Unlocking the Potential of Groundwater for the Poor

UPGro Hidden Crisis Research Consortium

Unravelling past failures for future success in Rural Water Supply

Initial project approach for assessing rural water supply functionality and levels of performance

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Executive Summary

The new Sustainable Development Goals (SDGs) set a much stronger focus on sustainability and performance of water services, and have highly ambitious goals to achieve universal access to safe and reliable water for all by 2030 (UN 2013[1]). Poor functionality of water points threatens to undermine progress, and a lack of knowledge for the reasons behind this make it difficult to recommend improvements and take corrective action. As a first step it is necessary to be able to reliably monitor current rates of functionality and to have a clear benchmark as to what constitutes a functional water point. Currently, there is no single accepted definition for functionality, although organisations are working towards this as a means of tracking progress towards the SDGs.

This report sets out the initial work by the *Hidden Crisis* project to develop a framework approach to assess functionality in terms of different levels of performance, and a set of standard indicators which can be used to assess functionality. The report presents the results of a literature review examining the following questions: (1) what are the current approaches to defining functionality of hand-pump boreholes; and (2) what are the robust standards by which the functionality of a HPB, or population of HPB's, can be assessed. From analyses of the literature we have developed preliminary guidelines and applied these to develop a preliminary framework.

Guidelines for assessing functionality

Within Hidden Crisis Project we suggest the following guidelines for assessing functionality:

- Functionality should be measured against an explicitly stated standard and population of water points.
- It should be measured separately from the users' experience of the service it provides.
- The assessments should be tiered, allowing for further information, but always being able to be reduced to a simple measure.
- A distinction should be made between surveying functionality as a snapshot (e.g. for national metrics) and monitoring individual water point performance (including a temporal aspect).

Defining functionality

The *Hidden Crisis* project has applied these guidelines to develop a framework approach to define functionality in terms of different levels of performance. This starts with a basic 'working yes/no' definition, and moves to a more detailed understanding of the reliability and yield of supply (see Figure 1). The final level introduces water quality to the performance assessment. As such the project examines the following definitions of functionality:

[1] UN Water 2013 A Post-2025 Global Goal on Water. 2013.

1. **Basic** – is the water point working (yes/no)
2. **Snapshot** – does the water point work and provide sufficient yield (10 L/min) on the day of the survey
3. **Functionality performance** – does the water point provide sufficient yield (10 L/min) on the day of survey, is it reliable (<30 days downtime in last year) or abandoned (not worked in past year)?
4. **Functionality including water quality** as 3 above, and also passes WHO inorganic parameters, and TTC standards.

Each of these definitions requires different amounts of data to be collected impacting the duration of survey. The 'Basic' and 'Snapshot' assessments reflect the requirements of national survey assessments, whilst the more performance-focused definitions are more relevant to local or regional surveys looking to track the functionality of individual water points or programmes through time.

Standard approaches will be used to assess the different levels of functionality within the project.

A survey of 600 hand-pumped boreholes across three countries in the first Survey phase of the *Hidden Crisis* project will:

- provide a suite interdisciplinary field data to examine the impact of using different definitions (i.e. levels of performance);
- establish data on the different levels of functionality of hand-pump equipped boreholes and the performance of the local water management committee;
- Provide a more nuanced understanding of the current functionality in each of the three countries in terms of performance levels.

The understanding and insights developed from the Survey 1 analysis, will inform the final framework approach proposed by the *Hidden Crisis* project to assess functionality. This will be a repeatable and robust framework which can be used by future surveys and studies, and can inform a single agreed international standard on assessing functionality.

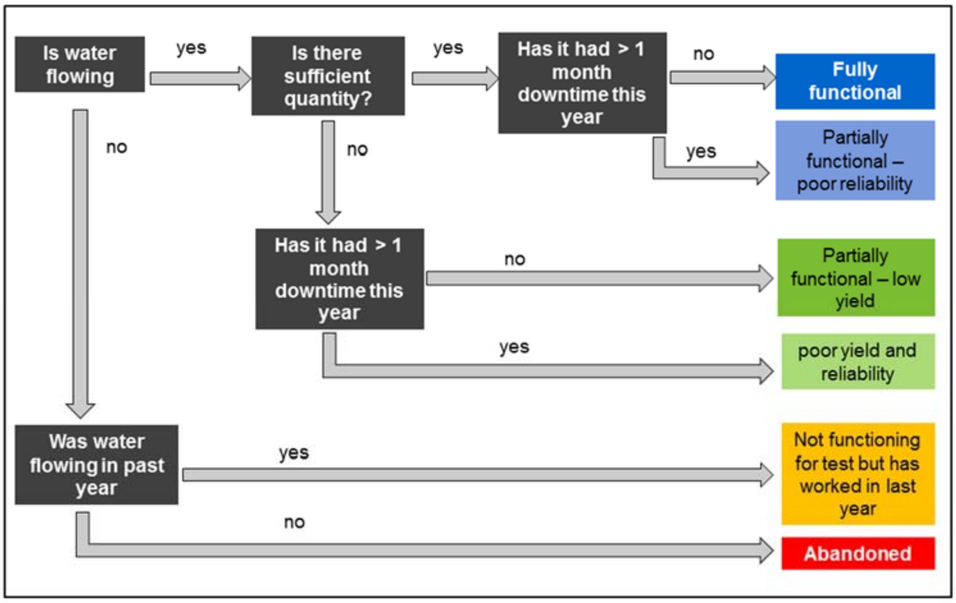

Figure 1 – A schematic diagram showing the proposed working categories of functionality performance (category 3 above) used in the Survey 1 analysis. These categories will be developed, and may evolve through the project.

1. The Hidden Crisis project

The *Hidden Crisis* project is a 4 year (2015-19) research project aimed at developing a robust evidence base and understanding of the complex and multi-faceted causes which underlie the current high failure rates of many new groundwater supplies in Africa, so that future WASH investments can be more sustainable. The project is being undertaken by an interdisciplinary team of established researchers in physical and social sciences from the UK, Ethiopia, Uganda, Malawi and Australia, led by the British Geological Survey. The research is focused to three countries – Ethiopia, Uganda and Malawi – to examine functionality and performance of groundwater supplies in a range of hydrogeological, climatic and social, institutional and governance environments.

The work is focused to handpump equipped borehole (HPB) functionality, and the indicators required to assess functionality – HPB's being the main form of improved water supply in rural Africa.

Three different survey phases will be conducted over two years (2016-17) to collect a significant evidence base, which can be used to develop a more detailed understanding of the causes of poor functionality within the three countries.

1. **Survey 1** – A rapid survey of 200 hand-pump boreholes supplies within each country to establish data on the different levels of functionality of hand-pump equipped boreholes and the performance of the local water management committee.
2. **Survey 2** – Detailed survey of 40-50 hand-pump equipped boreholes within each country, designed to provide detailed physical and social science datasets to better understand the underlying causes of poor functionality. Data will be collated by detailed community discussions, as well as deconstructing the water point to examine the construction and hydrogeological properties.
3. **Longitudinal Studies** – will be conducted at a small number of water points (6 -12) in Uganda and Malawi for at least 12 months to monitor temporal changes in: the use and performance of hand-pump boreholes; user perceptions; the capacity of community management; community livelihoods and dynamics; groundwater levels and rainfall.

2. Rationale for developing a functionality assessment framework

Understanding and documenting the functionality of HPB's has been considered for at least the last 30 years. Arlosoroff *et al.* (1987) recognised that there was a growing number of HPB's that were broken down and abandoned, or functioning much below capacity. Despite the significant contribution that this project made to the standardisation of hand-pumps, the issue of poorly functioning HPB's has continued.

The Millennium Development Goals (MDGs) established in 2000 served as a catalyst for significant investment in rural water services with a focus to increase water supply coverage. The percentage coverage of rural population in Africa with access to improved water sources, other than piped supply, has since increased from 44 to 52% between 1990 to 2010 (JMP 2012). Anecdotal evidence, and studies since undertaken by national governments, donor organisations and implementing bodies to determine if this investment has produced the intended benefits indicate, however, around 35% of improved water sources are non-functioning at any one time, and many fail for the first time within only a few years of installation, thereafter entering a cycle of failure and repair, or are abandoned (Rietveld et al. 2009, RWSN 2009, Lockwood et al. 2011). As a result, the original investment and the intended benefits – improved health, nutrition, time savings, and education –are ultimately lost (Hunter et al. 2012, UN 2013). Moreover, evidence suggests these breakdown rates have remained stubbornly high at between 30 and 50% over the last 40 years (McPherson and McGarry 1992; Lockwood and Smits 2011), despite various moves towards new community management and demand responsive approaches in the 1980s to try to improve sustainability of improved supplies.

Water point failure and functionality is a multi-faceted, multi-layered issue, with growing complexity as we look beyond the immediate causes of failure. A functionality pathway includes (Bonsor et al. 2015): ***primary causes*** (e.g. mechanical failure, reduced yield, poor water quality); ***secondary causes*** (e.g. geology, poor siting, lack of spare parts, basic maintenance, local governance arrangements); the ***underlying conditions*** (including the institutional, financial and social factors that shape an environment in which failure is more or less likely); and ***long term trends*** (e.g. changes in demand for water, evolution of governance arrangements, reduction in regional groundwater availability, climate change, deterioration of water quality). This hierarchy of factors and underlying conditions to functionality are illustrated in Figure 2.

The new Sustainable Development Goals (SDGs) set a much stronger focus on sustainability of water services, and have highly ambitious goals to achieve universal access to safe and reliable water for all by 2030 (UN 2013). For WASH investment and policy to be able to deliver lasting benefit, it is essential the research community, donors and practitioners alike can begin to understand the inter-related causes of water point failure and the actions that need to be taken to mitigate the risks. Water point functionality is only part of this story and three major research projects in the past

8 years - WASHCost, Triple S and Value For Money - WASH (VFM - WASH) – have examined different aspects underlying the sustainability of water services, (Triple-S 2009, Cross et al. 2013, Ross 2015). All three have highlighted the need for clearer definitions of water point functionality in order to be able to understand, and move towards, improving service sustainability.

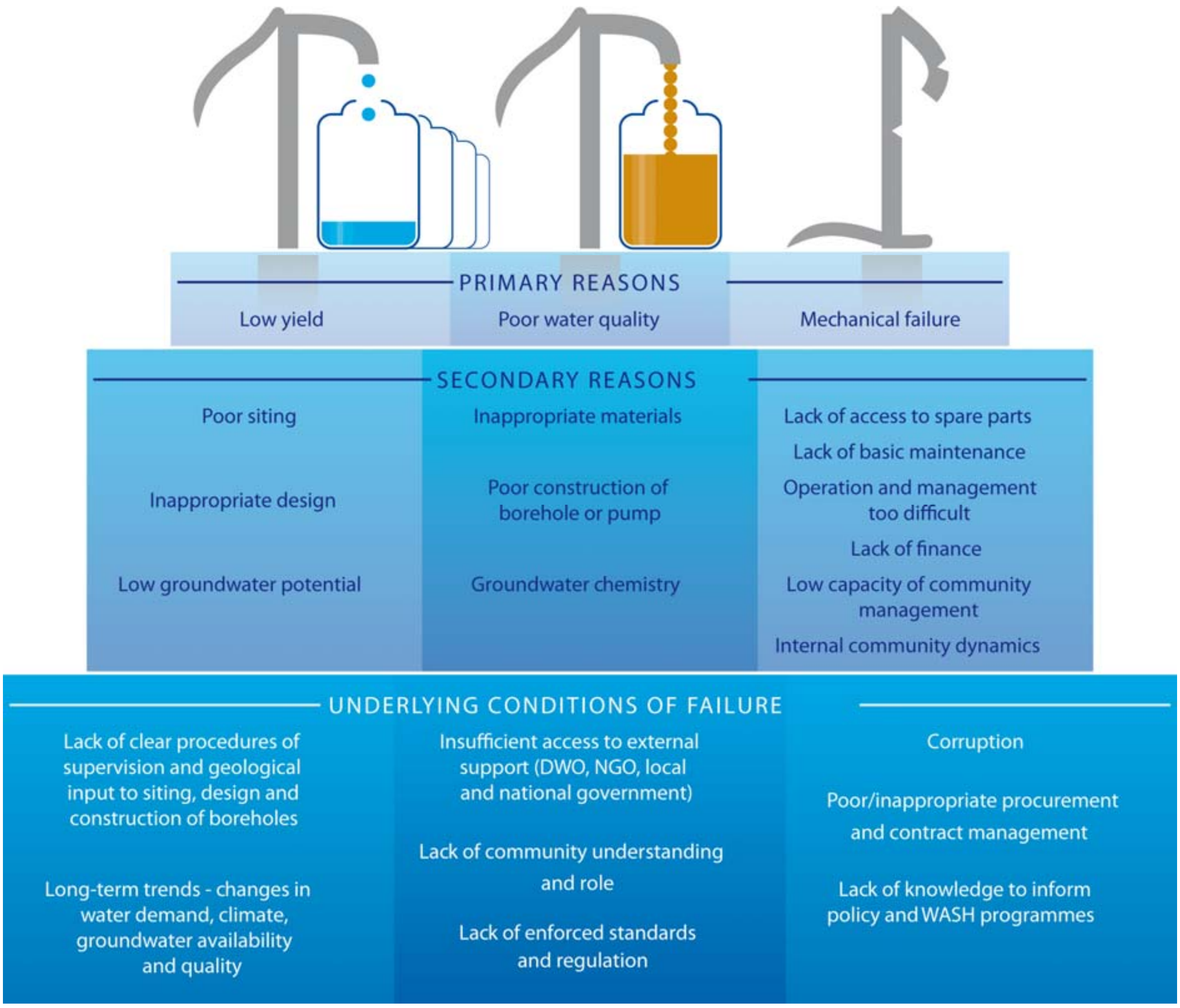

Figure 2 – A range of multiple factors and conditions are likely to underlie water point functionality in any one location.

3. Literature review

An extensive literature review was undertaken to: (1) appreciate how functionality is defined by previous surveys, with a view to informing the interpretation of results from these surveys; and, (2) to help inform a better understanding of what is a functioning HPB, and the indicators required to assess this.

Data review process

Over 111 studies were reviewed: more than 75 of these were unpublished grey literature, with only 24 within published peer reviewed literature. A further 7 existing regional-scale functionality database studies were reviewed from [WaterAid] WASH programmes. Most of the studies (90) were published since 2008, highlighting the general growing research interest in understanding the sustainability and functionality of water supplies.

The studies included within the review were identified by two methods. Published studies and publicly available grey literature were identified from a series of Boolean internet searches. Over 85% of the studies were identified and sourced by this method. The remaining studies and existing national databases on functionality were identified and collated through collaboration with regional project partners.

All 111 studies, including the quantitative datasets, were indexed, georeferenced and stored in an Access database. GIS (Arc 10.1) was used to spatially interrogate the different types of information held within the database. The studies were systematically reviewed to examine for each study: Is the functionality of water points explicitly defined? Is there one widely accepted definition or are different ones used? If different ones are used, are there any commonalities between them? What were the lessons or recommendations that we can learn from? Based on the information provided to these questions a value rank was applied to each study. Key criteria used to assign this value were: (1) the clarity of the definition of functionality; (2) sufficient methodological description of any data review or survey; (3) a range of indicators of functionality were examined; (4) the geographical scope of the data collation or review; and (5) the sample size of functionality data collated or reviewed. Studies which only partially satisfied these criteria were ranked to be of lower value. Of the 117 studies and data reviewed a third were classed as high value, whilst over a third did not include a clear definition of functionality or methods.

The final reports from three major recent research projects - WASHCost, Triple S and Value For Money - WASH (VFM - WASH) – were reviewed in greater detail. These projects have examined different aspects underlying water point functionality, and how more sustainable services could be delivered, in great depth (Triple-S 2009, Cross et al. 2013, Ross 2015).

Appendix 1 provides a full reference list of the literature review.

3. Findings

3.1 Literature review

The main findings from the literature review were:

- There is no single accepted definition of functionality or what constitutes a functioning HPB.
- It is generally invalid to systematically compare the results of different surveys or studies since they use different definitions of functionality.
- Over a third of the studies reviewed did not explicitly define functionality. A simple binary approach is the most common approach used in both national surveys and local studies: functioning or non-functioning.
- There is increasing demand in recent work for a common definition of functionality.
- The limitations of a binary approach to defining functionality has led some to define multiple categories such as *partially functioning* but this in itself has made comparison of surveys more difficult.
- Functionality is most commonly determined using qualitative assessment methods and direct quantitative measurements of function are rare.
- Most of the national and agency led functionality studies consider different water source types such as tap stands, shallow wells and rainwater harvesting, as well as HPB's. Each of these different source types presents a unique set of issues that influence functionality but these nuances are often lost by classifying them all as water points. [2]

The review found that nearly all of the studies reviewed could be placed in to 1 of 6 different categories of how functionality is defined and measured. Classifying the studies in this way enabled the different methods to be more easily considered, and for the attractive and unattractive qualities of each to be better appreciated. Table 1 below shows a summary of the 6 different classes, and the main studies which used such a method.

[2] Given this, the focus of this UPGro project is specifically on HPB's. HPB's accessing groundwater are one of the main water supply types in use across much of Sub-Saharan Africa, therefore this project is focusing on understanding the complex issues that influence HPB functionality in an effort to inform change that will improve the rates of poor functionality of HPB's.

Table 1 – The six main approaches to defining HPB functionality identified from the literature review

Definition Class	Summary	Key Studies
1 (n = 31)	Not defined - By default, working or not working.	van der Linde (2015), World Vision (2014), Deneke and Hawassa (2008), Miguel and Gugerty (2005), Gill (2014), Chowns (2014)
2 (n=38)	Defined - Working at the time of visit or 'in use', 'not in use'.	MWE (2010), UNICEF (2014), Samani et al. (2012), Fisher et al. (2015)
3 (n =17)	Multi Categories - Functional, not functional, needs repairs, semi-functional, minimally functional, functioning through difficulties, broken, missing parts, seasonal.	MoEWR (2012), SNV (2014), Government of Tanzania Ministry of Water (2015), Truelove (2013), Stawicki (2012),
4 (n=4)	Tiered definition – several different levels of assessment and indicators are used to assess functionality. As a minimum functionality is assessed using a binary approach of 'working/not working', but can be examined in greater detail using several levels of assessment.	Carter and Ross (2016), Leclert (2012), Tincani et al. (2015), Brocklehurst (2015).
5 (n =15)	Sustainability Assessment – A broader assessment which includes several factors indicating the reliability of the water supply. Functionality is one of several factors considered to assess sustainability.	Adank et al. (2013), SNV (2013), Lockwood and Smits (2011), Hoko et al. (2009), Water for People (2011), Calow et. al (2013), Moriarty et al (2013), Harvey and Reed (2004), Moriarty (2011), WaterAid (2009)
6 (n = 6)	Design yield - If the borehole produced at least the design yield at the time of visit	Baumann (2008), Harvey (2004).

Class 1 – Not defined – By default, working or not working (28% of studies reviewed)

The functionality of water points is reported but what classifies a functioning water point is not explicitly defined. This presumes that what is meant by a functioning water point is inherently known and does not require defining. By default, this means that a point is assessed as either working or not working. This is a subjective assessment and open to inconsistency meaning results between different water points are incomparable.

Class 2 - Defined – Working at the time of visit or 'in use', 'not in use' (34% studies reviewed)

This is similar to class 1 except that rather than being a presumed definition, it is expressly stated that a functioning water point is one that is either working, or is in use, at the time of visit. An assessment of whether a water point is working is usually made by a survey or study enumerator and involves them directly attempting to acquire a supply of water from a water point. The 'in use' / 'not in use' assessment can be as little as a visual observation that there are people gathered around a water point and it must therefore be in use. Whether a point is in use or not can also be determined by a community questionnaire.

Class 3 - Multi-categories (15% studies reviewed)

Some studies have used multiple categories of functionality to present a more nuanced definition of functionality. The simplest form defines a water point as: functional, partially functional or non-functional. In a number of studies, a variety of different categories have been used including: 'needs repairs', semi-functional, minimally functional, functioning through difficulties, broken, missing parts and seasonal.

The approach enables individual studies to present a more nuanced appreciation of the level and nature of water point functionality. With a simple binary approach, the results of a study may be 80% functional and 20% non-functional. If a category of partial functionality is included, the results may be 40% functional, 40% partially functional and 20% non-functional. However, the value of the approach for comparing results between studies is much less due to the variability in the categories used between studies. Universal adoption of agreed categories and terminology is required to realise the benefit of the approach.

Class 4 – Tiered approach (4% studies reviewed)

A tiered approach assesses functionality across several different levels – from a simple top level assessment of 'working/not working' based on if the HPB is working or not, to increasingly detailed assessments later on. This enables a more refined assessment of functionality to be undertaken where possible, whilst acknowledging that such detailed assessments are not feasible in all cases.

Class 5 – Sustainability Assessment (14% studies reviewed)

This involves a broader assessment than just the functionality of a water point at a point in time, and examines the sustainability of the service that the water supply provides. As an assessment, this takes account of the temporal nature of water services and what this will likely be in the future. Many other factors (e.g. the accessibility of the water service to users, the projected demand, reliability and frequency of service) are therefore considered beyond just the quantity and quality of water produced by a water point on the date of assessment. An example of this is the current WaterAid post-implementation water point monitoring tool – where how well a water point functions is included within an assessment of reliability. The VFM-WASH surveys also examined both functionality and service levels in relation to different time periods – asking households and communities about hours per day, days per week and months per year of service from each water point which they used (Tincani et al. 2015).

Functionality is commonly one factor defined and measured as part of sustainability assessments. How functionality is defined varies again from a simple binary 'in use/not in use' assessment to quantitative assessments of HPBs such as stroke and leakage tests. As a result, is often difficult to compare functionality scores between the different sustainability studies. The intricate links between the different indicators of functionality are also not always captured.

Class 6 – The HPB produces at least the design yield at the time of visit (5% studies reviewed)

Compared to the previous classes, this may seem like a simple binary definition and therefore lacks much depth. The approach, however, introduces a new component - a benchmark standard - to which functionality is measured against. In this case the 'design yield'[3].

This approach has the benefit of objectivity, but requires a systematic way of both knowing and measuring the design yield of each water point. Often the actual yield that the water point is designed for is not retained by implementing agencies contracting installation of new water points, or by drillers, and it is therefore difficult or not possible to access this information. A more appropriate approach may be to assess the designed yield of a handpump against standard design criteria, or national standards for HPBs.

[3] The use of the term "yield" can be ambiguous when used in relation to the water supply from a borehole. Borehole yield is a function of the transmissivity of the aquifer it accesses, the energy losses due to the borehole structure and the depth at which the pump intake is installed. A more accurate reflection of functionality is whether a HPB is continuing to supply the water quantity it was designed to, as opposed to yield.

4. Defining functionality – different levels of performance

Taking the findings from the literature review, the discussions with partners at our project workshop (Appendix 2), and developing thinking from an earlier paper (Carter and Ross 2016), the following framework for assessing functionality is proposed by the project. The results of the first survey phase of the project – a rapid survey of 600 hand-pump boreholes supplies across the three countries – will be used to review this proposed approach, and to inform the final approach proposed by the project to assess HPB functionality, alongside a requisite set of indicators.

Guidelines for assessing functionality

Within Hidden Crisis Project we suggest the following guidelines for assessing functionality:

- Functionality should be measured against an explicitly stated standard and population of water points.
- It should be measured separately from the users experience of the service it provides.
- The assessments should be tiered, allowing for further information, but always being able to be reduced to a simple measure.
- A distinction can be made between surveying functionality as a snapshot (e.g. for national metrics) and monitoring individual water point performance (including a temporal aspect).

Defining functionality

The *Hidden Crisis* project has applied these guidelines to develop a framework approach to define functionality in terms of different levels of performance. This starts with a basic 'working yes/no' definition, and moves to a more detailed understanding of the reliability and yield of supply – Figure 3. The final level introduces water quality to the performance assessment. As such the project examines the following definitions of functionality:

1. **Basic** – is the water point working (yes/no)
2. **Snapshot** – does the water point work and provide sufficient yield (10 L/min)
3. **Functionality performance** – (provides sufficient and reliability (<30 days downtime in last year))
4. **Functionality including water quality** (passes WHO inorganic parameters, and TTC)

Each of these definitions requires different amounts of data to be collected, and a requisite duration of survey. The 'Basic' and 'Snapshot' assessments reflect the requirements of national survey assessments, whilst the more performance-focused definitions are more relevant to local or regional surveys looking to track the functionality of individual water points or programmes through time.

Standard approaches will be used to assess the different levels of functionality within the project.

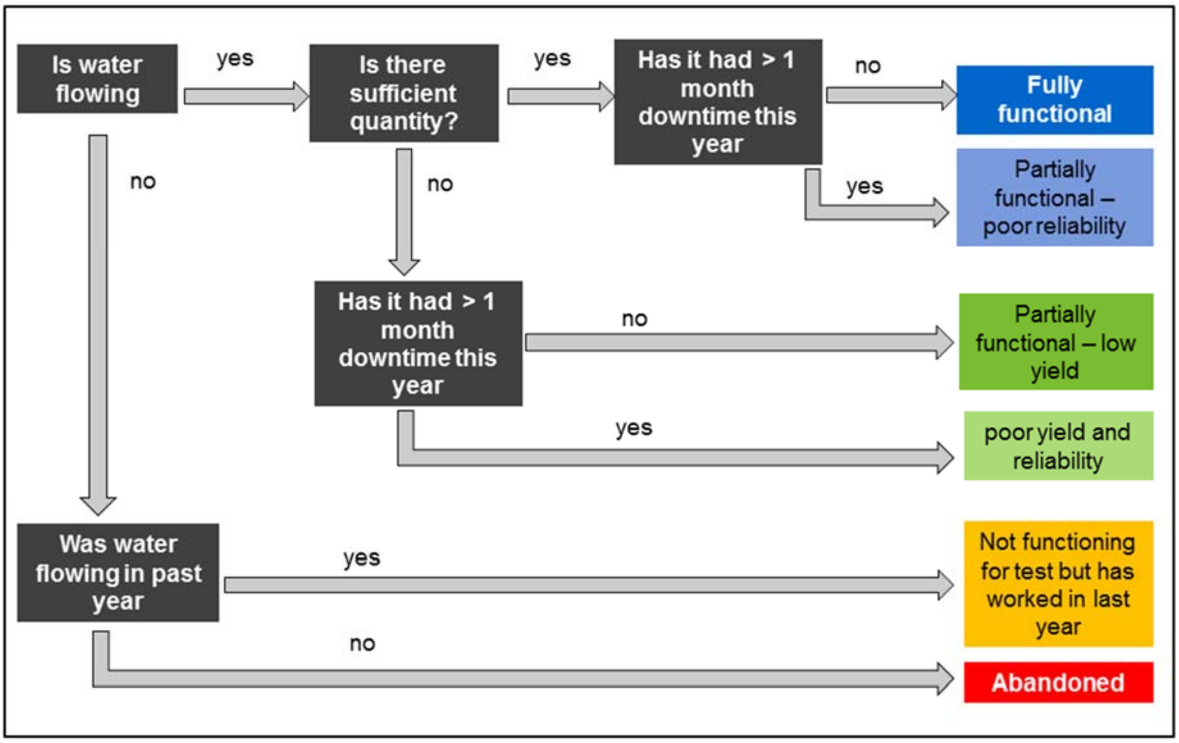

Figure 3 – A schematic diagram showing the proposed working categories of functionality used in the Survey 1 analysis. These categories will be developed, and may evolve through the project.

5. Standard suite of indicators to assess different levels of performance of functionality

Having a clear set of assessment criteria and indicators is essential to ensure sufficient relevant data are collated to assess functionality according to the survey focus. Each of the different levels of functionality performance proposed within the definition framework requires a greater, or lesser, amount of information to be collated by a survey to assess functionality.

A set of standard approaches have been identified by the *Hidden Crisis* project to collect sufficient relevant data to each of the proposed definitions of HPB functionality. A summary of these approaches, and how they relate to the tiered definitions of functionality, is presented below. Much more detailed information to each of the approaches is provided in Appendix 3.

Standard approaches proposed by the *Hidden Crisis* project to assess different definitions of functionality, include:

1. **Basic** – is the water point working (yes/no)
    - Handpump physically working and proving some water at time of survey visit.

2. **Snapshot** – does the water point work and provide sufficient yield (10 L/min)
    - Basic functionality assessment, plus:
    - Yield assessed from standard 30 minute stroke test conducted at the handpump borehole. The water point was assessed to pass the functionality test if the yield provided in the final 3 minutes was >10 L/min .
3. **Functionality performance** – (provides sufficient and reliability (<30 days downtime in last year))
    - Basic and Snapshot functionality assessment methods, plus:
    - Water point user survey used to assess the number of breakdowns and repairs in the last year, and number of days of downtime. The handpump borehole was assessed to be of sufficient reliability if the total downtime is <30 days in the last year.
4. **Functionality including water quality** (passes WHO inorganic parameters, and TTC)
    - Basic, Snapshot and Functionality performance assessments, plus:
    - Inorganic water sample analysis for major and minor ions – the water sample chemistry must meet WHO standards for inorganic parameters.
    - Thermo-tolerant coliform (TTC) water sample analysis – the TTC concentrations must meet WHO standard (<1 TTC)

6. Summary

Taking the findings from the literature review, the discussions with partners at our project workshop, and developing thinking from an earlier paper (Carter and Ross 2016), the *Hidden Crisis* project has set out a tiered framework approach for assessing functionality, and levels of performance. The results of the first survey phase of the project – a rapid survey of 600 hand-pump boreholes supplies across the three countries – will be used to inform the final approach proposed by the project to assess HPB functionality, and the requisite suite indicators.

The tiered framework approach to defining functionality, and required assessment indicators have clear linkage to the work of recent research projects examining service delivery (Triple-S 2009, Cross et al. 2013, Tincani 2015). These have been focused more to assessing the operational sustainability, life-cycle costs, and the service level provided by water supplies, and the cost efficiency and effectiveness of WASH investments. The *Hidden Crisis* project can contribute to these by providing robust definitions and assessments of the physical water point functionality and performance, which can be used to compare with users experience and perception of service. This will provide clarity to functionality data, and enable a systematic evidence base to develop to more informed opinions and policies for WASH investment.

The survey 1 functionality dataset will be used to address several key research questions by *Hidden Crisis.* These include, but are not limited to:

- what impact do different definitions of functionality and the standards against which they are assessed have on measured rates of functionality and performance?
- what impact does inclusion of water quality have on measured HPB functionality? (i.e. how does the number of HPBs categorised as functional change)
- and, can a score of functionality and performance be developed, which can be simplified to a simple binary assessment when needed?

Using the understanding developed, the definitions, indicators and assessment methods proposed in this report will be reviewed and refined by the *Hidden Crisis* project.

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Appendix 2 – Project workshop discussion, Addis Ababa

The six functionality definition classes identified from the literature review were presented at the project workshop in Addis Ababa in November 2015. Here a discussion was held to determine the key principles which should govern the approach of how to define the functionality of a HPB. The following is a summary of the key principles decided by the workshop:

1. The definition must be simple and fit in with what is already taking place – The simple binary approach of functioning/non-functioning is widely used and therefore this approach should be incorporated within the definition used.
2. A definition should be hierarchical, allowing for several layers of definition. Starting with a binary definition but allowing more nuanced categorisations behind that.
3. Different methods will need to be used for a national survey where a one of measure of the proportion of water points functioning is measured, or if it is referring to the performance of individual water points.
4. Functionality of a HPB in its purest form is best understood as a measure at a moment in time – in effect it is a health-check at which time symptoms of problems that affect the HPB from being able to function are observed.
5. Without repeat assessments, functionality cannot capture the temporal aspects of how well an individual HPB performs, such as seasonality and frequency of breakdown. A further tier or assessment is required to assess the temporal aspects. Ideally functionality assessments should be undertaken repeated at different times of the year. However, in reality, repeat assessment of the same HPB is unlikely to be possible due to time or monetary constraints. It was agreed that a good approach would be to focus functionality surveys to the most vulnerable times: at the end of the dry season to assess seasonality issues in quantity of supply; and the middle of the wet season to assess water quality issues.
6. Increasing demand placed on a HPB should not have a bearing on whether a HPB is functioning. This is more associated with the level of service which a HPB is providing, and although a useful measure, should be dealt with separately.

   A HPB should be assessed against what it was designed to do – for a HPB to have been commissioned, it should have been able to meet the design requirements for which it was installed, and therefore, the functionality of a HPB at a given moment in time should be determined against whether it still meets these design requirements.
7. Quantitative measurement of functionality should be defined, supported by subjective indicators.
8. Some provision must be made for whether a HPB is in use or– Even if a HPB does not pass a quantitative functionality assessment, it could still be in use.

The assessment of functionality should measure symptoms of poor functionality and not the causes – i.e. Assessment should be performed on handpumped supplies without any works to remove the handpump.

Appendix 3 – Indicators to assess functionality

The key indicators which will be used to inform the HPB functionality and performance within this are discussed below.

a. Quantity

Assessing whether a HPB produces at least the quantity of water that matches a standard is not a simple task. The first problem is ascertaining what the standard should be: the specific design yield of the individual borehole?; standard borehole design criteria?; or another accepted standard of water quantity for rural water supply provision?

MacDonald et al. (2008) considered that when commissioning a borehole or hand dug well, most organisations involved in rural water-supply suggest that community boreholes or wells should serve no more than 250 people each requiring 25 litres per day. This is a daily abstraction of 6.25 m^3/day, which assuming abstraction over a 12-hour period, gives a pumping rate of 0.145 litres/second or 520 litres per hour. Harvey and Reed (2004) suggested that a pragmatic approach to considering the service that will be expected of a handpumped source is a better way of estimating what a handpumped source should be capable of achieving. They suggested that a community of 200 people, each using 18 litres per day, collected during 2 hours at the start and 2 hours at the end of the day, will demand 20 litres per minute from a handpumped source (applying a margin of error of 1.1). This is a demand of 1200 litres per hour.

An alternative approach is to consider the capabilities of the handpumps installed to lift water from a borehole. The 2 most common pumps used for boreholes are the Afridev and India Mark handpumps. When pumped at 75 Watts, these will typically produce between 900 and 1000 litres per hour when the head lift is 20 m (Erpf, 2007 and Baumann and Keen, 2007). This is a useful benchmark because regardless of what the daily demand is, a handpump will likely be operated at the rate it is capable of operating at and if the borehole or well is not able to match this rate, a handpump will cease to supply water. Thus it could be argued that if a handpump is installed in a borehole or well, the water supply standard is that which the handpump is designed to pump.

What this concludes is that the design water supply quantity could be interpreted as anything between 500 and 1200 litres per hour. A decision is required to determine what this figure should be.

In the installation and maintenance manuals for both the Afridev (Erpf, 2007) and India Mark II (Erpf, 2008) handpumps, under preventive maintenance checks, the procedures for undertaking a discharge and leakage test are detailed. A functioning Afridev or India Mark II handpump should produce between 14 and 16 litres of water for 40 full length strokes of the handpump. The manuals define a discharge of less than 10 litres sufficient to warrant removal and inspection of the handpump components.

During the pilot in Malawi in November 2015, trials were performed to determine how feasible it was to continuously pump a HPB at a rate of 40 full strokes per minute for a period of up to 30 minutes. Two pumpers took it in turns every 5 minutes and the results of this trial were positive. Nine boreholes were tested with all successfully pumped continuously for 30 minutes. It was noted that this pumping rate is likely close to the optimum that could be achieved realistically. Therefore the Harvey ad Reed (2004) demand of 1200 litres per hour would seem unrealistic in the case of piston pumps. However, the design requirements defined by MacDonald et. al (2008) do seem reasonable when compared to the capabilities of the Afridev or India Mark II.

On the basis of this and taking the guidance contained within the maintenance manuals, a minimum discharge standard of 600 litres per hour seems reasonable (translated to 300 litres per 30 minutes).

Efforts were made at the project initiation workshop to identify a suitably robust quantity assessment that could be performed on a HPB. The following principles were used when reviewing tests and considering options:

- No dismantling of handpump
- Can be undertaken in less than 2 hours
- Does not put unreasonable burdens on the users of the pump
- Is simple to perform
- Uses easily accessible equipment
- Is repeatable
- Can be performed consistently by different operatives
- Will highlight supply problems due to both mechanical (handpump) and source (borehole or well)
- Likely to be adopted in the future

The supply quantity delivered by a handpumped borehole or well is a function of the lifting capability of the handpump but also the ability of the borehole or well to provide the water being pumped from the source at a rate which is at least the same as being pumped from it. Failure to achieve this will result in the water level falling to the level of the pump chamber and it will no longer be able to lift water until the water level recovers to a height above the chamber (as shown in Figure 4).

At the project initiation meeting, one suggestion was to use the discharge and leakage tests proposed within the Afridev and India Mark II maintenance manuals. The details of these are provided below. It was concluded that these tests were sufficient and reasonable for highlighting issues that would be derived from problems to do with an installed handpump. However, the tests would not highlight supply issues derived from the borehole (rather than handpump). Therefore, either a new test or a modified test would be required so that such problems would be highlighted.

Discharge test:

a) Operate the pump handle until a continuous water flow has been achieved (pump ratio approximately 40 full strokes per minute).

b) Place a bucket in the continuous water flow for exactly one minute.

c) Take the bucket off the water flow and check the amount of water drawn.

The water collected is often not less than 15 litres (but depends on exactly which pump has been installed). If the discharge is less than 10 litres for 40 full strokes, there might be a problem with the bobbins or the cup seal.

Leakage test:

a) Operate the pump handle until water is flowing from the spout.

b) Stop operating the pump handle for approximately 30 minutes (Note that in some situations this could put an unreasonable burden on the community – as part of the Hidden Crisis Fieldwork we will evaluate this).

c) Then operate the handle and count exactly how many strokes required until the water is starting to flow again. If more than 5 full handle strokes are required to make the water flow again, there must be a leakage in the rising main or the footvalve.

Points of consideration:

A 6 inch diameter borehole stores 18 litres of water for every 1 m length of casing. The vertical separation between the resting water level and the pump chamber could be anything from typically 15 m to 40 m, as shown in Figure 4. Pumping at a constant rate of between 600 and 900 litres per hour it could take anything from 18 minutes to over an hour for borehole water supply problems to be observed at the surface simply by the volume of water being pumped. This degree of uncertainty makes it difficult to undertake an assessment at surface of the overall supply quantity and any problems associated with this. It is worth noting that if a HPB is in-use on the day it is surveyed, it will likely have been pumped for some time prior to a pumping test and in cases where a borehole has a poor yield or there are seasonal issues due to declining groundwater levels, the pumping prior to the test will have pre-stressed the borehole and will increase the likelihood of such problems being highlighted during a shorter duration pumping test.

In theory, a declining pumping water level would be indicated at surface by an increase in the power required to drive a pump handle maintain the same flow rate whilst pumping at a constant rate. During the pilot study in Malawi in November 2015, trials were performed to see if it was feasible to measure the amount of force required to drive a handpump handle by using a bucket filled with water. If the force increased during a pumping test then this would indicate a declining pumping water level. However, the trials proved unsuccessful as it was found that there were too many other factors that influenced the pumping stroke and this was not consistent enough to allow a test to be performed in this way.

During the phase 1 survey, it is intended that 600 HPB's will be surveyed. To achieve this within the intended timescale means that undertaking a pumping test for longer than 30 minutes is not practical. However, since most HPB's will have been pre-stressed by the normal users, there is a high likelihood that water supply problems will be highlighted during a 30 minute duration test. However, if the HPB has not been used in the previous few hours such an issue will only be highlighted from interviewing users.

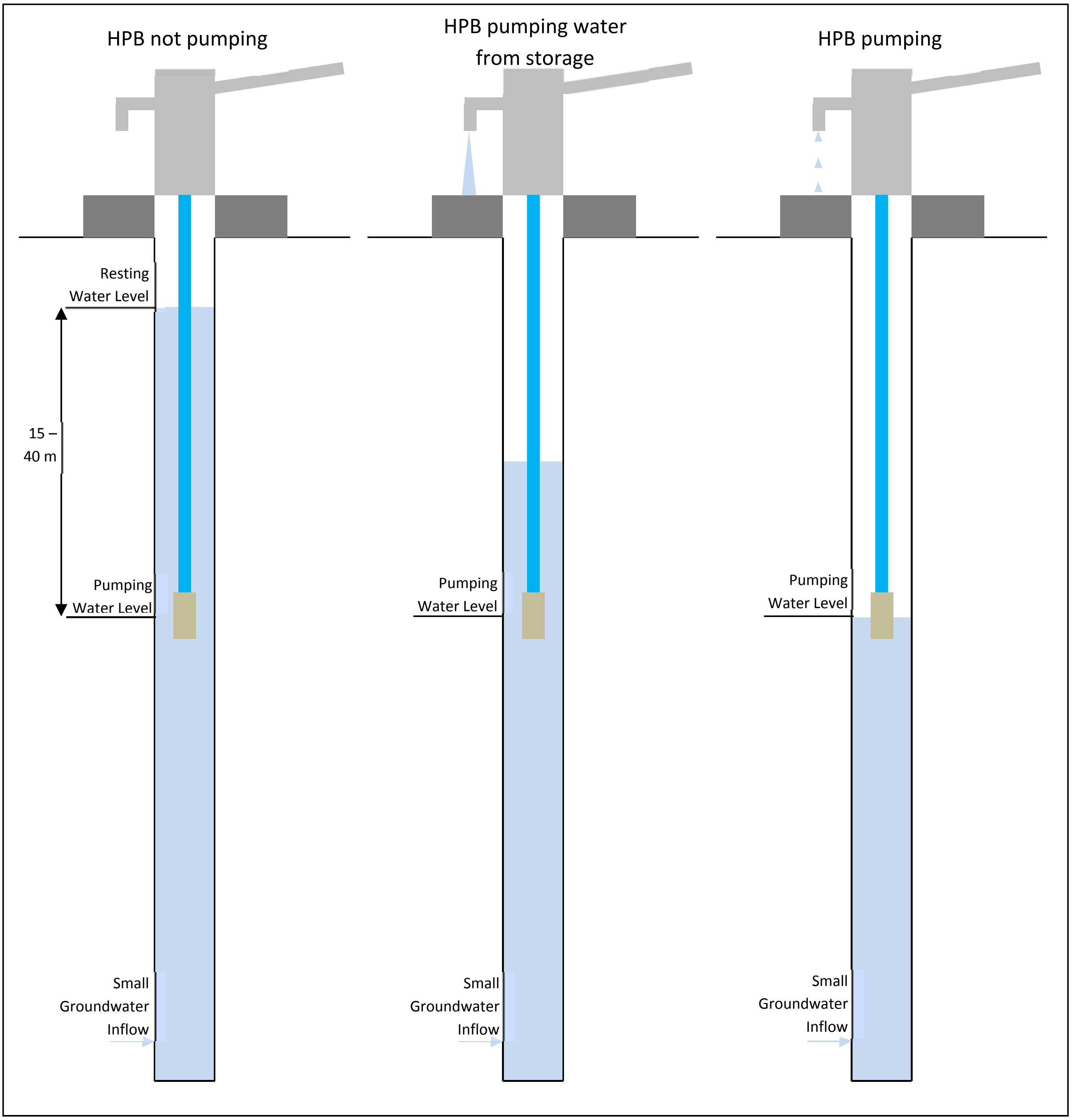

Figure 4 – The pumping of water from storage within a low transmissivity aquifer

Proposed Hidden Crisis Test – assessing water quantity delivered from a HPB

To assess the quantity of water delivered by a HPB, the following test is proposed:

1. Start pumping full strokes at a rate of 40 per minute (use a metronome placed on the pump head as a guide). Count the number of strokes before water is delivered. If no water is delivered within 100 strokes, cease pumping and do not continue.
2. Once a continuous flow of water is achieved, start a timer and restart counting strokes using a manual tally counter. Collect the water delivered in 10 litre buckets (note that the volume of the buckets should be measured not assume). Record the cumulative total number of strokes after each minute. Record the time when each bucket is full.
3. Continue pumping for up to 30 minutes except in the following cases:
    a. Water stops being delivered for a continuous of period of 5 minutes. Record the time and stop pumping.
    b. The time required to fill a 10 litre bucket is greater than 1 minute for a continuous period of at least 5 minutes. Record the time and stop pumping.
4. Cease pumping for 30 minutes
5. Start pumping again and record the number of strokes required before water is delivered (leakage test).

The key indicator is whether at least 300 litres of water is delivered during the test. A failure to achieve this indicates that the HPB will not satisfy the standard of 600 litres per hour. If the initial flow rate is less than 10 litres per minute, this will not improve during the test and the HPB will not achieve the standard.

A secondary indicator is if the flow rate of at least 10 litres per minute is maintained throughout the test. If the rate declines to less than 10 litres per minute, this indicates that the standard of 600 litres per hour is unlikely to be achieved.

A third indicator is if the HPB users report that the flow rate declines regularly after pumping for an extended period of time. Evidence to verify this should be found from the pumping test. There should be some evidence of a decline in flow rate or difficulties maintaining a stroke rate of 40 per minute.

If any of these three indicators are not achieved, the quantity assessment will have been failed.

The results of the leakage test will not be used as an indicator of functionality or performance. If more than 5 strokes are required before water is delivered then this indicates a leakage problem with the handpump. This is more a cause of poor functionality or performance. The causes will be looked at in more detail during phase 2 of the project. The reason for doing the leakage test as part of the phase 1 assessment is because it is easy to schedule while water chemistry testing is undertaken which takes about 30 mins. However, in other circumstances it may slow down the survey considerably or put unreasonable demands on the users of the pump.

b. Quality

Water quality will be assessed by a combination of in situ field techniques and by collecting samples for analysis in the laboratory. A preference was expressed at the project initiation meeting for robust field techniques to be used and for laboratory analysis to be kept to only essential parameters. However, following the pilot in Malawi in November 2015, it was decided that applying field techniques for all quality indicators would require too much time and reduce the overall number of sites that could be assessed during phase 1. Therefore, it was decided to use in-situ testing of only parameters that could not be accurately assessed by collecting a sample for laboratory testing and that all other parameters would be assessed by collecting samples to be transported to and tested in a laboratory.

At the project initiation meeting, the following key indicator parameters of poor quality water either from natural or anthropogenic sources were agreed:

- Electrical Conductivity
- pH
- Turbidity
- Nitrate
- Iron
- Manganese
- Arsenic
- Fluoride
- Ammonia
- Total Dissolved Solids
- Thermo-tolerant (faecal) Coliforms

Within first survey phase of *Hidden Crisis* these parameters will be assessed against national standards within each the 3 survey countries. This will enable the project to assess how differences in standards would influence functionality.

Water quality will be assessed at the end of the quantity tests. If the supply quantity test is failed and the HPB struggles to produce a sustained supply of water, whatever water can be collected should be what is tested.

A detailed methodology, with standardised protocols for sampling techniques and relevant national standards will be followed in all three countries within the phase 1 survey. The final version of this methodology which will be agreed following analysis of the Survey 1 data will be made available for others.

Performance

To assess HPB functionality a survey must include indicators which capture how well a HPB performs over time. Ideally, HPB performance would be assessed by repeating frequently the functionality assessments, detailed above, to monitor how the quantity and quality of water delivered varies over time. However, this is impractical within the time constraints of the *Hidden Crisis* survey phases of the project, as it is for many other rapid one-off functionality surveys. As a result, an appreciation of how the quantity and quality of water delivered by a HPB varies over time has to be captured within a single visit to each HPB.

The first survey phase of *Hidden Crisis* will assess the suitability and usefulness of ***visual observations survey*** and a ***user questionnaire*** to obtain an appreciation of HPB performance. The key performance indicator categories for which information will be collected are:

- Status – In use/normally in use/abandoned
- Quantity – Quantity assessment against the standard, and how the quantity supplied is perceived to perform during a day and across different seasons
- Quality – Quality assessment against the standards, and how the water quality supplied is perceived by users to perform during a day and across seasons
- Reliability – Mean time between failures and duration of downtimes, number of failures per year

The visual observations survey will be completed by the survey researcher, based on their own observations on arrival at each HPB. During the pilot in Malawi in November 2015, it was found that these observations were best made within the first few minutes of arriving at each HPB.

The user questionnaire survey is completed by the survey researcher based on discussions with water users at the HPB during the time of the survey sampling work (e.g. people waiting to collect water). Within the Malawi Pilot the user questionnaire was best conducted during the quantity test, when it was not uncommon to have one of two people to arrive at the HPB to collect water, and the person(s) could be interviewed to one side of the HPB without fear of their answers being reported to the water management committee. The same user questionnaire will also be incorporated into the water management committee questionnaire. This enables comparison, and some validation, of the survey information collated on user perception of HPB performance between the HPB committee and the HPB users. User questionnaires rely on having a cross section of people to question and also have recall issues associated with them. Survey 1 will be used to help evaluate the significance of some of these issues in Ethiopia, Malawi and Uganda.

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