GITEC Consult GmbH

East Mangochi
Rural Water Supply and Sanitation project (EMRWSS)

PREMATURE FAILURE OF HAND PUMPS

UNDERLYING CAUSE AND RECOMMENDATIONS AIMED AT REDUCING THE PROBLEM

A report to mark the 500th new EMRWSS community borehole

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Executive Summary

Under Demand Response Approach and the EMRWSS project, new boreholes are being drilled and old ones rehabilitated in the three TA's of Katuli, Jalasi and Mbwana Nyambi, Mangochi District.

A baseline waterpoint survey in 2003 showed that of the 340 recorded old hand pumps a consistent 46% per TA were broken down at the time of survey and 28% of all boreholes drilled since 1998, (excluding new EMRWSS boreholes), had failed.

The design life of a borehole and hand pump should be in the order of 25 years. Clearly an unacceptable number of hand pumps are failing prematurely. Poor management and maintenance of the hand pump by the User Community (CBM & VLOM) undoubtedly contribute significantly to this high rate of failure. However, this report investigates irregular aspects of borehole construction as possible causes of premature failure.

Borehole failure can be due to poor borehole siting practices leading to low and/or seasonal yield, poor water quality (saltiness) and poor position. In addition premature failure can also be caused by poor drilling practice, i.e. too shallow, too narrow, incorrect screen placement, lack of filter pack, bent or twisted drilling and subsequent to drilling - poor borehole development procedure. All of these inherent flaws in the borehole design exacerbate the frequency of hand pump breakdown, which lead to and promotes user neglect and eventual abandonment.

An opportunity to test the relative extent of these inherent borehole flaws presented itself with the EMRWSS borehole rehabilitation program. One hundred and forty-one old boreholes were assessed and selected for physical rehabilitation comprising:-

- re-development (cyclic jetting and pumping, up to 15 hours in duration)
- re-testing (step test, constant discharge test (4 hours) and recovery tests)

Analysis of the rehabilitation data shows that 41 % of the 39 boreholes that failed this rehabilitation had a problem that could be traced back to inadequate siting procedure and 51% to poor drilling and developmental procedures. Only 8% can be attributed to post-construction errors or negligence on the part of the users or community maintenance crews.

Some recommendations are made aimed at reducing the number of premature hand pump failures by targeting the borehole siting and drilling procedures and:-

- Improving the guidelines and specification of siting contracts
- Improving the guidelines and specification of drilling contracts
- Improving the in-field supervision of contractors
- Training of planners and supervisors in the above

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1 INTRODUCTION

Between 2000 and December 2004 six hundred and nineteen new community boreholes were drilled, constructed and equipped with hand pumps in the TA's of Jalasi, Katuli and Mbwana Nyambi by GITEC Consult GmbH on behalf of the Ministry of Water Development. This being a major component of the East Mangochi Rural Water Supply and Sanitation project (EMRWSS), funded by the German Development Bank (KfW). By completion in 2005 this figure will have risen to over 700 new community hand pumps and will also have addressed the underserved areas of Upper Chowe and the south of Lower Chowe.

The project practices the Demand Response Approach (DRA). DRA encourages communities to come forward and apply for GITEC assistance and it is this response and involvement that drives the project. Thus far, response has exceeded 90 % of the possible maximum response – this being a direct measure of the success of DRA and GITEC application thereof.

The project has also considered and delivered rehabilitation on * old boreholes via the comprehensive procedure described below. One hundred and fourteen boreholes have passed the rehabilitation criteria and been put back into commission. This latter program has, via careful analysis, yielded some interesting statistics and facts pertaining to the erratic behaviour or premature failure of boreholes equipped with hand pumps

The objective of this report is to draw attention to such. This will be of value to staff engaged in rural water supply programs, such as those within the Ministry of Water Development, Parastatals, Donors and NGO's. The report ends with some recommendations on preventative procedures aimed at reducing the number of hand pumps that fail prematurely.

2 IDLE HAND PUMPS: NATURE OF THE PROBLEM

2.1 NUMBER OF IDLE HAND PUMPS

Table 2.1 details temporal snap shots on hand pump functionality at the time of survey for various areas in Malawi. The percentage can vary from time to time and indeed according to remoteness from the regional service center. In Salima District the percentage functioning is much better because at the time of the water point survey, an NGO had just completed rehabilitating 140 broken hand pumps. Had the district not received this attention then non-functioning hand pumps would be more than 30%.

Table 2.1 Hand pump functionality, Mangochi and Salima Districts

TA	Total hand pumps	Not functioning	% not functioning	Source
Katuli*	104	49	47	Anscombe (2003)
Jalasi*	154	71	46	
Mbwana Nyambi*	82	38	46	
Chowe	237	64	27	Anscombe (2004a)
Salima District	1112	248	22	Survey of 10 TA's by Water Aid Stoupy and Sugden (2003)

* These figures apply to non-GITEC boreholes.

Table 2.2 shows percentages of breakdowns per category pre and post 1998. This year marked the onset of a major rural water development drive and a substantial increase in drilling activity. The analysis shows that the older borehole category has a higher percentage of dysfunction – as expected. The design life of a borehole with a hand pump should be greater than 25 years, thus suspicion can immediately be cast on the drilling fraternity considering 28 % are seen to fail within 5-years.

Table 2.2 Hand pump functionality according to age of borehole

TA	Drilled before 1998		Drilled after 1998	
	Broken (No)	**Broken (%)**	**Broken (No)**	**Broken (%)**
Katuli	34	62	15	31
Jalasi	47	67	24	29
Mbwana Nyambi	26	74	12	26
Total	107	67	51	28

Whichever way the data is manipulated and presented there is one overwhelming realisation – the percentage of dysfunctional hand pumps is unacceptably high. If one assumes a 25% non-functionality across the country at any one time it means that at least a quarter of all expenditure applied to drilling and equipping boreholes with hand pumps is, in effect, wasted. It also means that at least a quarter of all communities do not get the potable water they are reported to have received.

This is unacceptable and clearly every effort should be made by the planners and implementers of rural water supply projects to understand why boreholes and hand pumps fail and then to apply this knowledge to better contractor and project management.

2.2 TALKED-ABOUT REASONS FOR IDLE HAND PUMPS

The following reasons for hand pump dysfunction are in vogue and frequently proffered by the implementers of rural water supply projects in Malawi, most severe first:-

- Poor maintenance by community (inadequate CBM, VLOM)
- Poor availability of spare parts
- Poor quality pump parts leading to broken mechanism
- Theft and vandalism

If all boreholes were perfect in yield and construction, hand pump dysfunction would be minimised via good spare parts availability coupled with efficient Community Based Management (CBM) and Village Level Operation and Maintenance (VLOM). In such circumstance the above would undoubtedly be valid reasons for hand pump dysfunction.

However, in practice 100% functionality is not obtainable. This may be unrelated to the amount of effort and management applied by the user community simply because the boreholes concerned have an underlying problem related to the way they were sited or the way they were constructed (drilled). It is this type of inherent flaw that makes an individual hand pump more susceptible to repeated breakdowns – in turn promoting community despair and ultimately, abandonment.

2.3 UNDERLYING REASON FOR HAND PUMP FAILURE

Three areas (hereby referred to as categories) are apparent where problems can occur that will reduce the lifespan of a borehole and the hand pump (or any pump) placed therein.

Category 1: Poor borehole siting
Category 2: Poor borehole construction
Category 3: Post-construction damage

2.3.1 Category 1: Poor borehole siting

Poor siting can result in a borehole that has an inadequate yield, unpalatable quality or inappropriate position – all of which will promote premature pump failure either by more frequent breakdowns and/or community discontent.

With respect to inadequate yield it is important to point out that it can also be caused by poor borehole construction (see below), notably not drilling the borehole deep enough to reach the targeted aquifer. The depth should be at least 45 meters before even considering the siting as the cause of poor yield or dry borehole.

Salty or brackish quality water can often be avoided with competent geophysical siting (Section 6.2) – but not in areas where such water quality is ubiquitous.

Siting in inappropriate positions such as on ground liable to flooding or too far from the user community could just as easily be attributed to poor Community Based Management or poor project management. The targeted community should be able to advise the siting crew on these issues. However, assuming quality surveyors are employed, suitable position really lies in the jurisdiction of the siting crew noting that project management must be strong (preferably with a presence in the field at the time of surveying) and the community must be involved.

2.3.2 Category 2: Poor borehole construction

The art of good drilling is a science. Poor practices by drilling contractors in Malawi are numerous and a major concern. Worldwide, equipment, materials and methodologies vary considerably and have been developed to suit the many and varied hydrogeological environments. Malawi has its fair share of different hydrogeological environments from saturated lakeshore sediments (suited to mud drilling for deep or manual drilling for shallow holes) to hard-rock escarpment drilling (suited to air-percussion) to mixed hard/decomposed plateau drilling (suited to foam-assisted air, cable-tool or even mud drilling).

Unfortunately the drilling fraternity is not currently blessed with the necessary equipment or expertise and the outcome, when difficult or “strange” drilling conditions are encountered, is a continuous string of borehole botch-ups. What is hidden below the ground surface is just that…. Hidden from scrutiny. The Client pays the contractors invoices without knowing that the borehole has an inherent flaw that will cause premature borehole failure. This is really the fault of the project for not having adequate supervision on site and, indeed the fault of the Client and/or Donor for not insisting on such, (Section 6).

Without going into unnecessary detail Table 2.3 lists a few of the more common problems and errors practiced and/or encountered by drilling contractors together with their effect on the life of the borehole. Some examples are given in Appendix 1.2.

All of the tabulated categories and sub-categories will tend to reduce the life span of the handpump. The timing of the first pump breakdown will vary depending on the type and severity of the underlying problem. It may be within a few weeks in the case of a severely inadequate yield to some months in the case of a poor and seasonal yield. It may appear after the first or second rainy season where the flaw has allowed an excessive amount of silt to pass through the screens and into the borehole.

In all cases the user community, trained or otherwise, becomes negligent after repeated mechanical breakdown.

Table 2.3 Drilling errors contributing to premature borehole failure

Drilling error	Leading to	Premature failure can be caused by
Inappropriate drilling technique	Formation collapses on PVC (gravel not evenly applied)	Excessive intake of silt
		Inadequate yield
Misalignment of bore	Bent, corkscrewed, crooked	Irregular wear and stress on pump rods
Borehole too shallow	Borehole taps only first water or perched water	In adequate yield
		Silt intake & lack of sump space
		(Exposure to polluted water)*
Misalignment of screens and/ or improper insertion	Screens too high	Excessive intake of silt
	Yield zone cased-off	Inadequate yield
	Screens uncoupled or broken	Blockages when installing
Borehole too narrow (bit too small)	Insufficient room for gravel	Excessive intake of silt
	PVC pressed and spiraled	Irregular wear and stress on pump rods
Poor development procedure	Fine silt not cleared	Deterioration in yield
		Excessive intake of silt
Development compressor too large	Risk of rupturing of PVC casing and screens	Excessive intake of silt
		Blockages when installing
Poor yield assessment	During drilling	Inadequate yield
	During pump test	

* Increased coliform potential will seldom cause the borehole to be abandoned.

2.3.3 Category 3: Post-construction damage

Down hole pump components or foreign objects are sometime dropped down the borehole during servicing or repair episodes. When rehabilitation is considered the contractor employed often does not have the necessary equipment or know-how to fish the dropped items or is reluctant to drill them out for fear of damaging the drill bits (steel on steel). In such cases the borehole remains broken.

The loss of a borehole due to this type of problem can only be attributed poor community management. If the user group were properly trained then losses of this nature would be minimised.

3 EMRRSS PROJECT: BOREHOLE REHABILITATION PROGRAME

3.1 REHABILITATION PROGRAM

One hundred and forty-one communities from TA's Katuli, Jalasi and Mbwana Nyambi applied to GITEC to rehabilitate their old borehole between 2000 and 2004. Twenty eight percent (39 boreholes) failed the process (Table 3.1) and received a new borehole. The complimentary seventy-two percent passed the process and went on to receive a new and more durable civil works structure. All communities, by way of their individual Water Point Committees were integrated into the health and sanitation education program and water point management and maintenance program forwarded by the project.

Table 3.1 Summary of rehabilitation failures 2001-2004

TA.	No. of rehabs	Rehabilitation failures		% Failing
		Pre-fail	Post-fail	
Katuli	64	14	8	**34**
Jalasi	33	3	3	**18**
Mbwana Nyambi	44	4	7	**25**
Total	**141**	**21**	**18**	**28**

3.2 REHABILITATION PROCEDURE

Any community applying for rehabilitation of an old hand pump had the borehole subjected to feasibility assessment, development and testing. If the borehole passed all three stages then the old civil works was demolished and replaced with a new and more durable structure. Where the borehole failed (at any stage) then the community was granted a completely new borehole (sited and drilled). The stages are shown in Figure 3.1.

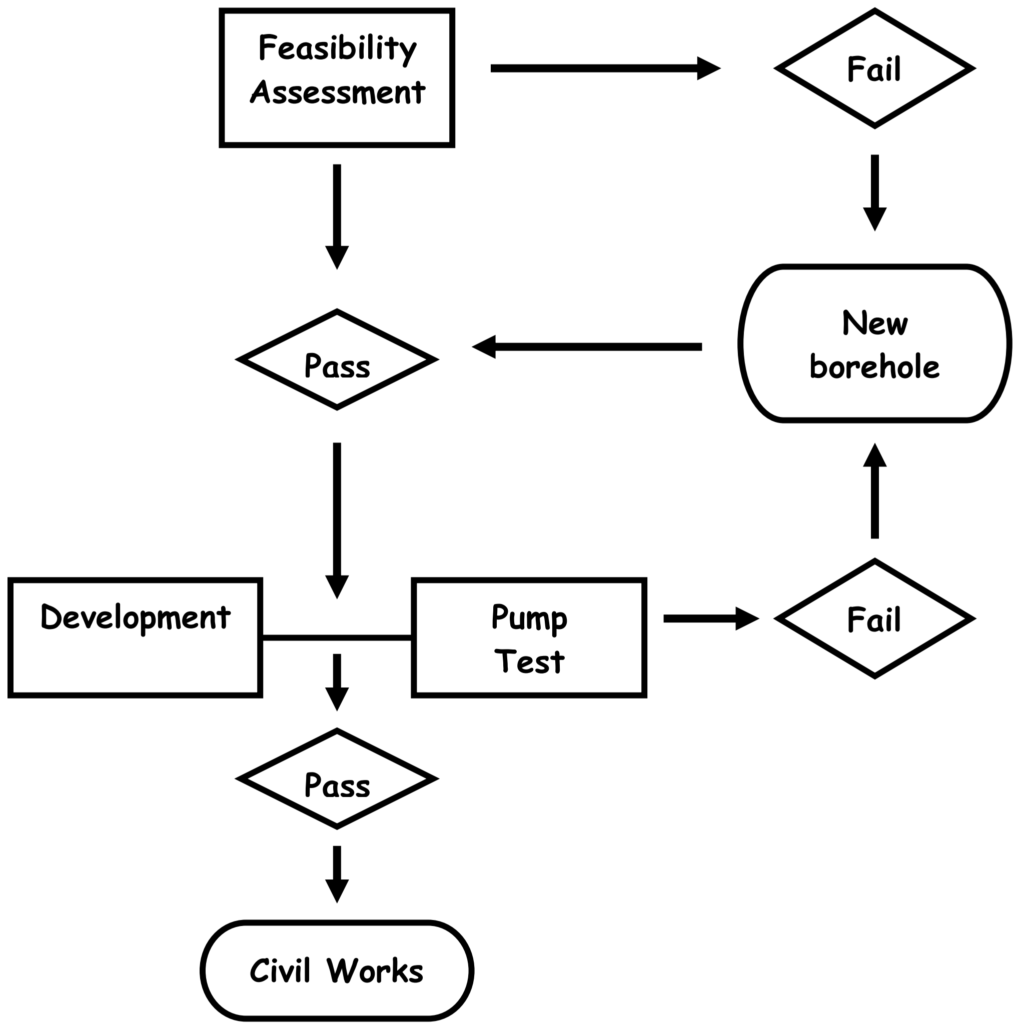

Figure 3.1 Flowchart: Stages of the rehabilitation process.

The feasibility assessment is a field exercise whereby the community is interviewed, borehole position and depth checked coupled with comparison with the available drilling documentation. The process concludes either with rejection and the siting of a new borehole (pre-fail) or approval for physical rehabilitation. The borehole can again be rejected after physical rehabilitation (post-fail) on a number of grounds including:-

- Inadequate yield
- Excessive and non-clearing sediment production

Details of the rehabilitation techniques are given in Appendix 2.

3.3 REHABILITATION ANALYSIS

Fifty-six percent of the boreholes considered for rehabilitation were broken down at the time of application. The initial impression is that the hand pump is broken because the user community is unable to fix it.

However, root causes of premature hand pump failure lie with the integrity of the borehole rather than the hand pump. The categories discussed in Section 2.3 derive from the analysis of the results of the EMRWSS rehabilitation program. Table 3.2 summarises the underlying reasons why thirty-nine boreholes failed the rehabilitation program. This has not been an easy exercise because often more than one symptom existed. But, it was normally possible to decide the main causative reason for rehabilitation failure. Appendix 1 gives a number of worked examples and presents a more detailed version of Table 3.2.

Table 3.2 Underlying reasons for 39 rehabilitation failures

TA.	MAIN REASON FOR REHAB FAILURE						
	Cat 2: Poor construction			Cat 1: Poor siting			Cat 3: Poor CBM
	Drilling probs	Excess sediments	Too shallow	Water quality	Yield	Position	
Katuli	4	4	2	0	9	3	0
Jalasi	1	0	1	0	1	0	2
Mbwana Nyambi	1	3	3	0	3	0	1
Total	6	8	6	0	13	3	3
%	**15%**	**21%**	**15%**	**0%**	**33%**	**8%**	**8%**
% by category	**51%**			**41%**			**8%**

It was found that despite 56% of the hand pumps being broken at the time of rehab only 8%, (those with pumping components or other objects jammed down the bore), could be attributed to post construction mismanagement - by the community. Ninety two percent had an underlying problem related either to the way they were sited (41%) or the way they were drilled (51%).

All the boreholes considered come from an upland plateau area where the groundwater is ubiquitously fresh and palatable. In other areas, such as in the shoreline vicinity of Lakes Malawi, Malombe, Chilwa and Chiuta boreholes are likely to be rejected (and become dysfunctional) by the communities on the basis of unacceptable salt content dissolved in the water. Thus the number of boreholes failing due to poor siting would increase. Other than this spatial aberration the percentage failing by category: 41%: 51%: 8% (poor siting: poor construction: poor CBM) are thought to be applicable countrywide.

4 SUMMARY

Forty-six percent of 340 old, (non-GITEC), hand pump boreholes were found to be dysfunctional when a water point survey was carried out in 2003 (Anscombe, 2003). Within this total 28% of the boreholes drilled since 1998 have dysfunctional hand pumps – demonstrating an unacceptably high premature failure rate.

One hundred and forty-one of these old boreholes were forwarded by their respective user communities for rehabilitation. Twenty eight percent of these failed the rehabilitation criteria. Fifty-six percent of these candidates were broken down at the time of application and 26% of broken down hand pumps were post-1998, i.e. less than 5 years old.

Analysis of the rehabilitation data shows that 41 % of the failures can be traced back to inadequate siting procedure and 51% to poor drilling and developmental procedures:-

Inadequate or inappropriate siting will cause a higher percentage of failures due to:-

- Boreholes tapping into a non-sustainable groundwater resource (inadequate yield)
- Boreholes more than 300 meters from extremity of community
- Boreholes on ground that floods or is vulnerable to pollution
- Boreholes tapping non potable, brackish or salty water

Poor drilling methods will cause a higher percentage of failures due to:-

- Boreholes that fail to penetrate the full aquifer thickness (too shallow) and consequently tap into a non-sustainable groundwater resource.
- Boreholes that are too shallow, have insufficient sump (silt trap) and consequently silt-up prematurely – exacerbated if the upper mobile layers are screened.

- Boreholes that choke because of incorrect placement of screens which either allow too much silt to enter and/or case-off the water bearing horizons.

- Boreholes that choke because the diameter of drilling was inadequate for a gravel filter/stabilizer to be installed properly, allowing silt to enter freely.

- Boreholes drilled bent or crooked causing premature failure of pump rods

- Boreholes that choke with silt because they are not developed properly. This is a reversible problem (provided the borehole has been drilled properly)

The main conclusion drawn is that an unacceptably high proportion of hand pumps are broken down because there exists a flaw in the manner in which they were sited or drilled. This is particularly so of boreholes drilled since 1998.

5 DISCUSSION

There has been a perceptible deterioration in the quality of borehole siting, drilling and development practices in Malawi over the years – notably since 1998 when the number of boreholes being drilled escalated and the pool from which to source experienced and well equipped contractors diminished. Remuneration rates for siting and drilling contracts have been pushed down in real terms by newcomers intending to profiteer – this preventing established contractors from replacing and maintaining their equipment and staff. Adding to the confusion are the seemingly innumerable aid agencies and NGO's all practicing rural water development and sanitation drives simultaneously with no apparent inter group liaison or coordination – many not knowing what it takes to achieve the term "a job well done". To compound the situation still further, Malawi is currently in the initial throws of an HIV epidemic, which seems to be preferentially depleting the sector containing those experienced in water related issues, (planners, supervisors and contractors).

The foregoing appears to cast an extremely poor picture for the future. However, the majority of problems caused by poor siting and construction practices can be overcome by the following

- **Ensuring that contract specifications are detailed and indeed specific**
- **Employing reputable siting and construction contractors and**
- **Enforcing the contracts via good, on-site supervision**

Obviously the application of experienced individuals using applicable techniques in the right place at the right time is the answer. If new millennium development goals are to be met and substantially more people are to gain access to ample and reliable potable water, via the hand pump, then these three simple policies must take precedence regardless of implementation cost. It has not been calculated but it is suspected that projects that professionally supervise (effectively "police") contractors to follow contract specification are actually more cost-effective. This is simply because the number of dry boreholes and the number of hand pumps meeting premature failure are reduced - by up to 25 percent.

6 RECOMMENDATIONS

Following on from the foregoing discussion the following recommendations are made:-

6.1 SITING CONTRACT GUIDELINES

Siting contracts should specifically address or state the following:-

- Preferred methods of siting (suited to the hydrogeology of the project area).
- One siting exercise per day to maintain standards.
- Maximum tolerated distance from the user group.
- Minimum tolerated distance from main roads and pollution sources.
- Requirement for a back-up site (at no additional cost).
- Requirement for GPS coordinates of sites together with physical markers.
- Requirement for professional report on siting and recommendations there to.

The siting should harness the skills of an experienced hydrogeologist or geophysicist with the flexibility and power of state-of-the-art geophysical equipment to target the deeper saturated wedges of regolith (less pollution, less fines, more sustainable, better overall yield). Many problems are caused by so called "siting experts" that do no more than site boreholes on non-sustainable, often polluted and silt-bearing, shallow or perched water. The siting team should produce a report that clearly tells the driller or the drill supervisor what is required in each individual case.

Experience on the EMRWSS project (escarpment and plateau type hydrogeology) shows that a dual technique approach is necessary for best results. This employs a rapid profile EM technique to generate targets, or "conductors", and a subsequent static resistivity sounding technique to vet the conductors and fine-tune the priority drill site and a "back-up" site. The dual approach is equally applicable to lakeshore areas because the EM can be used to isolate units of sand and gravel where the groundwater is inherently fresher (thus avoiding salty water). Suitable EM equipment are the "EM34" and the "Max-Min" manufactured respectively by Geonics and Apex Parametrics, both of Canada. Suitable resistivity equipment is the "G41" or the "SAS300" resistivity meter manufactured respectively by Geotron (South Africa) and Atlas Copco (Sweden). Other models and makes are available on the market.

A report detailing the method and techniques used on the EMRWSS project and other areas of Malawi is currently being prepared (Anscombe, 2004b) whilst a Groundwater Development Manual targeting 3rd world countries and the hand pump scenario is also in preparation (DFID, 2004).

6.2 DRILLING CONTRACT GUIDELINES

Drilling contracts should specifically address or state the following:-

- Preferred method of drilling (suited to the hydrogeology of the project area).
- Statement on envisaged drilling difficulties and equipment needed to overcome.
- Minimum end-of-borehole diameter (8” or 200mm for hand pump boreholes).
- Minimum borehole depth (certainly not less than 45 meters in Malawi).
- Maximum borehole depth requirement (80 meters for hand pumps in Malawi).
- Statement on preferred depth and method of screen placement.
- Statement on well head measurements (yield, penetration and geology)
- Tolerances of borehole verticality and alignment
- Grade, wall thickness and slot width specifications of PVC linings.
- Method and grade of gravel pack to be installed.
- Method and duration of development procedure
- Method and duration of aquifer yield tests
- Statement on prevention of on-site spills or leakage of lubricants, oils or fuels

Design specification for boreholes drilled for hand pump application should be available internationally. More specifically the Ministry of Water Development has drafted guidelines applicable to Malawi conditions although these do not seem to have been widely circulated. Other than these sources guidelines giving basic design specification and specific differences for boreholes intended for hand and electric submersible pump types are currently being prepared (Anscombe, 2004c). These latter will also contain information pertaining to development and test pumping, (provisional draft appended).

6.3 CONTRACT SUPERVISION

Hydrogeological conditions vary enormously and user groups have often developed in areas where there is no decent groundwater resource. Siting contracts are always going to plagued by dry boreholes and boreholes with a yield so low that they have to be rejected. This will be minimised, but not eliminated, even when sophisticated geophysics is employed. All the geophysicist can do is recommended a better site with better hydrogeological characteristics – there being no guarantee that water will be found in sufficient quantity. The EMRWSS project has an overall 100% community success rate using the described dual-technique geophysical technique, this comprising 85% via the priority site and 15 % via the back-up site, (i.e. 15% dry boreholes).

The main duty of a siting contract supervisor would be to ensure that the right equipment is used and that a number of targets are checked before advancing the drill site. It would also be paramount to make sure that a back-up site is placed. The supervisor can also act as the interface between siting crew and user group.

The best possible scenario with the drilling contract is to get it supervised by an experienced earth science consultant. This ensures that the borehole product is to the contract specification and is not sub-standard and inferior in any way.

Above all, borehole construction supervision is recommended – as the cost of such can be balanced against longer hand pump life and more durable service thereof.

6.4 TRAINING

It is noted that many of the supervisors and planners in the larger organisations operating in the groundwater development sector do not actually realise there is a problem with hand pump dysfunction, or if they have, then they are not aware of the siting and drilling abnormalities that cause such. The problem is fundamental. For example, when asked to check if a contractor is drilling the borehole at the contract specified diameter, the supervisor becomes confused and unable to decide because the driller quotes his bit size in imperial inches and the contract quotes in millimeters. The author has observed this on many occasions and the contractor has been allowed to drill undersized boreholes, (which is preferred because they are not as expensive). The consequence of course is a higher premature hand pump failure rate.

Training of planners and supervisors in basic siting and drilling techniques highlighting problem areas and good procedure is very much needed. The best possible place for this is on-site under the umbrella of an on-going project.

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APPENXIX 1

A1.1 Rehabilitation failures: Data summary

A1.2 Examples of boreholes with constructional flaws

DRILLING DETAILS

BH No.: FD218	**District:** Mangochi
New No.: FD218	**TA:** Jalasi
Date drilled: 1991	**Village:** Balakasi
Method: Mud	**Contractor:** Scan
Previous rehab: No	**Original yield:** 0.07 l/sec
Original depth: 30m	**Original pump:** AFD
Diameter drilled: 185mm	**Screens:** 12-30m
Water strikes: NR	**Problems noted:** None
Comment: Community report yield problems but some disagreement. Recommend rehab to confirm or otherwise.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL: 6.38m	**CRT yield:** 0.2 l/sec
Depth before: 28.66m	**CRT duration:** 120 minutes
Depth after: 28.80m	**End DWL:** 26.94m
Duration: 261 min	**Drawdown:** 20.54m
Sediment removed: 0.14m	**Specific Capacity:** 0.01
Visual quality (at end): clear	**5-min Recovery:** 4.01m
Sediment problem: No	**Yield zone:** 27m
Extra days: None	**Visual quality (at end):** clear
Comment: The borehole is rejected due to low and non-sustainable yield. **Pass/Fail:** Fail **Action**: Site and drill another borehole	

Example of a borehole equipped despite having a very low yield. The hand pump was neglected because of non-sustainable yield. The siting was poor and the drill supervision was poor. The Contractor should have drilled to 45-50 meters.

DRILLING DETAILS

BH No.: CD09	**District:** Mangochi
New No.: CD09	**TA:** Katuli
Date drilled: 2001	**Village:** Kwitambo
Method: NR	**Contractor:** Contact Drillers
Previous rehab: No	**Original yield:** 0.07 l/sec
Original depth: NR	**Original pump:** AFD
Diameter drilled: NR	**Screens:** NR
Water strikes: NR	**Problems noted:** NR

Comment: Pump installed at 9 metres and borehole dipped at just 10 meters deep!!!! REJECTED.

REHABILITATION DETAILS

Development	**Pump Test**
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**

Comment: Borehole rejected before physical rehab
Pass/Fail: Fail **Action**: Site and drill another borehole

Example of a borehole equipped despite having an extremely shallow depth. The hand pump was nevertheless working! Rejected simply because it would silt up very quickly and soon become dysfunctional. The Contractor should have drilled to 45-50 meters. Supervision of Contractor at fault.

DRILLING DETAILS

BH No.: NN	**District:** Mangochi
New No.: PK057	**TA:** Katuli
Date drilled: 1998	**Village:** Chiwaula School
Method: Air percussion	**Contractor:** Concern Univ.
Previous rehab: 2000	**Original yield:** NR
Original depth: NR	**Original pump:** AFD
Diameter drilled: 90mm	**Screens:** NR
Water strikes: NR	**Problems noted:** NR
Comment: School report borehole yields plenty of reddish-coloured silt before failure (at least twice). REJECTED.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**
Comment: Borehole rejected before physical rehab **Pass/Fail:** Fail **Action**: Site and drill another borehole	

Example of a borehole equipped despite having a major internal construction flaw. The yield zone had lenses of mobile micaceous silt – which was left open-hole (only 90mm) to progressively collapse. This design is due to the limitations of the rig (Eureka). The hand pump was neglected because of siltation. The siting was good but the drilling method and supervision were hopeless.

DRILLING DETAILS

BH No.: FD90B	**District:** Mangochi
New No.: FD90B	**TA:** Katuli
Date drilled: 1989	**Village:** Kwilindi
Method: ODEX	**Contractor:** Scan
Previous rehab: No	**Original yield:** 0.1 l/sec
Original depth: 40m	**Original pump:** AFD
Diameter drilled: 219mm	**Screens:** 11-20m
Water strikes: 7m	**Problems noted:** 20m collapse

Comment: Community report yield problems since drilled. Clear that the Contractor loss bottom 20m of hole when installing PVC and yield was inadequate. Contractor actually equipped the borehole!!!! REJECTED.

REHABILITATION DETAILS

Development	Pump Test
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**

Comment: Borehole rejected before physical rehab.
Pass/Fail: Fail **Action**: Site and drill another borehole

Example of a borehole equipped despite having a very low yield – caused by soft zone collapse before the casing was installed. The hand pump was neglected because of non-sustainable yield. The Contractor is at fault and the drill supervision was poor. Mud-rotary more appropriate

DRILLING DETAILS

BH No.: LP351	**District:** Mangochi
New No.: LP351	**TA:** Katuli
Date drilled: 1999	**Village:** Kwitunji
Method: Air-Percussion	**Contractor:** Scan
Previous rehab: No	**Original yield:** Good
Original depth: 45m	**Original pump:** AFD
Diameter drilled: NR	**Screens:** NR
Water strikes: NR	**Problems noted:** NR
Comment: Community report yield OK but water full of mica.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL: 9.18m	**CRT yield:** 0.5 l/sec
Depth before: 17.70m	**CRT duration:** 240 minutes
Depth after: 22.03m	**End DWL:** 11.83m
Duration: 150 min	**Drawdown:** 4.65m
Sediment removed: 4.33m	**Specific Capacity:** 0.11
Visual quality (at end): Turbid	**5-min Recovery:** 7.12m
Sediment problem: Yes	**Yield zone:** 14m
Extra days: None	**Visual quality (at end):** Mica
Comment: The borehole will fail again because it is too shallow and silt continues to yield and collect in the sump. **Pass/Fail:** Fail **Action**: Site and drill another borehole	

Example of a borehole continuously yielding silt despite having a good yield. With time the pump intake will be buried and fail. It is possible that the formation collapsed onto the PVC and no filter was installed. The Contractor is at fault and the drill supervision was poor.

DRILLING DETAILS

BH No.: NBC/28	**District:** Mangochi
New No.: NBC/28	**TA:** Mbwana Nyambi
Date drilled: 2000	**Village:** Mzinda
Method: Air-percussion	**Contractor:** National Boring
Previous rehab: No	**Original yield:** NR
Original depth: NR	**Original pump:** AFD
Diameter drilled: NR	**Screens:** NR
Water strikes: NR	**Problems noted:** NR
Comment: Community reports silt in water but no yield problems. Borehole dipped at just 19.5 meters	

REHABILITATION DETAILS

Development	Pump Test
SWL: 7.10m	**CRT yield:** 0.2 l/sec
Depth before: 19.00m	**CRT duration:** 240 minutes
Depth after: 28.00m	**End DWL:** 11.15m
Duration: 390 min	**Drawdown:** 3.55m
Sediment removed: 9.00m	**Specific Capacity:** 0.06
Visual quality (at end): Turbid	**5-min Recovery:** 13.55m
Sediment problem: Yes (mica)	**Yield zone:** 25m
Extra days: None	**Visual quality (at end):** Mica
Comment: The borehole breaks down when the pump intake buries in silt. Observed for 6-months, 1.5m silt build-up!!! **Pass/Fail:** Fail **Action**: Site and drill another borehole	

Example of a borehole continuously yielding silt despite having a good yield. With time the pump intake is buried and fails. It is possible that the formation collapsed onto the PVC and no filter was installed. Drilling halted before the aquifer was fully penetrated. Screens could have been installed below the mobile zones. The Contractor is at fault and the drill supervision was poor.

DRILLING DETAILS

BH No.: MH/MSF/8/99	**District:** Mangochi
New No.: MSF8	**TA:** Mbwana Nyambi
Date drilled: 1999	**Village:** Jilamu
Method: Air-Percussion	**Contractor:** Mozagua
Previous rehab: No	**Original yield:** NR
Original depth: NR	**Original pump:** AFD
Diameter drilled: NR	**Screens:** NR
Water strikes: NR	**Problems noted:** NR
Comment: Community reports are ambiguous. Borehole dipped at 25m depth. Recommended for physical rehab	

REHABILITATION DETAILS

Development	Pump Test
SWL: 14.85m	**CRT yield:** 0.2 l/sec
Depth before: 25.40m	**CRT duration:** 12 minutes !!!
Depth after: 25.80m	**End DWL:** 25.80m
Duration: 129 min	**Drawdown:** 10.69m
Sediment removed: 0.4m	**Specific Capacity:** 0.009
Visual quality (at end): clear	**5-min Recovery:** 4.35m
Sediment problem: No	**Yield zone:** 20m
Extra days: None	**Visual quality (at end):** clear
Comment: The borehole has been abandoned due to low and non-sustainable yield.	
Pass/Fail: Fail	**Action**: Site and drill another borehole

Example of a borehole equipped despite having a very low yield. The manner of siting is not known – it may have been at fault. However the problems lies with the Contractor for halting the borehole at too shallow a depth. The Contractor should have drilled to 45-50 meters. The Contractor and the drill supervision at fault.

DRILLING DETAILS

BH No.: SM260	**District:** Mangochi
New No.: SM260	**TA:** Mbwana Nyambi
Date drilled: 1979	**Village:** Chinama
Method: Cable-tool	**Contractor:** Govt. driller
Previous rehab: 1995	**Original yield:** 1.1 l/sec
Original depth: 41.18m	**Original pump:** Bush pump
Diameter drilled: 200/152mm	**Screens:** 13-20m
Water strikes: 12, 37m	**Problems noted:** None
Comment: 18m of rods and risers jammed down the borehole. Contractor unable to remove: REJECTED.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**
Comment: The borehole has been abandoned due to pump equipment jammed in bore. Otherwise an excellent borehole. **Pass/Fail:** Fail **Action**: Site and drill another borehole	

Example of a borehole well sited and drilled to good depth with good yield and no pumping of sediment. The fault lies with the community who attempted a mechanical repair and dropped the rods and risers down the borehole. Vandalism cannot be ruled out.

APPENDIX 1.2: EXAMPLES OF BOREHOLES WITH CONSTRUCTION FLAWS

DRILLING DETAILS

BH No.: CL/5/30	**District:** Mangochi
New No.: CL/30	**TA:** Mbwana Nyambi
Date drilled: 1999	**Village:** Budu
Method: Air-percussion	**Contractor:** Chitseme
Previous rehab: No	**Original yield:** 0.3 l/sec
Original depth: 56m	**Original pump:** AFD
Diameter drilled: 165mm	**Screens:** NR
Water strikes: 51	**Problems noted:** None
Comment: Community report yield problems but some disagreement. Recommend rehab to confirm or otherwise.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL: 18.05m	**CRT yield:** 0.2 l/sec
Depth before: 54.00m	**CRT duration:** 120 minutes
Depth after: 55.50m	**End DWL:** 55.50m
Duration: 297 min	**Drawdown:** 48.17m
Sediment removed: 1.50m	**Specific Capacity:** 0.06
Visual quality (at end): clear	**5-min Recovery:** 8.02m
Sediment problem: No	**Yield zone:** 38m
Extra days: None	**Visual quality (at end):** clear
Comment: Technically the borehole has insufficient yield. However due to very difficult area for water and small community size the borehole was approved for civil works. **Pass/Fail:** (Fail) **Action**: Monitor	

Example of a borehole that was drilled to good depth with drilling and reporting well executed. The siting is justifiably at fault.

DRILLING DETAILS

BH No.: FD225	**District:** Mangochi
New No.: FD225	**TA:** Katuli
Date drilled: 1991	**Village:** Mpita
Method: Air-percussion	**Contractor:** Scan
Previous rehab: No	**Original yield:** 1.0 l/sec
Original depth: 30m	**Original pump:** AFD
Diameter drilled: 165mm	**Screens:** 12-30m
Water strikes: NR	**Problems noted:** None
Comment: More than 500 meters from the extremity of user community. It is also vandalised. REJECTED	

REHABILITATION DETAILS

Development	**Pump Test**
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**
Comment: Technically the borehole is excellent. However it has been abandoned and subsequently vandalised due to large distance from the user community. **Pass/Fail:** (Fail) **Action**: Site and drill a new borehole	

Example of a borehole that was drilled adequately and attained a good yield but was abandoned due to distance. Siting and project management at fault.

DRILLING DETAILS

BH No.: FD262	**District:** Mangochi
New No.: FD262	**TA:** Katuli
Date drilled: 1991	**Village:** Malowa
Method: Air-percussion	**Contractor:** Scan
Previous rehab: No	**Original yield:** 0.3 l/sec
Original depth: 30m	**Original pump:** AFD
Diameter drilled: 165mm	**Screens:** 18-30m
Water strikes: NR	**Problems noted:** None
Comment: Community report flooding of the site during the rainy season. Also far from users REJECTED.	

REHABILITATION DETAILS

Development	**Pump Test**
SWL:	**CRT yield:**
Depth before:	**CRT duration:**
Depth after:	**End DWL:**
Duration:	**Drawdown:**
Sediment removed:	**Specific Capacity:**
Visual quality (at end):	**5-min Recovery:**
Sediment problem:	**Yield zone:**
Extra days:	**Visual quality (at end):**
Comment: Technically the borehole has sufficient yield. However due to flooding during the wet season the water has a high contamination potential.	
Pass/Fail: (Fail) **Action**: Site and drill a new borehole.	

Example of a borehole that was drilled adequately and attained a good yield but was abandoned due to distance. Siting and project management at fault.

APPENXIX 2

EMRWSS – STYLE
REHABILITATION PROCEDURE

Introduction

Any community applying for rehabilitation of an old borehole will have the borehole subjected to the following procedures:-

- Feasibility assessment
- Re-development
- Re-testing
- New civil works

If the borehole passes the first three stages then it will be approved for new and more durable civil works.

Under EMRWSS the community Water Point Committee is involved in all stages of the process and also receives complimentary training on water point management and maintenance together with health and sanitation education and more.

Feasibility Assessment

Under the Demand Response Approach the community Water Point Committee (WPC) comes forward and asks for assistance with their existing hand pump (functional or dysfunctional). The borehole then undergoes a feasibility assessment, whereby the position, vulnerability to pollution and other lesser issues are checked. Rehabilitation is rejected in favour of a new borehole if:

- The borehole has been drilled more than 300 meters away from the extremity of the user community. The main reason is because it will be underused and susceptible to theft or vandalism. Only under exceptional circumstance, such as very difficult hydrogeology, will a distant position be accepted.

- The borehole is on the edge of a dambo directly below or down gradient from the settlement and/or in a place where the ground floods during the wet months. The main reason for this is related to access and the susceptibility to coliform pollution. The dambo adjacent to a community is the sump to which pollution is directed – a phenomenon exacerbated via flushing with the onset of the rainy season. Occasionally a borehole has to be rejected on safety grounds because it is within 5 meters of a road or track that has been upgraded to allow passage of motorised vehicles subsequent to drilling.

- The yield is inadequate (say 3-buckets before recovery wait) or non-yielding during the dry months September-November (seasonal).

- The borehole is less than 20 meters deep. Such boreholes draw on near surface waters that have a greater tendency to be polluted with coliform bacterial (via coning from nearby pollution sources). Water deriving from near surface also tends to be turbid (suspended matter) and/or cloudy/milky (exsolving colloidal aluminuim) and/or reddish/brownish (suspended oxidized silt and mica). This happens because the weathered zone is screened rather than cased-off. All of these problems are exacerbated with the onset of the rainy season and it is not uncommon for the sump and pump intake on a shallow borehole to fill with silt and mica. A borehole less than 20 meters deep should only be approved under exceptional circumstance. The water should be completely clear and sediment free and an estimate of the boreholes vulnerability to pollution should be made (methodology in DFID, 2001). This is particularly relevant where the borehole supplies a vulnerable population (e.g. a school) or is located near a potential pollution source (e.g. a Hospital, Clinic or Maternity Unit).

With the latter two criteria it is necessary to physically dip the borehole depth (after removing the down hole components) and to cross check with the depth and yield on the original drilling documentation. Any significant reduction in depth or yield will usually be related to silt build up in the sump. The reasons for such build up are many and physical rehabilitation may restore both the depth and the yield. Rejection should only occur if the original yield documented is also notably poor.

In Malawi regolith, deriving from the in-situ weathering of metamorphic and igneous rock types, the groundwater is typically mildly acidic (pH 4.5 – 6.5). Boreholes constructed prior to 1991 were usually lined with steel casing. Acidic groundwater will have rusted and dissolved these casing in the interim period – to varying degrees. This is a process that puts Fe^{+++} ions into the drinking water. The Fe ion, despite being non-poisonous and beneficial to health (<10mg/liter), does impart a metallic taste (>2mg/liter), which is reported to alter the taste of food (notably “nsima” or maize) and stain washing. Consequently this borehole water is unpalatable to the average rural dweller and affected boreholes are often under utilised or abandoned altogether. Many were rehabilitated in 1995, during which time inner PVC casings were inserted. These inner linings effectively conceal the original steel casing, which remain. Obviously high concentrations of Fe^{+++} ions continue to bother the users. In such instances it is worth while interviewing the community to see if they accept the water quality and taste. If they do not then a new borehole with PVC insert is the sensible alternative.

Finally when the borehole depth is checked, hidden obstructions are often found (dropped risers, rods, unknown debris). These often prove difficult to remove and the borehole has to be rejected in favour of a new one. Occasionally, in high yield holes, new pumps can be fitted above the obstruction.

Physical Rehabilitation

Physical rehabilitation comprises two components. The borehole is firstly re-developed (cleaned as thoroughly as possible) and secondly re-tested via a controlled test pump procedure to determine the availability of a sustainable yield. It is possible, where there is no documented history, that the borehole has not been developed or tested prior to rehabilitation. Indeed the cause of hand pump dysfunction is often due to silt build-up around the pump intake in turn caused by lack of development after drilling. Thus it is not always possible to determine if a borehole is full of silt due to misplaced or uncoupled screens, lack of gravel pack or due to lack of development. The latter scenario can be remedied by fresh development while the former two are irreparable. The borehole should be given the benefit of the doubt and developed afresh to see if it can indeed be salvaged.

Development

There are many and varied types of development equipment and techniques of application. The EMRWSS project has developed a dual-technique method suited to cleaning-up boreholes drilled through thickness' of saturated regolith. Development consists of the following steps:-

- The existing pump, rods and risers are removed. If they are to be re-installed in the interim before the new civil works are constructed then they should be lifted out and replaced in one piece using the Mpanda system. If the civil works are to be constructed immediately then it would be feasible to remove the existing installation in sections, (requiring cutting). With the latter the community should make alternative arrangements for water for the 3-weeks or so that it takes to construct and cure the civil works and install the new mechanism.

- The Static Water Level below the top of the casing is measured before pumping

- The casing "stick-up" above plinth or ground level is measured

- The borehole depth is measured before development starts

- The borehole and adjacent aquifer/formation is cleaned over the entire length of screens via gently up and down application of an air-jetting tool that directs its cleaning activity horizontally. The air-supply must not be from a 750/900 cfm drilling compressor as these have been known to dislocate or shatter the PVC screens. A smaller compressor such as that used to power jackhammers is more suitable. It is normally possible to feel when the PVC end cap has been reached. The tool is typically cycled up and down for half an hour and then removed. Before continuing the depth of the borehole is measured and recorded.

- The sump is then cleared of the accumulated silt by lowering a small, durable electric submersible pump down to the base of the borehole and running it until the water becomes clear or the borehole is emptied. A portable generator can power this pump. This is also a simple method to assess the borehole yield. This exercise is termed "over-pumping" and lasts between 6 -20 minutes. The borehole is then left to recover.

- The previous two steps are cycled until clean water is achieved from all areas of the screened section of the borehole. At the end of each cycle the time and depth of the borehole is recorded such that a record of how long development takes and how much sediment has been cleared is achieved. The number and length of development cycles, (jetting and over-pumping) vary according to the type of regolith drilled, where the screens have been placed and the yield and recovery of the aquifer. Where the screens have been incorrectly placed over the first water within the clayey and micaceous saprolite section then development will be extended and may not clear the problem - the water can still be dirty after four days. Where the screens have been correctly placed over the lower and usually the main water strike zones in the saprock and fractured bedrock sections then development is usually accomplished within 3 hours actual work time.

- The borehole depth is measured after the end of the above development cycles. The total amount of material cleared from the sump can be calculated by subtracting the first from the last depth measurement. The total development time is calculated by summing the individual components. The visual sediment load or opaqueness of the water would also have been noted at the end of the development process.

A decision can be made on site as to whether the borehole is worthy of a yield test (test pump) or not. The EMRWSS project carried out a yield tests irrespective of development results but funds may be short and the rehabilitation procedure could be aborted at this stage. Factors that may assist in a rejection decision are as follows:-

- Gravel or pieces of PVC casing issuing during development suggests ruptured casings and the borehole should be rejected, as it is a prime candidate for premature failure.

- The borehole is shallow at 20-25 meters deep and yet has 5-10 meters of silt accumulated in the sump since the time of drilling. If the borehole cleared completely during development then this seems to indicate that it is the first development procedure and that the condition will not reoccur. It could be re-installed and observed for 6-months, with new civil works on-hold, and then re-dipped to see if silt is still coming in. Obviously if it is then the borehole should be rejected. If the borehole failed to clear during development then it suggests that the problem is caused by absent or patchy gravel filter or screens seriously out of position and adjacent to a very mobile silt or micaceous saprolite layer. In such instance the condition is irretrievable and the borehole should be rejected.

If in doubt the borehole should be subjected to a pump test (which continues the development process).

Pump Test

Again there are many and varied types of pump test together with equipment to execute such. For a borehole to sustain a hand pump it only has to yield 0.2 liters per second over the period of peak demand (early morning). In practice a borehole yielding 0.15 liters per second from a deep strike zone (below 25 meters depths) can adequately sustain a community of 60 houses/250 people, provided it exhibits good recovery characteristics (see below). A lower yield still can also be successful provided the same conditions apply and the community can be trained to schedule their water collection evenly through the day light hours. The EMRWSS project has developed a pump test procedure tailored for a hand pump borehole. The test consists of the following components and simple calculations:-

- An electric submersible pump powered by a generator that is capable of delivering steady yields at 0.2, 0.5, and 1.0 liters per second at depth ranging from 15 to 60 meters.

- An electronic dip meter with calibration in centimeters and millimeters. This has to be introduced to the borehole down a dipper-tube. In practice this consists of 1" electrical conduit in 6-meter sections, which is fastened together on site using parcel tape. The dipper cannot be lowered into the borehole without the dip tube because splash-back and incorrect dipper readings occur when the Dynamic Water Level falls below the top of the shallow aquifer. A safety rope is advisable which is fastened to the pump and secured at surface. It is necessary to feed pump, discharge pipe, dipper pipe, electric cable and the security rope down the bore evenly. Some expertise is required to do this properly.

- A 30 meter long discharge line with tap valve at the discharge end is required. This is run to a "V-notch" weir tank, set in horizontal position with a spirit level. This tank is pre-calibrated with marks on the side near the V representing the three flow rates. With practice one member of the testing crew can quickly adjust the valve and the flow rate between tests as required.

- A stop watch and record form.

- The first test is the Step Test, which consists of 3 short pumping steps run concurrently with the pump in the sump at rates of 0.2, 0.5 and 1.0 liters per second. The duration is 1 hour per step with water levels recorded at 0.5, 1.0, 1.5, 2.0, 3, 4, 5, 6, 8, 10, 12, 14, 18, 24, 30, 40, 50 and 60 minutes. Three operators are required to perform this operation accurately. The recovery is also measured for ½ an hour at the end of the third step when the pump is switched off, (same time intervals).

- The step test results allows the foreman to decide a rate for the Constant Discharge Test - CDT, (0.2, 0.5 or 1.0 liters per second). The CDT runs for 4 hours with measurements recorded at the same time intervals plus additional measurements at 80, 100, 120, 180 and 240 minutes. The CDT is also immediately followed by a recovery test of 60 minutes duration. It is important to try and choose a rate for the CDT that will fully test the behaviour of the aquifer over the full length of the bore whilst at the same time not causing the DWL to drop to pump intake. With practice it is not difficult to judge the CDT rate from the results of the Step Test such that it will sustain for 4-hours of the CDT.

- Boreholes that cannot sustain 0.2 liters per second for 4-hours are the only ones that need to be examined carefully as all others will easily meet the demand that the user community puts on them. These latter are recommended for Civil Works without further fuss. The only advice necessary is where to set the AFRIDEV pump intake. This can be judged from the DWL attained at the end of the CDT. For those just managing to sustain 0.2 liters per second over 4-hours then the pump setting should be as deep as possible. Thirty nine meters is a common setting for this type of borehole, provided that there is at least another 6-meters of sump below (silt trap). Those yielding more than 0.2 liters per second can be set progressively higher in the hole using the CDT results as a guide. Occasionally, where the yield is between 0.15 and 0.2 liters per second the pump intake can be set as deep as 45 meters, although this is not good practice as the handle becomes heavy to operate and more susceptible to bearing wear. Generally speaking depth of installation should be minimised because lengths or rods and risers and wear and tear during use, effect the hand pump lifespan

- Low yield boreholes are those yielding less than the threshold 0.2 liters per second. They will fail prematurely if they are equipped when they should really be rejected in favour of a new site and a new bore. Some guideline principals and calculations are useful:-

    - If the DWL reaches pump intake (bomb-out) or the 42-metre level before 80 minutes of pumping during a 0.2 liter per second CDT then it should be rejected.

    - For boreholes that bomb-out (as defined) within 100 or 120 minutes then the following should be considered. If the yield zone appears to be within the top 10 meters then the borehole is likely to behave erratically during the dry months (September to November). Given the above criteria it would definitely be rejected. The yield zone can be deduced from the CDT results where there is a sudden increase in drawdown per unit time. This marks the depth when the water level suddenly drops below the yielding portion of the borehole. If it then plummets to pump intake then it is the only yield zone but if it stabilises again, even for a short period then another, lower, yield zone is indicated.

- The Specific Capacity (SC) is a useful measure to calculate. The CDT rate is divided by the maximum drawdown (difference between the lowest recorded DWL and the Static Water Level measured at the start before pumping). The units must be consistent. A SC below 0.005 together with <100 minutes (bomb-out on CDT) and < 10 meters (yield zone) equates to rejection.

- Finally the recovery of the borehole is also a fine way to judge whether a low yield borehole will perform over years of pumping. It is the only test that shows the natural behaviour of the aquifer - and can, for that reason, be trusted. On the EMRWSS project it has been found that a borehole recovering by more than 7 meters in the first 5-minutes of the Recovery Test will sustain a community (empirically derived). It should be noted that extent of recovery is related to the diameter (and volume) of the borehole. The EMRWSS boreholes are drilled at 200 mm diameter and thus seven meters of recovery in 5-minutes would have to be re-calculated to a larger number on boreholes with a lesser diameter.

Note.

Pump test techniques and method of analysis are necessarily more involved with boreholes designed to supply a higher yield such as to towns, trading centers or irrigation projects. The type of production pump with also be different (diesel-driven mono pump or electric submersible).

New Civil Works

Civil works structures are designed to be durable and cater for the needs of the User Group - consequently they vary in design and appearance. The EMRWSS project favours a structure that comprises the following elements:-

- Drainage route is surveyed to circumvent waste water ponding
- A reinforced slab for both pump and wash stand.
- A pointed and reinforced brick wash stand with plastered base courses and top.
- A wash stand with double pre-cast basins draining straight to the discharge drains
- 10 meters of pre-cast and reinforced drains between pump and wash stand
- 10 meters of pre-cast and reinforced drains between wash stand and outlet
- Reinforced concrete pavements surrounding pump and wash stand slabs
- Reinforced concrete pavements either side of first 10 metre drain segment
- A fenced banana grove at the end of the drain to utilise waste water
- Compaction below concrete slabs and drains with compaction equipment
- Settlement of concrete during pouring with mechanical pokers
- Aggregate of + 25mm grade and B10 concrete formula
- 50 bags of Portland cement per completed structure
- Lock ring inserted into concrete so that User Group can immobilise.