

**FIELD TRIALS OF THE PROTOTYPE POUNDER RIG,
UGANDA, 20th AUGUST – 13th NOVEMBER 1999**

a human-powered drill rig for shallow small diameter wells
for domestic and agricultural water supply

*developed in Uganda and UK through project funding and support from
Government and People of Uganda, DFID, Danida, Sida, and Unicef*



Peter Ball and Kerstin Danert

November 1999

Project Manager: Dr Richard C Carter, Institute of Water and Environment, Cranfield University, Silsoe, Bedford, MK45 4DT, UK
Tel + 44 (0)1525 863297; fax + 44 (0)1525 863344; email r.c.carter@cranfield.ac.uk

Drilling Consultant and Rig Designer: Mr Peter Ball, Eureka UK Ltd, 11 The Quadrant, Hassocks, West Sussex, BN6 8BP, UK
Tel + 44 (0)1273 844333; fax + 44 (0)1273 844332; email peterball@eurekawater.com

Uganda Project Team: Eng Kerstin Danert (Team Leader); Mr Ezron Rwamwanja (Community Water Supply Specialist); Mr Jamil Ssebalu (Small Business Specialist)

Website: <http://www.silsoe.cranfield.ac.uk/lcdrilling/>

Reference as: Ball, P and Danert, K (1999) Field Trials of the Prototype Pounder Rig, Uganda, 20th August – 13th November, 1999. Report of DFID KAR Project R7126 "Private Sector Participation in Low Cost Water Well Drilling", Cranfield University. ISBN 1861940 556

CONTENTS

| | Page |
|-------------------------------------|------|
| Abstract | 3 |
| Acknowledgments | 3 |
| Introduction | 4 |
| Introduction to the Equipment | 5 |
| Pounder Well Descriptions | 6 |
| Other Issues | 26 |
| Appendix: drilling penetration data | 29 |

TABLES, TEXT BOXES, AND FIGURES

| | |
|--|----|
| Table 1 Summary of Wells Drilled | 4 |
| Text Box 1 Hydrostatic Head | 9 |
| Text Box 2 Polymer, Bentonite, and Fibre | 12 |
| Text Box 3 How Does Sludging Work? | 13 |
| Text Box 4 Gravel Packing | 16 |
| Text Box 5 Cement Grouting | 17 |
| Text Box 6 Annulus Calculation | 17 |
| Figure 1 PW 2/7(2) Profile | 19 |
| Figure 2 PW 2/8 Profile | 20 |
| Figure 3 PW 2/9 Profile | 21 |
| Figure 4 PW 2/11 Profile | 23 |

ABSTRACT

A prototype low-cost drilling rig was imported to Uganda in August 1999 and handed over to Mpigi District Government. Field trials of this machine were undertaken between 20th August and 13th November 1999. This work was enabled through a tripartite Memorandum of Understanding between the Cranfield University/DFID Low Cost well Drilling Project, the Directorate of Water Development (DWD) of the Government of Uganda, and the local Government of Mpigi District.

A total of fourteen holes were drilled in a range of geological formations, and six of these were equipped with U3 handpumps installed by the direct install method (screen directly attached below pump cylinder, with rising main doubling as well casing). Of these six, one gave inadequate yield, while the other five were put into use as community water supply wells.

The trial of the prototype Pounder Rig offered much opportunity to learn about its capability, the practicalities of well construction by the direct install procedure, and the acceptability of the technology to the Ugandan crew. A full design review followed the field trials, and this is reported under separate cover.

A number of practical issues arose during this period, including methods of crew payment, funding of trials, logistics, and conflicts between the requirements of drilling trials and the expectations of rural communities. These were addressed as they arose, but with the benefit of hindsight they could no doubt have been resolved in better ways.

ACKNOWLEDGMENTS

The Project is funded by the UK Government Department for International Development (DFID), with supplementary funding from Danish International Development Assistance (DANIDA). Partnership arrangements with Government of Uganda Directorate of Water Development and the local Government of Mpigi District have provided funding through the Water and Environmental Sanitation (WES) Programme, funded jointly by GoU, Swedish International Development Assistance (SIDA), the United Nations Children's Fund (UNICEF), and the Government and People of Uganda. All these funding sources are gratefully acknowledged.

A great many individuals and organisations, too numerous to name, have contributed through ideas, encouragement, and interest. They too receive the grateful thanks of the Project Team.

The Project Team consists of Dr Richard Carter (Project Manager), Eng Kerstin Danert (Team Leader – Uganda), Mr Peter Ball (Drilling Consultant), Mr Ezron Rwamwanja (Community Water Supply Specialist), and Mr Jamil Ssebalu (Small Business Specialist).

INTRODUCTION

This report narrates the experiences of drilling with the Pounder Rig in Mpigi District, Uganda and discusses other issues relating to the crew and District which took place between 20th August and 13th November 1999. Details regarding penetration rates for wells P/W 2/7 to P/W 2/11 and P/W 'Hard Rock' are given in the Appendix.

Arrangements for food, accommodation and crew payment for wells 2/7 to 2/11 inclusive were made between Mpigi district and the Katabi sub-county Chief (LC3 Chairman). The Chief also provided some additional paid labour for the wells. Following the completion of the Katabi wells, two further wells were drilled to investigate rig capability as follows:

- investigation of maximum depth,
- investigation of rig (and crew) capability of drilling very hard material.

The initial sites were chosen with the purpose of introducing the equipment and the method to the drill crew and in order to explore their capabilities. Further sites for the test drilling were selected for their known potential hydrogeology to enable the new Pounder technology to be introduced and measured.

The first six drill sites were at locations which would have little impact as community water supply sources.

Table 1 Summary of Wells Drilled

[Wells shown in **bold** completed with handpumps and put into use]

| Ref No. | Location | GPS Reference | Remarks |
|-------------------|------------------------------|---------------------------------|---|
| PW 1/1 | Prison Centre | N 00 13.804 E 032 19.316 | first trial of rig and crew, 4m |
| PW 1/2 | Mayembe Lower | | sand & clay, 6m |
| PW 1/3 | Gala | N 00 13.329 E 032 20.260 | collapse at 12m – insufficient head |
| PW 1/4 | Gala | N 00 13.355 E 032 20.246 | 19m, pump installed, inadequate yield |
| PW 2/5 | Kasenyi | | coarse, caving sand – hole abandoned |
| PW 2/6 | Kajubi "Fence" | N 00 08.104 E 032 31.956 | 6m; U3 pump installed; good yield |
| PW 2/7 (1) | Kawuku Village | | very hard ground; hole abandoned |
| PW 2/7 (2) | Valley Zone "Captain" | N 00 08.495 E 032 32.140 | 7m; U3 installed; adequate yield |
| PW 2/8 | Ndaula "Pond" | N 00 07.950 E 032 31.871 | 3m; U3 pump installed; good yield |
| PW 2/9 | Zzika "Steep Slope" | N 00 07.166 E 032 31.632 | 3m; U3 pump installed; good yield |
| PW 2/10 | Bunande Kande "Huts" | | 3m; rest level 1m, but yield very low |
| PW 2/11 | Bukandekade | N 00 07.212 E 032 31.410 | 3.5m; U3 installed; adequate yield |
| PW Depth Test | Mpigi District HQ | N 00 13.874 E 032 19.135 | pipe friction investigation |
| PW Hard Rock | Namawa | N 00 32.477 E 032 34.756 | trial in shallow hard rock |

INTRODUCTION TO THE EQUIPMENT

A day was spent at the Mpigi District Council headquarters laying out the equipment and explaining the purpose and use of various pieces – with a series of adaptations and modifications being made to prepare the equipment ready for site. Missing with British Airways were all the drilling bits, and this delayed immediate plans for any drilling.

The drillcrew comprised:

Makaema James - Foreman
Kigganira Godfrey
Kizza Umaru
Nkulabwile Tadeo
Ssekamata Vincent
Kasibante George - Pick up Driver

A Toyota twin cab pick-up had been made available to Mpigi by the Directorate of Water Development, in accordance with terms previously agreed in a tripartite Memorandum of Understanding (between Cranfield University, DWD, and Mpigi District). The pick-up body is short and could benefit from a simple welded steel pipe rack to store the 3-meter long drillpipe and casing pipes for better transport of the drilling equipment.

POUNDER WELL DESCRIPTIONS

PW 1/1

Village: Prison Centre
 Parish: Mayembe
 Sub-County: MUT.1 Mpigi
 County: Mawokota
 Date: 31st August 99

A valley bottom site adjacent to a protected spring about 1 km from Mpigi District Headquarters. The equipment was set up for the first time and the crew were introduced to 'sludging', the reciprocating up and down drilling action at the heart of the Pounder drilling technique.

The 75mm drilling proceeded through the clay topsoil and into very fine saturated sandy clay, which led to continual blocking of the drill bit. The drilling action at this stage was utilising the 'T' bar – a 2m length of tube clamped to the drillpipe, directly raised and dropped by the crew. It proved hard work, with the crew tiring very quickly as they were unfamiliar with the drilling action. Under the fine sand layer at 2m, there was firmer clay which did not block so easily and allowed the pivot tube and lever bar to be erected and used in place of the 'T' bar. The hole was taken down to 4m before heavy rain curtailed the site work for that day.

Two early modifications were identified:

- An upturned plastic bucket was fitted over the sludging valve. This guided the evacuating water directly down onto the borehole cover plate in a contained manner rather than splashing it everywhere.
- The pivot tube needed a better arrangement to allow more operators to work the lever motion.

Total hole depth: 4m
 Diameter: 75mm
 Drill Shoe: No.4
 Drilling time: 45 mins.

PW 1/2

Village: Mayembe Lower (Mpigi Town)
 Parish: Mayembe
 Sub-County: MUT.1 Mpigi
 County: Mawokota
 Date: 1st September 99

Another valley bottom site – 1km up valley from PW 1/1 – adjacent to another protected spring.

Initial set up and drilling went considerably more smoothly, with the crew having benefited from their first experience. Once more, under the topsoil, the first 2m comprised soft water logged fine sand and silt before encountering firm stiff clay. The first 3m were drilled with direct 'T' bar before erecting the pivot and lever handle.

The hole was taken down to a final depth of 6m using the 75mm cutting shoe (No.4). Drilling started (cutting soil) at 12noon and finished at 4pm.

- **The first topsoil of 2m** took 1 hour, having one blockage.
- **2m -3m** took 10 minutes before clay became more solid and required more drilling strokes to cut.
- **4m -5m** took 950 strokes in a combined 45 minutes – with lots of stopping to swap crew about and chat about things
- **5m-6m** - the crew worked consistently with minimum of delays, drilling the 1m with 509 strokes in 14 minutes. This equates to about a second a stroke, with some time taken up to adjust equipment. Penetration was at an average of 2mm per blow.

On completion of these 2 initial holes a site was sought to drill deeper and strike water. The crews' confidence in the drilling method and equipment was beginning to grow.

PW 1/3

Site: Gala - by houses opposite Jowenna petrol station next to turn to Mpigi
 Village: Mpami
 Parish: Ssabadu
 Sub-County: MUT.1 Mpigi
 County: Mawokota
 Date Started: 2nd September – Completed 6th September (4th&5th weekend no work)

A site was selected off the valley floor some 100m up slope at an estimated elevation of +2m from valley floor.

Equipment set up from pick-up truck in about 1 hour to allow drilling to commence.
 Drilling 75mm cutting shoe (No .4).

2nd September

| Depth (m) | Drilling Time (mins) | No of Drill Strokes | Notes |
|-----------|--|---------------------|--|
| 0 - 1 | 2 | 133 | Soft & quick |
| 1 - 2 | 18 | | |
| 2 - 3 | 7 | 302 | |
| 3 - 4 | 61 | 1157 | Hard stiff clay |
| 4 - 5 | 82 | | Changed to 75mm button bit (N0.3) for 0.5m |
| 5 - 6 | 130 | | 50 to 100mm penetration per 100 strokes |
| | Changed down to 50mm cutting shoe – drilling rate quicker but bit blocked with clay and crew requested to switch back to 75mm cutting shoe | | |
| 6 - 7 | 90 | | |

3rd September

Water level @ 0.75m and hole plumbed to 6.8m depth.

The hole was bailed down to about 5m depth and water recovered 10mm per 10 seconds. The drilling was continued with the 75mm cutting shoe.

| Depth (m) | Drilling Time (mins) | No of Drill Strokes | Notes |
|-----------|----------------------|---------------------|--|
| 7 – 8 | 40 | | White clay mixed with coarse sand & large pebbles |
| 8 – 9 | 38 | 750 | Penetration measured at 100/200mm per 100 strokes. |
| 9 – 10 | 42 | 500 | |
| 10 – 11 | 29 | 538 | |
| 11 – 12 | 33 | 600 | |
| 12 – 13 | 34 | | Into predominantly fine sand. |

The hole was investigated for the presence of water by extensive bailing and recovery test. Recovery was slow, indicating insufficient water for a hand pump. The borehole was plumbed to 11.20m. It was assumed that the fall in was due to extensive bailing.

Water level was resting at 0.78m and the hole was plumbed to 9.65m. The hole was slowly reamed out but it proved difficult to get the flushing water through the sludging valve and drilling stopped at 12m. The ground seemed hard and no headway was made. In fact, the hole became shallower, indicating collapse. On the basis of water rest level at 0.78m and evidence of collapsing ground, there was insufficient 'hydrostatic head' (3 metres required) to support borehole walls and hole was abandoned.

Text Box 1: Hydrostatic head.

The Pounder technique uses a fluid filled hole to remove debris from the hole bottom by pulling it up through the sludging valve on the top. The hole must be flooded to the surface with water for the method to work.

Fluid acts as a very good method of stabilising a hole through 'collapsing' ground, preventing collapse, but there are some basic rules which must be followed:

- *To exert sufficient pressure on borehole walls to prevent collapse, a fluid head of 3metres above the rest water level must be maintained.*
- *This head must be maintained throughout the drilling operation and insertion of casing screen and gravel pack. The borehole may require water to be topped up throughout the operation, including overnight.*

In practical terms it normally makes sense to tackle such holes to complete in a single working shift or use drill mud to slow losses.

Site Investigation.

In order to seek a preferred site that was off the valley bottom and would provide a water table of 3m below ground, some site investigation was undertaken. 3 No 30mm diameter hand auger holes were drilled in a line up the valley side. At about 2m elevation above the borehole site, an augered hole recorded a water rest of 1.8m, indicating a groundwater gradient of about 1m rise in 18m distance. Holes further up the valley at elevations of approximately 6 & 8 m (linear distance of 60 & 90m respectively) were bored to a depth of 7.6m and did not strike any water.

PW 1/4

Site: Gala, up valley from PW 1/3
 Village: Mpami
 Parish: Ssabadu
 Sub-County: MUT.1 Mpigi
 County: Mawokota
 Date: Started 7th September – Completed 11th September

This site was selected at an approximate elevation of 8m from the valley floor. It was at the same elevation as a group of houses and it was hoped that a 10m+ hole located in a weathered open layer could produce a water source.

Drilling commenced 11.00 am 7th September. 75mm cutting shoe (No.4)

| Depth (m) | Drilling Time (mins) | No of Drill Strokes | Notes |
|-----------|----------------------|---------------------|---------------|
| 0 - 1 | 5 | | Soft red clay |
| 1 - 2 | 10 | 175 | Soft red clay |
| 2 - 3 | 6 | 106 | |
| 3 - 4 | 9 | 107 | |
| 4 - 5 | 9 | 84 | |
| 5 - 6 | 4 | 58 | |

The above drilling was accomplished with the crew using the 'T' bar to drop and lift the drillpipe. The last 0.4m was very soft dropping, covering a distance of 0.4m in about 6 strokes. This was followed by a gurgle as the water drained completely from the pit to the hole resulting in complete 'lost circulation'. No water level could be recorded.

Whilst more water was carried from valley bottom to re-fill the storage barrel, polymer drill mud additive was fetched from the District Stores and a supply of sawdust was obtained.

2 no 20-litre buckets comprising 1/3rd sawdust were then filled with polymer and well mixed. This was poured directly into the hole followed by two buckets of mixed polymer only. The hole was subsequently full and the lost circulation zone was 'plugged'. Drilling then recommenced, with the polymer sludging up the samples well. The lost circulation zone was found to be red silt with lots of lateritic stones.

The crew drilled on into evening to a depth of 13m through red clay, getting lighter in colour at depth.

Text Box 2: Polymer, Bentonite, and Fibre

The polymer, when added at a concentration of 1 to 2 litres to 200 litres of water produces a viscous fluid mix known as 'Drill Mud' that will resist flow out into very porous formations. For very porous zones, if fibre is added this will assist with the blocking off of these porous zones. Any source of fine fibre will help blockage. Sawdust, grain husks or indeed cow manure are all very effective. The drawback of using fibre is that if used below the water table, the fibre will tend to permanently block water production, and effectively block any well screen set in the permeable formation.

The alternative to polymer drill mud is bentonite. Bentonite is a natural clay, and when mixed with water at the ratio of 25kgs to 200 litres, will produce a viscous drill mud with very good sealing properties. Polymer will 'yield' i.e. mix to a viscous mud in about 30minutes. Bentonite needs a full 12-24 hours to build viscosity (i.e. overnight), before it can be used effectively. Additionally, polymer will break down in 2-3 days, adding very few solids whilst bentonite is a solid lining material and will not break down. The latter requires very positive washing, and even the use of chemical 'polyphosphates' to aid break up and wash out.

9th September

Water rest 4.27m at 7.30am, then 4.41m at 10.06am showing water level dropping slowly but probably not indicating the true water table level. Hole plumbed to 12.75m.

Drilling recommenced, but it proved very difficult to progress the hole deeper than 15m. The sludging valve was not passing fluid. It only pumped when the crew used the 'T' bar directly on the drillpipe and directly worked the drillpipe on the drillstroke. Once primed, an attempt was made to keep the water pumping by reverting to the lever but this proved increasingly futile.

15m of drillpipe at a weight of 13 kg for each 3m piece means oscillating a load of 135Kg. (Note that this ignores flotation effect of water filled hole) The load is oscillated over a distance of 300mm by a lever arranged with a mechanical advantage of 2:1. This requires a substantial manual input to work continuously, particularly when the drilling rate has slowed due to insufficient water flushing.

To overcome the problem of insufficient water flow a counterbalance weight was added to the other side of the pivot. This balanced out the drillpipe load. The crew was thus required to just oscillate the lever in order to raise and lower the drillpipe in the sludging action. In this case, ½ an oil drum was hung and filled with sand until the load balanced.

Introduction of the counterbalance and positioning of the crew with ropes on each end of the pivot allowed the drillpipe to lift 20-24" (500 – 600mm), and to be dropped quite

fast. This additional stroke and speed once more enabled the water to be sludged through the valve.

Text Box 3: How does Sludging Work?

'Sludging' works because the speed of the down stroke is faster than the column of water, thus allowing the water to be discharged. On the upstroke, the sludging valve is closed and the water is pulled up by suction. On the down stroke, the valve opens and the water is ejected

The 'fit', or tightness of the drillbit against the borehole wall is thought to be very pertinent for efficient operation because this would prevent or slow the descending water column from dropping out of the drillpipe. As a consequence, if the hole erodes to a large diameter (e.g. in a loose formation), this may result in poor water flow.

The other factor that could be affecting water flow is friction between the water column and inside of the drillpipe. This would be a factor if water flow continues to diminish at depth. Whilst it is expected that the effect of friction is nominal, it could be this little variable which has a big effect on the sludging valve's ability to pass water.

In a normal pipe system, a friction loss calculation is a rudimentary step. However, with sludging action it becomes complicated very quickly. The fluid does not flow at a constant speed due to the oscillating action of the pipe. Further the fluid is not just water but is mixed with borehole drilling debris, some of which (clay) form into pistons 50 to 150mm long which are ejected through the sludging valve.

As the drilling trials continue it is hoped that more will be learnt and understood.

The hole was progressed from 15 metres to 18 metres with time taken to learn the new drilling action and to arrange the new lever bar and counterbalance. The following day, the hole was progressed from 18m to 21.5m, when the sludging water ceased to pump. This made further penetration unlikely. The effects of drill bit clearance and friction were still under consideration, so the drill string was lifted to 18m and indeed the water pumped through valve once again.

Water Usage

As this was experimental drilling, this hole was drilled with water carried by commercial water carriers at cost of 100 shillings (4.3 pence) per 20 litre jerry can. The daily consumption varied from 400 litres to a maximum of 720 litres. At times, polymer was used to slow consumption, particularly at the end of the working shift to ensure that the water level stayed up during the night.

Hole Completion

Whilst the formation did not look promising for a water supply, it was felt important to complete a well with screen, cylinder and gravel pack as a dry run for the crew.

This hole was then reamed with 100m cutting shoe (Serial No 3) to 19m. The most promising horizon for water being 16/18m in a gravelly material. A direct installation of a U3 was made attaching a Tara sand trap at 19-18m, 0.5mm wellscreen at 18-16m, plain 2" uPCV at 16m-10m. The U3 cylinder and then 75mm rising main casing to surface. The hole was packed with fine gravel pack, using approximately 40 litres to bring packed level up to 3m below ground level.

After leaving the hole for 24 hours over Sunday, the water level was recorded at 12m. (This shows the aquifer/ ground water system up the valley side was disconnected to those found in the valley bases). After priming, insignificant water was pumped with the piston effectively locking in place.

PW 2/5

Village: Kasenyi
Parish: Nkumba
Sub-County: Katabi
County: Busiro
Date: Started 14th September

Fishing market on the shores of Lake Victoria East of Entebbe.

300m back from the lakeside was a Tara Pump installation. The hole had been constructed into sand, and attempts made with both a percussion rig and hand auger rig suffered badly with sand running into the casing.

The pump was removed and the water table was found to be around 3 metres. Elevation of the site was 3m above the lake.

The surface was sand - area was flat but with evidence in the bay of outcropping rock.

The mud pit was dug and plastered with cement to prevent water loss through pit walls - this allowed drying overnight.

Sludging failed to get going. It seemed impossible to pump water through the sludging valve for more than a few strokes. The formation was coarse uniform sand - very clean. Attempts were made with all bit sizes and using polymer. The most significant discovery was that 4" plastic casing would easily slide down with the drill bit and that this provided the most consistent water returns.

This hole was probably collapsing because the formation was soft and needed at least 3m of casing at the surface to stabilise it. The pounder action does put a high suction force at the drill bit face, which is very likely to pull in both the borehole walls and floor.

PW 2/6

Site: Kajubi
 Village: Kawuku
 Parish: Kisubi
 Sub-County: Katabi
 County: Busiro
 Date: Started 15th September – Completed 17th September

Adjacent to main Entebbe/Kampala Road, just East of Entebbe. A valley bottom site - a much shallower valley than those seen previously. The site was in a valley bottom, which ran through the large village in which there were a number of protected springs and 2 hand pumps. One was installed on a hand augered well and the other on a hand dug well. Rock had been encountered at 2-3m.

A site near a valley bottom spring producing discoloured water was chosen. A 75mm hole progressed through clay into hard laterite at 3m. At this point, water level dropped to 1.23m and proved impossible to make up to surface level. The sludging action continued due to the shallow water table and the hole progressed down to 5m.

As the hole was stable, the treadle pump was used to abstract water from the hole revealing a drawdown of 100mm for a good steady flow. The hole was reamed out to 100mm with the button bit, and taken down from 5 to 6m. The average penetration was about 2mm a blow.

The hole was lined with 3m 2" screen on the base of the U3 Cylinder and 75mm-uPVC pipe to the surface, and gravel packed to within 2m of surface before top being cement grouted. Treadle pump was connected once more to the AQ drillpipe, and the hole was test pumped and developed to yield a clean water supply.

Text Box 4: Gravel packing

To be effective, gravel pack has to pass down the annulus between the 93mm U3 cylinder and the nominal 100mm-drilled hole into the 60mm/100mm annulus between the screen and borehole. This is best achieved using a very fine sand, ideally a sand that is just consistently coarser than the slot of the screen.

Uganda is blessed with good natural sources of gravel, and good material can be sieved to meet these requirements.

After landing the casing and screen at the design depth, keep the hole full of water and add the gravel by steadily pouring it into a large fuel type funnel, with the spout in the annulus. Whilst keeping up this steady pouring, the effects of the water level in the casing/rising main should be observed. As the gravel drops, it will displace water both up the annulus and up the centre of the casing/rising main. The water comes through the screened section. As soon as the gravel covers the screen, the water flow up the casing will slow or indeed stop. This gives a positive indication that the gravel has covered the screened section. After a little more is added, a cement grout sanitary seal can then be placed.

Text Box 5: Cement Grouting

Apparently normal Ugandan shallow well practice is to add dry cement to the annulus to a standard depth from 3/4m (the lower part being gravel packed). The correct procedure is to mix cement to the ratio of one 50 kg sack to 27 litres of water. This will yield 33 litres of cement grout. This can then be poured into the annulus. Mixed to this ratio, it will not soak into and block the previously placed gravel pack.

Text Box 6: Annulus calculation

To give an indication of the amount of gravel and cement to use, the following information gives the approximate volumes required. Care will have to be taken as it is apparent that the sludging drill bits drill oversize to a certain extent, which will affect the actual volume required.

Annulus between 100mm-sludged hole and 60mm (2") screen/casing requires minimum of 7 litres per metre to fill.

Annulus between 100mm-sludged hole and 75mm (2.1/2") casing/rising main requires minimum of 5 litres per metre to fill.

Annulus between 75mm-sludged hole and 60mm (2") screen/casing requires a minimum of 2.5 litres per metre to fill.

PW 2/7(1)

Village: Kawuku
Parish: Kisubi
Sub-County: Katabi
County: Busiro
Date: Started 30th September – Not Completed

A valley bottom site, similar to PW 2/6. The crew had undertaken a site investigation and found that they hit hard formation (believed to be murrum) at 1.5m.

The crew arrived at 1.15pm and took 1h 45 mins to set up the equipment.

Drilling was started with the 75mm shoe, but quartzite material started to emerge, so crew switched to 75mm button. Progress was very slow from the start, with the equipment hardly progressing at all (initial average 1cm/100 strokes and subsequently slowing considerably). It took 1 hour to drill 5cm. The sound of the pipe banging off the rock indicated that the material was VERY hard, and that the button bit was merely grinding the surface. In view of the fact that the crew was being paid for successful wells only, they did not want to continue at this site. The crew stopped drilling at 5pm.

Several crew members started to investigate an alternative site, and the crew moved in the evening.

PW 2/7(2)

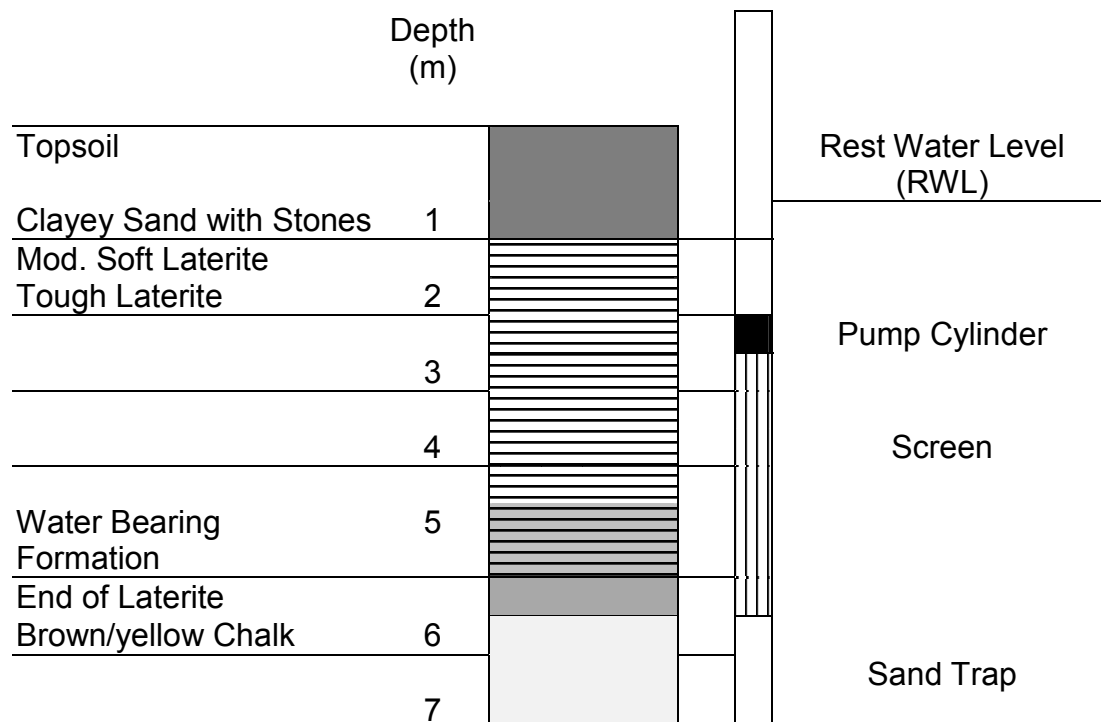
Village: Kawuku
 Parish: Kisubi
 Sub-County: Katabi
 County: Busiro
 Date: Started 28th September – Completed 29th September

This site was in the same valley as site 2/7(1) but further along the slope. The crew commenced at 7:30am and took two hours to set up the equipment.

Drilling: Started with 75mm shoe
 Total Depth drilled: 10m at 75mm
 Total Depth reamed: 7m at 100mm
 Cylinder installed at depth of 3m
 Drawdown: 1m in 30 min (with treadle pump)
 Recovery: 10cm in 1 min

Crew deemed the yield poor (in comparison to the last successful well), but sufficient for a handpump.

Figure 1: PW 2/7(2) Profile



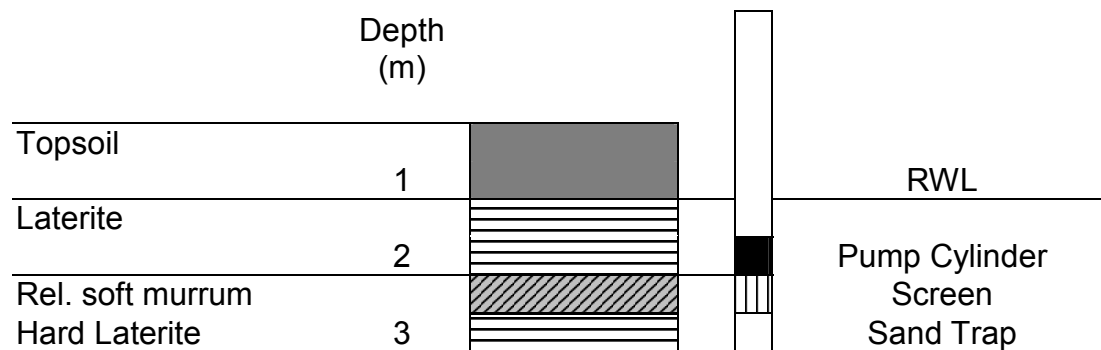
PW 2/8

Site: Ndaula
 Village: Zzika
 Parish: Kisubi
 Sub-County: Katabi
 County: Busiro
 Date: Started 30th September – Completed 30th September

This is another valley bottom site near a waterhole. The crew arrived on site at 10.50am. Set up took 1h 40 mins.

Drilling: Total Depth = 3m
 Aquifer: 2.5m below ground
 Rest Water Level: 1m below ground level
 Drawdown: 50cm in 10 min
 Recovery to rest level takes 7 sec.
 Yield is good

Figure 2: PW 2/8 Profile



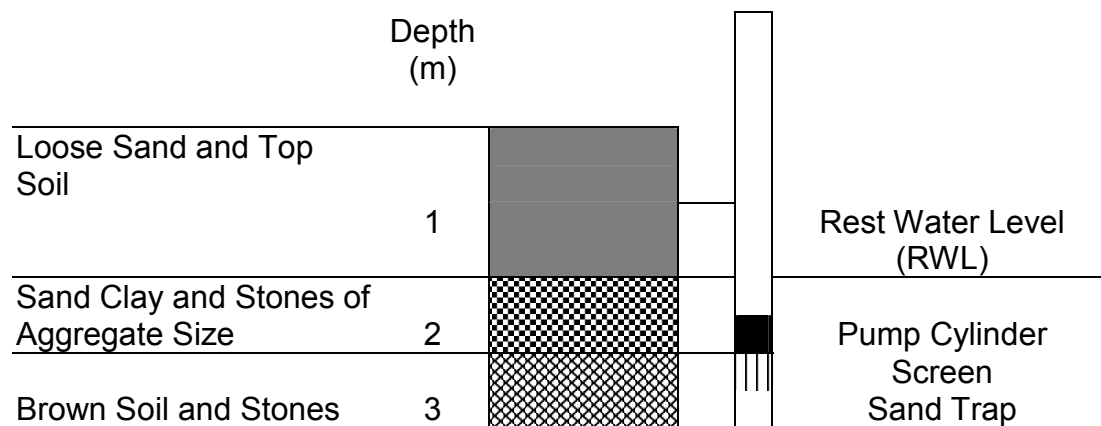
PW 2/9

Site: Zzika zone
 Village: Zzika
 Parish: Kisubi
 Sub-County: Katabi
 County: Busiro
 Date: Started 1st October

The crew arrived on site at 10.30am and took approximately 1h 30mins to set up.

Drilling: Reamed with 100mm button bit to 3m
 Total depth drilled: 3m
 Rest Water Level 0.9m
 Aquifer is at 2.5m
 Cylinder installed at depth of 1.8m
 Drawdown: 1m in 10 min
 Recovery to rest level takes 5 sec
 Yield is good

Figure 3: PW 2/9 Profile



PW 2/10

Site: Bunande Kande
Village: Kitala
Parish: Kisubi
Sub-County: Katabi
County: Busiro
Date: Started 7th October

Crew arrived at site at 9:15, and the setting up took 35 mins.

Started drilling with the with 75mm button bit. The crew drilled to less than 3m, and pump tested. The yield was deemed too low for a hand pump

Pump testing:

- Rest Water level: 1m
- Drawdown is 1m in 1 minute
- Recovery to RWL takes 1 minute so it is slow
- Abandoned the well

Test augered to find an alternative site.

PW 2/11

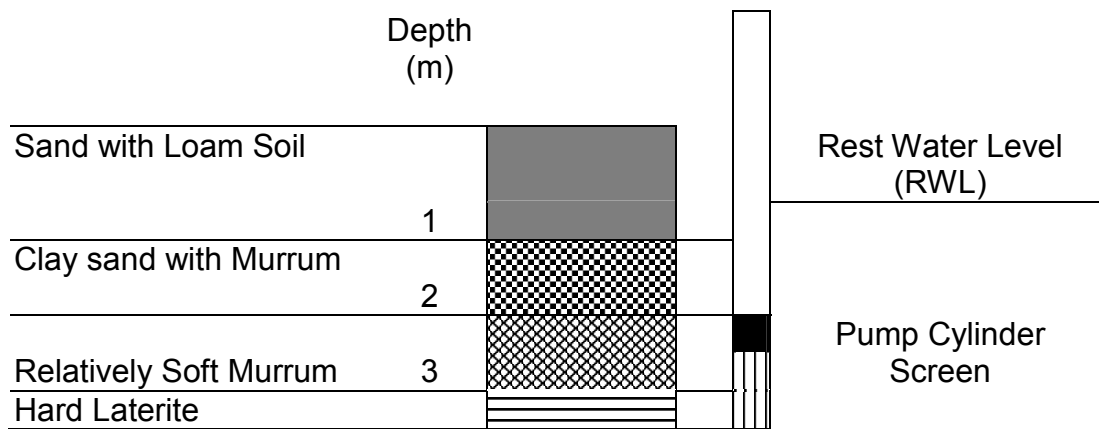
Site: Bukandekade
 Village: Kitala
 Parish: Kisubi
 Sub-County: Katabi
 County: Busiro
 Date: Started 8th October

The crew arrived on site at 9.05am, and spent 50 mins test augering to find a suitable site. Subsequently set-up took 30 minutes.

Drilling: Started 75mm button bit.
 Reamed with 100mm button bit down to 3.5m
 RWL: 0.40m
 Aquifer at 2.8m
 Drawdown: 2.5m in 10 min
 Recovery to RWL: 10 min

Yield is relatively low but sufficient for a hand pump

Figure 4: PW 2/11 Profile



PW “Depth Test”

Site: Outside the Mpigi District Council Headquarters

A trial in September revealed an effective ‘stall’ in the flow of the circulating water at a hole depth of 22m. However vigorously the pipe (AQ wireline) was sludged, little or no water emerged through the valve. With the only assumed variable being length it was surmised this flow loss was due to friction. In November a hole was drilled to 18m before the ‘stall’ became effective and then uPVC pipe of 2” 61 x 50mm bore and 1½” 48 x 38mm bore were inserted into the hole to compare the relative difference in flow. The 1½” pipe gave a low flow, while the 2” pipe gave a much improved flow easily capable of lifting cuttings.

Conclusion: to sludge much beyond 20m is impossible with the AQ wireline drillpipe.

Why did we reach 22m in September and stopped at 18m in November? The November hole had been rested over a Sunday and the crew had added a very thick mix of polymer to the hole, it is therefore assumed this thick mixture of dirty water affected the depth because of internal pipe friction.

PW “Hard Rock Test”

Site: Namawata
Village: Namawata
Parish: Ssabadu
Sub-County: Busukuma
County:
Date: Started 9th November

The purpose of this site was to investigate the rig capability in VERY hard material, i.e. unweathered bedrock.

The hard rock surface was very close to the ground surface (1 to 2m) which meant that there was very little weight behind the button in comparison to that which would be there for a deeper rock surface. Polymer was added to the hole at the end of the first day of drilling, however, there was still a considerable amount of silt in the bottom of the hole. It took the crew 2½ hours to clean this material out the following morning.

The soil formation was as follows:

Topsoil to 1m
Laterite to 2m
Hard Formation from 2m

OTHER ISSUES

Casting

The concrete aprons were cast on the 8th and 9th October and the following materials were used:

| | |
|---------|---|
| PW 2/6 | 1 bag cement seal 5 bags cement for concrete 1 ¼ bags of gravel pack (1 course, ¼ fine) ½ tonne of lake sand ½ tonne river sand ½ tonne of aggregate stones 1 tonne of hard core 80 blocks |
| PW 2/7 | 2 bags gravel pack (coarse) |
| PW 2/8 | 1 bag gravel pack (coarse) |
| PW 2/9 | 1 bag gravel pack (coarse) |
| PW 2/11 | 1½ bags gravel pack |

Note that cement, lake sand, river sand, aggregate blocks and hard core quantities are uniform.

Pump Testing

Pump testing is currently undertaken using the ApproTec designed treadle pump attached to the drill rod. This pump has the limitation of lifting a maximum of 7m from the rest water level. The pump cannot be used for water resting at greater depth. A system for testing at greater depth still needs to be developed. The treadle pump has a discharge of 0.5 to 0.75l/s which is significantly higher than that of a handpump.

Vehicle Problems

The vehicle suffered problems travelling back on the 9th October. It took some time for the district to release funds for repair. As a consequence, the crew did not drill for the two week period from the 18th October to the 22nd October. During this period, the crew had been scheduled to drill in Gombe sub-county following a visit by the DWO, the foreman and Kerstin.

Equipment

- The flap valve wore out during the drilling of PW 2/8. The chamois leather was worn though and the neoprene underneath had torn. The crew relocated the flap so that the top of the pipe was sealing on unworn material – this worked fine. The valve was fully worn out by the end of PW 2/10.

- The metal welded on to the pivot pipe, which prevents it from sinking into the ground, had broken off. James was given money to have a larger piece of metal welded on.
- Cross bar – the scaffold clamps are not sufficient to fully grip the AQ. I left James some cash to purchase some rubber to insert between the clamp and AQ.
- The auger broke and needed re-welding.

Comments from the drill crew

- Pounding is quicker than augering, as there is no time wasted in removing the auger.
- The Pounder is better as it can overcome hard formations.
- It is sometimes possible to drill 1m in less than 2 minutes!
- You have to let go of the cross bar when it hits the ground to avoid pain.
- The crew would like some reserve funds to cater for minor repairs to the vehicle.
- The crew would prefer that a payment advance be left at home prior to them leaving for the field.
- When drilling more than one site with the crew living in one place, a considerable amount of travelling needs to be undertaken. This should be taken into account when the vehicle is filled with fuel.

General

The crew and district were very keen to fully utilise the equipment. The crew had planned to drill three wells in one week following the trials. These wells are 'normal' WES wells in terms of payment, other than the fact that the Project has paid for the screen and casing. The Sub-County chief has paid for four wells to be drilled, and the crew will be paid USh90,000 per well (15,000 each, i.e. 2 wells in a week means 30,000 per driller) from the LC3. It was organised in this way as we still did not have money to pay the crews.

Payment: It took over two weeks for the crew to be paid for the work undertaken. The sum paid was 60,000 per person, i.e. 15,000 per person per well or 90,000 per well for the entire crew.

The district crew has the distinct advantage of having experience of hand augering and are thus able to make a good comparison between the two systems in terms of technology. Furthermore, the district has a sense of ownership of the equipment and sees its potential to operate in the shallow well sector, which is a useful promotional strategy in itself. However, there are a number of drawbacks to working with the district. The first problem is that of the vehicle and breakdowns. During October/November the vehicle broke down and the crew were not able to drill for two weeks while funds were released for service and repair. This has delayed the drilling programme by at least three wells. The repair was not paid for to avoid setting a precedent, as the LCD project will not be able to continue repairing the vehicle in the future, and already has limited funds. In hindsight, considering the implications of the delay, the decision not to pay may have been a mistake.

It should be noted that the final quarter of the year sees the district low on funds for water well construction. This is the so-called lean time, when both the Sub-county and district coffers are low. Thus it is an ideal time of year for the LCD project to be undertaking test drilling, provided that the crews can be paid appropriately.

The of issue funding for test drilling was a problem from the start of the project. In reality, this is why the project teamed up with the Directorate of Water Development in the first place. However, the ground reality is that the drill crew is not all salaried. Three of the six-crew members receive USh45,000 per month, while the others are only paid for successful wells. Moreover, the salaries themselves are not a living wage and thus need to be supplemented by additional payment when in the field. This problem was not realised until the crew was about to commence the field trials, when a great deal of concern was expressed regarding payment. Thus for the initial trial period of the first five wells, the crew were paid a weekly salary of USh20,000 plus allowances for lunch, and, where appropriate other meals. This was undertaken by the LCD team before they even knew where the funds were coming from.

A further issue is that of the conflicting goals of the LCD programme and that of the district WES programme. 15 sites were selected by the district and Sub-county staff, and agreed by the project team following site visits. The initial three sites to be drilled were selected based upon their differing geologies and community preparedness for the hand pumps, should the wells be successful. However, on commencement of the field trials this plan was radically changed, and it was decided not to drill at these sites to allow the crew some time to become familiar with the equipment as well as prevent raising high expectations in communities in dire need of improved water supplies. Thus a number of test sites were chosen by the crew themselves and the drilling consultant. These sites were chosen at locations which apparently 'did not matter' if they were successful or not. However, it should be noted that there is always expectation when a drilling rig starts to operate in a particular location.

Following the drilling of the first six trial wells (one of which – PW 2/6 - was a successful water well), the drilling consultant left Uganda for the UK. The next wells drilled by the crew were in the same village as PW 2/6. Four wells (PW 2/7(2), 2/8, 2/9, 2/10) were drilled in Kawuku primarily due to the financial constraints on the project, with the wells being paid for by WES funds. These four wells were drilled, completed and have had pumps installed.

As the Kawuku wells were nearing completion, the next test sites were being selected. Kira Sub-county, where the initial three test sites had been selected, was a favourite for the next drilling to take place. However, following a visit to Gombe county by the DHI and the DWO, it was suggested that there may be more suitable locations for drilling there. This was discussed at length with DWD staff, who were of the view that the Pounder rig should be trying to move to sites with considerably different geology from that near the lake, as well as moving beyond the periphery of Kampala to show that the Rig can operate in more distant, rural areas. Following a site visit to Gombe county to view three sites, it was believed that two of them would be ideal for the next trial wells. The Sub-county health assistant was charged with the responsibility of checking the social aspects of the sites (land ownership and community mobilisation) to enable the crew to move to Gombe. Unfortunately, the breakdown of the vehicle prevented this from taking place.

Appendix

Drilling Penetration Data

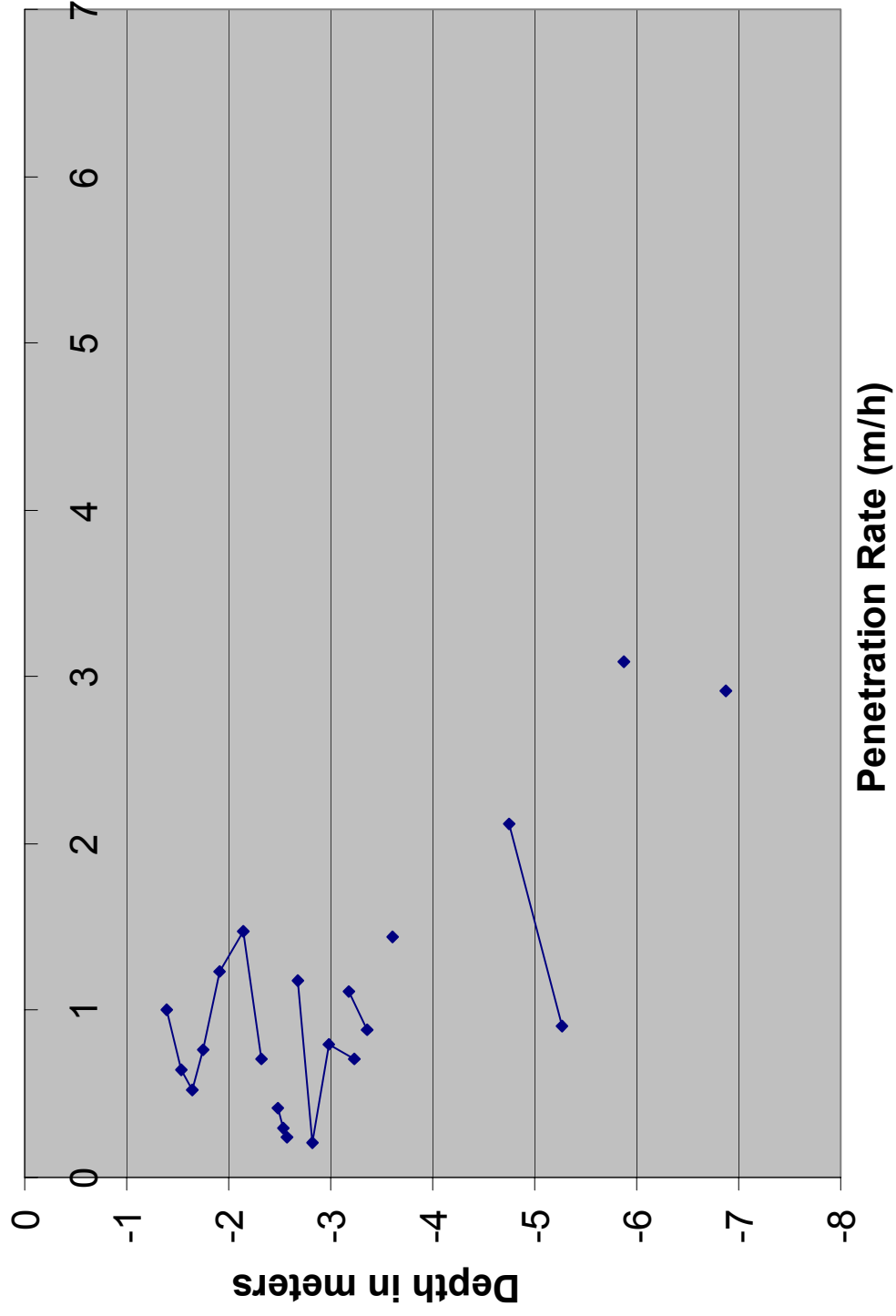
PW 2/17 (2)

| Penetration Data (all in cm) | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 200 strokes (cm) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|------------------------------|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|----------------------------------|--------------------------|--------------------------|------------------------|
| measure to join distance | 26 | | | | | | | | | | |
| Total Length of drill pipe | 300 | 12:50 | 12:58 | 8 | 143 | 126 | -1.395 | | 17 | 0.017 | 60.00 |
| | 300 | 12:58 | 13:03 | 5 | 126 | 115 | -1.535 | | 11 | 0.011 | 92.73 |
| | 300 | 13:03 | 13:13 | 10 | 115 | 106 | -1.635 | | 9 | 0.009 | 113.33 |
| | 300 | 13:13 | 13:30 | 7 | 106 | 93 | -1.745 | | 13 | 0.013 | 78.46 |
| | 300 | 13:30 | 13:47 | 17 | 93 | 72 | -1.915 | | 21 | 0.021 | 48.57 |
| | 300 | 13:47 | 14:00 | 14 | 72 | 47 | -2.145 | | 25 | 0.025 | 40.80 |
| | 300 | 14:00 | | | 47 | 35 | -2.33 | | 12 | 0.012 | 85.00 |
| | 400 | | | | | | | | | | |
| | 400 | 17:38 | 17:38 | | 130 | 123 | -2.475 | | 7 | 0.007 | 145.71 |
| | 400 | 17:38 | 17:45 | 7 | 123 | 118 | -2.535 | | 5 | 0.005 | 204.00 |
| | 400 | 17:45 | 17:55 | 10 | 118 | 114 | -2.58 | | 4 | 0.004 | 255.00 |
| GAP IN DATA? | | | | | | | | | | | |
| | 400 | 18:01 | 18:15 | 14 | 65 | 46 | -3.185 | | 19 | 0.019 | 53.68 |
| | 400 | 18:15 | 18:25 | 10 | 46 | 31 | -3.355 | | 15 | 0.015 | 68.00 |
| Next Day | | | | | | | | | | | |
| No more times | 400 | | | | 116 | 96 | -2.68 | | 20 | 0.020 | 51.00 |
| Penetr every 200 | 400 | | | | 96 | 89 | -2.815 | 7 | 3.5 | 0.003 | 291.43 |
| | 400 | | | | 89 | 62 | -2.985 | 27 | 13.5 | 0.013 | 75.56 |
| | 400 | | | | 62 | 38 | -3.24 | 24 | 12 | 0.012 | 85.00 |
| | 500 | | | | 138 | 89 | -3.605 | 49 | 24.5 | 0.024 | 41.63 |
| End of Laterite | 600 | | | | 135 | 63 | -4.75 | 72 | 36 | 0.035 | 28.33 |
| | 600 | | | | 63 | 32 | -5.265 | 31 | 15.5 | 0.015 | 65.81 |
| | 700 | | | | 139 | 34 | -5.875 | 105 | 52.5 | 0.051 | 19.43 |
| | 800 | | | | 136 | 37 | -6.875 | 99 | 49.5 | 0.049 | 20.61 |

Mean Drill Time for 100 Strokes

10

PW 2/7(2) - Penetration Log



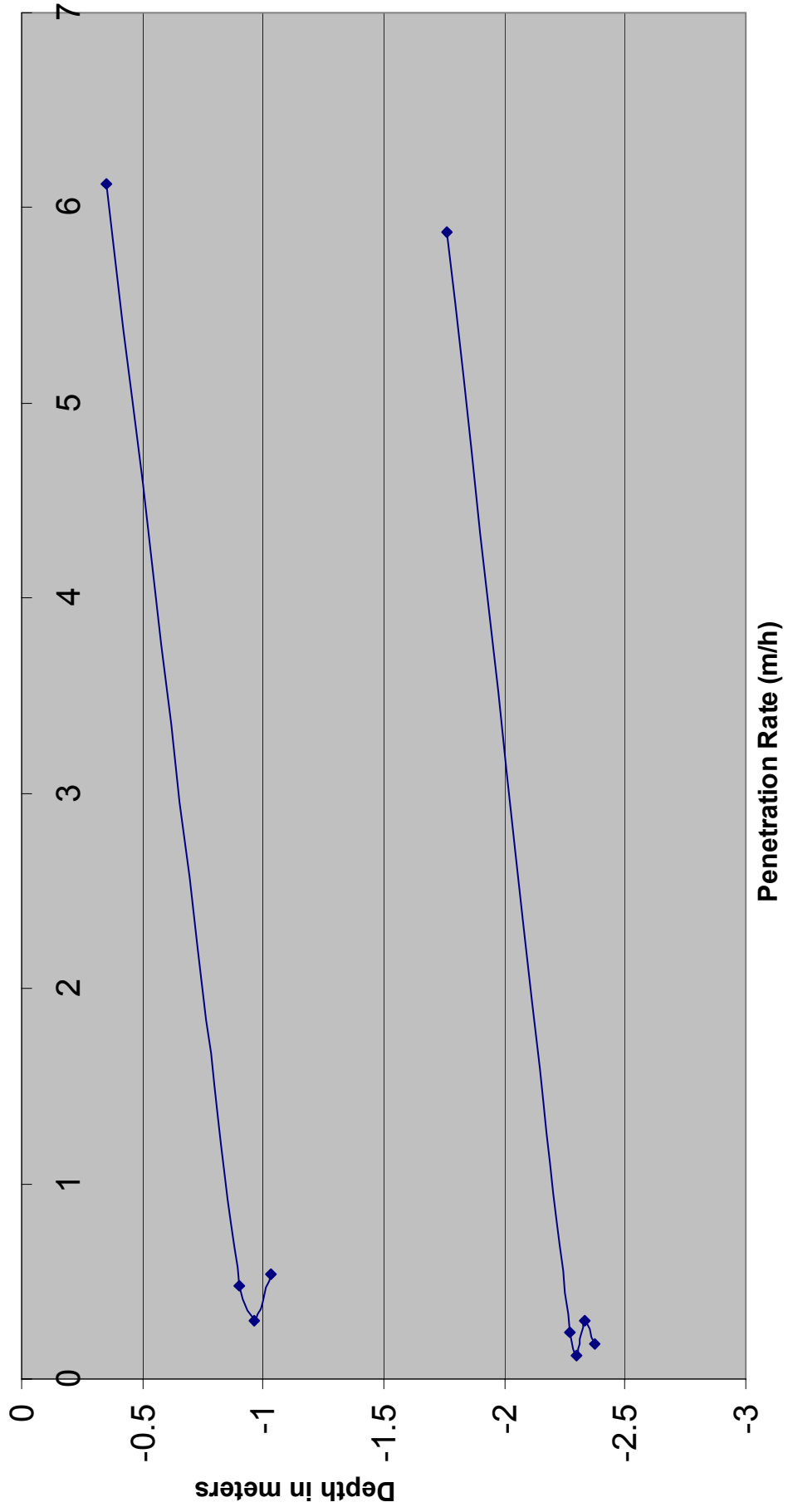
PW 2/8

| Penetration Data | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|---------------------------------|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|--------------------------|--------------------------|------------------------|
| measure to join distance (cm) | 26 | | | | | | | | | |
| Total Length of drill pipe (cm) | 200 | | | 190 | 88 | -0.35 | 102 | 0.102 | 9.80 | 6.12 |
| | 200 | | | 88 | 80 | -0.9 | 8 | 0.008 | 125.00 | 0.48 |
| | 200 | | | 80 | 75 | -0.965 | 5 | 0.005 | 200.00 | 0.30 |
| | 200 | | | 75 | 66 | -1.035 | 9 | 0.009 | 111.11 | 0.54 |
| | | | | | | | | | | |
| | 300 | | | 147 | 49 | -1.76 | 98 | 0.098 | 10.20 | 5.88 |
| Rel. soft Marram | 300 | | | 49 | 45 | -2.27 | 4 | 0.004 | 250.00 | 0.24 |
| Laterite | 300 | | | 45 | 43 | -2.3 | 2 | 0.002 | 500.00 | 0.12 |
| | 300 | | | 43 | 38 | -2.335 | 5 | 0.005 | 200.00 | 0.30 |
| (Quartz) | 300 | | | 38 | 35 | -2.375 | 3 | 0.003 | 333.33 | 0.18 |

Assumed Mean Drill Time (mins)

10

PW 2/8 - Penetration Log



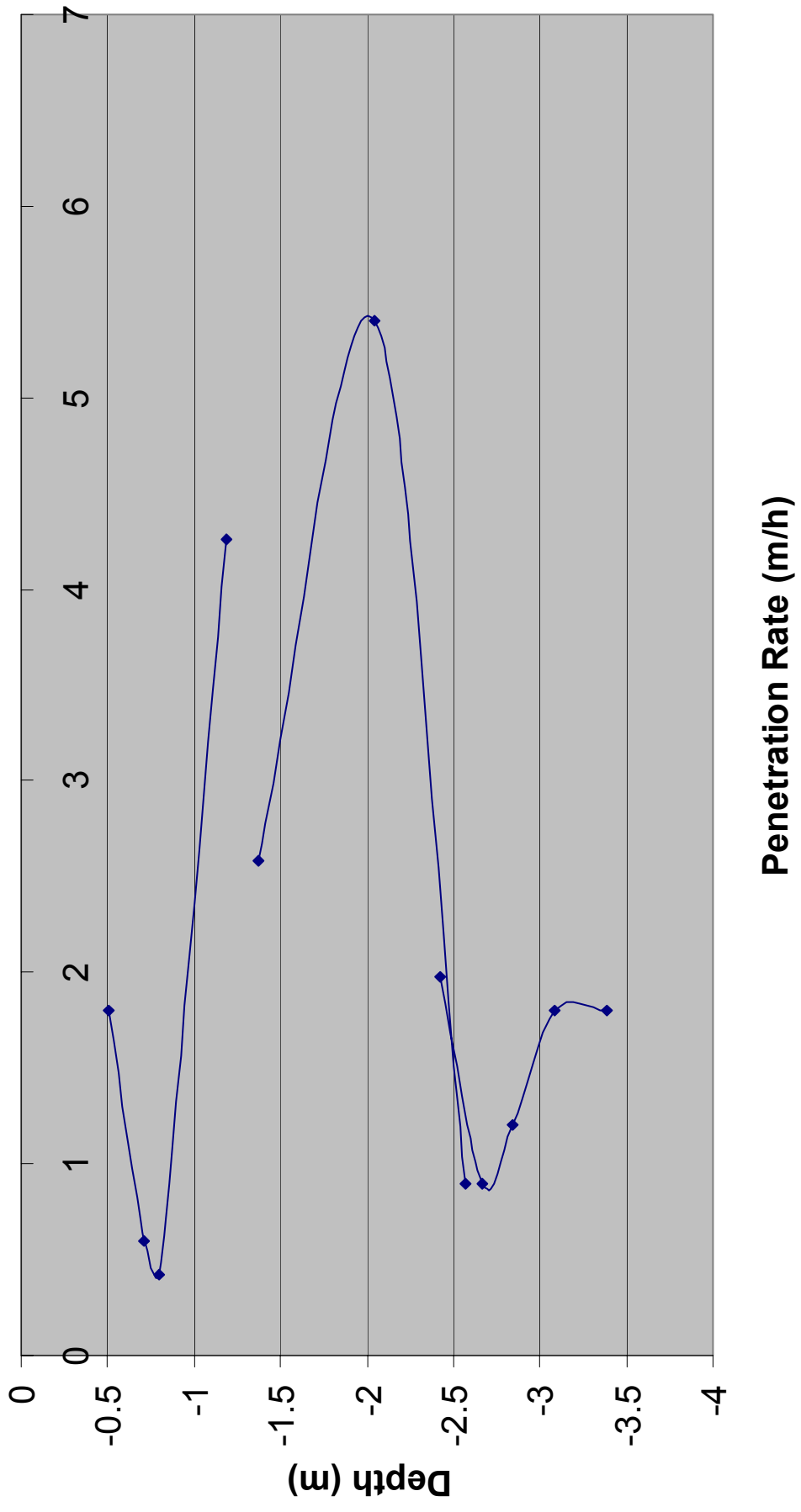
PW 2/9

| Penetration Data (all in cm) | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|------------------------------|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|--------------------------|--------------------------|------------------------|
| measure to join distance | 26 | | | | | | | | | |
| Total Length of drill pipe | 200 | | | 138 | 108 | -0.51 | 30 | 0.030 | 33.33 | 1.80 |
| | 200 | | | 108 | 98 | -0.71 | 10 | 0.010 | 100.00 | 0.60 |
| | 200 | | | 98 | 91 | -0.795 | 7 | 0.007 | 142.86 | 0.42 |
| | 200 | | | 91 | 20 | -1.185 | 71 | 0.071 | 14.08 | 4.26 |
| | | | | | | | | | | |
| | 300 | | | 158 | 115 | -1.375 | 43 | 0.043 | 23.26 | 2.58 |
| | 300 | | | 115 | 25 | -2.04 | 90 | 0.090 | 11.11 | 5.40 |
| | 300 | | | 25 | 10 | -2.565 | 15 | 0.015 | 66.67 | 0.90 |
| | | | | | | | | | | |
| | 400 | | | 148 | 115 | -2.425 | 33 | 0.033 | 30.30 | 1.98 |
| | 400 | | | 115 | 100 | -2.665 | 15 | 0.015 | 66.67 | 0.90 |
| | 400 | | | 100 | 80 | -2.84 | 20 | 0.020 | 50.00 | 1.20 |
| | 400 | | | 80 | 50 | -3.09 | 30 | 0.030 | 33.33 | 1.80 |
| | 400 | | | 50 | 20 | -3.39 | 30 | 0.030 | 33.33 | 1.80 |

Assumed Mean Drill Time (mins)

10

PW 2/9 - Penetration Log



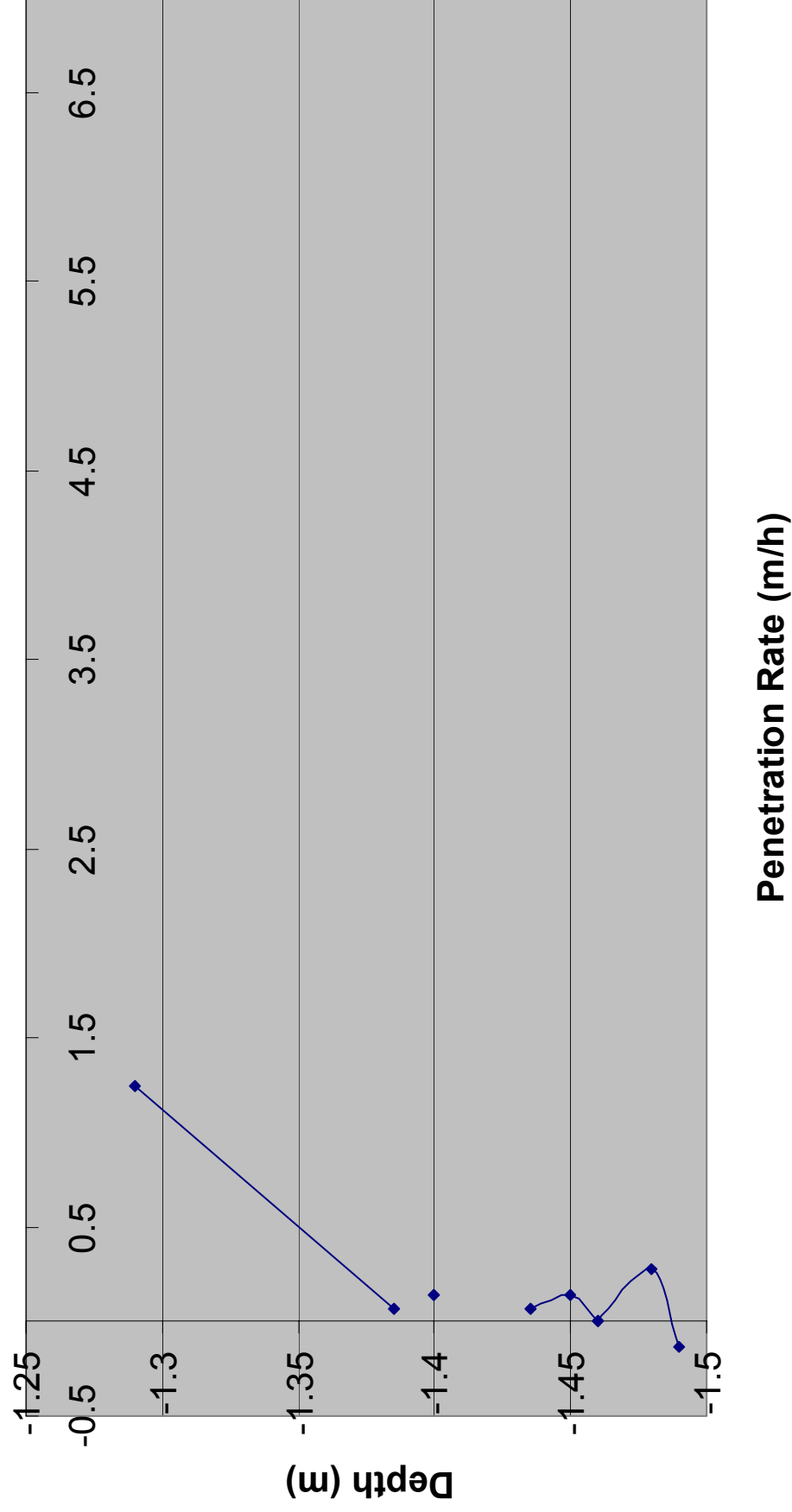
PW 2/10

| Penetration Data (all in cm) | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|------------------------------|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|--------------------------|--------------------------|------------------------|
| measure to join distance | 26 | | | | | | | | | |
| Total Length of drill pipe | 200 | 10:15 | 10:24 | 9 | 54 | 36 | -1.29 | 18 | 0.021 | 48.33 |
| Loose sand with loam soil | 200 | 10:24 | 10:28 | 4 | 36 | 35 | -1.385 | 1 | 0.001 | 870.00 |
| | 300 | 10:46 | 10:50 | 4 | 135 | 133 | -1.4 | 2 | 0.002 | 435.00 |
| | 300 | 10:50 | 11:03 | 13 | 133 | 131 | -1.42 | | | |
| | 300 | 11:03 | 11:10 | 7 | 131 | 130 | -1.435 | 1 | 0.001 | 870.00 |
| | 300 | 11:10 | 11:30 | 20 | 130 | 128 | -1.45 | 2 | 0.002 | 435.00 |
| | 300 | 11:30 | 11:40 | 10 | 128 | 128 | -1.46 | 0 | 0.000 | #DIV/0! |
| | 300 | 11:40 | 11:42 | 2 | 128 | 128 | -1.46 | 0 | 0.000 | #DIV/0! |
| | 300 | 11:42 | 11:57 | 15 | 128 | 124 | -1.48 | 4 | 0.005 | 217.50 |
| | 300 | 11:57 | 12:03 | 3 | 124 | 126 | -1.49 | -2 | -0.002 | -435.00 |

Mean Drill Time for 100 Strokes

9

PW 2/10 - Penetration Log

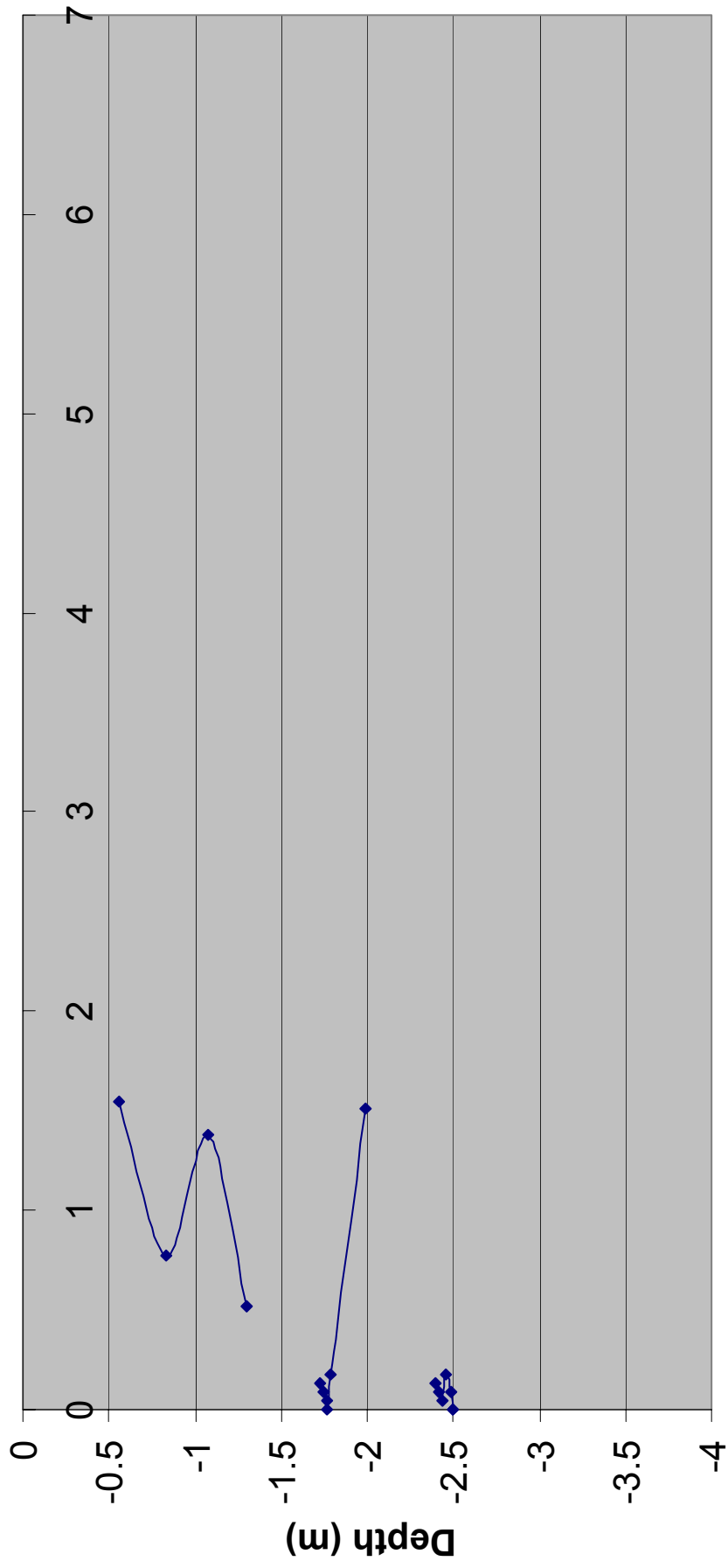


| Penetration Data (all in cm) | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|---------------------------------------|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|--------------------------|--------------------------|------------------------|
| measure to join distance | 26 | | | | | | | | | |
| Total Length of drill pipe | 200 | 10:05 | 10:25 | 10 | 136 | 100 | -0.56 | 0.026 | 38.73 | 1.55 |
| | 200 | 10:25 | 10:50 | 25 | 100 | 82 | -0.83 | 0.013 | 77.45 | 0.77 |
| | 200 | 10:50 | 11:09 | 19 | 82 | 50 | -1.08 | 0.023 | 43.57 | 1.38 |
| | 200 | 11:09 | 11:37 | 28 | 50 | 38 | -1.3 | 0.009 | 116.18 | 0.52 |
| | 300 | 11:51 | 12:03 | 8 | 103 | 100 | -1.725 | 0.002 | 464.71 | 0.13 |
| | 300 | 12:03 | 12:09 | 6 | 100 | 98 | -1.75 | 0.001 | 697.06 | 0.09 |
| | 300 | 12:09 | 12:20 | 11 | 98 | 97 | -1.765 | 0.001 | 1394.12 | 0.04 |
| | 300 | 12:20 | 12:36 | 16 | 97 | 97 | -1.77 | 0.000 | #DIV/0! | 0.00 |
| | 300 | 12:36 | 12:51 | 15 | 97 | 93 | -1.79 | 0.003 | 348.53 | 0.17 |
| Change (mixture of laterite and sand) | 300 | 12:51 | 13:05 | 14 | 93 | 58 | -1.985 | 0.025 | 39.83 | 1.51 |
| | 400 | 1:45 | 1:54 | 9 | 136 | 133 | -2.395 | 0.002 | 464.71 | 0.13 |
| | 400 | 1:54 | 2:02 | 8 | 133 | 131 | -2.42 | 0.001 | 697.06 | 0.09 |
| | 400 | 2:02 | 2:20 | 18 | 131 | 130 | -2.435 | 0.001 | 1394.12 | 0.04 |
| | 400 | 2:20 | 2:38 | 18 | 130 | 126 | -2.46 | 0.003 | 348.53 | 0.17 |
| | 400 | 2:38 | 2:47 | 9 | 126 | 124 | -2.49 | 0.001 | 697.06 | 0.09 |
| | 400 | 2:47 | 2:59 | 12 | 124 | 124 | -2.5 | 0.000 | #DIV/0! | 0.00 |
| | 400 | 2:59 | 3:10 | 11 | 124 | 124 | -2.5 | 0.000 | #DIV/0! | 0.00 |

Mean Drill Time for 100 Strokes

14

PW 2/11 - Penetration Log



PW Hard Rock

Penetration Data (all in cm)
measure to join distance

Total Length of drill pipe

| | Start time | Finish Time | Mean Time (min) | Start Height (cm) | Finish Height (cm) | Mean Depth (m) | Penetration per 100 strokes (cm) | Penetration Rate (m/min) | Penetration Rate (min/m) | Penetration Rate (m/h) |
|-----|------------|-------------|-----------------|-------------------|--------------------|----------------|----------------------------------|--------------------------|--------------------------|------------------------|
| 26 | | | | | | | | | | |
| 200 | | | | 125 | 91 | -0.66 | 34 | 0.034 | 29.41 | 2.04 |
| 200 | | | | 91 | 80 | -0.885 | 11 | 0.011 | 90.91 | 0.66 |
| 200 | | | | 80 | 75 | -0.965 | 5 | 0.005 | 200.00 | 0.30 |
| 200 | | | | 75 | 72 | -1.005 | 3 | 0.003 | 333.33 | 0.18 |
| 200 | | | | 75 | 50 | -1.115 | 25 | 0.025 | 40.00 | 1.50 |
| 200 | | | | 50 | 38 | -1.3 | 12 | 0.012 | 83.33 | 0.72 |
| 200 | | | | 38 | 33 | -1.385 | 5 | 0.005 | 200.00 | 0.30 |
| | | | | | | | | | | |
| 300 | | | | 125 | 120 | -1.515 | 5 | 0.005 | 200.00 | 0.30 |
| 300 | | | | 120 | 119 | -1.545 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | 119 | 118 | -1.555 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | 118 | 118 | -1.56 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 118 | 118 | -1.56 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 118 | 118 | -1.56 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 118 | 117 | -1.565 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | 117 | 113 | -1.59 | 4 | 0.004 | 250.00 | 0.24 |
| 300 | | | | 113 | 100 | -1.675 | 13 | 0.013 | 76.92 | 0.78 |
| 300 | | | | 100 | 96 | -1.76 | 4 | 0.004 | 250.00 | 0.24 |
| 300 | | | | 96 | 91 | -1.805 | 5 | 0.005 | 200.00 | 0.30 |
| 300 | | | | 91 | 65 | -1.96 | 26 | 0.026 | 38.46 | 1.56 |
| 300 | | | | 65 | 61 | -2.11 | 4 | 0.004 | 250.00 | 0.24 |
| 300 | | | | 61 | 61 | -2.13 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 61 | 61 | -2.13 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 61 | 61 | -2.13 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | 61 | 57 | -2.15 | 4 | 0.004 | 250.00 | 0.24 |

| | | | | | | | | | | | | |
|-----|--|--|--|--|--|------|------|---------|------|--------|----------|-------|
| 300 | | | | | | 57 | 48 | -2.215 | 9 | 0.009 | 111.11 | 0.54 |
| 300 | | | | | | 48 | 50 | -2.25 | -2 | -0.002 | -500.00 | -0.12 |
| 300 | | | | | | 50 | 50.5 | -2.2375 | -0.5 | -0.001 | -2000.00 | -0.03 |
| 300 | | | | | | 50.5 | 37 | -2.3025 | 13.5 | 0.014 | 74.07 | 0.81 |
| 300 | | | | | | 37 | 27 | -2.42 | 10 | 0.010 | 100.00 | 0.60 |
| 300 | | | | | | 27 | 26 | -2.475 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | | | 26 | 26 | -2.48 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | | | 26 | 26 | -2.48 | 0 | 0.000 | #DIV/0! | 0.00 |
| 300 | | | | | | 26 | 27.5 | -2.4725 | -1.5 | -0.002 | -666.67 | -0.09 |
| 300 | | | | | | 27.5 | 28 | -2.4625 | -0.5 | -0.001 | -2000.00 | -0.03 |
| 300 | | | | | | 28 | 26 | -2.47 | 2 | 0.002 | 500.00 | 0.12 |
| | | | | | | | | | | | #DIV/0! | 0.00 |
| 300 | | | | | | 38 | 34 | -2.38 | 4 | 0.004 | 250.00 | 0.24 |
| 300 | | | | | | 34 | 29 | -2.425 | 5 | 0.005 | 200.00 | 0.30 |
| 300 | | | | | | 29 | 28 | -2.455 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | | | 28 | 27 | -2.465 | 1 | 0.001 | 1000.00 | 0.06 |
| 300 | | | | | | 27 | 25.5 | -2.4775 | 1.5 | 0.002 | 666.67 | 0.09 |
| 300 | | | | | | 25.5 | 24 | -2.4925 | 1.5 | 0.002 | 666.67 | 0.09 |
| | | | | | | | | | | | | |
| 400 | | | | | | 112 | 107 | -2.645 | 5 | 0.005 | 200.00 | 0.30 |
| 400 | | | | | | 107 | 106 | -2.675 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 106 | 101 | -2.705 | 5 | 0.005 | 200.00 | 0.30 |
| 400 | | | | | | 101 | 103 | -2.72 | -2 | -0.002 | -500.00 | -0.12 |
| 400 | | | | | | 103 | 102 | -2.715 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 102 | 102 | -2.72 | 0 | 0.000 | #DIV/0! | 0.00 |
| 400 | | | | | | 102 | 102 | -2.72 | 0 | 0.000 | #DIV/0! | 0.00 |
| 400 | | | | | | 102 | 101 | -2.725 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 101 | 100 | -2.735 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 100 | 103 | -2.725 | -3 | -0.003 | -333.33 | -0.18 |
| 400 | | | | | | 103 | 102 | -2.715 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 102 | 101 | -2.725 | 1 | 0.001 | 1000.00 | 0.06 |
| 400 | | | | | | 101 | 98 | -2.745 | 3 | 0.003 | 333.33 | 0.18 |
| 400 | | | | | | 98 | 100 | -2.75 | -2 | -0.002 | -500.00 | -0.12 |
| 400 | | | | | | 100 | 100 | -2.74 | 0 | 0.000 | #DIV/0! | 0.00 |
| 400 | | | | | | 100 | 100 | -2.74 | 0 | 0.000 | #DIV/0! | 0.00 |

75 mm Button Bit

50 mm button bit

| | | | | | | | | | | | | |
|-----|--|--|--|--|-----|-----|--------|----|--------|----------|-------|-------|
| 400 | | | | | 100 | 100 | -2.74 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 100 | 102 | -2.73 | -2 | -0.002 | -500.00 | -0.12 | -0.12 |
| 400 | | | | | 102 | 103 | -2.715 | -1 | -0.001 | -1000.00 | -0.06 | -0.06 |
| 400 | | | | | 103 | 101 | -2.72 | 2 | 0.002 | 500.00 | 0.12 | 0.12 |
| 400 | | | | | 101 | 98 | -2.745 | 3 | 0.003 | 333.33 | 0.18 | 0.18 |
| 400 | | | | | 98 | 100 | -2.75 | -2 | -0.002 | -500.00 | -0.12 | -0.12 |
| 400 | | | | | 100 | 100 | -2.74 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 100 | 101 | -2.735 | -1 | -0.001 | -1000.00 | -0.06 | -0.06 |
| 400 | | | | | 101 | 99 | -2.74 | 2 | 0.002 | 500.00 | 0.12 | 0.12 |
| 400 | | | | | 99 | 98 | -2.755 | 1 | 0.001 | 1000.00 | 0.06 | 0.06 |
| 400 | | | | | 98 | 98 | -2.76 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 98 | 98 | -2.76 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 98 | 98 | -2.76 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 98 | 99 | -2.755 | -1 | -0.001 | -1000.00 | -0.06 | -0.06 |
| | | | | | | | | | | | | |
| 400 | | | | | 73 | 70 | -3.025 | 3 | 0.003 | 333.33 | 0.18 | 0.18 |
| 400 | | | | | 70 | 68 | -3.05 | 2 | 0.002 | 500.00 | 0.12 | 0.12 |
| 400 | | | | | 68 | 66 | -3.07 | 2 | 0.002 | 500.00 | 0.12 | 0.12 |
| 400 | | | | | 66 | 57 | -3.125 | 9 | 0.009 | 111.11 | 0.54 | 0.54 |
| | | | | | | | | | | | | |
| 400 | | | | | 57 | 58 | -3.165 | -1 | -0.001 | -1000.00 | -0.06 | -0.06 |
| 400 | | | | | 58 | 57 | -3.165 | 1 | 0.001 | 1000.00 | 0.06 | 0.06 |
| 400 | | | | | 57 | 57 | -3.17 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |
| 400 | | | | | 57 | 57 | -3.17 | 0 | 0.000 | #DIV/0! | 0.00 | 0.00 |

Friday

Saturday

Valve worn out

Mean Drill Time for 100 Strokes

10

P/W Hard Rock - Penetration Log

