Making boreholes work – rehabilitation strategies from Angola

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IN AREAS OF the world where primary water supply is obtained from boreholes drilled in fine grained drift, there is potential for 'sand' or 'media' intrusion. This can result in clogging of borehole screens, damage to submersible pumps and blocked handpumps. Many boreholes encountering this problem of media intrusion are abandoned due to expensive rehabilitation procedures. This paper discusses field solutions adopted in Kuito, Angola where boreholes are highly susceptible to fine media ingress. Findings presented are based on the authors field experience between 1993 and 2002 whilst working for Oxfam GB in Angola. It outlines three remedial measures, namely, internal gravel packs, geotextile stockings and telescoped borehole design.

Background

Due to the total destruction of water treatment and distribution systems in the central highland city of Kuito during the Angolan civil war, the majority of the residents and displaced population are dependent on groundwater sources. These sources are located to depths of 40 to 60m in what might be 'Kalahari Sands' a wind blown fine structure or the weathered mantle of underlying rock structure. By 2001, more than 120 boreholes had been drilled into this formation. However in areas with fine water bearing formations, there was a 20% failure rate. This failure began with a reduction of yield due to extensive clogging of the lower casing with 'fines,' production of turbid water and then an ultimate breakdown of the pumps due to extensive wear of the cylinders moving parts (such as the nitrile rubber U seal).

Immediate remedial measures to resolve this problem involved the raising of the setting of the handpump cylinder and regular flushing of the borehole with compressed air. Despite this, the problems continued with boreholes encountering siltation within hours of rehabilitation. Further longer term remedial measures were therefore required. This paper outlines three of these remedial measures. Prior to describing these, the paper details justification for the conventional borehole design used in Angola.

Conventional borehole design

Boreholes on the Oxfam GB programme in Kuito were drilled using either rotary mud flush or occasionally slow foam techniques at a diameter of 6" (150mm) to a depth of 30-40m dependent on the aquifer yield (see figure 1). The bores were lined with uPVC 4" casing, with 70% of the saturated zone being screened with a 0.5-1mm slot size screen and backfilled with an appropriately sized washed gravel pack (1 to 3mm). The bores were then developed using surged compressed air, protected using puddle clay/ cement sanitary seal, headworks and fitted with an Afridev handpump (Godfrey, 2001).

It is acknowledged that drilling at 6" (150mm) to set a 4" casing and a gravel pack is contrary to the 'rule of thumb' which dictates a larger diameter hole (10") is required to achieve a minimum thickness of a 3" gravel pack around a 4" casing. Nonetheless, experiences has shown that the use of flexible uPVC casing inserted into a clean open hole and packed with clean graded gravel can achieve minimum thickness of gravel pack of ½" or 13mm which is sufficient to obtain an adequate filter. (Driscoll, 1995).

The advantage of drilling a 6" (150mm) hole as opposed to a 10" (250mm) is to reduce the required 'up hole velocity' and therefore volume of water in the mud pit (Ball, 2001). Following the rule of thumb, a volume of 3 times the borehole volume is required therefore drilling a 10" (250mm) hole and not a 6" (150mm) would triple the required flow of the mud pump with resultant friction build up in swivels and drill string of the lightweight drilling equipment (Driscoll, 1995). Additionally three times the quantity of water would be needed for transportation to site (an increase of 3000 litres to over 10,000 litres) which is it not feasible in areas with limited water resources.

Solution 1: Internal gravel packs

The use of internal gravel packs was initiated by Engineer Mark Osola, whilst working for Oxfam GB in Kuito in 1996 (see figure 1) (Osola, 1998). Practically, the process involved the removal of pump and rising main, the flushing of borehole with compressed air, the addition of a volume of 1-5mm gravel inside the borehole casing to 0.5m above the top of the slotted area of screen and the redevelopment of borehole with compressed air to develop an internal filter. An alternative method adopted by the author in 1999-2001 included the use of a light mobile rig mounted on existing concrete platform (see photo 1).

After removing the hand pump the depth of silting up was determined by probing the hole depth with a weighted tape or inserting a drill string with a 100mm 3.7/8" drillbit inside the 4" casing. The silt would then be flushed clear by circulating water through the drillpipe and rotating drillbit until the hole bottom was reached. A careful calculation was then made of the depth of silt removed and its volume added as grade gravel pack 1-2mm inside the casing.

The borehole was then redeveloped as above. After two hours of redevelopment of the internal gravel pack, turbidity reduced to within World Health Organisation (WHO) guidelines of <5NTU (WHO, 1997).

This unconventional solution has drawn criticism (Sutton, 1999) but it is still a working solution in some existing functioning holes in Kuito. Nonetheless, scientifically there is a direct correlation between the up hole velocity of 0.03m/s in through the internal gravel pack and the required yield of an Afridev handpump (750 litres/hour).

Solution 2: Geotextile stocking

In areas of fine geological formations, borehole screens can also be inserted with a white geotextile polyester stocking material. The 10 micron filter cloth is said to reduce the screen intake by 50% whilst retaining some of the flexibility of a mobile filter bed to allow fines to pass or bridge during development. It was used in Kuito on a standard 0.5mm slotted uPVC pipe and in accordance with the 50% guideline the yield of the well halved. After insertion of the geotextile stocking, it also proved essential to flush clear drilling mud with clean water to prevent the clogging of the filter cloth during insertion of the screen.

Photo 1: Borehole Rehabilitation – Kuito, Angola

Solution 3: Telescoped design

In areas where there is adequate depth of aquifer, a long length of well screen can be inserted, allowing the pump cylinder to be placed high enough for sufficient drawdown. On the controversial supposition made above that gravel pack will be placed to a minimum of ½" (13mm) thickness in a 6" (150mm) hole set with 4" casing it is possible to provide a telescoped design that would positively allow a thickness of graded gravel to be placed around the centralised well screen. A high capacity – large open area 2" screen can be selected that will provide the same open area as a conventional 4" slotted screen ensuring there is no impedance in flow. Materials were purchased to effect this design, mesh purchased to allow sieving of finer grades of gravel pack but due to limitations a hole has yet to be drilled to this design in Kuito.

In a fine formation the well screen and its placed gravel pack is the essential feature that will determine if water is silt free and available in sufficient quantities. Given this it would be possible to use a well screen of the highest specification – a stainless steel wedge wire of appropriate slot and high open area. Whilst per metre it is 10 to 20 times the cost of uPVC slotted pipe in the context of an emergency drilling programme with a drilling cost per hole of 8000USD would add a nominal 5% to the construction cost but provide a more permanent solution.

Conclusions

Emergency water supplies are often seen as quick emergency fixes for an often transient displaced population. In the absence of comprehensive hydrogeological & geophysical surveys, there is often reasons to move away from convention and try some simple remedies. In the case of Kuito the residents needed 'fines' free water. Due to the remedial measures outlined in this paper, the residents are still drawing water from these boreholes 10 years on from the initial emergency engineering intervention.

References

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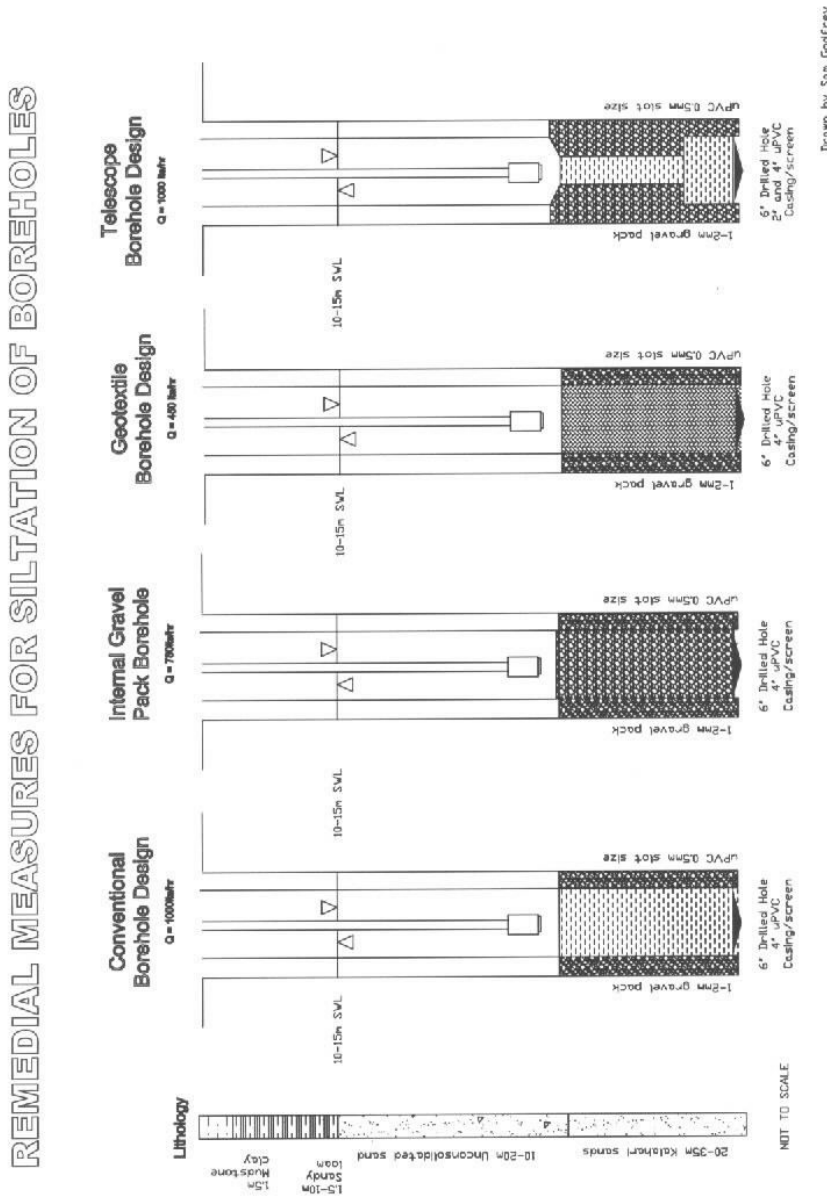

Figure 1. Remedial measures for siltation of boreholes