

**36th WEDC International Conference, Nakuru, Kenya, 2013**

**DELIVERING WATER, SANITATION AND HYGIENE SERVICES  
IN AN UNCERTAIN ENVIRONMENT**

**Grading system for analysing technical failure  
in hand-dug water supplies in rural Sierra Leone**

*P. Byars, J. Barrie & B. Antizar-Ladislao, UK*

**REFEREED PAPER 1757**

---

*As the Millennium Development Goal (MDG) of halving the number of people without access to sustainable source of drinking water was reportedly reached in 2012 the long term sustainability of these water supplies can be questioned. This paper investigates the success and failure of water supply systems of the district of Tonkolili, Sierra Leone. The primary focus of this research is on rural hand-dug wells that have been provided by Non-Governmental Organisations (NGOs). To fully appreciate the current condition of the water supply systems a grading system, based on quantitative measurements, was developed. This system allowed comparisons between NGO provided water points and highlighted current successes and failures of the water supplies. The grading system suggests that the water supply sector in Tonkolili is in an exceptionally poor condition. This undermines the valuation of the success in water supply coverage statistics monitored by the Millennium Development Goals in Sierra Leone.*

---

## **Introduction**

At the Millennium Summit of 2000 eight wide-ranging and global development goals were officially established. All 193 United Nations (UN) member states agreed to achieve these goals by the year 2015. For water supplies the most notable target was goal seven. This was designed, and is being used, to increase global environmental sustainability. This goal included an explicit mention and targets for achieving water supply in the new millennium: “to halve, by 2015, the proportion of the population without sustainable access to safe drinking water” (Target 7C). It was declared by the UN in March 2012 that this global target had been reached (UN 2012). These conclusions were taken from the statistics of the Joint Monitoring Project (JMP) but there is little indication to suggest that the sustainability of the implementation and service delivery models has been fully considered (UNICEF & WHO 2012). This paper considers one of the many aspects of water supply systems- the technical success of the systems and their contribution to global water supply coverage.

## **Sierra Leone and water supply systems**

Sierra Leones brutal civil war (1991-2001) resulted in widespread destruction of infrastructure. Since 2001 the country has seen a steady growth and progression with regards to international development targets. In 2012 a water point mapping exercise was carried out by the Ministry of Energy and Water Resources in Sierra Leone. This was used to document progress on improved water coverage (Hirn 2012). This report estimated that international donors have funded a total of 11,178 water supplies since the end of the conflict. These constructions were facilitated by many of the world’s largest international NGOs and supported by innumerable Sierra Leonean partner organizations, construction companies and engineering contractors. These donor funded projects constitute almost 39% of the total water supplies in Sierra Leone. Given the national socio-economic situation, the basis for international assistance in this regard is the valid assumption that the communities cannot afford to provide these systems for themselves. To provide sustainability it is also assumed that the communities, with assistance from their local government, will be able to cover the operation and maintenance costs for their systems (Harvey & Reed 2004).

The Ministry of Energy and Water Resources datasets indicate that 69% of the handpump well systems are currently ‘functional’ 13% are ‘partly damaged’ and 14% are ‘broken down’. The remaining 4% are still

‘under construction’ at the time of surveying. One of the worst affected areas was Tonkolili District in the Northern Region. The report indicated that this district had a total of 702 handpump wells and 154 protected sources - of these 29.8% of their handpump wells and 31% of the protected wells were ‘broken down’. The failure rate of these sources (averaging 27.8% for the district) is higher than the reported national average (14%). For this reason Tonkolili District was identified for primary field research on sustainability. A technical survey was carried out in this region. This survey was more inclusive of different individual mechanisms of failure utilized in the water point mapping exercise (Hirn 2012). A total of 294 water supplies (212 handpumps and 82 protected pulley well systems) were assessed. Therefore this project analyzed over 31% of the NGO provided water supplies in Tonkolili, across 150 villages in five chiefdoms, and investigating projects by 23 different implementing agencies. To narrow the cases studies used for this paper only the hand-dug well systems have been considered.

### The categorisation of handpump wells components

Over their natural lifespan hand-dug shallow wells consist of more than a single component which can have technical issues and require maintenance. These are not limited only to the functionality of the handpump or pulley technologies alone. Due to the varied nature of designs for water supply systems there is no fixed international standard for the inclusion of different well components. Since the UN water decade which began in the 1980s there have been several developments in well system design (Baumann & Druck 2000; Skinner 2003). This has resulted in the designs evolving over time and becoming more standardised in the process. The frequency of these shared components provides a mechanism for comparing sources. The main areas of the well system fall under the nine categories described in Table 1.

No.	Component	Description
1	Lining	If the well is correctly lined it is enough to raise the standard of the well from unimproved to an improved source (UNICEF & WHO 2012). The well lining ideally extends from the ground surface to the water table. Its purpose is to retain the soil at the sides of the well and prevent infiltration from surface water near the ground level (Collins 2000; OXFAM 2008).
2	Head wall	Prevent infiltration of surface water into the well. The well wall is an extension of the well lining and will usually be capped (Collins 2000; Boschi 1982).
3	Well cap (cover slab)	Placed at the top of the headwall, ensuring that water does not enter from above (Brikké & Bredero 2003; Boschi 1982; UNICEF 2009).
4	Well Apron	An easily cleanable area around the well. Should slope towards the drainage channel around the edge of the apron (Brikké & Bredero 2003; Smet & Wijk 2002; Collins 2000).
5	Spillway	Collect water from the drainage channel and carry it to a soak pit. (Skinner 2012).
6	Drainage area	Surrounds the well and is designed to collect wastewater (UNICEF 1999; Brikké & Bredero 2003; USAID 2010).
7	Manhole cover	Designed to allow access for maintenance. It also allows a pump system to revert to an improved pulley system in the case of an emergency. Most NGOs provide a manhole cover, however some are capped (sealed with concrete) to avoid tampering (Collins 2000; Smet & Wijk 2002).
8	Handpump or pulley systems	Wells provided by NGOs normally fall under these categories. There are a range of differing technologies such as piston, direction action, suction and in the case of pulley wells; the pulley mechanism (Collins 2000; Brikké & Bredero 2003; Harvey & Reed 2004; Erpf 2002).
9	Lifting systems	This includes the system for raising the groundwater, such as the rising pipes, washers, cylinders, bearings, connector rods, cylinders and in the case of pulleys; the rope and bucket (Erpf 2002).

Each of these components has their own build specifications however some well designs combine certain areas - such as the well apron and the draining system being provided as a single unit. Some designs can also omit technical aspects - such as not including spillways or manhole covers. The purpose of the evaluation method used in this study is to allow components of well systems to be contrasted and compared, both within the context of an individual system, and to other hand-dug well systems. Therefore, for the sake of

presenting a standard, where technical areas are combined then they were assessed for their fitness of fulfilling each of the criteria separately. Similarly all components are assessed primarily on their ability to complete their unique function. For example a water tight spillway comprised of block-work would not be unfavourably compared to a concrete screed lined runoff. The changes in hand-dug well designs over the previous decade have shown that all the technical components, indicated in Table 1, are necessary for the continued sustainability of the sources. Correctly designed spillways, soak-ways and aprons offer an important example. Omissions can cause short term problems due to ponding such as allowing water vectors like mosquitoes to be able to breed near the sources (Harvey & Reed 2004; Skinner 2012). The evaluation of many case studies has indicated that, in the long term, the lack of runoff areas leads to erosion of the head wall, apron and lining. For this combination of reasons it is assumed that all of the individual well components are necessary for the long term sustainability of the well systems.

### **The need for a technical grading scale**

Current monitoring targets have created a definition whereby water points can be considered ‘potentially safe’ (UNICEF & WHO 2012; Sphere 2011). To accurately evaluate the condition of hand-dug well systems in Tonkolili an evaluation of the inverse is required; a way in which a hand-dug well could be considered ‘potentially unsafe’. This paper proposes a grading system that can be used to determine, in general terms, an evaluation of the financial costs and human resources that would be required to return the source to its ‘safe’ condition. It is important to establish that the grading system presented in this paper is not intended to be a measurement of the magnitude or impact of risk at the water points. A full technical analysis, combined with an extensive review of important water quality indicators, would have to be considered to determine the actual risk to the communities (Godfrey et al. 2011; Onda et al. 2012). This would be intensive in both, time and financial resources, and without an abundance of both, it would not offer an understanding of the scale of water supply problems in Sierra Leone. Instead of viewing risk subjectively the alternative is to use the objective assumption that any failure, no matter its magnitude or impact, introduces an equal amount of risk at the source. Therefore all damaged sources can be classified as ‘unsafe’ until repairs are carried out.

A full technical assessment of the water point, to provide an exact bill for maintenance, would involve taking each component apart to assess its actual functionality. Even a small selection of case studies would result in a varied range of complications regarding accuracy. There are distinct differences in technologies and their design criteria. As such, each of the individual technical components can have alternating materials prices. They can also be dramatically different logistical and labour costs for repairs. If exact pricing was required then the range in designs would necessitate different survey criteria at each source. Approximating the financial cost of human resources required to repair each technical issue would also differ depending on the type of technical problem. Additionally accurately costing human resource expenditure would present a sizable margin of error depending on the implementing agency, the locally available human resources and the location of the problems. Exact definitions of costs are further exacerbated by the observable conditions of water supply systems in Tonkolili. Many of the evaluated water sources were found to be beyond rehabilitation, and getting accurate estimates for repairs would be unrealistic. The opposite was also true - many of the issues observed could have potentially been dealt with at a local level where the cost of repairs is marginal or non-existent.

Therefore a system of evaluation is required that allows for both extremes of technical issues, from the critical to the marginal, to be taken into consideration. Simultaneously a degree of accuracy is required for this evaluation method which does not result in unrealistically large survey expenses or in the assessment becoming limited to evaluating a small number of water points. This technical evaluation should consider the financial capacities of the communities, a rough approximation for repairs, and the minimum technical support that is required to resolve the issues.

There are other considerations that have to be acknowledged that directly affect the nature of an ‘assumed safe’ source that are not rationalised by only viewing the individual well components. The number of people using the sources, the amount of time that the sources are in use, the location of the sources (in particular the proximity to high risk structures such as latrines) and the groundwater quality, also have to be considered as part of the technical evaluation into the well (DIFD 1998; Harvey & Reed 2004; Davis & Lambert 2002). These categories have been included as part of this technical evaluation.

### **The grading system**

This paper presents a grading system that can be used to evaluate the success and failure of water supply systems in Sierra Leone. This addresses the intermediate nature of failure witnessed in Tonkolili and is not

dependent on binary (working/not working) assessments of failure. By separating the criteria for the wells into individual sections, assessing them independently, and using pre-defined quantitative assessment methodology, then sufficient information can be gathered to define the quality of the existing well constructions. The results for each well, and their components, fall into specific categories of failure:

**Grade A: (*Extreme failure*):** This is the most dramatic of all failure modes. Wells that fall under this category have, in most cases, clearly noticeable defects. The systems are usually completely non-functioning, and in many scenarios, have been for a long while. The cost of remediation for the wells is comparable to replacing the well system entirely. In some cases, particularly in the areas of highly contaminated water or incomplete systems that have been left unfinished, the wells may continue to offer continual danger to the community. Before a new system can be provided, wells of a Grade A failure would have to be dealt with to ensure that any associated risks of the previous systems are mitigated. This could involve either the dismantling and back filling the well, or providing a complete water treatment system capable of dealing with water quality issues.

**Grade B: (*Severe failure*):** This is the highest level of failure for systems where the option of rehabilitating the well remains. The price of a repair would be comparable to providing a new system. Failure in this category usually affects a significant component of the well system, usually structural in nature. Wells that are classed as having ‘severe failure’ offer significant risk to communities. The defects of a Grade B failure will continue to offer risk to their hosts, such as standing groundwater being able to enter through the partial collapse of a well wall. Extreme seasonal failure will also contribute to the grade B categorisation of the well. Like Grade A failure, the cost of repairing these wells will exceed the financial capacities of the community. Much of the rehabilitation would also require an engineer, as steel reinforcement design, for example is beyond the capacities of the NGO technicians. Severe failure, like extreme failure, usually indicates poor practices in the manufacturing and construction process.

**Grade C: (*Significant failure*):** This is the first mode of failure that has a parallel with existing standards. Wells that fall under this category have exceeded the standards laid out in the Sphere guidelines (Sphere 2011). The wells in this category do not have sufficient yield to supply the communities with water all year round, and may require added depth (and extra casings) to their wells system. Technical failures, such as the piping or handpump rusting, may contribute to the system not working. These would have to be re-supplied and refitted where necessary. There may also be issues with certain important, but inexpensive external components of the well, such as the spillways, aprons and well walls. Communities with a functioning tariff system, which has been operating successfully for a number of years, will be able to afford the costs of fixing these well problems.

**Grade D: (*Moderate failure*):** Wells that fail in this category will have only temporary, rather than permanent, issues. The reasons for these wells not working would only be a minor defect usually caused by wear and tear on fast moving parts (such as a rusted chain, broken seals or damaged, but repairable, pipes). Structural damage would be minimal, no more than hairline cracks present, which require simple rehabilitation. The remedial action for these should not require expensive solutions. Inexpensive fencing would be considered a Grade D problem. Providing solutions to any of these problems should not exceed the financial capacity of the communities, even without a properly functioning tariff system. The remedial actions should also be within the capacity of an NGO-trained technician to repair.

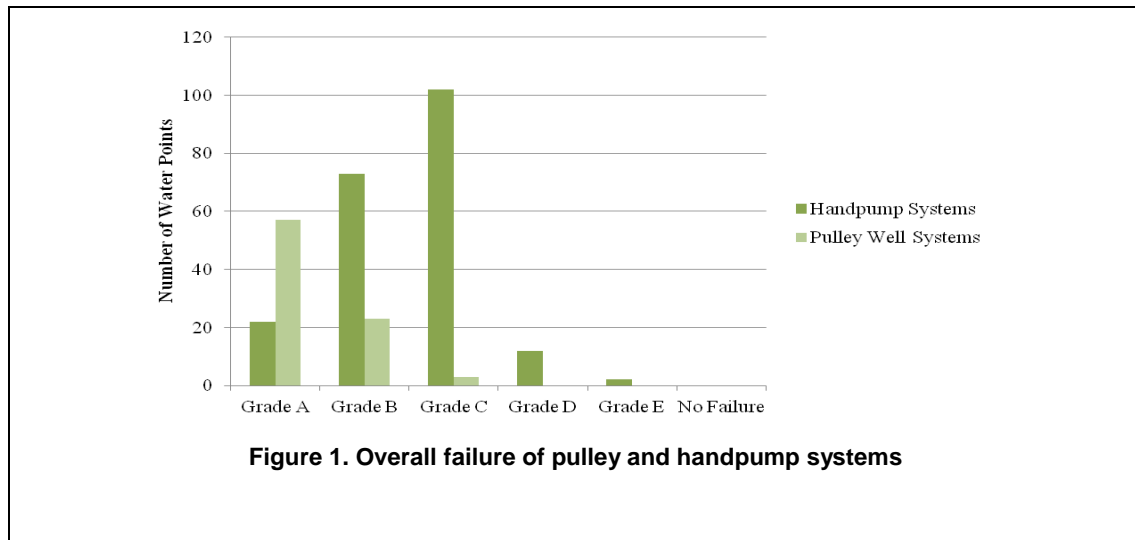
**Grade E: (*Mild failure*):** This grading of failure is used as a counterpoint to ‘extreme’ failure. Though it could argued that wells that fail to pass this criteria are being judged, harshly these wells would still not be acceptable in a developed country. Mild failure is typified as having superficial structural and mechanical problems. Examples of this include; exposed formwork, surface level rusting of technologies. Examples such as spillways that are incompletely constructed, missing ball-stones in their soak-ways, or an incomplete fence, would all constitute to a grade E failure.

The individual analysis of the well components is combined with the definitions given for each of the categorisations of failure. This result in a matrix of indicators that can provide an overview of the condition of the water points at the time of survey (the extensive table of events and their checklist is not shown in this paper). The placement of each component is a function of the cost to repair the source as well as the required human resources. There are some important considerations: firstly, certain categories do not have a high classification of failure - a missing spillway, for example, cannot be classed as Grade A or B as it is not expensive to replace, nor does it require advance technical assistance to construct. Secondly, certain categories can have multiple failure types at each point - the cover slab, for example, can have steel damage causing it to sag, it can have a range of different erosion types, and can be cracked to various extents. All of these have been considered as part of the evaluation. Finally the majority of the issues can be assessed using

simple quantitative measurements at the source. The two exceptions are yield at the source and water quality. Both of these require repeated monitoring and are therefore outside the scope of this study.

### Results of the field survey on water points

In total 295 water points were assessed as part of the technical survey into hand-dug wells. Of these, 211 were handpump well systems and 84 were pulley wells. These were assessed to consider the both the number of failings on each technical category at each source, and the maximum reached per source. A well can be classed as the highest ‘grading’ it has received, rather than a culmination of multiple failings, as only the highest would be most significant. The maximums for the wells are shown in Fig. 1.



Though none of the wells exhibited a maximum grading of ‘no failure’, many examples of satisfactory technical aspects were found. Out of the 4,704 criteria that were monitored 41% offered no negative contribution to issues at the source. However, over the 295 water points that were evaluated, there were examples of every type of technical hazard presented in this paper. A total of 82 case studies identified 122 forms of extreme failure (Grade A), often with multiple problems at a single source. Similarly there were 161 case studies which identified 332 forms of significant failure (Grade B). Both of these categories incurred more expenses than any community could reasonably resolve independently. This alone indicated significant engineering service delivery problems. However the most common issues identified were found to be within the capacity of the host community to resolve. Over 2,300 individually monitored issues could have been resolved internally by the communities. Local maintenance was found to be less likely if significant failure has not been addressed. A total of 52.8% of the Grade A and B classed wells were still in use at the time of the survey, but maintenance in other areas, such as fencing or spillways on these wells was much less frequent at these wells.

### Conclusion on the grading of water supplies in Tonkolili

The conclusion drawn from the site visits indicate that Tonkolili's water supply systems are in a state of disarray. There was insufficient evidence to suggest that any of the NGOs were providing technically sound rural water supply systems. The varied technical issues observed at each of the water points, their intermediate nature, and the range of problem types which were shown to have occurred at each source, has justified the approach of using multiple indicators and a grading system for evaluating the water supplies. If the results of the surveys found in Tonkolili were replicated in other sections, though the District may present a worst-case scenario, then the MDG water supply targets in rural Sierra Leone may require a further downscaling in estimations of growth in the sector. Severe technical water supply issues are common in systems found throughout rural Tonkolili. The prevalence of Grade A and B failures indicate a poor level of engineering practices by NGOs. Community resolvable issues (grade C or below) result in almost 83.6% of the total issues observed on the water supplies. The inability, incapacity or unwillingness of the host communities to repair water supply sources indicate a serious cause for concern; particularly as certain ‘higher’ failure modes can be attributable to years of neglect. This suggests that the failure is not limited

only to poor technical design but also to unaddressed socio-cultural and socio-technical aspects which are providing their own profound contribution to the failure of wells in Tonkolili.

---

### Acknowledgements

The authors would like to thank the field researchers Alannah Dela Hunty, Alfred Sesay and Ibrahim Sheku for their contribution to this research, and the staff at Concern Worldwide-Sierra Leone for hosting the research in Tonkolili. The funding for this research provided by the Humanitarian Innovation Fund (HIF) is acknowledged. Special thanks are given to the Engineering and Physical Sciences Research Council (EPSRC) for funding the PhD studentship for Byars.

---

### References

- Baumann, E. & Druck, N., 2000. *Water Lifting*, St. Gallen: SKAT, Swiss Centre for Development Cooperation in Technology and Management.
- Boschi, I., 1982. *Construction Of Hand Dug Wells And Protection Against Pollution*, Geneva.
- Brikké, F. & Bredero, M., 2003. *Linking technology choice with operation and maintenance in the context of community water supply and sanitation*,
- Collins, S., 2000. *Hand-dug Shallow Wells* SKAT, ed., Switzerland: SKAT, Swiss Centre for Development Cooperation in Technology and Management.
- Davis, J. & Lambert, R., 2002. *Engineering in Emergencies*.
- DIFD, 1998. *Guidance Manual on Water Supply and Sanitation Programmes*, Loughborough: DFID. Available at: [www.lboro.ac.uk/well/](http://www.lboro.ac.uk/well/) [Accessed February 15, 2013].
- Erpf, K., 2002. *Technology Selection—and Buyers' Guide for Public Domain Handpumps for Drinking Water. HTN/SKAT, St. Gallen, Switzerland*.
- Godfrey, S., Labhassetwar P., Wate S., Pimpalkar S., 2011. How safe are the global water coverage figures? Case study from Madhya Pradesh, India. *Environmental monitoring and assessment*, 176(1-4), pp.561–74.
- Harvey, P. a & Reed, B., 2004. *Rural Water Supply in Africa*,
- Hirn, M., 2012. *Sierra Leone Waterpoint Report*.
- Onda, K., LoBuglio, J. & Bartram, J., 2012. Global access to safe water: accounting for water quality and the resulting impact on MDG progress. *International journal of environmental research and public health*, 9(3), pp.880–94.
- OXFAM, 2008. *Repairing, cleaning and disinfecting hand dug wells*, Available at: <http://policy-practice.oxfam.org.uk/publications/>.
- Skinner, B., 2012. *An engineer 's guide to apron slabs for water points*.
- Skinner, B., 2003. *Small-Scale Water Supply: A Review of Technologies*, London: Stylus Pub Llc.
- Smet, J. & Wijk, C., 2002. *Small community water supplies: technology, people and partnership. IRC Technical Paper*.
- Sphere, 2011. *The Sphere Project*, London: Oxfam Publishing.
- UN, 2012. *World meets goal of boosting access to clean water but lags on better sanitation*. Available at: <http://www.un.org/apps/news/story>.
- UNICEF, 1999. *A Water Handbook*, New York: UNICEF/Programme Division, Water, Environment and Sanitation Section.
- UNICEF, 2009. *Technical Guidelines for the Construction and Management of Borehole Handpumps*.
- UNICEF & WHO, 2012. *Progress on Drinking Water and Sanitation 2012 Update*,
- USAID, 2010. *Environmental Issues And Best Practices For Small-Scale Infrastructure*. In *Environmental Guidelines for the USAID Latin America And Caribbean Bureau*. pp. 1–46.

---

### Contact details

Name of Principal Author: Paul Byars  
 Address: The University of Edinburgh, UK  
 Tel: +44 (0)131 650 5712  
 Email: [p.byars@ed.ac.uk](mailto:p.byars@ed.ac.uk)  
 www: [www.see.ed.ac.uk/seed](http://www.see.ed.ac.uk/seed)

Name of Second Author: Jack Barrie  
 Address: Mott MacDonald, UK  
 Tel: +44 (0)1223 465059  
 Email: [jack.barrie@mottmac.com](mailto:jack.barrie@mottmac.com)  
 www: [tastethewater.co.uk](http://tastethewater.co.uk)