{d,\max})} \quad \leq \quad 1$$

5.2 Example 3

A village has a water supply arrangement where water is supplied from 06h00 to 16h00 every day. Random interviews were conducted in a village where two questions were posed to each interviewee, namely a) how many interruptions of less than 48h were there in the past two weeks, and how long were they; and b) how many interruptions of more than 48h were there in the past two weeks, and how long were they?

The results were as follows:

In the past 14 days ...	# interruptions < 48h?	Total duration?	# interruptions > 48 h?	Total duration?
Interviewee 1	1	4 h	1	3 days
Interviewee 2	0	-	1	3 days
Interviewee 3	1	2h	0	
Interviewee 4	1	2h	1	2 days
Interviewee 5	1	3h	1	3 days
Assume	1	3h	1	3 days

The sub-index for short interruptions is based on a normal supply period of 10 hours per day (from 06h00 to 16h00):

I_{short} = (10 – 3) / 10 = 0.70

The sub-index for long interruptions is:

I_{long} = $e^{-0.5(3-0.58)}$ = 0.30

Given that long interruptions have more serious consumer effects than short interruptions, the weighting of the overall continuity index is strongly slanted towards the long interruptions:

$$I_{cont} = 0.20 . I_{hours,day} + 0.80 . I_{day,month}$$

Therefore:

I_{cont} = 0.20 * 0.70 + 0.80 * 0.30
= 0.38

6 Condition

6.1 Indicators

Is the water supply infrastructure still in good shape? Previous proposals for this criterion included the concept of durability, expressed as the expected remaining lifetime of a system (Ashley et al., 2004). This is not considered to be useful for rural water supply systems, as the expected lifetime of a system is heavily dependent on the degree of use, the level of maintenance and the extent of vandalism. The preferred criterion is thus condition, which is the current status of the system in terms of its serviceability. For a water supply system, all the components (i.e. pipes, pumps, reservoir, standpipes, hand pumps) must ideally be assessed to give an overall picture of the system condition. A detailed examination of all elements of the water supply system will be time-consuming and not practical. Therefore, the condition of the water outlet points (the taps on a communal standpipe, hand pumps or water meters where present) is selected as an indicator for the condition of the system, assuming that a poorly maintained water point will probably indicate the same state of neglect of the other system components. For rural systems, almost all the water points are standpipes and the condition index has to be extracted from the standpipes only. Following a critical review of standpipe design and maintenance (Haarhoff and Rietveld, 2009), four readily observable indicators were identified:

- Condition of the tap(s) connected to the standpipe;
- Condition of the standpipe platform;
- Condition of the tap support;
- Presence and condition of secondary water connections.

The index for condition is obtained by weighting:

$$I_{cond} = \delta_1 . I_{tap} + \delta_2 . I_{platform} + \delta_3 . I_{support} + \delta_4 . I_{sec}$$

6.1.1 Condition of taps

The taps used at public standpipes are subject to a high degree of wear and tear. Our field surveys indicated that the average standpipe tap is opened and closed about 62 000 times per year. Given that the SANS standard specifies a minimum number of 200 000 actions under light torque per year, a tap of good quality will only last about three years. Taps must therefore be replaced much more frequently than the other hardware elements in the system. Moreover, the South African market is currently flooded with cheap, inferior imports which are indiscriminately purchased by ill-advised tender committees. These taps do not meet the required specifications and compound the need for regular and preventative tap replacement. The condition of a tap will be good and serviceable if it is without excessive leakage, a broken handle or a bent spindle. The sub-index is simply the proportion of serviceable taps:

$$I_{tap} = \frac{N_{tap,good}}{N_{wp,total}}$$

6.1.2 Condition of platforms

A serviceable standpipe platform is one that is large enough, sturdy and properly drained. It requires considerable effort by women and children to manoeuvre water containers of 20 to 25 kg and load them onto heads or a wheelbarrow. The presence of mud, puddles, bricks/stones or drainage upstands introduces the hazard of slipping or falling. The sub-index for platform condition is the proportion of serviceable platforms:

$$I_{platform} = \frac{N_{platform,good}}{N_{wp,total}}$$

6.1.3 Condition of tap supports

Often taps are supported by flimsy steel spikes, or loosely tied to shrubs or trees. This makes the standpipe more vulnerable to damage, leakage or vandalism. The sub-index for tap supports is thus the proportion of taps with a proper, sturdy support:

$$I_{\sup port} = \frac{N_{\sup port,good}}{N_{wp,total}}$$

6.1.4 Secondary connections

In almost all villages surveyed, it is prohibited to make hose connections to the standpipes. The reasons are self-evident – the hoses make access to the standpipes more difficult to others, the connections are flimsy and mostly leak profusely, and the water demand increases without compensation to the water authority. (A notable exception is to allow home builders to have a temporary hose connection while the home is being built.) Despite the prohibition, it is not uncommon to find some villages with rampant secondary connections. The presence of hose connections is thus considered as an indicator of how frequently and thoroughly the water system is patrolled and maintained. The sub-index for secondary connections measures the proportion of standpipes without illegal or home-made secondary hose connections:

$$I_{\sec} = \frac{\left(1 - N_{\sec,connect}\right)}{N_{wp,total}}$$

6.2 Example 4

In a village with 13 standpipes, it is found that 6 taps are leaking, 3 platforms have been badly cracked and partly washed away, all of the tap supports are sturdy, and 5 taps had secondary connections.

Sub-index for taps:
I_{tap} = 7 / 13 = 0.54

Sub-index for platforms:
I_{plat} = 10 / 13 = 0.77

Sub-index for support:
$I_{support}$ = 13 / 13 = 1.00

Sub-index for secondary connections:
I_{sec} = 8 / 13 = 0.64

The condition index, using equal weighting for the sub-indices:
I_{cond} = 0.25*0.54 + 0.25*0.77 + 0.25*1.00 + 0.25*0.64
= 0.73

7 SUMMARY OF DATA REQUIREMENTS

Having defined the assessment criteria and having picked appropriate indicators, all the data requirements are known. They are summarised in Table 2.

Table 2: Data requirements for technical assessment

Parameter	Note on measuring
Number of standpipes	Count during field visit
Number of yard connections	Ask water supply authority
Number of house connections	Ask water supply authority
Population served by each	Determine number of persons per household from demographic data. Count households on site or from aerial photographs.
	Use preliminary 1.25 to account for spillage and washing of laundry
Water loss adjustment factor	Use pump capacity or treatment capacity for ground- or surface water
	Measure on site and laboratory
Source capacity	Check pump rating or do volumetric test
	Measure on site
Water quality parameters	Measure town area from maps or photographs
Supply capacity	Measure with bucket and stopwatch
Storage volume	Ask consumers
Water point density	Score on site, photograph for later verification
Water flow rate at standpipes	
Time without supply	
Standpipe condition	

8 CASE STUDIES

The proposed assessment procedure was verified in the Mutale Local Municipality within the Vhembe District Municipality during October 2007 and October 2008. The Vhembe District Municipality embraces a large area with small villages and towns far from the metropolitan centres of South Africa. The Mutale Local Municipality consists of 58 villages and towns and has about 60,000 inhabitants. The study area comprised about 20 villages, with a total of about 8000 inhabitants, all in the Nwanedi basin close to the Zimbabwean border. The villages had piped water systems, most of them built during the past decade. In the past, the Department of Water Affairs and Forestry was responsible for water supply, but this responsibility was being transferred during the assessment to the local municipality, assisted by the district municipality. This period of transition, when new institutional structures were taking up new responsibilities, could have influenced the results of the assessment. The assessment was only made in villages where the primary water supply system was a piped water supply with standpipes. Secondary supplies such as tanker services, hand pumps, springs and rivers were thus omitted.

The assessment relies on numerous weighting factors, providing the ability to adjust the procedure to best reflect the most pressing concerns and priorities or different water supply authorities. The weighting factors, as used here, are shown in Appendix One, but other users can translate their specific concerns to other weighting factors.

To translate the numbers back into categories for easy comparison and interpretation amongst different locations, a three-tier bench-marking scheme (unacceptable, fair, good) was used. The following cut-off values were applied:

- Critical (0.0 < I < 0.5) [labelled with red];
- Fair (0.5 < I < 0.75) [labelled with yellow];
- Sufficient (0.75 < I < 1.0) [labelled with green].

Two assessments were made. The first assessment of October 2007 (15 villages) used the same criteria and indicators as proposed in this report, but some of the indices were calculated slightly differently. These results were captured in a journal paper (Rietveld et al, 2008) and a presentation. For these outputs, please refer to Section 8, Chapter 1 of the main WRC report 1700/1/12 *"The impacts of rural small-community water supply interventions in rural South Africa"*. The second assessment (14 villages), made in October 2008, was done exactly according to this report. These results are summarised in Table 3 on the following page.

Table 3: Results of a rapid assessment of 14 small community water supply systems in Vhembe District, Limpopo Province (October 2008)

	Gumela	Guyuni	Helula	Madimbo	Mashangwaduvha	Musunda	Muswodi-Dipeni	Muswodi-Tshisimani	Thondoni	Tsaanda	Tshaluwi	Tshapinda	Tshikwarakwara	Tshitandani
Quantity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
pH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Conductivity	1.00	1.00	1.00	0.56	1.00	1.00	0.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total coliforms	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.14	0.00	0.00	0.00	0.03
Turbidity	0.64	0.79	0.66	0.88	0.89	0.62	0.84	0.76	0.84	0.64	0.84	0.86	0.83	0.75
Quality	0.66	0.70	0.66	0.61	0.72	0.66	0.88	0.69	0.71	0.70	0.71	0.71	0.71	0.70
Availability	0.83	0.85	0.83	0.80	0.86	0.83	0.94	0.85	0.86	0.85	0.86	0.86	0.85	0.85
Pump	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Storage	1.00	0.93	1.00	0.15	1.00	1.00	1.00	1.00	1.00	0.91	1.00	1.00	1.00	1.00
Distribution	0.92	1.00	0.90	1.00	1.00	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Density	1.00	0.42	1.00	0.42	1.00	1.00	0.50	0.49	1.00	1.00	1.00	0.92	1.00	1.00
Capacity	0.98	0.84	0.98	0.64	1.00	1.00	0.85	0.87	1.00	0.98	1.00	0.98	1.00	1.00
Short interruptions	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.90	1.00	1.00	0.98	1.00	0.99	1.00
Long interruptions	1.00	0.30	1.00	1.00	1.00	1.00	0.04	1.00	0.49	0.30	1.00	0.49	1.00	0.04
Continuity	1.00	0.44	1.00	1.00	1.00	1.00	0.23	0.98	0.59	0.44	1.00	0.59	1.00	0.23
Taps	1.00	0.67	0.80	0.86	1.00	1.00	0.60	0.75	0.55	0.80	1.00	0.91	0.40	0.90
Platforms	0.75	0.00	0.40	0.71	0.38	0.40	0.90	0.75	0.45	0.60	0.38	0.36	0.50	1.00
Supports	0.92	0.67	0.60	0.57	0.46	1.00	0.90	1.00	0.73	0.00	0.50	0.82	0.50	1.00
Connections	1.00	0.67	0.60	0.71	0.69	1.00	0.10	0.25	0.45	0.80	0.63	0.73	0.60	1.00
Condition	0.92	0.50	0.60	0.71	0.63	0.85	0.63	0.69	0.55	0.55	0.63	0.70	0.50	0.98
Overall	0.93	0.66	0.85	0.79	0.87	0.92	0.66	0.85	0.75	0.70	0.87	0.78	0.84	0.76

9 INTERPRETATION OF RESULTS

9.1 Availability

The measurement of the source capacity turned out to be more difficult than anticipated. In almost all cases, there were little or no indication of the installed pumping capacity – the borehole pumps were devoid of the usual industrial labelling indicating their duty points. There was very little installed instrumentation (pressure gauges and flow meters) and where it was found, it was not working. But in all fairness, even if the installed pumping capacity could be determined, it would be impossible to assess the sustained geo-hydrological capacity of the boreholes without a properly conducted borehole test. Such a test would be beyond the reach of a rapid single-visit assessment as desired of this project. Rather than trying measure the pumping capacity, the field workers only determined whether the pump, if it was working properly, could supply adequate water to the village. If it could, the pump capacity was set equal to the estimated water demand, thus forcing the sub-index for quantity to unity.

Of the 14 villages assessed, all the boreholes could supply enough water. A noteworthy case was the cluster of five villages – Mashangaduvha, Tshaluwi, Tshkwarakwara, Tsapinda and Thondoni, collectively known as the town of Folovhodwe. These five villages are supplied by a single borehole and reservoir. Because the five villages of Folovhodwe are different in terms of their layout, their proximity to the Nwanedi River and the age of their distribution systems, they were independently assessed. During the past three years, during which field work was done, a strong growth in population, as evidenced by the construction of many new homes, was observed. This has led to a situation in October 2008 (admittedly the driest and hottest time of the year) where the daily supply time had to be curtailed due to insufficient storage. Where the capacity falls behind, as in these cases, the solution can be possibly found in tighter control of leakage and water wastage, but generally it can only be fixed by a major engineering intervention such as new boreholes, larger pumps or larger storage tanks.

The water quality was not good in 13 of the 14 villages. The components of the sub-index show that this is primarily due to poor microbiological quality. Microbiological quality can be relatively easily fixed by heavier and more frequent chlorination. At present, a practice of weekly shock dosing is followed which does not seem adequate.

9.2 Capacity

The capacity throughout was adequate. The exceptions were one case where storage was inadequate, and four cases where the water point density was inadequate. In the latter cases, it was due to growth of the villages beyond the original borders, without a concomitant increase in new standpipes.

9.3 Continuity

Of the 14 villages, the continuity was poor in 6 cases. More seriously, in these six cases it was due to interruptions longer than 48 h, which have serious health consequences. More evidence was collected to understand the reasons. The problem predominantly lies with poorly managed repair and maintenance procedures. Practically all the maintenance and repair is centralised, with long response times. Even relatively trivial failures, easily fixed locally if the village was empowered to do so, dragged on to become unacceptably long interruptions.

A lack of continuity can generally be ascribed to insufficient maintenance and support systems. Once systems are built, systems should be in place for rapid reporting of interruptions, availability of spare parts and qualified maintenance personnel, and their rapid deployment to get the problem fixed. Problems with inadequate continuity will therefore require more attention to, and funding for repairs and maintenance.

9.4 Condition

The condition of the public standpipes was good in only three of the 14 systems, which is disturbing for relatively new systems. Where these systems failed, it was either due to many poor and illegal secondary connections, or missing or damaged platforms. It appeared that the original standpipes of the systems, as they were constructed by a contractor subject to proper supervision and project management, were quite good. Where newer standpipes were installed where older ones failed, or where distribution systems were extended to supply newly developed areas, the standpipes are little more than a piece of pipe tied to a tree or simply sticking out of the ground without a proper support or a platform. Once again, this points to a lack of discipline, skills, materials and quality control by the municipal authorities.

9.5 Comparison with earlier assessment

The 2007 survey covered 15 villages, of which 8 overlapped with the 2008 survey. In general, the findings of the two surveys, done a year apart in a partially overlapping area, are in agreement. Although the indices were slightly differently weighted and in some cases calculated differently, it was found that the availability and capacity of the systems were adequate to good, but the continuity was poor, and the condition of some standpipes were completely unacceptable. Overall, given that the systems were relatively new, the assessment concluded that the technical performance was poor. The conclusion, both after the 2007 and 2008 surveys, is that insufficient attention is paid to efficient management of maintenance and repair systems. Although there were some problems with the engineering provided, the dominant problem laid with poor municipal management with a direct and disastrous effect on continuity and condition.

10 Evaluation of project

It may be of interest to make a brief comparison of this project with a similar project, conducted on a much grander scale, by the Department of Water Affairs and Forestry to develop a system for spot check assessments of water and sanitation projects constructed under the Municipal Infrastructural Grant programme of the national government. The project is being conducted by the CSIR Built Environment Division and was first reported on in April 2007 (DWAF/CSIR 2007). This work only came to the notice of our project team in October 2008, after the conclusion of our model development and field work.

There are marked similarities between the DWAF and our approaches. Observations were based on what could be determined during a site visit, without any external data sources. All data had to be collected during a single visit, thus providing a snap-shot only. As DWAF worked with larger projects, they devised a transect sampling strategy to include only a sample of households. The DWAF project considered both sanitation and water supply, both at bulk and household level. The overlap between the DWAF project and our project is thus only the bulk water supply system.

The DWAF project measured the overall compliance of bulk water supply in five dimensions:

- *Technical quality* was measured in terms of the quality of pipe laying and illegal secondary connections. (Technical quality corresponds with our *capacity* criterion.)
- Adherence to *design standards* was determined for street taps, yard taps, yard tanks, roof tanks and household connections. (Of these, only street taps are applicable to the case studies covered in this report. This aspect was covered by our *capacity* criterion.)
- *Water quality* was considered important, but could not be properly quantified. The water was simply observed for aesthetics, i.e. clarity, taste and smell. (Water quality was more comprehensively and quantitatively covered by our sub-index for water quality as part of our *availability* criterion.)
- *Reliability* was estimated by compliance to the guidelines of not more than 15 days of interrupted supply and not more than 48 consecutive hours per breakdown. (This corresponds exactly to our *continuity* criterion, with the exception that we used a maximum total of seven days of interrupted supply per year.)
- *Training* was assessed as the compliance to a programme of communicating good water-use, hygiene and related practices. (This was not attempted at all during our project, which focused on technical matters only.)

It is clear that the two independent projects came up with similar approaches, with strengthens the credibility of both. The scope of the DWAF project was much broader and directed its primary attention at *finding* problems. Our project, more modest, directed its primary attention to finding indicators which were not only easily measurable, but would also suggest the logical means of fixing the problem.

The findings of the pilot roll-out of the DWAF project (the results of subsequent work are not available yet) found similar results as found in our project. For the comparable part of the DWAF findings regarding bulk water supply systems, their *reliability* component was found to score the lowest, corresponding to our finding of *continuity* being unacceptably poor. (Our sub-index for water quality scored lower due to the poor microbiological quality, an aspect not covered by the DWAF study.)

11 Summary and conclusions

A new framework was developed for the rapid technical assessment of rural water supply systems, systems comprising of piped distribution systems with communal standpipes, fed by groundwater or springs. Four criteria were selected, such that the assessment would also suggest how the systems could be improved – availability, capacity, continuity and condition. For each of these criteria, a number of indicators were used which could be readily measured on site during a single visit. The indicators were next mathematically scaled to sub-indices between 0 (complete failure) to 1 (perfect) and finally aggregated to a single technical performance index.

Having developed the methodology, it was first applied to 15 villages in the Nwanedi basin in Venda, located in the north-eastern corner of South Africa during October 2007. The results demonstrated that the systems could be rapidly ranked in terms of their relative performance, and the reasons for their non-performance, where applicable, could be pinpointed. Where availability was a problem, the problem was predominantly the drying up of boreholes, with unacceptable water quality encountered in two cases – these defects can only be corrected with substantial engineering input and investment. Capacity was not a serious problem, except for insufficient storage in some cases. The largest problem was the lack of continuity caused by poor operation, arguments about the payment of fuel, and unacceptable repair times for broken equipment – problems that should be easy to correct without major interventions. The condition of the systems, all relatively new, were still good although the taps were generally in poor condition, caused by a combination of installing taps of poor quality in the first place, and a lack of scheduled replacement and rehabilitation.

After a few refinements, the final proposed procedure was used for a second time to 14 villages in the same approximate study area during October 2008. The general findings of the first survey were broadly confirmed, with the exception of more rigorous water quality testing, which showed that the water quality at the taps was microbiologically significantly poorer than before. (The survey of the 2007 used water quality measured at source, while the 2008 survey sampled water at the taps.)

The findings suggest that planners of water supply projects gave priority to water systems that would deliver sufficient quantities of water, thereby improving the availability and the capacity of the systems. Little attention, however, seems to be given to the operation and maintenance of the installed systems. This has led to poor continuity and, to a lesser degree, poor condition of the systems. This finding is in line with an independently study by DWAF, where reliability scored the lowest of all their chosen indicators.

It is evident from the results of this project that, in addition to rigorous adherence to technical design standards, which appear to be adequate, much more attention must to directed to improve the centralised and really poor municipal maintenance and operation. Unless better resources, training, discipline and accountability are provided, the current investment in rural water supply systems will only provide temporary relief, as the systems will remain unsustainable.

Overall, the proposed methodology was demonstrated to be a simple, rapid benchmarking tool for water supply authorities responsible for rural water supply systems, thus providing a suitable building block for the larger HESET assessment suite.

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APPENDIX 1: TEMPLATE FOR ASSUMPTIONS AND WEIGHTING FACTORS

INPUT PARAMETERS

Water demand parameters					
Per capita use for standpipes			25		l/cap/day
Per capita use for yard connections			60		l/cap/day
Per capita use for house connections			120		l/cap/day
Water loss factor			1.25		-

Water quality parameters	**ideal**	**suggested**	**max**		**I at suggested**
pH (low)	5.0	4.5	4.0	-	0.5
pH (high)	9.5	10.0	10.5	-	0.5
Conductivity	70	150	370	mS/m	0.5
Total coliforms	0	10	100	#/ml	0.8
Turbidity	0.1	1	20	NTU	0.8

Capacity parameters		
Required storage for gravity systems	1.0	days
Required storage for pumped systems	2.0	days
Minimum flow rate for standpipes	10	litre/minute
Minimum water point density	15	#/km2
Continuity parameters		
Normal operating hours per day	10	h/day
Allowable days of non-supply	7	days/a
Lambda factor	0.5	-

WEIGHTING FACTORS

Availability sub-index	Quantity	0.50	
	Quality	0.50	1.00
Quality	pH	0.25	
	Conductivity	0.25	
	Total coliforms	0.25	
	Turbidity	0.25	1.00
Capacity	Pump	0.25	
	Reservoir	0.25	
	Distribution	0.25	
	Carrying	0.25	1.00
Continuity	Short interruptions	0.20	
	Long interruptions	0.80	1.00
Condition	Taps	0.25	
	Platforms	0.25	
	Supports	0.25	
	Secondary connections	0.25	1.00
Overall	Availability	0.25	
	Capacity	0.25	
	Continuity	0.25	
	Condition	0.25	1.00

Appendix 2: Template For Field Data

Village

Date

FIELD DATA

Village data		
# served by standpipe		no
# served by yard connection		no
# served by house connection		no
Water demand	0	litre/day
Village footprint		ha
Short interruptions		h/14 days
Long interruptions		days/month
System hardware		
Pump capacity		litre/day
Storage capacity		litre
Number standpipes		no
Water point density	#DIV/0!	#/km2
Standpipes with adequate flow		no
Standpipes with good taps		no
Standpipes with good platforms		no
Standpipes with good supports		no
Standpipes without connections		no
Water quality		
pH		-
Conductivity		mS/m
Total coliforms		#/ml
Turbidity		NTU

INDICES

Availability	#DIV/0!	Quantity	#DIV/0!		
		Quality	0.75	pH	0.00
				EC	1.00
				TC	1.00
				NTU	1.00
Capacity	#DIV/0!	Pump	#DIV/0!		
		Storage	1.00		
		Distribution	#DIV/0!		
		Density	#DIV/0!		
Continuity	1.00	Short	1.00		
		Long	1.00		
Condition	#DIV/0!	Taps	#DIV/0!		
		Platforms	#DIV/0!		
		Supports	#DIV/0!		
		Connections	#DIV/0!		
Overall	#DIV/0!				