

BRITISH GEOLOGICAL SURVEY
Natural Environment Research Council

TECHNICAL REPORT WD/91/27R

Hydrogeology Series

Technical Report WD/91/27R

Report on a Visit to Zimbabwe
20th to 30th April 1991

P J Chilton

This report was prepared
for the Overseas
Development Administration

BRITISH GEOLOGICAL SURVEY

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EXECUTIVE SUMMARY

The first collector well at the Lowveld Research Station at Chiredzi continues to operate successfully, pumping usually for one or two short periods per week to provide several thousand litres of water for the irrigation experiments. The programme of hydrogeological observations at and around the well continues. The report on the siting, construction, testing and operation of the well has been completed and distributed.

Potential sites for the first collector well off the station in the communal lands were chosen in April 1990 and the site at Tamwa Kraal was confirmed as suitable by exploratory drilling in May 1990. Well digging commenced in May, and the well was completed to 12.0 m in July 1990. Radial drilling was delayed by activities in other BGS research projects in Zimbabwe (collector wells in alluvium, hydrofracturing and borehole siting), and was carried out in March 1991. Test pumping before and after the drilling of the radial collectors suggests that the yield has in this case not been dramatically improved by the drilling. Nevertheless, a long-term (7 day) test was carried out in April 1991 at a discharge rate of 0.78 l/sec.

The well has been completed by the installation of two Bush pumps (handpumps). Arrangements will be made to meter abstraction for irrigation and domestic use, and a programme for monitoring the performance of the well was agreed. Preliminary estimates of the total costs of the well, including pumps, suggest a figure of about Z\$25,000.

Additional exploratory drilling has been undertaken at the Lowveld Research Station to determine the configuration of the groundwater table at the site. Preliminary analysis of the data obtained from this and the previous exploratory drilling suggests that groundwater levels may be elevated in the south-west part of the station, possibly by enhanced recharge from the irrigated sugar fields or the irrigation on the station. Water samples were collected for chemical and isotope analysis as a further method of studying the origins of groundwater under the station.

Progress with other BGS research in Zimbabwe was discussed with the BGS contract driller and the Ministry of Water Resources Development. The next stage of fieldwork on the collector wells in alluvium was about to commence, and arrangements were made for Dr Herbert to go to the site during his visit to Zimbabwe in May. Core drilling for the BGS Keyworth borehole siting project was visited and the logistical arrangements for this project were discussed with Ministry of Water Resources Development.

The TC proposal for developing small-scale irrigation from collector wells in communal lands remains with BDDSA and is being edited after revisions from IH and BGS.

1. INTRODUCTION

The Lowveld of Zimbabwe is the location for field activities in the project "Development of Limited Groundwater Resources for Small-Scale Irrigation". The project is a joint one between BGS and IH and IH have a member of staff resident at Chiredzi. Regular short visits are made by staff of both institutes, BGS concentrating on the hydrogeological aspects of the work and IH on the irrigation.

The Hydrogeology Group of BGS has another project in Zimbabwe entitled "Development of Horizontal Drilling for Alluvial Aquifers", with present field activities at Lupane in the Gwai River area of NE Zimbabwe. A third project, "Assessment of Hydraulic Fracturing in the Basement Aquifer of Zimbabwe" was carried out in 1990-91. This has been reported on, and a possible TC project has been developed from it. Regular BGS visits (by either R Herbert or J Chilton) review activities in these projects, in consultation with the Ministry of Water Resources Development (MWRD) and the British High Commission.

2. OBJECTIVES OF VISIT

The principal objectives of the present visit were to:

- (a) collect all technical data and information on costs from the construction, horizontal drilling and testing of the collector well at Tamwa Kraal. This will be incorporated into a report similar to the one on the collector well at Chiredzi (BGS Report WD/90/20),
- (b) collect monitoring data from the collector well at LRS and review the performance of the well,
- (c) discuss the approach to monitoring the performance of the well at Tamwa Kraal,
- (d) collect data from the additional drilling at LRS Chiredzi, which was carried out to determine the configuration of the local water table beneath the station,
- (e) collect water samples for chemical and stable isotope analyses.

Additional general objectives related to BGS activities in Zimbabwe were to:

- (f) review progress on the project to develop collector wells in alluvium, with especial reference to planning the timing of a visit by Dr Herbert,
- (g) discuss all current BGS Hydrogeology Group activities in Zimbabwe and proposed new activities (the TC small-scale irrigation project and a new hydrofracturing proposal) with MWRD and the British High Commission.

The visit had been intended to coincide with the long-term test on the collector well at Tamwa Kraal, but in the event commitments in UK meant that the visit came immediately after the completion of the test. It remained timely, however, in relation to the objectives outline above.

3. ITINERARY

19/20 April London Heathrow to Harare.

20 April Collected BGS Landrover in Harare and drove to Chiredzi.

- 21 April Report writing for another project. Discussions with BGS driller.
- 22 April Review data obtained from Tamwa collector well and additional drilling at LRS, Chiredzi. Visit drilling sites. Collect water samples for chemical and isotope analysis.
- 23 April Local leave.
- 24 April Discussions of programme for BGS driller. Logging lithological samples for boreholes and wells at Tamwa Kraal. Collect water samples. Peter Rastall left for Masvingo to prepare for fieldwork at Lupane.
- 25 April Report writing. Visit to collector well at Tamwa Kraal with Chris Lovell and Monica Murata. Collect water samples.
- 26 April Collect water samples and measure water levels in exploratory boreholes at LRS. Produce first draft of contours of piezometric level. Discuss monitoring of Tamwa collector well.
- 27 April Chiredzi to Masvingo to meet up with Peter Rastall. Visit to inclined coring at Nemarundwe.
- 28 April Masvingo to Harare.
- 29 April Meetings with MWRD and British High Commission. Making arrangements for Dr Herbert's visit. Visit to MWRD workshop and stores at Eastlea.
- 30 April Return to MWRD to enquire about progress with import licenses.
- 30 April/1 May Harare to London Heathrow.

4. PEOPLE MET

BRITISH HIGH COMMISSION (BHC)

David Ward, First Secretary, Aid

LOWVELD RESEARCH STATION (LRS)

Dr Chris Lovell, IH Agrohydrology Section
 Emlyn Jones, TC Agriculturalist
 Michael Brown, TC Agricultural Economist
 Monica Murata, Agronomist

MINISTRY OF WATER RESOURCES DEVELOPMENT

George Nhunhama, Chief Hydrogeologist
 Michael Mtetwa, Hydrogeologist
 Peter Rastall, BGS Contract Driller

5. COLLECTOR WELL AT TAMWA KRAAL

This section of the report summarises the results from the collector well at Tamwa Kraal. Fuller details and interpretation of the results of the test pumping, and full breakdown of the costs will be given in a technical report similar to the one produced for the well at Chiredzi.

5.1 Siting and Construction

The site at Tamwa Kraal was initially selected in April 1990. Great interest had been expressed in the idea of developing vegetable gardens, and the people of the village had requested and received help from their extension worker in identifying an area suitable for a communal garden. Exploratory drilling was carried out in 1990. Four boreholes were constructed to depths of 17.0 m. Water was encountered at 8-16 m and the rest water level at the site was in the range 2 to 3 m (Table 1). Drilling samples were retained at one metre intervals and logged on the present visit. The strongly confined groundwater conditions confirm the clayey nature of material encountered in the drilling.

Table 1. Results of Exploratory Drilling at Tamwa Kraal

Borehole Number	Drilled Depth (m)	Water Struck (m)	Rest Water Level (m)
1	13.0	8.0	2.0
2	17.0	10.0	3.0
3	15.0	10.0	3.0
4	17.0	16.0	2.0

A site for the collector well was selected close to borehole 3. Digging commenced in May, using four local labourers and a supervisor, and supervised by the BGS contract driller. The formation consisted of weathered and broken gneiss, becoming harder towards the base of the well. Samples of the excavated material were logged and some pieces were taken to BGS for full petrographic description. Water was first encountered at 9.0 m. The first Armco lining was inserted when the well had reached 4.0 m. The well was completed to 12.0 m in mid July. Fifty-two working days had been required to complete the digging and a further 12 to complete the headworks.

5.2 Radial Drilling

The radial drilling was carried out in late March. Four horizontal laterals were constructed in order, starting from the SW and then SE, NE and NW. The first encountered soft, weathered material for 5 m and then hard rock to 24 m with fractures about every two metres. There was little water inflow from this lateral. The second was soft to 4 m and weathered to 26 m with many fractures and a good inflow of water. The third was in hard rock to 2 m and then moderately weathered material. Drilling was halted at 20 m because of difficult, dry dusty conditions. However, after standing for about an hour, a steady inflow of water developed. The fourth lateral encountered hard rock to 8 m with several large fractures and solid hard rock from 8 to 16 m. The first 8 m provided an inflow of water to the well.

5.3 Well Testing

Two pumping tests were carried out on the well before the radial drilling:

	<u>20 March</u>	<u>21 March</u>
Static water level (bd)	5.70 m	5.84 m
Duration of pumping	70 mins	100 mins
Pump discharge rate	0.6 l/sec	4.38 l/sec
Final water level	6.36 m	11.60 m
Final drawdown	0.66 m	5.76 m
25% recovery	160 mins	230 mins
50% recovery	350 mins	560 mins
75% recovery	1200 mins	1300 mins

After the radials have been completed, the standard procedure is to carry out a test in which the water level is drawn down to pump suction (similar to the test on 21 March), followed by a longer test at a lower pumping rate to simulate a possible operating schedule for the well. The former is compared to the similar test performed before the radial drilling and the latter is used to assess the long-term sustainable yield of the well.

4 April

Static water level (bd)	5.92 m
Duration of pumping	100 mins
Pump discharge rate	4.38 l/sec
Final water level	11.37 m
Final drawdown	5.45 m
25% recovery	210 mins
50% recovery	540 mins
75% recovery	1220 mins

Recovery from 11.35 m to 11.0 m took 40 minutes after the radial drilling, compared to 50 minutes before. Similarly, recovery from 11.25 m to 9.50 m took 310 minutes after the radial drilling compared to 340 minutes before. The improvement in yield achieved by the radial drilling is less than at Chiredzi.

A long-term test was carried out from 12 to 18 April, following a strict daily regime of three two-hour pumping periods, separated by three hour recovery periods. The pump discharge rate was 0.78 l/sec. The water level in exploratory borehole 3, at a distance of 6.9 m from the centre of the collector well, was measured at the beginning and end of each day.

The well has been completed by the installation of two Bush handpumps mounted side-by-side on a frame across the well and a cover with brackets and housing for an autographic float-operated water level recorder. The well head was completed with a 2 m deep sanitary seal and narrow apron around the well.

5.4 Well Costs

Full details of the costs of all operations at Tamwa are being kept, and are summarised below. All costs are in Zimbabwe Dollars (5.1 Z\$ = £1).

Table 2. Preliminary Estimates of Well Costs

Month	Salaries	Diesel	Compressor	Misc.	Total
<u>Digging:</u>					
May 1990	388	63	-	-	451
June 1990	1461	630	2950	248	5,289
July 1990	523	210	-	180	913
					6,653
Plus 12 m of Armco lining:					7,514
					14,167
<u>Radial Drilling:</u>					
March 1991	320	1540	3750	80	5,690
<u>Test Pumping:</u>					
March/April 1991	250	210	1200	-	1,660
<u>Pump and Headworks:</u> (2 Bush pumps, rods, rising main pipes, bricks, cement and materials for frame and cover)					
					3,345
Total cost of well and pumps:					24,862

5.5 Hydrogeological Monitoring

It is anticipated that the collector well will be used for vegetable gardening from about the end of May. As at Chiredzi, monitoring the performance of the well under normal operating conditions is an important objective of the fieldwork, and the scope for such monitoring was discussed during the visit to Tamwa Kraal.

Monitoring of the amount of water abstracted is complicated as water will be used for domestic supply as well as irrigation. The two Bush pumps will discharge together into a small tank at the wellhead. Water meters will be installed to monitor domestic and irrigation outlets from this tank. A second storage tank has been constructed at the garden, about 150 metres downslope from the well.

Following the long-term test, the Munro float-operated water level recorder remains in place on the well. On the visit to Tamwa Kraal, the chairman of the garden committee was taught to change the charts and generally look after the recorder, under the general supervision of IH and LRS. The continuous record of water levels on a weekly scale is expected to provide a check on the lengths of time the well is operated, in addition to monitoring the effects of abstraction on water levels. If weekly changing proves difficult to maintain, then a monthly chart could be adopted, but this would not have sufficient resolution to provide information on pumping times. The quality of the groundwater will also be monitored. The suggested programme of monitoring is given in Table 3.

Table 3. Programme of Hydrogeological Data Collection at Tamwa Kraal

Measurement	Frequency	By Whom	From Date	Remarks
Water level in collector well	continuous	Chairman of garden committee	4/91	Munro recorder weekly chart IH/LRS to check
Well discharge	continuous	IH/LRS	5/91	Water for domestic use and irrigation separately metered
EC, chloride of well discharge	monthly	IH/LRS	5/91	
Water level in exploratory borehole 3	when visited	IH/LRS	4/91	As check on collector well water level
Full chemical analysis of well water	infrequent	BGS	4/91	Analysis at BGS

6. ADDITIONAL WORK AT LRS, CHIREZI

Discussion of the results obtained from the collector well at LRS (Chilton et al., 1991) suggested that consideration should be given to the representativeness of the site conditions there. The possibility of locally-enhanced recharge from the irrigated sugar estates to the south was discussed, and further work to investigate the question of local recharge sources was suggested.

Thus in March 1991, a further 20 shallow exploratory boreholes were drilled at selected points within the station (Figure 1) to provide additional data on depth to groundwater (Table 4). Three of these have been lined and are now included in the weekly water level network.

From the data in Table 4 it can be seen that water levels over much of the southern part of the station are particularly close to ground level, being within 1.5 to 2 metres under the area where the main irrigated trials are carried out. This must pose questions about the usefulness of the results obtained from the trials, especially for deep-rooting tree crops. The clayey nature of the subsoil and upper part of the weathered basement is indicated by the often substantial rises between the depth at which water is struck and the final rest water level, so the situation may not be as bad as appears at first sight. Nevertheless, it seems likely that regular irrigation over a long period of time has produced additional infiltration and a rise in water levels in this part of the station. As all but one of the exploratory boreholes remain open, there is merit in the station monitoring water levels under the irrigated part of the site for their own benefit, as well as in relation to the performance of the collector well.

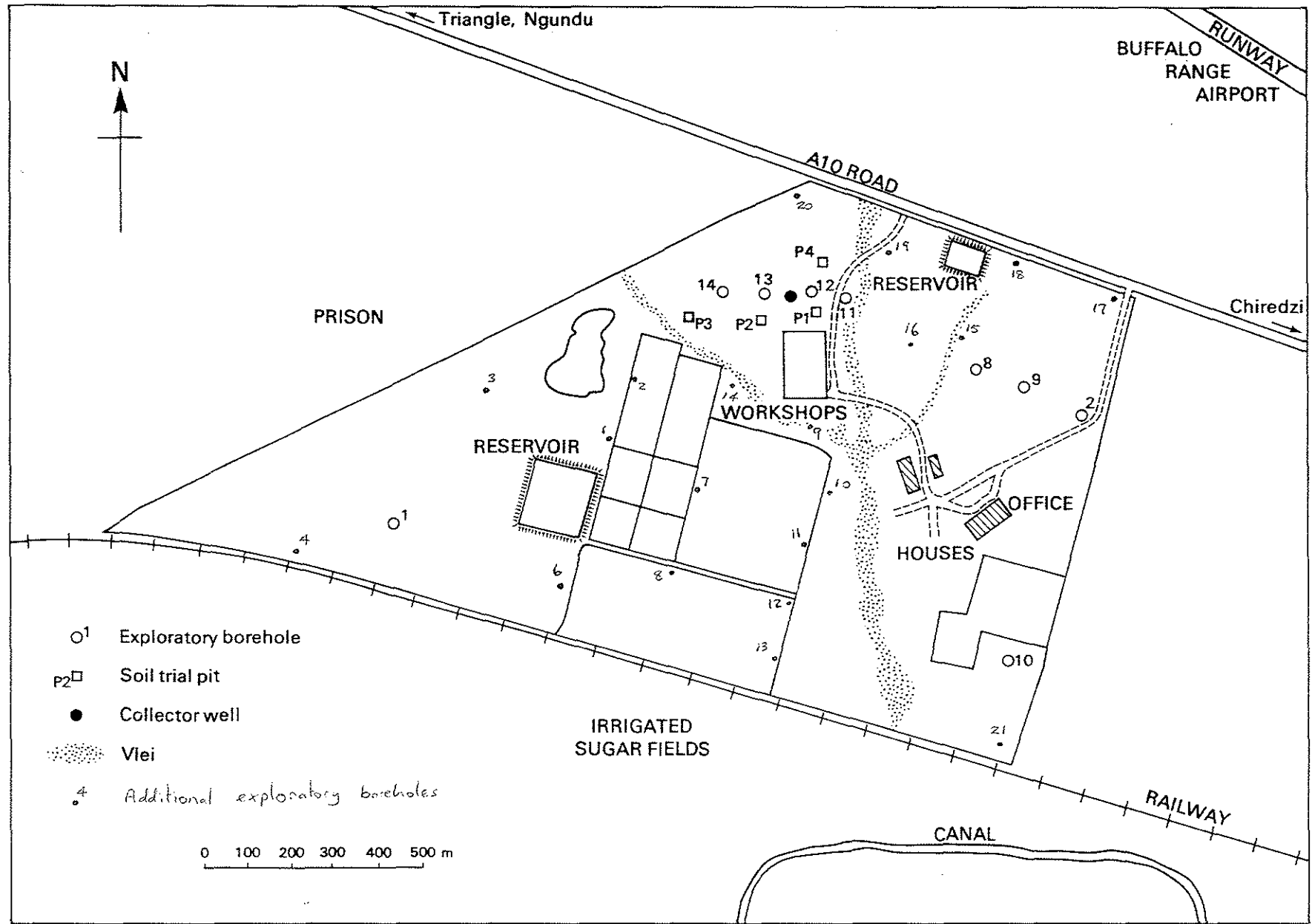


Figure 1. Locations of Additional Exploratory Boreholes.

Table 4. Additional Exploratory Drilling at LRS, Chiredzi

Borehole Number (A Series)	Drilled Depth (m)	Water Struck (m)	Rest Water Level, 3/91 (m)	Rest Water Level 26/4/91 (m)
1	7.5	5.0	2.75*	2.95*
2	11.0	11.0	3.25	3.52
3	7.5	7.5	4.60	4.80
4	16.5	16.5	4.00	4.35
6	3.75	3.75	1.53	1.71
7	4.50	4.50	1.97	2.22
8	4.50	4.50	1.40	1.60
9	11.25	11.25	1.30	1.22
10	3.75	3.75	1.67	1.90
11	10.50	10.50	2.22	2.47
12	3.75	3.75	1.95	2.25
13	6.75	4.75	2.24*	2.31*
14	4.25	4.25	2.00	2.20
15	10.50	10.50	5.72	5.65
16	8.25	8.25	4.19	blocked
17	9.75	9.75	7.65	7.75
18	12.00	12.00	6.65	6.60
19	12.00	12.00	5.57	5.67
20	28.50	28.50	8.25*	8.23*
21	15.00	15.00	6.27	-

Boreholes 1A, 13A and 20A have been incorporated in the monitoring network.

* corrected to ground level

Using a contour map of LRS with 5 feet vertical intervals, a preliminary attempt to plot water level contours from this new data and that from the existing boreholes indicates a hydraulic gradient from SW to NE in the southern part of the site and a gradient from north to south in the northern and eastern part of the site. Groundwater flow appears to be generally towards the vlei. However, the lowest groundwater levels appear to be offset to the east of the vlei, rather than coinciding with the present line of the vlei. This local water table configuration may be indicative of groundwater recharge from the irrigated sugarcane fields and/or from the irrigated part of the station and the storage reservoirs (Figure 1). The data will be examined further and the exploratory boreholes plotted more accurately to produce a groundwater level contour map.

Water samples were taken for chemical and stable isotope analysis from the collector well, from the canal and reservoirs on the station, from some of the new exploratory boreholes and from boreholes away from the station to give the regional groundwater chemistry. These were taken for analysis at BGS.

7. CORE DRILLING

En route from Chiredzi to Harare, a visit was made to the MWRD rig at Nemarundwe. The rig is carrying out inclined coring adjacent to a major geophysical anomaly identified in the Basement Aquifer Project, and which has been the subject of further intensive study in the BGS project "Development

of Techniques for Hydrogeological Mapping and Borehole Siting". Coring was in progress and had reached 8 m. The formation appeared hard and fresh and the rate of penetration was slow, several hours per metre. Core recovery was good, almost 100%, indicating soft grey, clayey topsoil and clay to 2 m, soft weathered gneiss to about 4 m and hard pale gneiss below that, in which fracture traces were clearly seen. While the crew were doing well at the time, overall progress had been slow due to a couple of breakdowns with the rig. At this rate of progress, the inclined coring is going to be a long programme, causing delay to the visit of Dr Greenbaum, who wishes to be in Zimbabwe towards the end of the coring programme to log the cores from all three sites in the study.

Additional geophysical fieldwork is also planned in the same project. The timing of this depends on obtaining temporary import licences for the equipment. Application for these is being made by MWRD, and the progress with this was discussed in Harare. MWRD has taken this up at high level with the Ministry of Finance, and the issue of the licences appeared to be imminent. The drilling of vertical, uncored holes for the geophysical studies was therefore being planned to commence in mid May, using one of the MWRD rigs.

8. COLLECTOR WELLS IN ALLUVIUM

At the site at Makusia School, additional test pumping had been proposed on an earlier visit by Dr Herbert. The intention was to pump the well at a very low discharge and measure water levels in the observation well. This had not been carried out because the cap of the exploratory borehole had been removed and stones thrown into the borehole. An attempt was made to clean it out with a rig, but it became stuck in the PVC lining. The hole had been filled with topsoil which had become wet clay, and this could not be drilled out. The Bush pump on the well was not working and there was also rubbish in the well. This was cleaned out, the pump repaired and a wire mesh cover constructed over the well.

Having completed the test pumping at Tamwa Kraal, Peter Rastall was preparing for the next stage of the programme on collector wells in alluvium. Equipment was prepared, the Bedford truck repaired and loaded and work at Lupane was due to commence from 1 May. Arrangements were made for Dr Herbert to go to Lupane during his visit to Zimbabwe in May.

9. TECHNICAL COOPERATION PROPOSALS

At the British High Commission, the First Secretary, Aid was briefed on progress on the work at Chiredzi and Tamwa Kraal. Additional copies of the BGS report (WD/90/20) on the collector well at Chiredzi were given to the High Commission and MWRD. The Technical Cooperation proposals for collector wells and hydraulic fracturing were discussed in general terms. The latter would be discussed again during the visit by Dr Herbert, and appointments were made for him at the BHC and MWRD. The TC proposal for 'Small-scale irrigation using collector wells' remains with BDDSA for final editing before formal submission.

MONITORING REPORT: ACTION SUMMARY SHEET

*NB This sheet should be kept prominently on file until all recommended action taken or otherwise dealt with
Then to be filed with Monitoring Report as Key Document*

Project / Programme	ODA Engineering Division Subvention R & D Development of Limited Groundwater Resources for Small-Scale Irrigation.
Name(s) of Monitor(s)	P J Chilton
Date of Monitoring Visit	20th to 30th April 1991

SUMMARY OF RECOMMENDED ACTION IN ORDER OF IMPORTANCE

Recommended Action	Recommended Timing	Action to be Initiated by	Recommendation considered; approved action (if any) taken (initials and date)	See Item
Finalisation of associated TC proposal on Development of Small-scale Irrigation.		BDDSA In discussion with BHC and if necessary IH/BGS.		9