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Norway

Project Title: **Capacity-Building and Institutional Cooperation in the Field of Hydrogeology for Faryab Province, Afghanistan**

Report Title:

Hydrogeological Investigations, Drilling and Testing Maimana Airport Aquifer, Faryab, Afghanistan

Version: F2.1

Status: Final

Issue Date: 10th May 2016

Client: Ministry of Rural Rehabilitation and Development (MRRD), RuWatSIP Department, Islamic Republic of Afghanistan

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Status		Final
Author	D Banks (Sections A,C,D), Andreas de Jong (Section B)	
Reviewed by: / date	D Banks / project team	November 2015

Abbreviations used in this report:

AGS = Afghan Geological Survey

AUWSSC = Afghan Urban Water Supply and Sewage Corporation (privatisation of CAWSS)

CAWSS = Central Authority for Water Supply and Sewage (reporting to MUDA). Now AUWSSC

FAO = Food and Agriculture Organization of the United Nations.

EC = electrical conductivity

GWM = groundwater monitoring point

IBE = ion balance error

m asl = metres above sea level

meq/L = milliequivalents (of ionic charge) per litre

mg/L = milligrams per litre

mmol/L = millimoles per litre

mOD = metres above Ordnance Datum (i.e. above sea level)

m bgl = metres below ground level

m bwt = metres below well top

MAIL = Ministry of Agriculture, Irrigation and Livestock

MoEW = Ministry of Energy and Water

MoM = Ministry of Mines

MUDA = Ministry of Urban Development Affairs

MRRD = Ministry of Rural Rehabilitation and Development

OBH = observation borehole

PBH1/PBH2 = production boreholes 1 and 2

RWL = rest water level (i.e. static groundwater level)

USGS = United States Geological Survey

WMO = World Meteorological Organization

WSG = Water and Sanitation Group (set up by UNICEF in Afghanistan)

1 Objective

The objective of this report is to summarise the results of hydrogeological investigations at sites in the vicinity of Maimana Airport, Faryab Province, Afghanistan, carried out in the period 2013-2015. This comprised:

- Hydrogeological appraisal (desk study). Part A of this report.
- Geophysical investigations. Part B of this report.
- Drilling. Part C of this report.
- Test pumping. Part D of this report.

2 Summary

Following a programme of desk study and geophysics, two exploratory production wells have been drilled in the alluvial aquifer to the west of Maimana Airport.

The first borehole, PBH1, was drilled to 106 m. The geology proved in the borehole did not tally with the prediction from the VES survey. The actual aquifer base was around 34 m, as compared with the predicted 73 m. It should, however, be noted that the borehole was drilled a short distance north of the VES sounding D14. The static water level was reported as 25 m bgl following drilling and as 30 m bgl on 25th September 2014.

The completed well was only constructed to a total depth of 62.4 m, with a string of 8" diameter PVC well casing and screen being emplaced. The screen section was positioned between depths of 27.3 and 35.1 m, within a strata section described as "clay and gravel". The hydrogeological properties of the well were poor, due to the main potential aquifer horizon (gravel/conglomerate) being located above the static water table level of 30 m.

The second borehole, PBH2, was drilled to 131 m. The geology proved in borehole PBH2 did broadly tally with the prediction from the VES survey. The actual aquifer base was around 76 m, as compared with the predicted 73 m.

The hydrogeological properties of the well appeared promising, with at least 50 m of gravelly aquifer strata below the static water level. A 130 m string of 8" diameter PVC well casing and screen was emplaced to complete the well.

Borehole PBH2 was subject to step and constant rate testing in May-June 2015, when the rest water level was c. 35.5 m bgl. Yields of up to 6.25 L/s were proven, with 2 hour drawdowns of less than 4 m.

In addition to the pumped borehole, the drawdown responses in two monitoring wells (at distances of 30 m and 65 m from PBH2) were analysed. The test suggested an aquifer transmissivity of c. 900 m^2/d and a dimensionless storage of 16-20%. The production well response indicated, however, a hydraulically inefficient well construction.

The groundwater from well PBH2 appears to be of a wholesome quality in terms of inorganic chemistry. Nitrate concentrations are modest (8-9 mg/L), but not negligible, suggesting that there may be some source of diffuse nitrogen pollution in the groundwater

The pumping test has failed to demonstrate conclusively that a large abstraction can be sustainably derived from the aquifer - indeed, the test has demonstrated the presence of negative boundary conditions near to PBH2. We would advise against further large-scale exploitation of the Maimana Airport aquifer until sources of recharge, and potential continuity with the Maimana River, are adequately identified and quantified.

Part A. Desk Study, Maimana Airport

Prepared July 2013 **(and cross-sections modified July 2014 on the basis of new borehole information)**

Author: David Banks

PRELIMINARY: DESK STUDY - MAIMANA AIRPORT STUDY SITE

v1.2 July 2013

A1 Location

The proposed study area is located immediately NW of Maimana city.

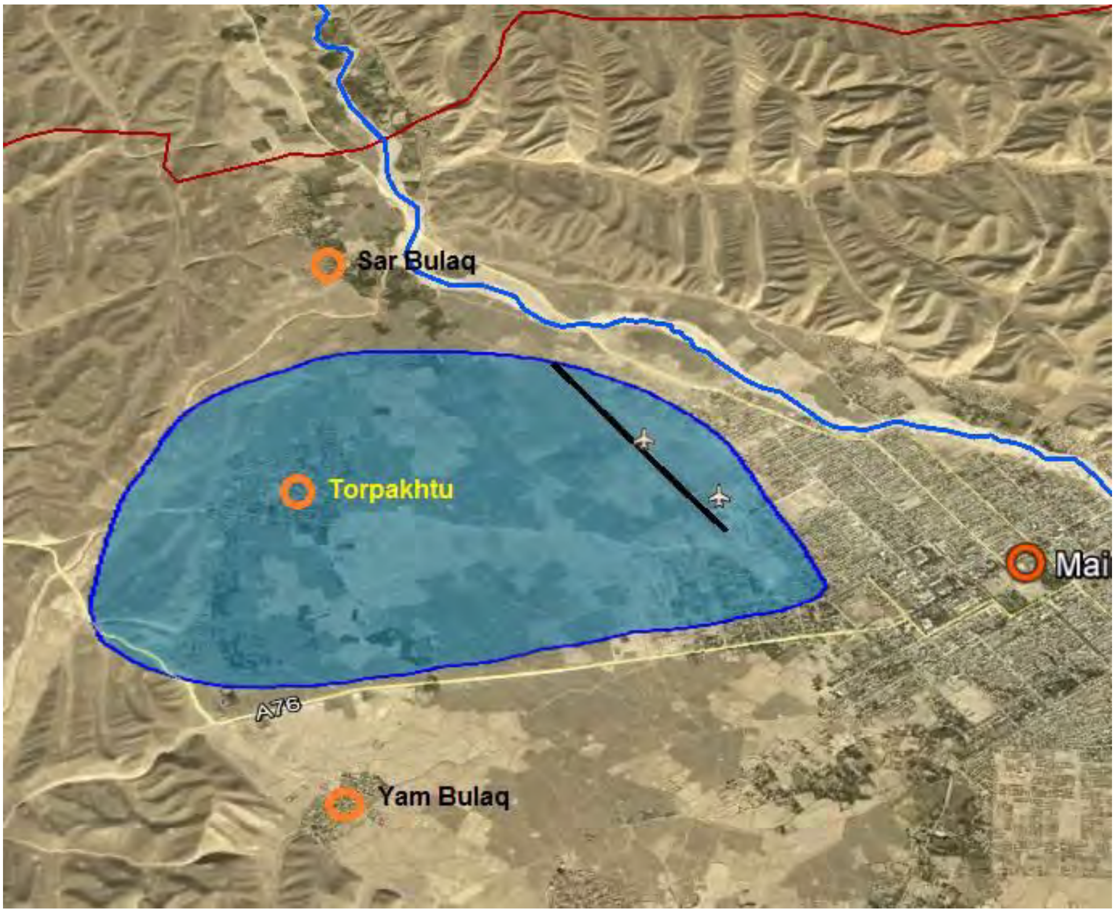

Figure A1. Location of Maimana study area (Google Earth). *(Airport runway shown as black line and is c. 1.65 km long). The blue line shows the Maimana River, flowing north.*

The study area occupies a flat plain, sloping gently from around 850 m asl in the west to around 830 m asl in the east, towards the Maimana River.

The southern end of the airport runway lies around 1.5 km NW of Maimana city centre.

The study area contains several inhabited villages, especially in the west, of which the largest is Torpakhtu. The study area is largely occupied by agricultural land.

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A2 Geology

The published Afghan Geological Survey / USGS maps show that the plain is underlain by Quaternary alluvial deposits of the Maimana River. These are described as:

Q_{34}a - Conglomerate and sandstone (Holocene and late Pleistocene) - Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay.

These alluvial deposits are underlain at unknown depth by Neogene sediments, described as

N_{1m}csl - Clay and siltstone (middle Miocene) - Brown clay, siltstone more abundant than sandstone, conglomerate, limestone.

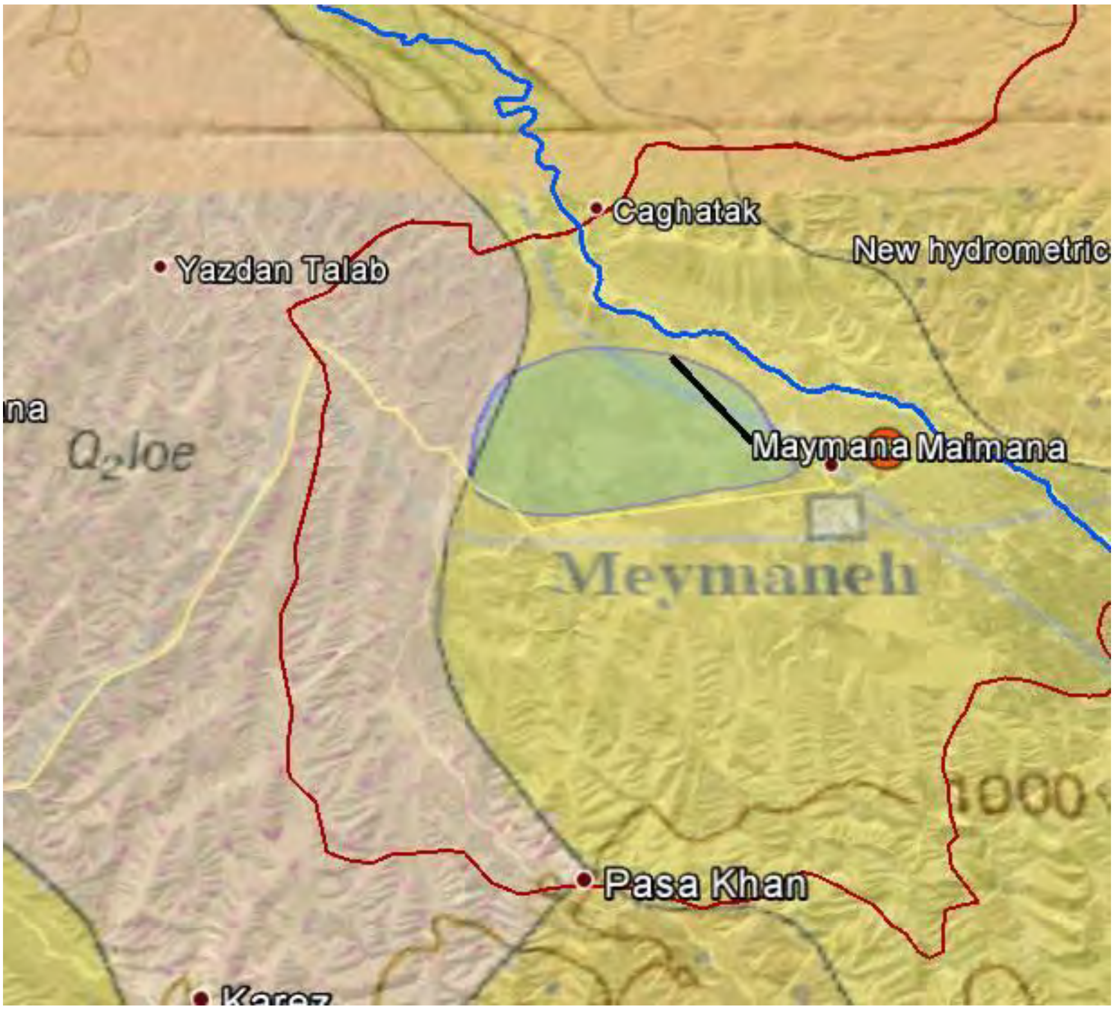

Figure A2. Geology of Maimana study area (Google Earth). *AGS / USGS geological maps overlaid. See key below.*

Q_{34}a	Conglomerate and sandstone (Holocene and late Pleistocene)—Alluvium: shingly and detrital sediments, gravel, sand more abundant than silt and clay	
Q_2loe	Loess (middle Pleistocene)—Loess more abundant than sand, clay	Q_2loe
N_{1m}csl	Clay and siltstone (middle Miocene)—Brown clay, siltstone more abundant than sandstone, conglomerate, limestone	N_{1m}csl

A3 Registered Wells

No dug wells are registered in the study area. Several are, however, registered in the valley of the Maimana River (Figure A3)

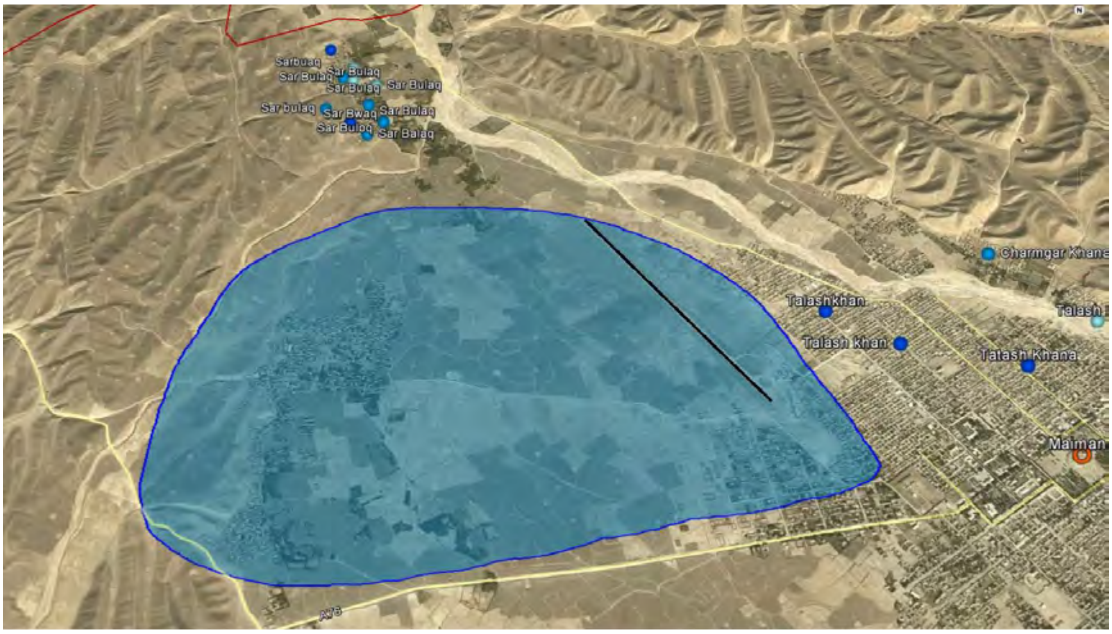

Figure A3. Registered dug wells in the Maimana study area (Google Earth).

There are, however, a number of drilled boreholes registered in and around the study area.

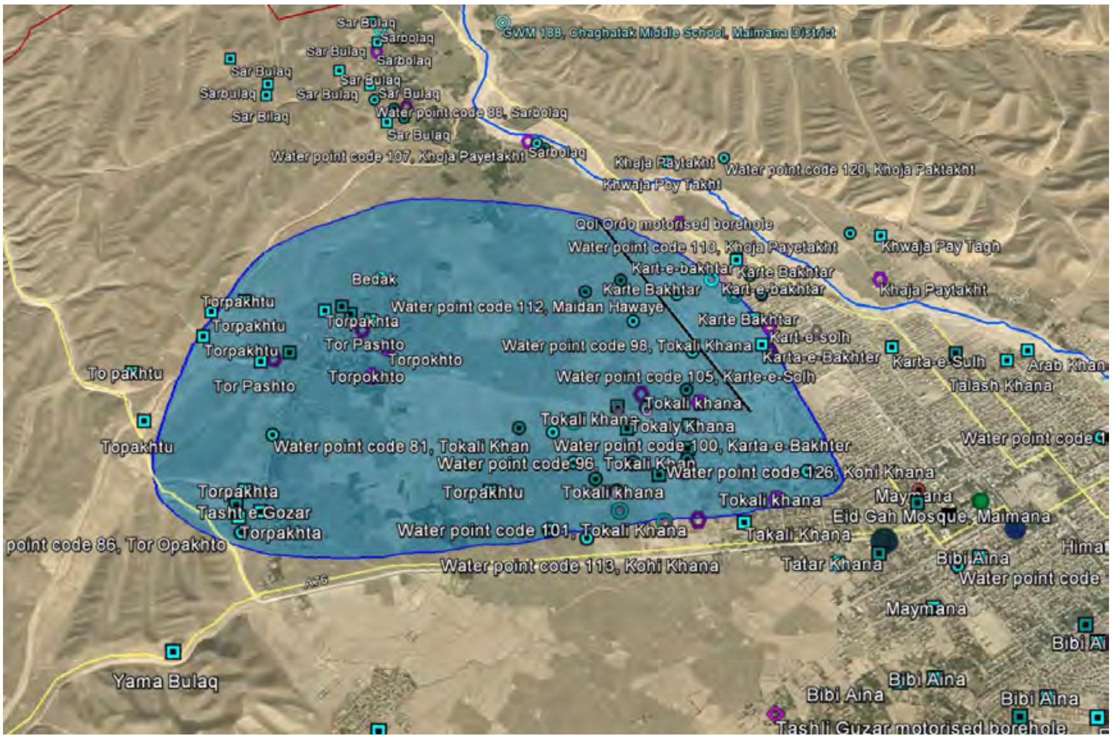

Figure A4. Registered drilled boreholes in the Maimana study area (Google Earth).

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Groundwater levels typically range from 40 m below ground level in the extreme west of the study area to around 30 m bgl in the east.. It should be noted that this appears to be **below** the level of the Maimana River, suggesting:

1) There is a degree of discontinuity between river and aquifer
2) The River is likely to be infiltrating water into the ground.

There are three groundwater monitoring wells in the near vicinity of the study area:

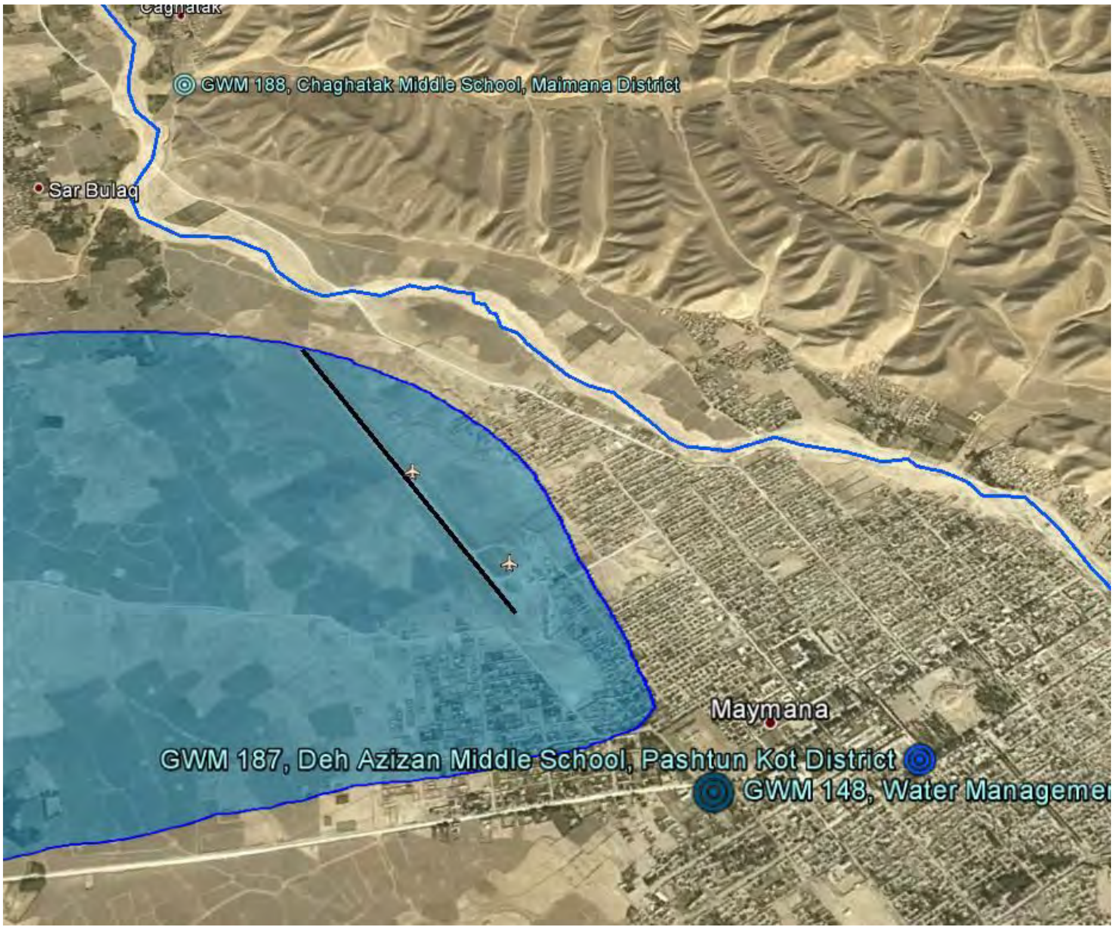

Figure A5. Registered groundwater monitoring boreholes near the Maimana study area (Google Earth).

GWM 148: Water Management Department, Maimana District is 52.5 m deep and has a typical water level of 38 m bgl.

GWM 187: Deh Azizan Middle School is 63 m deep and has a typical water level of 32 m bgl, and an electrical conductivity of 2030 µS/cm.

GWM 188: Chaghatak Middle School is 63 m deep and has a typical water level of 14 m bgl, and an electrical conductivity of 2300 µS/cm.

A4 Water quality

There is a considerable amount of data on electrical conductivity within the study area (Figure 6).

The majority of boreholes have are colour coded green (1203 - 1517 µS/cm) or yellow (1517 to 1996 µS/cm), implying a slightly brackish water quality, with conductivity in the range 1200 - 2000 µS/cm. In the extreme south-west of the area, higher conductivities of 2300-3600 µS/cm occur, maybe associated with the boreholes penetrating to the underlying Neogene sediments, at the edge of the Quaternary alluvial plain.

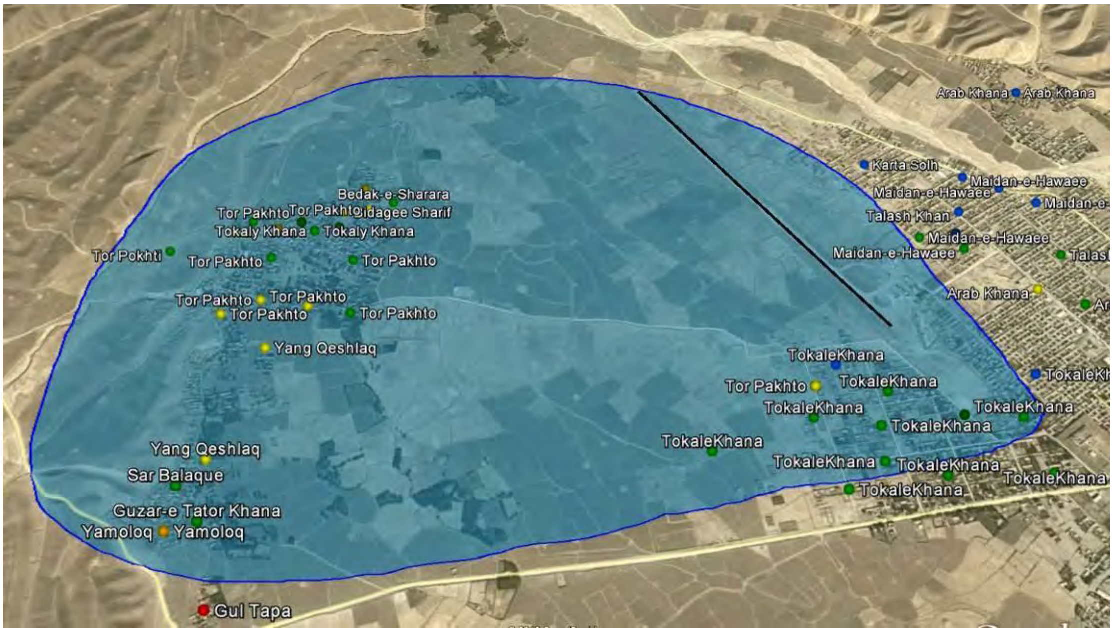

Figure A6. DACAAR groundwater electrical conductivity observations in the Maimana study area (Google Earth).

- Blue = <1203 µS/cm
- Green = 1203 - 1517 µS/cm
- Yellow = 1517 to 1996 µS/cm
- Orange = 1996 - 2950 µS/cm
- Red = 2950 - 5000 µS/cm

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A5 Meteorology

A considerable amount of data exists on the meteorology of Maimana. The World Meteorological Organization data from 1959-83 result in the graphs in Figures 7 and 8.

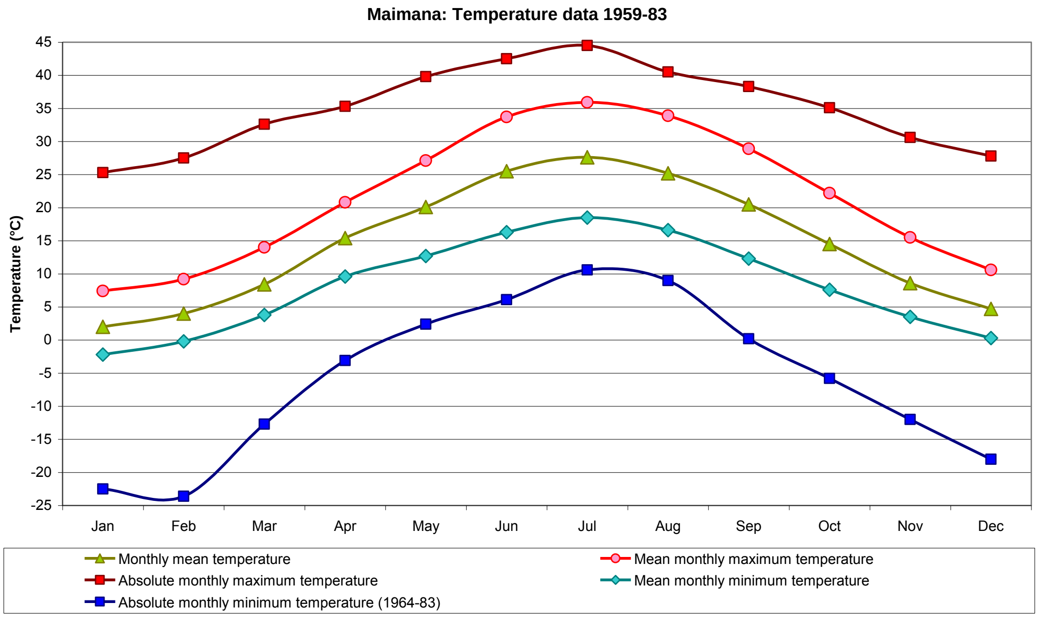


Figure A7. Monthly mean temperature data 1959-83 for WMO station 40922 Maimana.

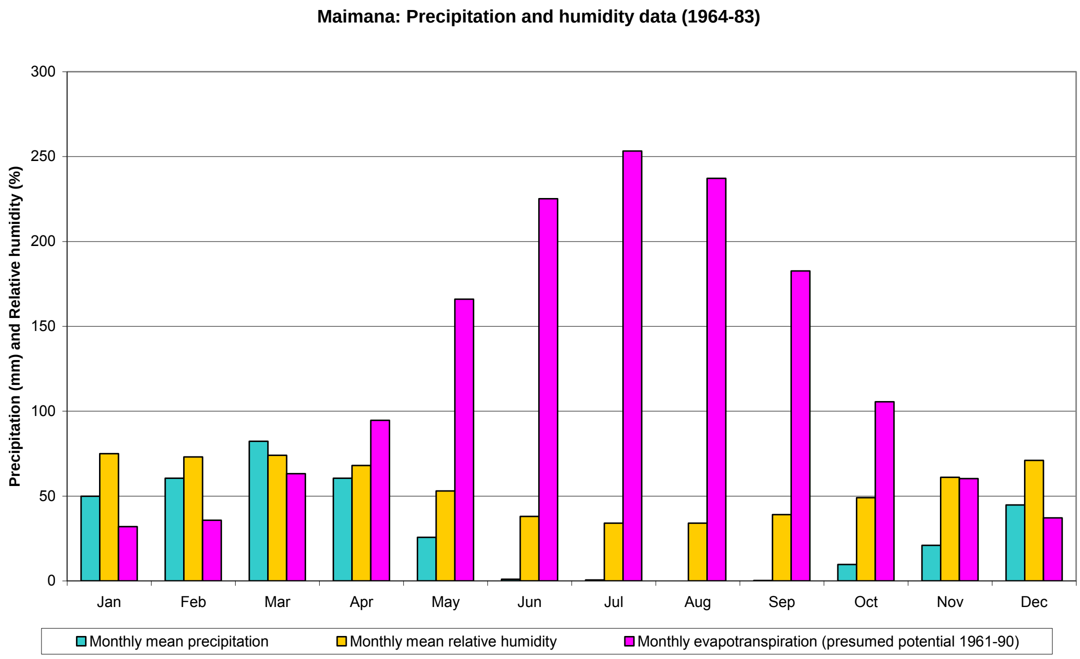


Figure A8. Monthly mean precipitation data 1964-1983 for WMO station 40922 Maimana.

Mean annual precipitation is around 356 mm and temperature around 14.7°C. The low precipitation and semi-arid climate suggest that opportunities for direct recharge of groundwater systems are very limited. Some opportunities for small amounts of direct recharge may exist in the wettest, coolest months (January and February) or during

snowmelt. The other potential source for groundwater recharge is infiltration from the Maimana River.

A6 Cross sections

Three geological cross-sections have been constructed as follows:

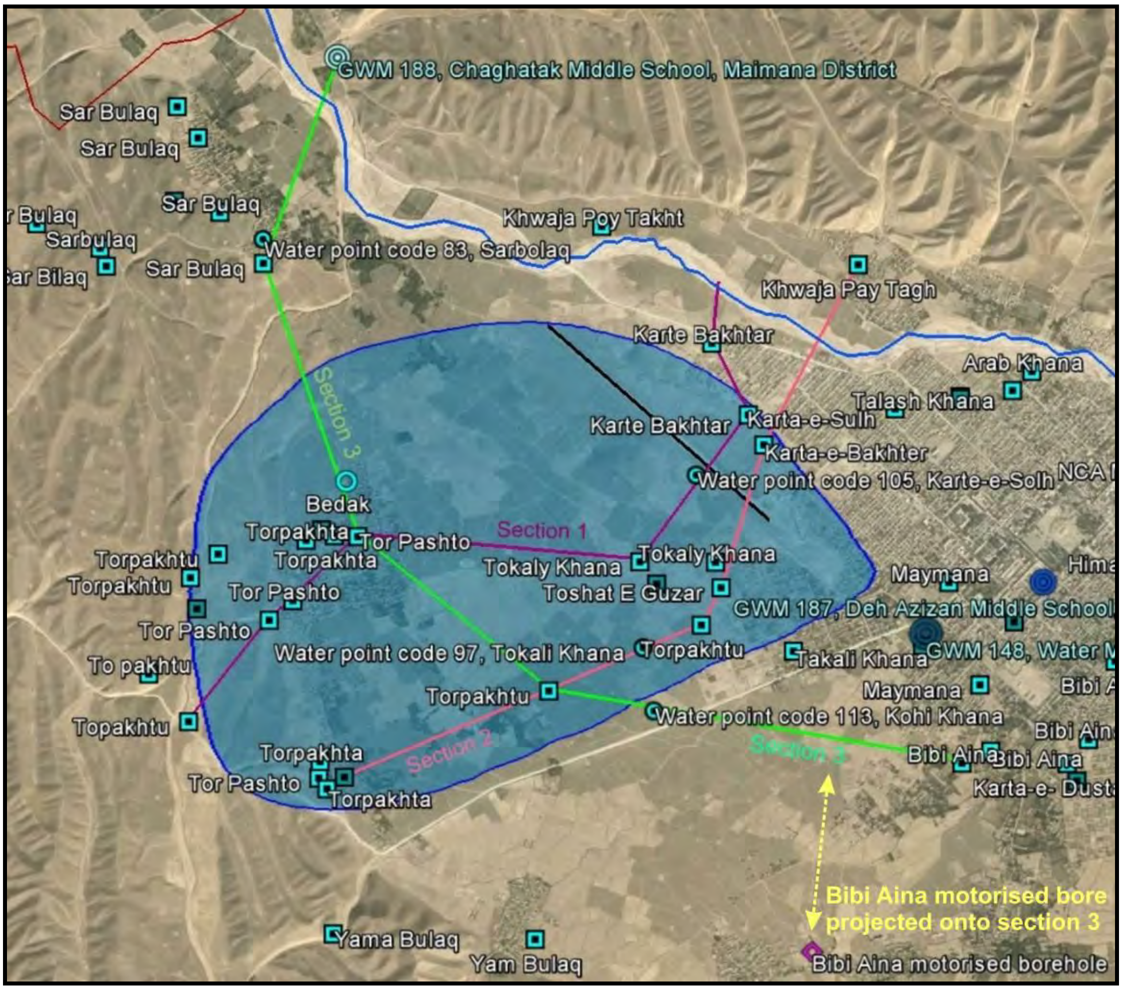


Figure A9. Locations of cross-sections 1-3 in study area Maimana (only selected boreholes are shown)*. Section 1 = purple, section 2 = pink, section 3 = green. North is up the page. Runway (black line = c.1.6 km). Note the Bibi Aina motorised borehole at the lower right of the frame, which has been projected onto Section 3.*

Cross section 1

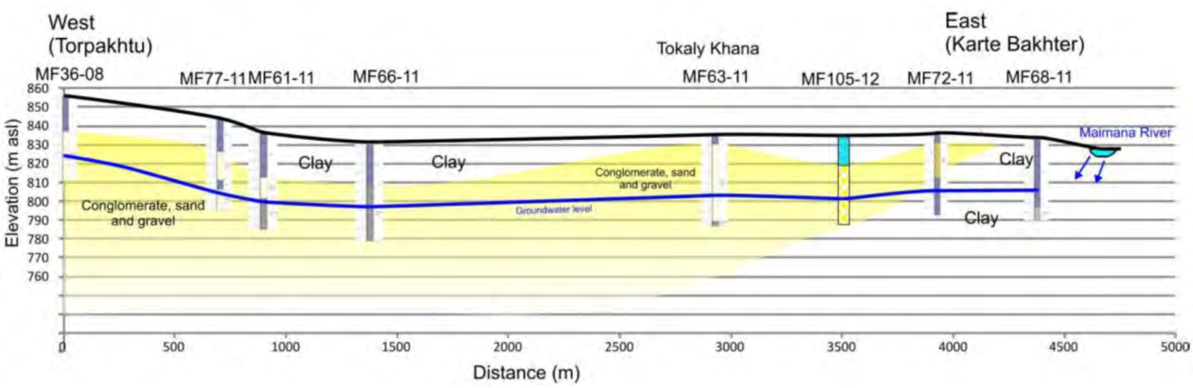


Figure A10. Cross section 1 of study area Maimana*. Elevation in m asl, horizontal distance in m.*

Cross section 1 suggests that, below the study area, there is an initial clayey layer of thickness < 20 m, underlain by a substantial gravelly/sandy aquifer unit, whose base has not been proved but which appears to be at least 30-40 m thick (saturated and unsaturated total thickness). This appears to disappear towards the east, to be replaced by clayey sediments (at least within the depth range of 50-60 m penetrated by the boreholes).

The groundwater level is around 30 m below ground level and appears to be below the elevation of the Maimana River, suggesting:

1) There is a degree of discontinuity between river and aquifer
2) The River is likely to be infiltrating water into the ground.

However, the sediments in the vicinity of the river are generally clayey, so the degree of river infiltration to the aquifer is likely to be rather limited.

Lack of good terrain elevation data renders the following observation very tentative, but it appears there is a slight slope of the groundwater level surface away from the Maimana River over much of the section, again suggesting an infiltrating river regime.

Cross section 2

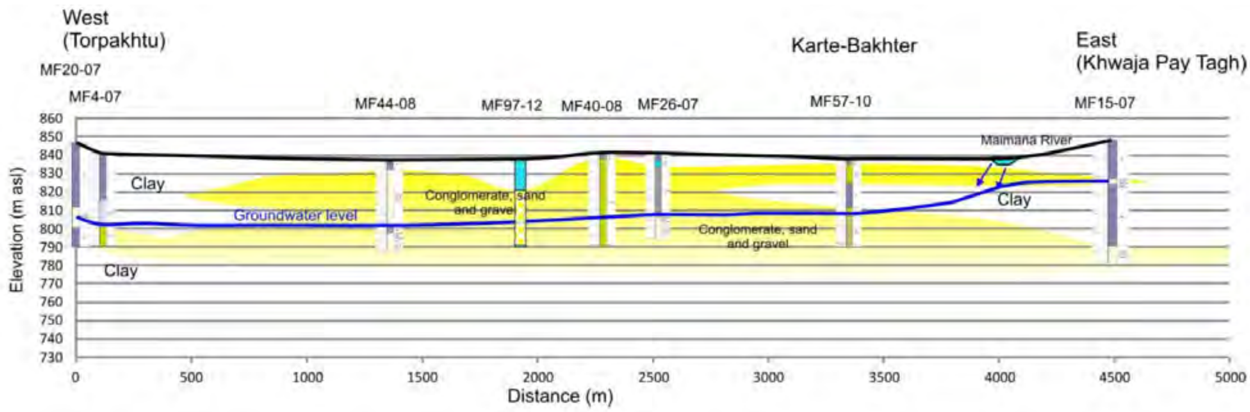


***Figure A11. Cross section 2 of study area Maimana**. Elevation in m asl, horizontal distance in m.*

The second east-west cross-section, cross-section 2 (Figure A11) broadly supports the findings of cross-section 1.

Cross section 3

The third cross section (Figure A12) is roughly north-south. The 200 m deep Bibi Aina production borehole, supplying water to a piped network in Maimana, and test pumped at 8 L/s with only 6 m drawdown (specific capacity 115 m2/d, likely transmissivity = c. 200 m2/d, average hydraulic conductivity based on 120 m aquifer thickness = c. 1.6 m/d) is projected onto the cross section (although it lies some distance to the south of the section - see Figure 9).

The Bibi Aina borehole encountered clayey-dominated strata with some gravels to 56 m depth, then a gravel aquifer to 185 m (at least 129 m good aquifer thickness, of which 120 m is saturated). At 185 m depth, the borehole encountered lower permeability Neogene deposits (although there is some debate amongst hydrogeologists regarding where the Quaternary - Neogene boundary is located in the borehole).

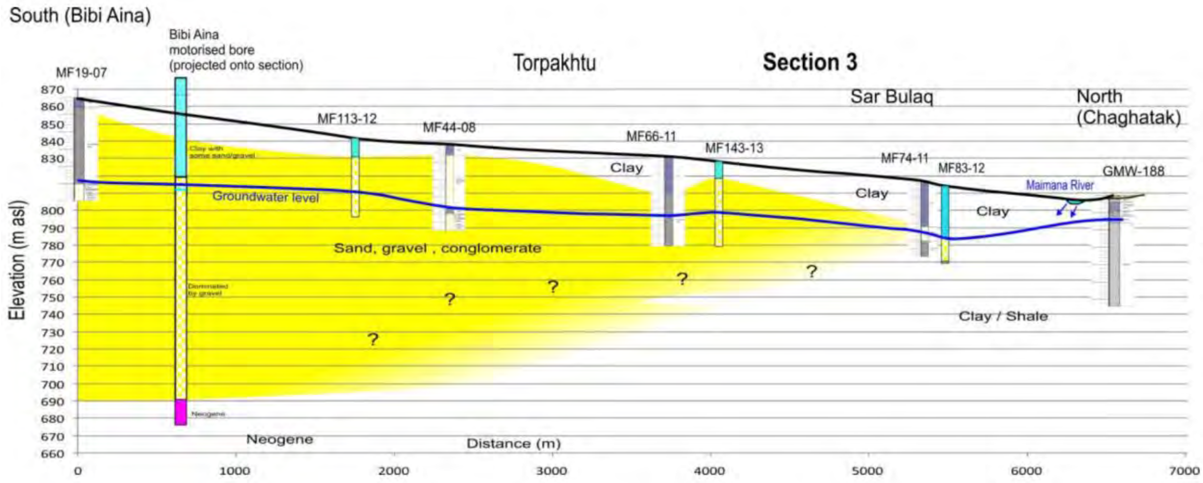


*Figure A12. **Cross section 3 of study area Maimana**. Elevation in m asl, horizontal distance in m.*

Cross section 3 also confirms that groundwater levels are below the level of the River Maimana.

Finally, the gravel aquifer seems to peter out (at least, at shallow depth) towards the River, in the region of Sar Bulaq, being replaced by clayey / shaley strata. The aquifer does not seem to extend, at shallow depth, to the eastern bank of the Maimana River.

A7 Conclusions

There appears to exist a substantial aquifer storage of moderately fresh to brackish groundwater below the study area in a Quaternary alluvial sand/gravel/conglomerate unit of thickness at least 30-40 m.

If the Bibi Aina borehole is representative of the Maimana Airport study area (including the rather tentative depth to Neogene), then the aquifer thickness could be in excess of 100 m. The aquifer's indicative transmissivity at Bibi Aina is around 200 m2/d, with hydraulic conductivity between 1 and 2 m/d on average.

The aquifer is overlain by clayey sediments ranging in thickness from a few metres to around 20 m.

The aquifer appears to be underlain by Neogene lower permeability materials at 185 m bgl at Bibi Aina (although the depth to Neogene is controversial). The Neogene may be encountered at shallower depths beneath the study area depending on the basement topography.

The aquifer is generally unconfined with groundwater levels typically a little over 30 m bgl in shallow boreholes.

The river-aquifer system seems to be characterised by downward vertical head gradients, with the Maimana River seemingly disconnected from regional groundwater heads and presumably with a tendency to infiltrate river water into the ground.

BUT the source of recharge to the aquifer is not clear.

- The climate (and the clayey overburden) means that opportunities for direct recharge are very limited.
- The aquifer tends to be separated from the Maimana River by lower permeability clayey materials.

Thus, a large question mark must be placed over the ultimately sustainability of major groundwater abstraction from this aquifer.

A8 Proposed Investigatory Programme

A8.1 Summer 2013

Send a field hydrogeological and geophysical team to Maimana to

1) Interview locals about possible deep motorised boreholes constructed recently in the area, possibly by Norwegian occupying forces based around Maimana Airport. NORPLAN to make enquiries regarding this in Norway.
2) Field team to locate and sample any such boreholes for chemical and isotopic composition.
3) Field team to carry out Water Features Survey within 1 km radius around study focus area (study focus area = orange area in Figure A13) and to locate any springs or karezes within 2 km of study focus area. Electrical conductivity to be determined at all visited boreholes.
4) Field team collect chemical and isotopic samples from up to 15 boreholes in and around study area, and in the potential infiltration zone (green area in Figure A13) near to the Maimana River. Electrical conductivity to be determined at all visited boreholes. To include deep Bibi Aina borehole. Samples to be sent to BGS England for analysis.
5) Identification of geophysical lines within study focus area (orange area in Figure A13). Obtain permissions and consent for geophysical survey.

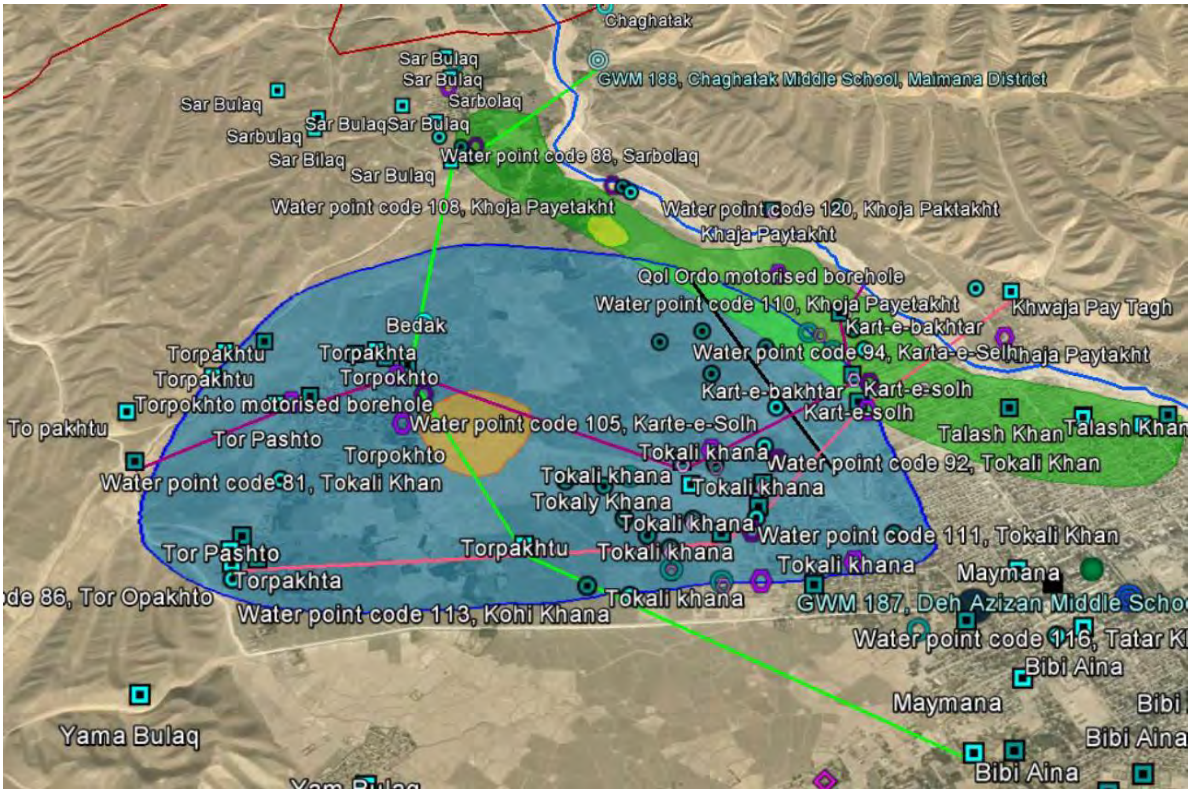


Figure A13. Orange area = proposed study focus area; green area = potential infiltration area from Maimana River; Yellow area = proposed area for observation borehole in infiltration area.

6) Identification of possible drilling sites for
   - 1 deep exploration borehole to up to 200 m within the study focus area (orange area in Figure A13).

- 1 observation borehole up to 120 m (depending on findings from deep exploration borehole), no more than 30 m distance from exploration borehole.
- 1 observation borehole to 50 m, no more than 30 m distance from exploration borehole.
- 1 observation borehole to 60 m in the zone of infiltration, in or near the yellow area in Figure 13.

- Obtain permissions and consent for drilling

7) **August-September 2013.** Geophysical survey [1] of study area using identified geophysical lines (Step 5). **Eng. Jalil (MRRD), possibly assisted by DACAAR.**

A8.2 Spring/Summer 2014

Drilling and test pumping program to commence

8) **April 2014.** Drilling of boreholes at study area. Tentatively:
   - 1 x exploration well to c. 200 m depth at 200 mm final diameter
   - 1 x Quaternary observation well up to 120 m (depending on findings from deep exploration borehole), at 150 mm final diameter.
   - 2 x Quaternary observation wells (1 and 3) to c. 50-60 m depth at 150 mm final diameter.
   - Sampling and geophysical logging of all boreholes.
   - Installation of 4 water level divers in boreholes
   - Installation of 1 barometric diver
   - Installation of river level gauging post in Maimana River
   - Possible installation of 1 water level diver in Maimana river, (within constructed, protected unit).
   - Accurate surveying (levelling) of all well-heads and Maimana gauging post.

9) **July 2014**. Test pumping and water sampling of all wells.
   - Clearance pumping.
   - Short term (6 hour) test of all 3 observation wells, with drawdown response being monitored.
   - Regular monitoring of electrical conductivity during test pumping.
   - Water sample from all 3 wells after 1 hour pumping and after 6 hours pumping.

10) **August 2014.** Test pumping of exploration well
   - Step testing of exploration well at 4 different rates
   - Constant rate testing of exploration well for at least 7 days (and possibly longer), with regular water sampling.
   - Recovery test of production well.

11) **August-September 2014.** Securement of all well heads and conversion to permanent monitoring facilities.

[1] At present, it is envisaged that the geophysical survey will comprise a systematic series of VES soundings along pre-agreed lines. Following the recommendations of Eng. Jalil and Dr de Jong, these may be upgraded to full 2-D resistivity profiles.

A8.3 Necessary purchases

- Surveying equipment (presumably already available from MRRD??) with 1 cm accuracy.
- Geophysical equipment and teams from MRRD or DACAAR
- Drilling rigs from MRRD capable of constructing 8" completed diameter holes to 200 m.
- Geophysical logging equipment
- 5-6 SWS water level divers with appropriate ranges.
- Flow meter gauging kit
- River gauging post
- Water sampling bailer / Waterra type hand sampling pump.
- Appropriate pumps (possibly two different types required, depending on well yield characteristics)
- Generator.

A8.4 After the Studies

It will be problematic to prevent the wells being utilised following the study. This would be especially difficult if private farmers take them into use for motorised irrigation. While the short term capacity of the aquifer may be high, we know nothing about the long-term capacity or sustainability. NORPLAN needs to develop a strategy to limit the unauthorised use of the wells following the study (e.g. restricting the diameter at the headworks and installing monitoring equipment).

Part B. Geophysical Investigations

Prepared March 2016

Author: Andreas de Jong

B1 Introduction

Surface geophysical surveys were conducted in the Maimana area for groundwater exploration during 2013, with the purpose of mapping the Quaternary aquifer for locating drill sites.

B2 Planning the Fieldwork

On the 13/10/2013 a detailed field work plan and budget was developed in Kabul by Andreas de Jong together with six staff from MRRD and DACAAR. The key issues agreed at that time were:

1. Two geophysical teams will be deployed to maximize productivity.
2. The survey will be carried out during November 2013.
3. For security reasons, travel to Faryab for staff will be by air. Heavy equipment to be transported by vehicle.
4. DACAAR should check if all available information has been included in the existing baseline survey, or if there is any other information available.
5. On arrival in Maimana, the field team should talk with:

a. The governor of the Province for an update on security issues. Security in Torpakhtu is “questionable”, and in Yam Bulaq it is “bad”. This needs to be verified, before the exact groundwater exploration area is fixed by the team.

b. The MRRD driller for local knowledge of the aquifers (e.g. MRRD has drilled a well in Torpakhtu three years previously).

6. A baseline survey needs to be carried out once the groundwater exploration area is fixed.
7. An important issue to address is who the potential beneficiaries are, or are we performing an academic study with monitoring wells which will be handed over to MEW? Water demand surveys should be carried out in nearby villages such as Torpakhtu, if it is safe to do so.
8. Fridays are rest days.
9. Following the baseline survey, the rest of the time will be spent on geophysics (estimated 12 working days). The approach should be:

   a. Calibration soundings near all wells where good geological logs are available e.g. the Bibi Aina borehole.

   b. 3 – 5 profile lines will be surveyed, starting at the Maimana River and extending perpendicularly to the river across the survey area. Resistivity profiles can be carried out at one or two places near the river to check for rapid lateral changes, but mostly we are looking for regular VES soundings along the profiles. Try to choose profiles which run close to existing wells that can be used as calibration soundings.

   c. The VES arrays should be centred on the profile line, and perpendicular to the profile if possible. However, if there are straight roads or other features that make the survey easier, these can be followed.

10. We should view this field survey as a training exercise for groundwater exploration techniques. It is unclear who the beneficiaries are at this stage, but this should become clearer during the baseline survey. The geophysics will be followed up by exploration drilling so it is important to think about the whole conceptual hydrogeological model of the area – what are the potential pollution sources etc.

#	Project		October							November																				
			Week 43							Week 44							Week 45							Week 46						
		Day	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
		Date	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Mobilisation Kabul - Maimana	1																												
2	Meetings Administration Faryab	1										?																		
3	Baseline Survey	3													?															
4	Geophysical Survey	12																												
5	Rest days	2																												
6	Demobilisation Maimana - Kabul	1																												
	Total days	**20**																												

Figure B1. Geophysical Survey Work Plan for November 2013

B3 Fieldwork

The resistivity survey was carried by two field teams staffed by DACAAR and MRRD field geophysicists, using SYSCAL Pro resistivity equipment from IRIS Instruments of France. The field teams had received practical training in the execution of resistivity surveys and data interpretation in Kabul by NORPAN during June 2013.

Vertical Electrical Soundings (VES) were carried out in the Schlumberger array with AB/2 spacing of up to 300m, and all data plotted in the field on MRRD field sheets. Plotting of the calculated apparent resistivity on graph paper was an important quality control tool to identify bad data points in the field and decide if any readings needed to be repeated.

The field survey achieved 50 VES, of which 23 were completed by the DACAAR field team, while the MRRD team completed 27 VES.

(a) The MRRD Geophysical Field Team

(b) The SYSCAL Pro resistivity equipment

Figure B2. Photographs from field work

B3.1 Fieldwork Issues

<u>Health & Safety</u>: Security was a major issue and the project had to be adjusted according to which areas were safe to work in. There were communication problems with the government officials and the field teams. On one occasion, DACAAR carried out geophysics over a mine field - fortunately, nobody was hurt. There were technical problems with contact resistance between the electrodes and the ground in several locations. This could be overcome by applying salty water to the electrodes.

<u>Field data quality:</u> Overall the field data was of a satisfactory quality, but in some soundings the MN spacing was not accurate and had to be corrected during the interpretation. There were also numerous typing errors of the coordinates. It was

recommended that, in the future, coordinates should be hand written on the field sheets as a backup, and always transferred electronically from the GPS to avoid typing errors.

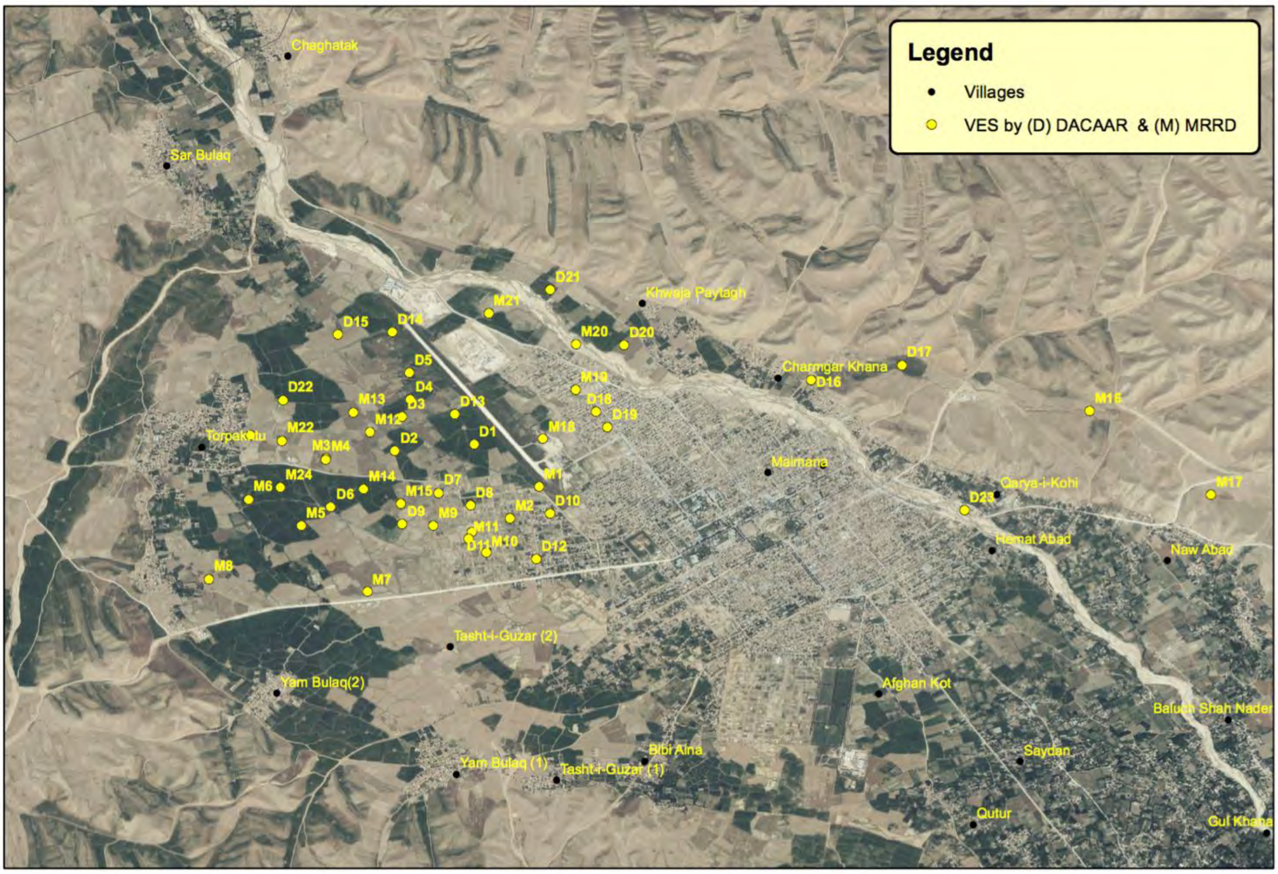


Figure B3. Locations of Vertical Electrical Soundings (VES) *(Source: DACAAR)*

B4 Data Interpretation

From 24th to 26th May 2014 a three-day practical workshop was run by NORPLAN in Kabul (Course 1.12: *Practical Interpretation of Geophysical Data*) to interpret the Faryab surface resistivity data conducted by MRRD & DACAAR field teams during 2013. The course was facilitated by Andreas de Jong and Prof. Naim Eqrar and its main objectives were to:

1. Review practical issues concerning the implementation of the geophysical surveys.
2. Conduct quality control on the VES interpretations.
3. Extract relevant data for maps & cross sections.
4. Correlate the data together with existing geological records.
5. Propose drill sites for exploratory drilling in Faryab.

Participants included six persons from RuWatSIP/MRRD, two from MEW and one from DACAAR. Most of the participants had been involved in the Faryab fieldwork.

B4.1 VES Interpretation in GeoVES

The VES data were interpreted using a free, Excel based software called GeoVES. GeoVES models the apparent resistivity of Schlumberger Soundings using Gosh (1971) linear filters. GeoVES has been tested extensively in Ghana and Pakistan, and results are comparable with commercially available geophysical software. The main advantage of GeoVES is that all steps in the interpretation are transparent to facilitate data quality control.

Unfortunately, no calibration soundings had been carried out next to wells with lithological descriptions, so the interpretation of the soundings was based on experience from similar hydrogeological areas. With AB/2 spacings of up to 300m, the expected depth of investigation is approximately 200m (1/3 of AB = 600/3 = 200m).

B4.2 Geophysical Maps for Drill Site Selection

Many of the VES showed a conductive upper layer (clay rich soils?) underlain by a resistor (gravel aquifer?) which is underlain by a conductor (Neogene clays?).

Once a good model was obtained, the following data were extracted for each sounding

1. Depth to base of aquifer (m)
2. Aquifer thickness (m)
3. Aquifer resistivity (Ohm-m)

This data were contoured in ArcGIS using Kriging techniques, and then exported to Google Earth for interpretation together with interactive pop-up tables of the VES data.

The contoured VES data highlights the complexity of the Quaternary aquifer near Maimana. Although VES were made at regular intervals of some 300 to 500 metres, there is considerable variation between adjacent soundings. This indicates that the subsurface is very complex, and that the top of the Neogene is probably highly irregular. A much closer spacing between the soundings would be required in order to achieve better levels of accuracy. A number of calibration soundings next to known boreholes would also improve the interpretation.

B4.3 Proposed Drill Sites

The conclusion of the May 2014 workshop was to agree on a number of drill site locations based on the interpretation of the VES data. The proposed locations of the wells were:

Location ID	VES_ID	Latitude (WGS84)	Longitude (WGS84)	Estimated Depth to Base of Aquifer (m)
Well #1	M05	35.92100	64.74800	72.6
Well #2	D15	35.93545	64.75076	48.6
Well #3	M18	35.92755	64.76629	113
Well #4	M11	35.92000	64.76064	96
Well #5	M13	35.92958	64.75194	89.3

Table B1. Proposed locations of exploration wells, based on VES geophysical interpretation.

Due to various field reasons outside of NORPLAN's control, the two wells drilled by the project were located 40m (Well-1) and 70m (Well-2) from their preferred locations based on the VES. The drilling results did not fully correspond to the sounding interpretation, particularly for Well-1 which was not very productive. It was recommended to repeat a VES next to each of the drilled well, to see if the differences are due to rapid lateral geological variations in the area, or interpretation issues. Unfortunately, this has not been implemented to date.

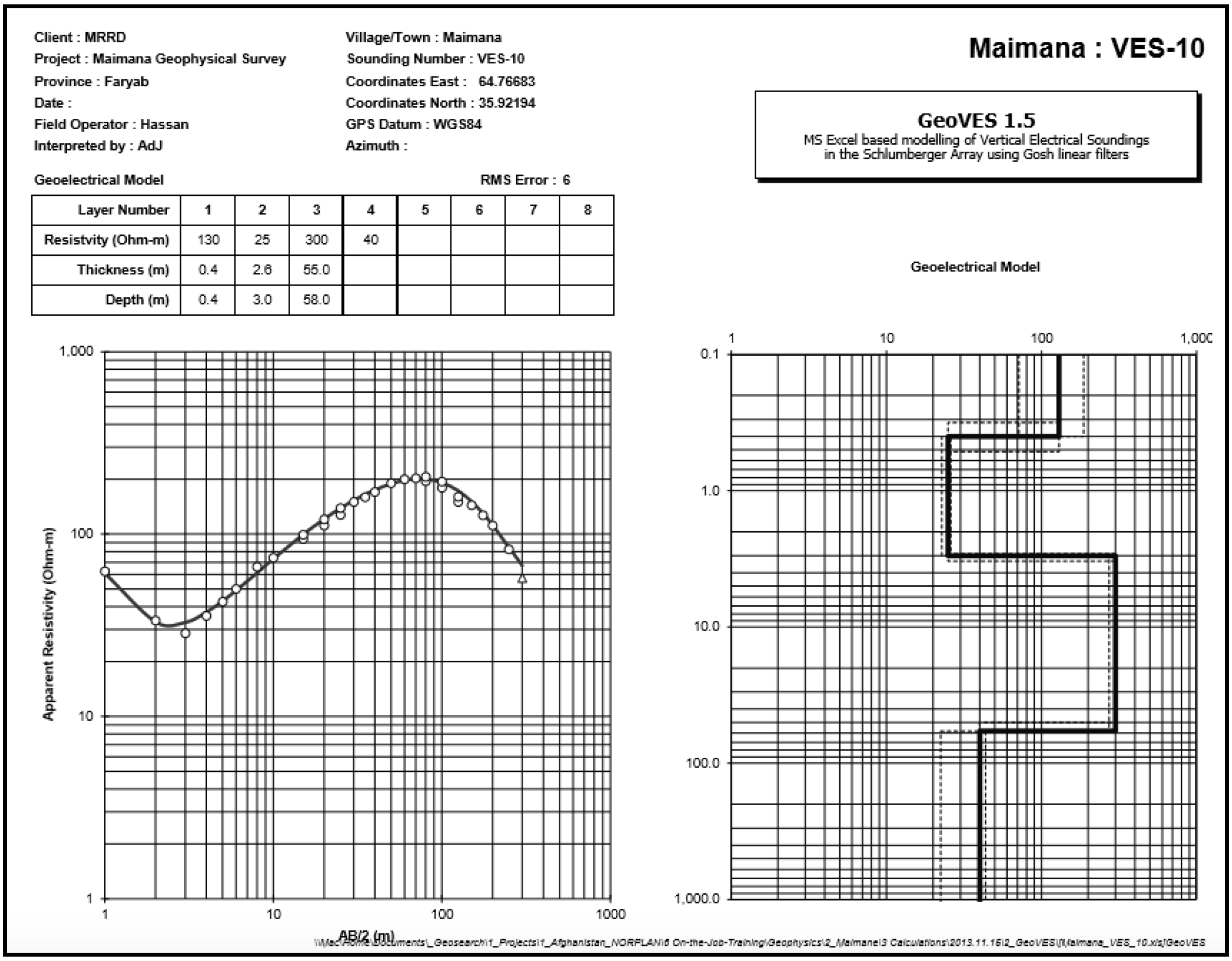


Figure B4. Example VES data

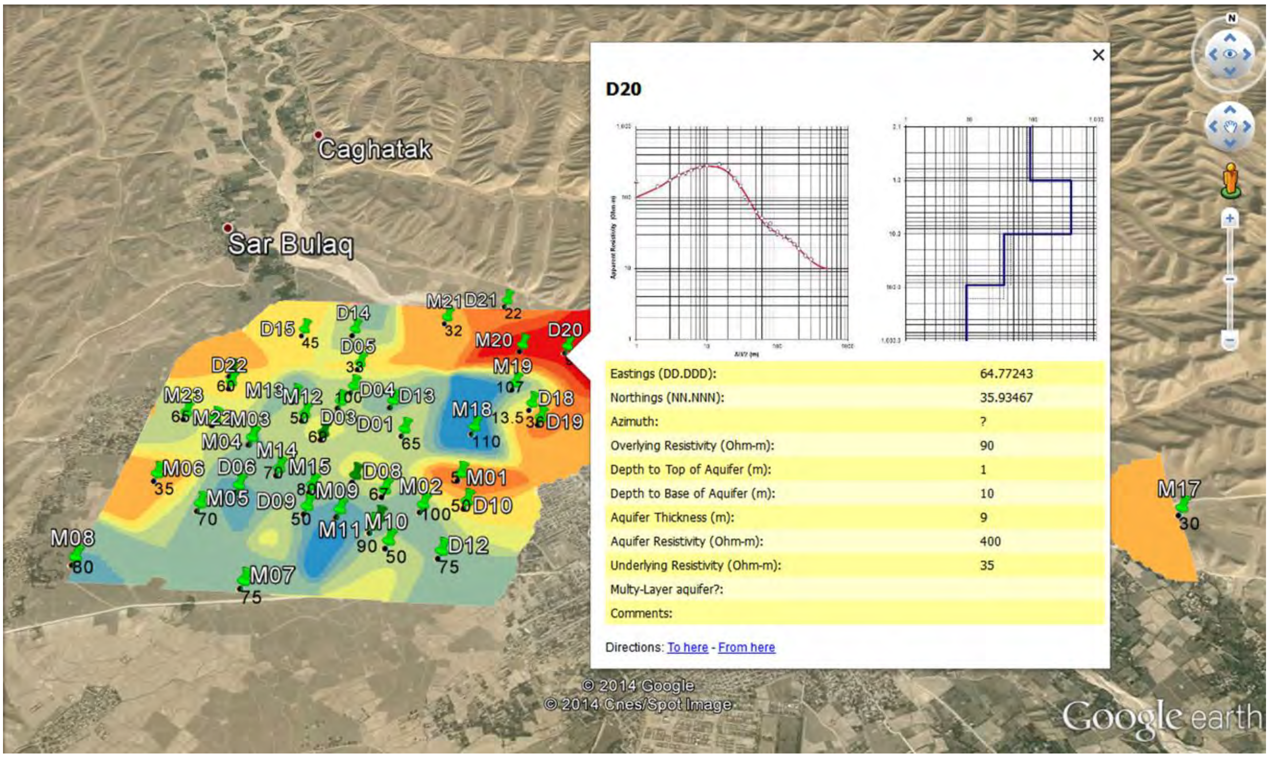


Figure B5. Google Earth map of Maimana Aquifer with VES pop-up

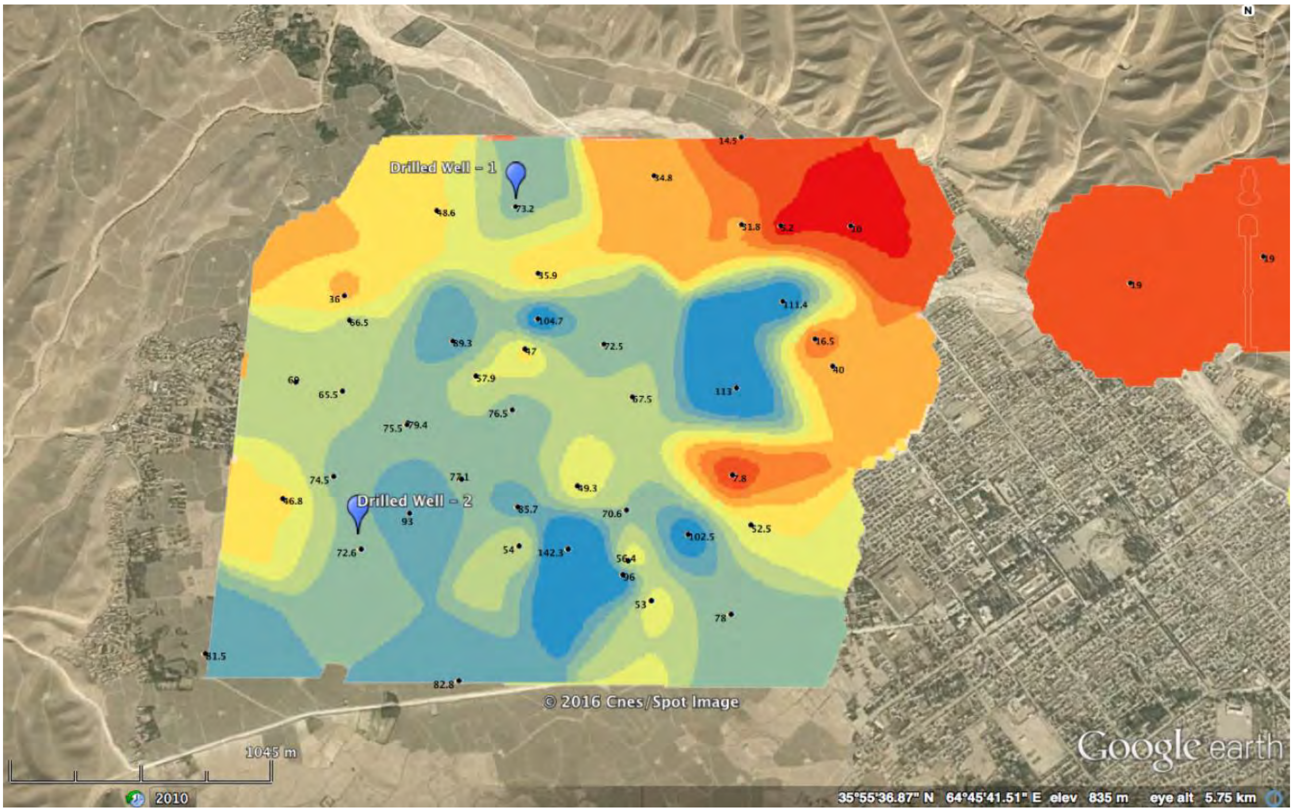


***Figure B6**. **Google Earth Map of Depth to Base of the Aquifer (data points in m below ground surface)**. Red = shallow, blue = deep.*

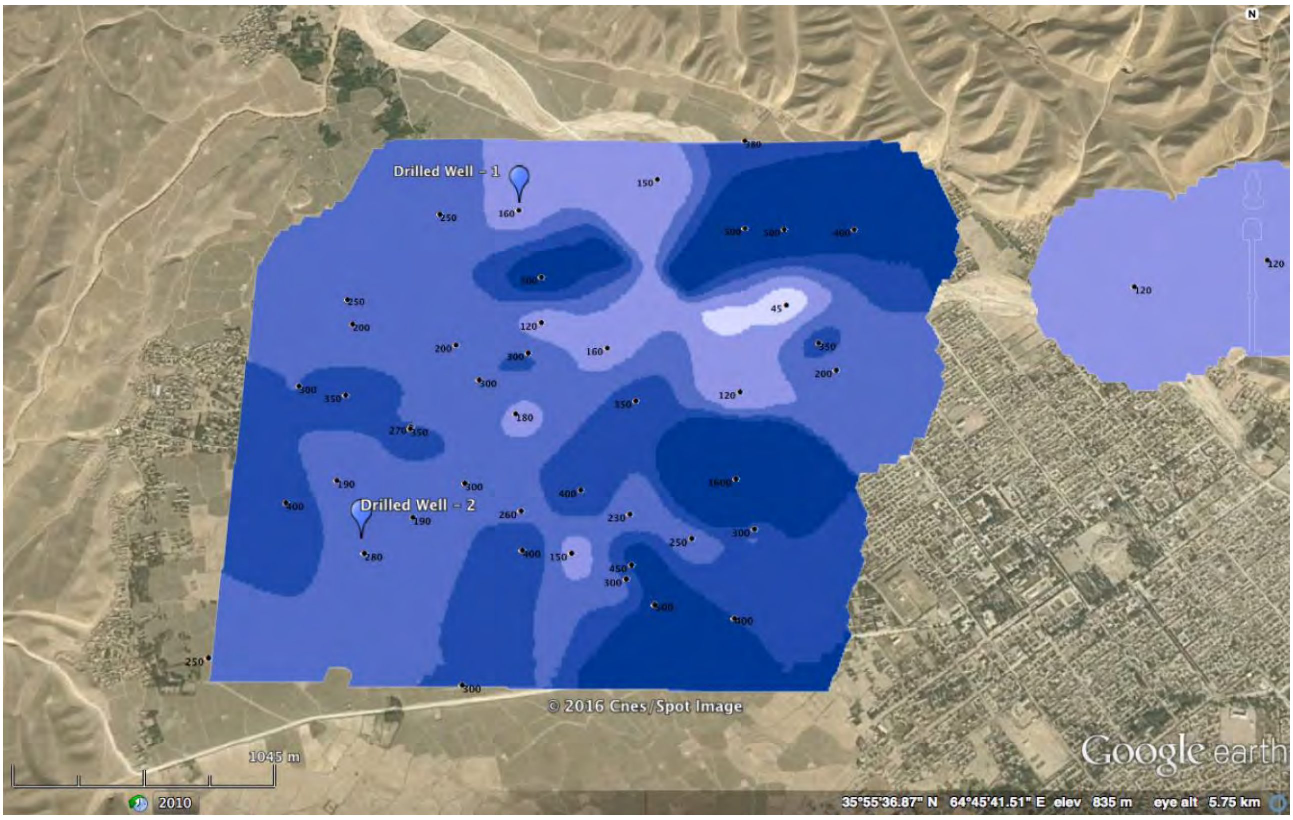
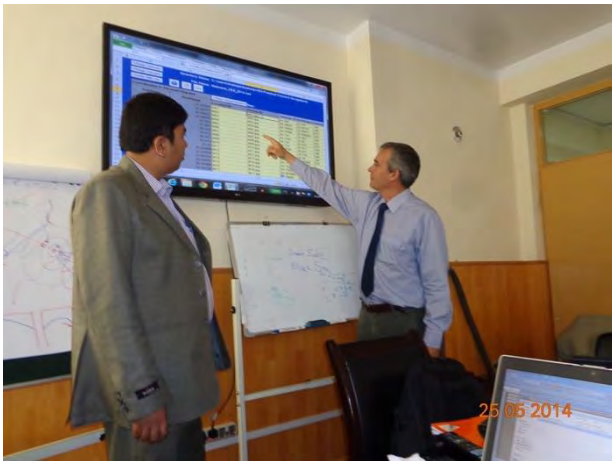


***Figure B7**. **Google Earth Map of Aquifer Resistivity (data points in Ohm-m)**. Pale blue = low resistivity, dark blue = high resistivity.*

(a) Participants discussing VES modelling in GeoVES

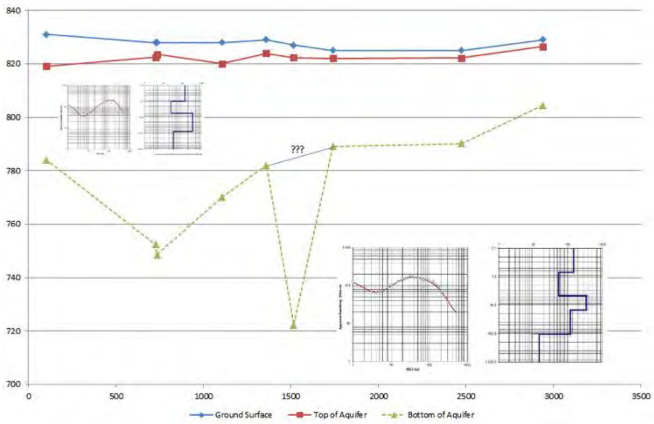
(b) Eng. Poya, co-presenter

(c) Learning the use of the Excel based Google Earth KML file exporter.



(d) Andreas & Eng. Poya introducing data export from Excel to Google Earth.

(e) Producing contour maps and pop-ups in Google Earth



(f) Sections in Excel based on VES soundings

Figure B8. VES geophysics interpretation sessions.

Part C. Drilling

Prepared June 2015

Author: David Banks, based on information supplied from MRRD field teams.

Two wellfields were drilled near Maimana Airport in late 2014 / early 2015 by the Ministry of Rural Rehabilitation and Development (MRRD) as part of the MRRD/NORPLAN project.

- Wellfield 1 - comprising a single production borehole (PBH1) close to the location of geophysical station D14.
- Wellfield 2 - comprising a single production borehole (PBH2) and two observation wells (OBH2A, OBH2B), close to the location of geophysical station M05.

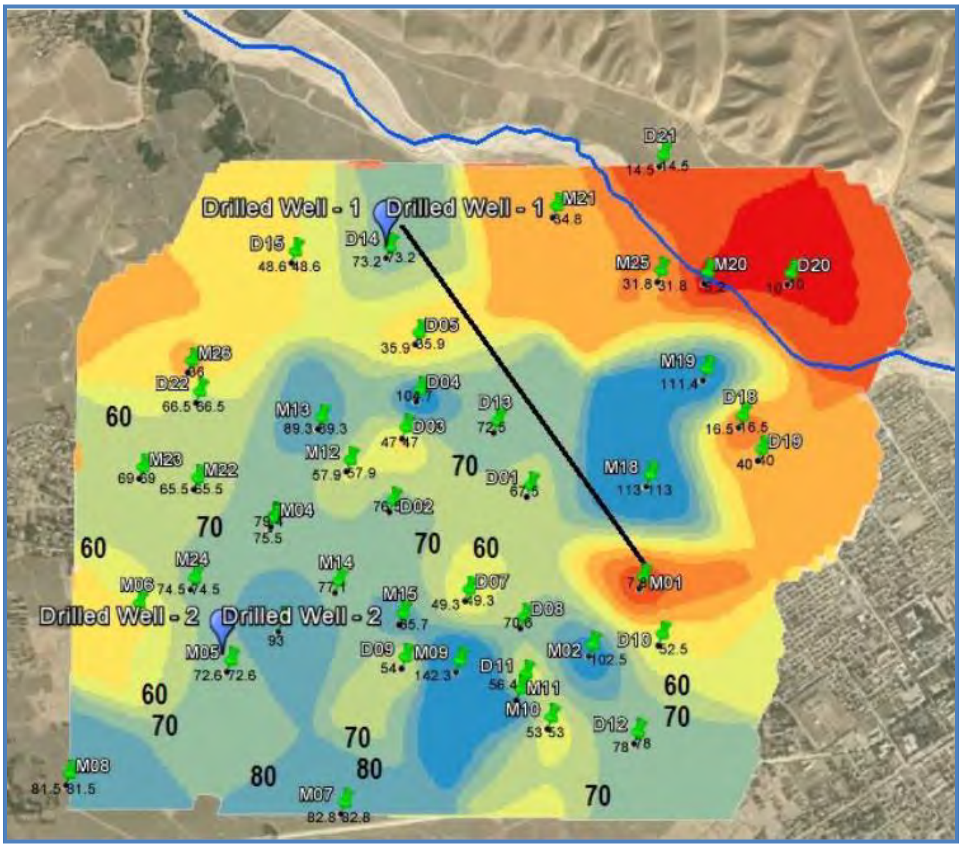


Figure C1. ***Google Earth image used as background to show locations of VES soundings (green pins) with estimated depth to base of aquifer (m bgl) as small black figures.*** *Larger black figures are labels on contours (blue = deep, red = shallow). The depth of the aquifer broadly increases from NE to SW. The black line shows Maimana Airport runway and the blue line is the Maimana River. North is up the page. The uppermost large blue pin shows the location of Wellfield 1, the lower blue pin shows Wellfield 2.*

C1 Wellfield 1

C1.1 Location and Rationale

Wellfield 1 was located at coordinates 35.93602°N 64.75487°E (elevation estimated +824 m asl), close to the location of geophysical station D14. It was selected because the VES geophysics indicated a “pocket” of relatively high aquifer thickness, and the location lay near the corridor of the river Maimana (Figure C1). D14 VES sounding estimated a depth of 73 m to the aquifer base. It was hoped that test-pumping this well might yield information on the connectivity between the river and the aquifer.

Due to security issues and conflicts with local landowners (despite permissions having been acquired prior to drilling), it was not possible to return to the borehole following drilling to carry out test-pumping or sampling.

NORPLAN Consulting Engineers and Planners

Figure C2. The drilling of production well PBH1, showing mud circulation system (21st September 2014).

Figure C3. The drilling of production well PBH1, showing general impression of terrain (21st September 2014).

C1.2 Drilling and Geology

The production borehole PBH1 was drilled using an MRRD drilling rig and conventional mud flush rotary techniques.

The well was drilled to a total depth of 106 m between 9th and 20th September 2014. Figure C5 shows the driller's time log. The drilling diameter was nominal 16" from 0 - 6 m, followed by 12" from 6 - 106 m bgl. From 0 - 6 m, 14" steel conductor pipe was cemented in place at the top of the borehole.

Final Time Log of first Drilled Well Located Near to Faryab Airport

No	Date	From	To	Drillied in Meter	Drillid per hour (m)	Drilling per Day (m)
1	9/9/2014	9:00	10:00	6	6	6m+Conductor Installation
2	11/9/2014	8:30	9:30	4	4	12 m
3	"	10:00	11:00	12	2	
4	"	11:30	12:30	14.5	2.5	
5	"	12:30	1:30	16	1.5	
6	"	1:30	2:30	18	2	
7	12/9/2014	9:30	10:30	19.5	1.5	6m
8	"	10:30	11:30	21.5	2	
9	"	11:30	12:30	22	0.5	
10	"	12:30	1:30	23	1	
11	"	1:30	2:30	24	1	
12	13/9/2014	3:30	4:30	25	1	2.5 m
13	"	4:30	5:30	26	1	
14	"	5:30	6:30	26.5	0.5	
15	14/9/2014	8:30	9:30	27.5	1	15.5 m
16	"	10:00	11:00	28	0.5	
17	"	11:00	12:00	30	2	
18	"	12:00	1:00	31	1	
19	"	2:00	3:00	33	2	
20	"	3:00	4:00	33.5	0.5	
21	"	4:00	5:00	36	2.5	
22	"	5:00	6:00	40	4	
23	"	6:00	6:40	42	2	
24	15/9/2014	7:30	8:30	48	6	12m
25	"	9:50	10:50	51	3	
26	"	10:50	12:50	54	3	
27	17/9/2014	10:30	11:30	58.5	4.5	30m
28	"	12:30	1:30	66	7.5	
29	"	1:30	2:30	72	6	
30	"	2:30	3:30	78	6	
31	"	5:00	6:00	84	6	
32	18/9/2014	8:20	9:20	88	4	14.5m
33	"	10:00	10:45	90	2	
34	"	11:30	12:30	93	3	
35	"	12:30	1:30	94.5	1.5	
36	"	1:30	2:30	96	1.5	
37	"	3:30	4:30	98.5	2.5	
38	20/9/2014	8:30	9:30	100.5	2	7m
39	"	9:30	10:30	102.5	2	
40	"	10:30	11:30	106	3	
					Total Drillid	106

Final Lithological Description

Depth (m)	Description
0 - 0.5	Top Soil
0.5 - 8	Silt
8 -15,	Dark Sand
15 - 27	Conglomerate with yelow, back & white color
27 -32	Clay with Gravel
32 - 34	Clay & Gravel
34 - 52	Red & Yellowish Clay
52 -106	Clay

Drilling Time Log on the basis of Drilling Speed

Depth (m)	Average Drilling Speed in m/hr
0 - 15	4
15 - 21.5	2
21.5 - 22	0.5
22 - 26	1
26 - 28	0.75
28 - 33	1.7
33 - 33.5	0.5
33.5 - 42	2.8
42 - 58.5	4.1
58.5 - 84	6.4
84 -93	3
93 - 106	2.5

Figure C4. Driller's final time log for Production Well PBH1*. Additionally, Prof. Eqrar (2014) described the sediment from 8 - 18 m as follows: 8 - 12 m Fine Sand; 12 - 15 m Coarse Sand; 15 -18 m Sand and Gravel (collapsible formation). The completion log in Figure C12 gives some more detail in the lower clayey section.*

Geologists from MRRD and DACAAR examined the geological sequence in the local terrain and compared it with samples from the borehole. The expressed the opinion that the compacted clay sequence below around 50 m bgl could be ascribed to Neogene argillite strata (Jamaluddin 2014).

Figure C5. Section on left hand side of Maimana - Khwaja Sabz Posh road (26/9/14).

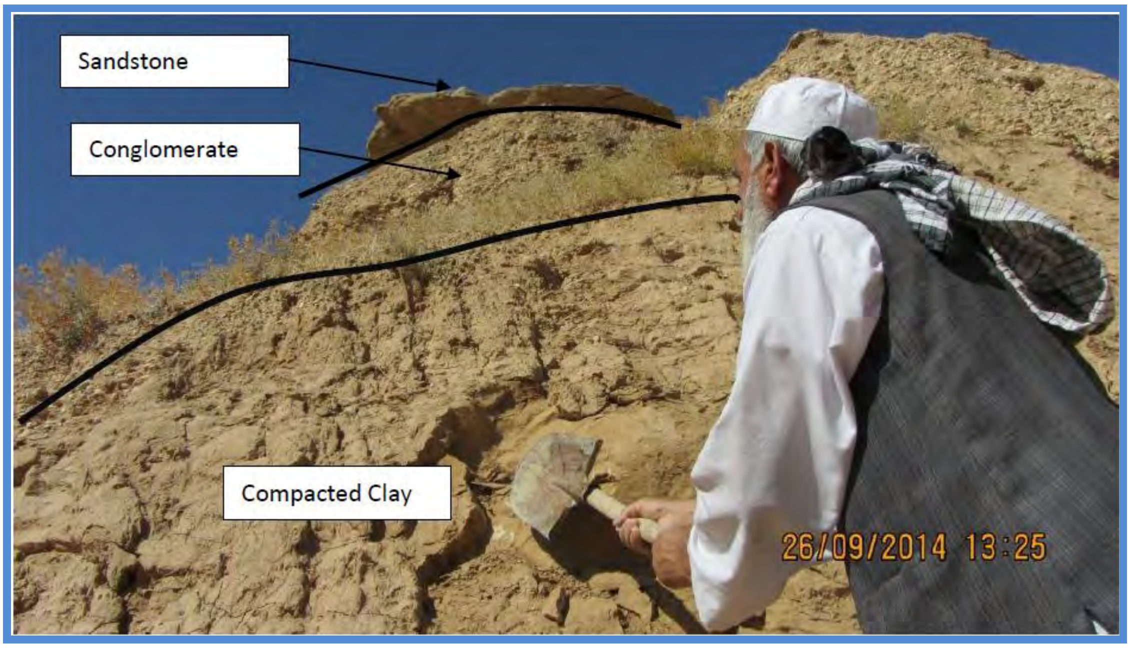


Figure C6. Sampling the section on left hand side of Maimana - Khwaja Sabz Posh road (26/9/14).

Figure C7. Section on left hand side of Maimana - Khwaja Sabz Posh road (26/9/14).

Figure C8. Section on left hand side of Maimana - Khwaja Sabz Posh road (26/9/14).

Figure C9. Red coloured formation (2m thick) on left hand side of Maimana - Khwaja Sabz Posh road (26/9/14).

Figure C10. Comparing borehole cuttings (84-88 m left, 88-96 m right) with field samples collected from the section on the left side of the Maimana Khwaja Sabz Posh road.

C1.3 Static Water Level

The static water level was reported as 25 m bgl following drilling (Eqrar 2014), and as 30 m bgl on 25th September 2014 (Anwary & Jamaluddin 2014).

C1.4 Well completion

On 25th September 2014, the well was found to have collapsed from 50 - 106 m. This section thus had to be redrilled before casing and screen could be installed (Anwary & Jamaluddin 2014).

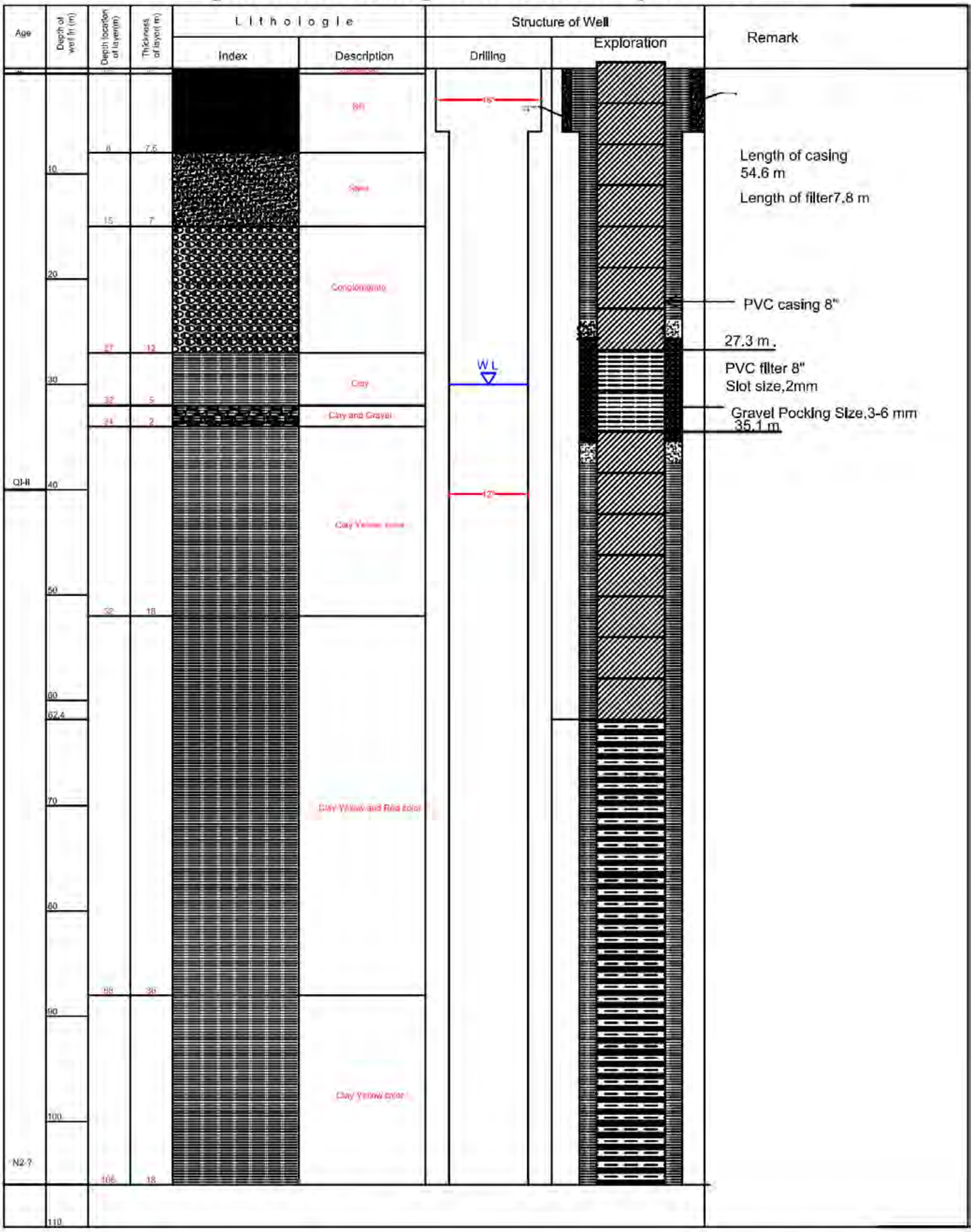
Figure C11. Casing prepared to be installed at PBH1 (30th September 2014)

Because no potentially productive horizons had been found within the lowermost, clayey (possibly Neogene) section of the borehole, the borehole was backfilled to a depth of 62.4 m. A string of 8” diameter PVC well casing and screen was then installed to 62.4 m.

A screen section was positioned between depths of 27.3 and 35.1 m, within the strata section described as “Clay and gravel”. The screen slot size was 2 mm (this being the size that was immediately available). A gravel pack of clast size 3-6 mm was installed in the annulus to a short distance above and below the screen and this was separated from the annular backfill by a layer of sand. The gravel pack was thus nominally 2” thick.

Well No	I W - 01	Drilling Diameter	12"	Drilling Depth	106 m
L0cation	Maimana city	Casing Diameter	8"	Well Depth	62,4 m
Static W L	30 m	Drilling operator	Ayazodin	Site Engineer	Mohmmad Amin

Investagition well Drilling Data in the Faryab Province



Prepared by Engineer Abdul Jalil

Figure C12. Final construction log for well PBH1, prepared by Eng. Abdul Jalil Anwary (MRRD). *Note that the geology in the section 27-32 m is given here as "Clay", but "Clay with Gravel" in the time log.*

C1.5 Conclusion

Due to security issues and conflicts with local landowners (despite permissions having been acquired prior to drilling), it was not possible to return to the borehole following drilling to carry out test-pumping or sampling.

The geology proved in the borehole did not tally with the prediction from the VES survey. The actual aquifer base was around 34 m, as compared with the predicted 73 m. It should be noted that the borehole was drilled a short distance north of the VES sounding D14.

The hydrogeological properties of the well were poor, due to:

- the main potential aquifer horizon (gravel/conglomerate) was located above the static water table level of 30 m.
- the saturated aquifer horizon was thus only around 4 m and was described as “clay and gravel” which does not sound promising.

Nevertheless, we recommend that, in the interests of scientific completeness (i.e. it is important to document and understand negative results, as well as positive) we would recommend that the well is revisited when circumstances permit. The static water level should be monitored for an annual cycle, the well test pumped (step testing only initially) and water samples collected.

C1.6 References

Anwary, J. and Jamaluddin, S. (2014). *Submitted Report- Monitoring of Mimana Water Well*. Informal report from field site, 28/9/14. Jalil Anwary and Sayed Jamaluddin Himat (MRRD).

Eqrar, N. (2014). Drilling progress in Faryab. Email sent from Prof. Naim Eqrar (NORPLAN) to David Banks (NORPLAN), 21/9/14.

Jamaluddin, S. (2014). *Re: Report - Monitoring of Memana Water Well*. Email sent from Sayed Jamaluddin Himat (MRRD) to Prof. N. Eqrar (NORPLAN), 28/9/14.

C2 Wellfield 2 - Production Well PBH2

C2.1 Location and Rationale

Wellfield 2 was located close to the location of geophysical station M05. It was selected because the VES geophysics indicated a substantial area in the south-west of the study area, where the aquifer is thick and deep (Figure C1). M05 VES sounding estimated a depth of 73 m to the aquifer base.

Borehole	Grid reference	Estimated elevation (m asl)
Production well PBH2	64.74776°E 35.92160°N	834 m asl (Google Earth)
Observation well OBH2A	64.74802°E 35.92175°N	833 m asl (Google Earth)
Observation well OBH2B	64.74835°E 35.92196°N	833 m asl (Google Earth)

Table C1. Grid references of boreholes at Wellfield 2.

C2.2 Drilling and Geology

The production borehole PBH2 and observations boreholes were all drilled using an MRRD drilling rig and conventional mud flush rotary techniques.

Production borehole PBH2 was drilled to a total depth of 131 m between 26th October and 10th December 2014. Figure C13 shows the driller's time log. The drilling diameter was nominal 16" from 0 - 6 m, followed by 12" from 6 - 131 m bgl (Hadi and Eqrar 2014).

A detailed lithological description was provided by the field geologist and this is reported as Figure C14. The main potential sand/gravel aquifer horizon was located between 12 and 76 m bgl (which ties in well with the geophysically predicted aquifer base at 73 m). A further, lower gravelly layer was found between 102 and 113 m bgl.

C2.3 Static Water Level

The static water level was reported as 35.4 m bgl following drilling (Hadi, 2014; see Figure C17).

C2.4 Well completion

A string of 8" diameter PVC well casing and screen was installed to 130 m. Screened sections were installed in three intervals of gravelly aquifer.:

- 42-46 m bgl
- 54-74 m bgl
- 104-112 m bgl

The screen slot size was 2 mm (this being the size that was immediately available). A gravel pack of clast size 3-5 mm was installed in the annulus from 40 - 130 m bgl. The gravel pack was thus nominally 2" thick. A fine sand layer was emplaced from 38 - 40 m bgl, and a bentonite seal from 35-38 m bgl. Above the bentonite seal, the annulus was backfilled with a cement-based grout. From ground level to 2 m bgl, a concrete seal was emplaced, with a 100 mm thick concrete slab around the well top. The casing protruded to 500 mm above ground level.

The details are summarised in the combined log of Figure C17.

The well was developed by air lift pumping in late December 2015, until the recovered water ran clear.

Time Log of Second Drilled Well Located Tokali Khana Maimana

No	Date	From	To	Drillied in Meter	Drillid per hour (m)	Drilling per Day	Lithological Description: Depth (m)	Lithological Description: Description
1	26/10/2014	2:00 PM	4:00 PM	6	3	6	**0-1**	**Top soil**
2	27/10/2014	9:00	9:20	6.5	0.5	6	**(1-6)**	Clay
3		9:50	10:50	9	2.5		**(6-9)**	Silt
4		10:50	11:50	12	3		**(9-12)**	fine sand
5	28/10/2014	9:15	10:00	13.3	1.3	10.7	**12-22.5**	Gravel
6		10:25	11:25	15	1.7		**22.5-24**	gravel+clay
7		11:25	12:25	16.5	1.5		**24-39**	gravel
8		12:25	1:25	17.5	1		**39-41**	Clay+gravel
9		1:25	2:00	18	0.5		**41-47**	gravel
10		2:15	3:15	20	2		**47-49**	gravel+clay
11		3:15	4:15	22	2		**49-51**	gravel
12		4:15	5:15	22.7	0.7		**51-52**	gravel+clay
13	29/10/2014	8:20	9:20	23.5	0.8	11.8	**52-76**	gravel
14		9:20	10:00	24	0.5		**76-87**	Clay gravel
15		11:30	12:30	25.5	1.5		**87-102**	Clay+Gravel partical
16		12:30	1:30	26.5	1		**102-110**	gravel+clay
17		1:30	2:30	28.5	3		**110+118**	Clay+gravel
18		2:30	2:40	30	0.5		**118-121**	Clay
19		3:00	4:00	33	3		**121-126**	Clay+gravel
20		4:00	5:00	34.5	1.5		**126-130**	Clay
21	30/10/2014	8:25	9:25	35.3	0.8	7.5		
22		9:25	9:55	36	0.7			
23		10:15	11:15	37.3	1.3			
24		11:15	12:15	38.8	1.5			
25		12:15	1:00	39.3	0.5			
26		2:15	3:15	41	1.7			
27		3:15	4:15	42	1			
28	1/11/2014	8:45	9:45	43	1	9.7		
29		9:45	10:45	45.3	2.3			
30		10:45	11:45	46.5	1.2			
31		11:45	12:45	47.5	1			
32		12:45	1:32	48	0.5			
33		1:50	2:50	49.5	1.5			
34		2:50	3:50	50.5	1			
35		3:50	4:50	51.7	1.2			
36	2/11/2014	8:40	9:40	52.7	1	4.8		
37		9:40	10:40	53.5	0.8			
38		10:40	11:40	54	0.5			
39		1:00	2:00	55.5	1.5			
40		2:00	3:00	56.5	1			
41	3/11/2014	10:50	11:50	57.5	1	6.8		
42		11:50	12:50	58.5	1			
43		12:50	1:50	59.7	1.2			
44		1:50	2:30	60	0.3			
45		2:50	3:50	61.5	1.5			
46		3:50	4:50	63.3	1.8			
47	4/11/2014	7:50	8:20	64.8	1.5	1.5		
48	9/11/2014	8:40	9:40	65.8	1	7.2		
49		9:40	10:00	66	0.2			
50		10:25	11:25	67.8	1.8			
51		11:25	12:25	69.5	1.7			
52		12:25	1:25	70.5	1			
53		1:25	2:25	71	0.5			
54		2:25	3:25	71.4	0.4			
55		3:25	4:25	72	0.6			
56	10/11/2014	8:50	9:50	73.3	1.3	5.4		
57		9:50	10:50	75	1.7			
58		2:45	3:45	76.6	1.6			
59		3:45	4:30	77.4	0.8			
60	14/11/2014	8:40	10:10	78	0.6	3.9		
61		10:40	11:40	78.6	0.6			
62		11:40	12:40	79.5	0.9			
63		12:40	1:40	80	0.5			
64		1:40	2:40	80.5	0.5			
65		2:40	3:40	81.3	0.8			
66	18/11/2014	3:00	4:00	84	2.7	4.2		
67		4:15	5:15	85.5	1.5			
68	19/11/2014	8:00	9:00	87.5	2	21		
69		9:00	10:00	89.5	2			
70		10:00	10:30	90	0.5			
71		10:50	11:50	93	3			
72		11:50	12:30	96	3			
73		1:10	2:10	100.5	4.5			
74		2:10	2:40	102	1.5			
75		3:00	4:00	104	2			
76		4:00	5:00	106.5	2.5			
77	20/11/2014	8:30	9:25	108	1.5	13.5		
78		9:35	10:35	110.2	2.2			
79		10:35	11:35	112.5	2.3			
80		11:35	12:25	114	1.5			
81		12:50	1:50	116.2	2.2			
82		1:50	2:50	119	2.8			
83		2:50	3:50	120	1			
84	26/11/2014	10:55	11:55	121.9	1.9	6		
85		11:55	12:55	122.9	1			
86		12:55	1:55	123.7	0.8			
87		1:55	2:55	124.8	1.1			
88		2:55	3:45	126	1.2			
89	10/12/2014	2:00	3:00	129.2	3.2	4		
90		3:00	3:20	130	0.8			

Figure C13. Driller's final time log for Production Well PBH2.

Revised Lithological Description of Second Investigation Well Faryab Province, Maimana City

Depth in Meter	Description
0-1 `	Top Soil
1-6	Clay
6-9	Silt
9-12	Fine Sand
12-13.5	Sand with Gravel
13.5-20	Sub Rounded Grave
20-22.5	Sand with Gravel
22.5-24	Gravelly sand with Silt
24-39	Gravel with Sand
39-41	Silt with Gravel & Sand
41-47	Gravel with Sand
47-49	Gravel with Silt & Sand
49-51	Gravel with Sand
51-52	Silt with Sand
52-76	Gravel with Sand
76-77	Silt with Gravel & Sand
77-81.5	Silt with Sand
81.5-87.5	Silt with Gravel & Sand
87.5-90	Sand with Silt
90-102	Silt with Gravel & Sand
102-113	Gravel with Sand & Silt
113-118	Silt with Gravel
118-121	Clay
121-126	Silt with Sand
126-131	Silty Clay

Figure C14. Lithological log from PBH2, provided by Eng. Sayed Jamaluddin, based on the field geologist's (M. Hadi) observations during drilling (Figure C13) modified by subsequent examination of drilling samples (Appendix A). *Note that there are some discrepancies with the final construction log in Figure C20.*

Figure C15. Drilling production well PBH2, 28th October 2014.

Figure C16. Drilling production well PBH2, 28th October 2014.

Figure C17. Measuring the water level in well PBH2 on 8th November 2014.

Figure C18. Installation of casing in production well PBH2. *19th December 2014.*

***Figure C19**. **Air lift development pumping of production well PBH2**. 23rd December 2014.*

C2.5 Conclusion

The geology proved in borehole PBH2 did broadly tally with the prediction from the VES survey. The actual aquifer base was around 76 m, as compared with the predicted 73 m. It should be noted that the borehole was drilled a short distance away from the exact location of the VES sounding M05.

The hydrogeological properties of the well appear very promising, with at least 50 m of gravelly aquifer strata below the static water level.

It was recommended that a full step-test / constant rate / recovery pumping test be carried out.

C2.6 References

Hadi, M. (2014). *Fwd. FW: NORPLAN Second well progress*. Information from field geologist Mohammed Hadi, communicated in email via Prof. Naim Eqrar on 10th November 2014.

Hadi, M. & Eqrar, N. (2014). *Report from Eng Hadi (DACAAR) with a little bit more explanation from Prof.Eqrar. Faryab province, second exploratory production well.* report provided by email to David Banks, NORPLAN, 28th October 2014.

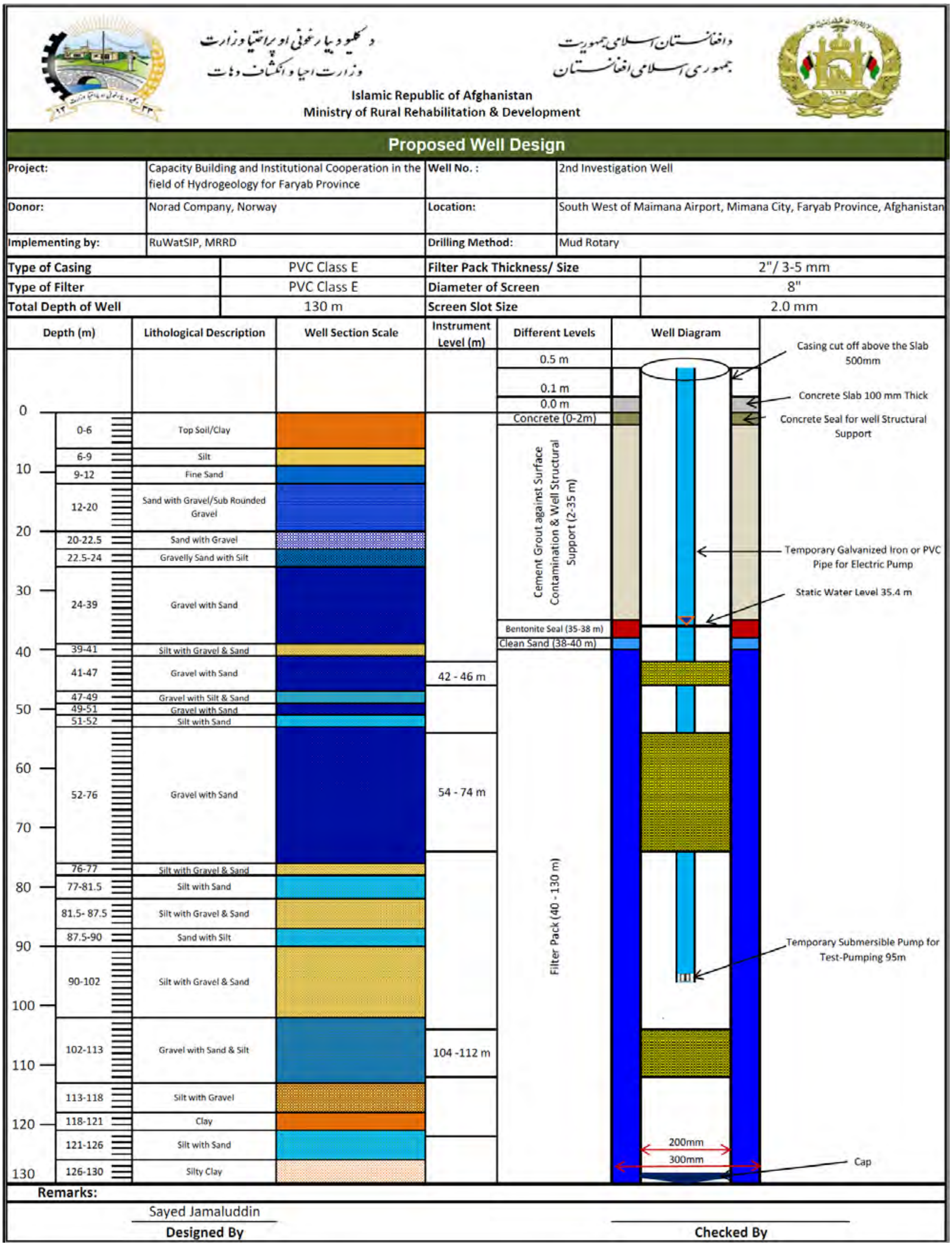


Figure C20. Final construction log for well PBH2 prepared by Eng. Sayed Jamaluddin (MRRD).

C3 Wellfield 2 - Observation Boreholes OBH2A and OBH2B

C3.1 Location and Rationale

Observation boreholes OBH2A and OBH2B were drilled at approximate distances 30 m and 65 m (respectively) east (north-east, according to grid references provided) of the production well PBH2, in order to monitor drawdowns in the aquifer during test pumping.

The wells penetrated the same aquifer (that encountered down to 76 m in PBH2 - Figure C20) as the main production well. They were, however, shallower than PBH2 and did not penetrate the thinner deeper aquifer horizon (102 -113 m). This should be borne in mind when interpreting the results of the pumping test.

C3.2 Drilling and Geology

The production borehole PBH2 and observations boreholes were all drilled using an MRRD drilling rig and conventional mud flush rotary techniques.

The observation wells were drilled at a nominal 10” diameter (Jamaluddin 2015) and subsequently installed with 6” PVC well screen.

The first observation well OBH2A was drilled to a total depth of 76 m between 25th March and 4th April 2015. The geological sequence was consistent with that reported from PBH2: a layer of c. 7 m of clayey material, overlying mostly gravelly strata (Figure C21).

The second observation well OBH2B was also drilled to a total depth of 76 m between 8th - 16th April 2015. The geological sequence was consistent with that reported from PBH2: a layer of c. 8 m of clayey material, overlying mostly gravelly strata (Figure C23).

C3.3 Static Water Level

The static water level was reported as 35.5 m bgl following drilling (see Figure C25 and C26) in both Observation boreholes OBH2A and OBH2B.

C3.4 Well completion

A string of 6” diameter PVC well casing and screen was installed in both Observation boreholes OBH2A and OBH2B. The completion of both OBH2A and OBH2B was essentially identical and is shown in Figures C25 and C26.

2 mm slotted screen was installed from 42 to 74 m bgl. Plain casing was installed from 0 to 42 m and 74 to 76 m. The annulus outside the screen was gravel packed with gravel of clast size 3 - 5mm. The gravel pack extended from the base of the well (76 m) almost up to the static water level.

C3.5 References

Jamaluddin, S. (2015). RE: WELL TESTING PROGRESS -2ND INVESTIGATION & OBSERVATION WELLS. Email from site engineer Sayed Jamaluddin (MRRD) to David Banks (NORPLAN) dated 10th June 2015.

Time Log of Firsr Observation Drilled Well Located Tokali Khana Maimana

No	Date	From	To	Drillied in Meter	Drillid per hour (m)	Drilling per Day	Depth (m)	Description
							Lithological Description	
1	25/3/2015	11:50 AM	12:05 PM	4.4	4.4	11.3	**0-7**	**Clay**
2		12:20	12:50	6	1.6		**(7-15)**	Gravel
3		2:20	3:20	9.3	3.3		**(15-18)**	Clayey Gravel
4		3:20	4:20	11.3	2		**(18-36)**	Gravel
5	26/3/2015	8:10	8:20	12	0.7	10	**36-39**	Clay gravel
6		9:25	10:25	13.5	1.5		**39-48**	Clayey Gravel
7		10:25	11:25	15.4	1.9		**48-63**	gravel
8		11:25	12:25	16.3	0.9		**63-65**	Clay with gravel
9		12:25	1:25	17.5	1.2		**65-76**	Gravel
10		1:25	2:10	18	0.5			
11		2:40	3:40	19.5	1.5			
12		3:40	4:20	21.3	1.8			
13	28/3/2015	11:30	12:30	22.3	1	4.2		
14		12:30	1:30	23.2	0.9			
15		1:30	2:30	23.8	0.6			
16		2:30	3:00	24	0.2			
17		3:40	4:40	25.5	1.5			
18	29/3/2015	8:00	9:00	28	1.5	12		
19		9:00	10:00	29	1			
20		10:00	11:00	31	2			
21		11:30	12:30	32.3	1.3			
22		12:30	1:30	33.1	0.8			
23		1:30	2:30	34.5	1.4			
24		2:30	3:30	36.1	1.6			
25		3:30	4:10	37	0.9			
26		4:30	5:30	38.5	1.5			
27	30/3/2015	7:10	8:10	40	1.5	10.5		
28		8:10	9:10	40.9	0.9			
29		9:10	10:10	42	2.1			
30		11:20	12:20	43	1			
31		12:20	1:20	44.2	1.2			
32		1:20	2:20	45.3	1.1			
33		2:20	3:20	47.2	1.9			
34		3:20	4:40	48	0.8			
35		12:20	1:20	49.4	1.4			
36	31/3/2015	1:20	2:20	50.6	1.2	4.5		
37		2:20	3:20	51.6	1			
		3:20	4:20	52.6	1			
38		4:20	5:00	53.5	0.9			
	1/4/2015	9:15	9:30	54	0.5	9.4		
39		10:00	11:00	55.3	1.3			
40		11:00	12:00	56.3	1			
41		12:00	1:00	57.1	0.8			
42		1:00	2:00	58.1	1			
43		2:00	3:00	60	1.9			
44		3:40	5:00	62.9	2.9			
45	2/4/2015	7:30	8:30	64.7	1.8	9.1		
46		8:30	9:30	66	1.3			
47		9:50	10:50	67.5	1.5			
48		10:50	11:50	68.9	1.4			
49		11:50	12:50	69.4	0.5			
50		12:50	1:50	70.6	1.2			
51		1:50	2:50	71.6	1			
52		2:50	3:30	72	0.4			
53	4/4/2015	8:10	9:10	73.5	1.5	4		
54		9:10	10:10	74.4	0.9			
55		10:10	11:10	74.9	0.5			
56		11:10	12:10	75.6	0.7			
57		12:10	12:50	76	0.4			
58								
59								

Figure C21. Drillers' time log for Observation well OBH2A.

Figure C22. Drilling site OBH2A, 31st March 2015.

Time Log of Second Observation Drilled Well Located Tokali Khana Maimana

No	Date	From	To	Drillied in Meter	Drillid per hour (m)	Drilling per Day	Depth (m)	Description
							Lithological Description	
1	8/4/2015	7:30 AM	8:00 AM	6	6	18	**0-8**	**Clay**
2		9:50	10:50	10.5	4.5		**(8-12)**	Clay with gravel
3		10:50	11:20	12	1.5		**12--18**	Sub rounded gravel
4		11:50	1:00	18	6		**18-34**	Gravel
5	11/4/2015	11:40	12:40	19.5	1.5	7.5	**34-36**	Clay
6		12:40	1:40	21.3	1.8		**36-44**	Gravel
7		1:40	2:40	22.8	1.5		**44-46**	Gravel+Clay
8		2:40	3:40	24	1.2		**46-76**	Gravel
9		4:00	5:00	25.5	1.5			
10	12/4/2015	7:40	8:40	26.5	1	9		
11		8:40	9:40	27.5	1			
12		9:40	10:40	29	1.5			
13		10:40	11:40	30	1			
14		12:20	1:20	31	1			
15		1:20	2:20	31.8	0.8			
16		2:20	3:20	33	1.2			
17		3:20	4:20	34.5	1.5			
18	13/4/2015	7:40	9:10	36	1.5	9.7		
19		9:35	10:35	37.7	1.7			
20		10:35	11:35	39	1.3			
21		11:40	12:40	39.9	0.9			
22		12:40	1:40	41.1	1.2			
		1:40	2:40	43	1.9			
23		3:40	4:40	44.2	1.2			
24	14/4/2015	7:20	8:20	45.3	1.1	10.8		
25		8:20	9:20	46.2	0.9			
26		9:20	10:20	47.8	1.6			
27		10:20	11:05	49	1.2			
28		11:35	12:35	50.6	1.6			
29		12:35	1:35	52	1.4			
30		1:35	2:35	53.5	1.5			
31		2:35	4:00	55	1.5			
32		8:00	9:00	57	2			
33		9:00	10:00	58.3	1.3			
34	15/4/2015	10:00	11:00	59.6	1.3	8		
35		11:00	12:10	61	1.4			
36		3:25	4:25	63	2			
37	16/4/2015	7:00	8:00	64.2	1.2	13		
		8:00	9:00	65.3	1.1			
38		9:00	10:00	66.5	1.2			
		10:00	11:00	67	0.5			
39		12:00	1:00	70.3	3.3			
40		1:00	2:00	71.7	1.4			
41		2:00	3:00	73	1.3			
42		3:30	4:30	76	3			

Figure C23. Drillers' time log for Observation well OBH2B.

Figure C24. Drilling site OBH2B, 18th April 2015.

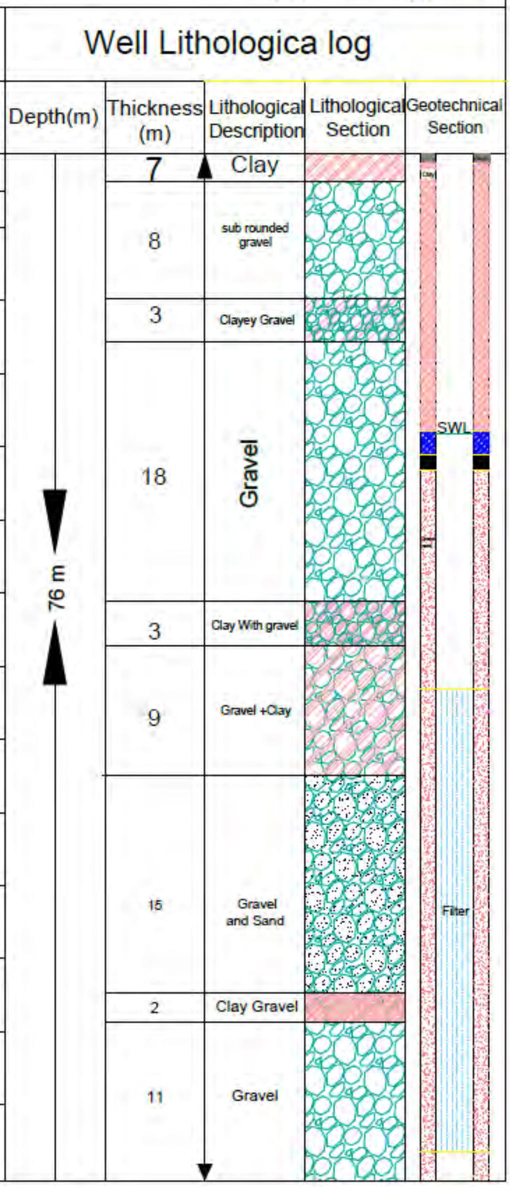
DACAAR

CAPACITY BUILDING AND INSTITUTIONAL IN THE FIELD HYDROGEOLOGY OF FARYAB PROVINCE

Project Name:NORPLAN
Date: 6/4/2015
LAT:35.92175
LON:64.74802
Scale:

Province:Faryab
District:Maimana
Village:Tokali khana
EC: PH:

S/No	Well Data	
1	Well ID	First Observation Well for Well No2
2	Started Date	25/03/2015
	Completed Date	05/04/2015
3	Depth of Well(m)	76
4	Diameter of Well (inch)	10"
5	Type of pipe and Screen	PVC E Class
6	Diameter of pipe and Screen (inch)	6"
7	Interval of Screen(m)	(42-74)
8	Interval of Pipe (m)	(0-42) (74-76)
9	Length of pipe (m)	46
10	Size of screen slot (mm)	02
11	Length of Screen (m)	32
12	Static Water Level (m)	35.5
13	Size of gravel (mm)	(3 - 5) mm
14	Discharge lit/sec	-
15	Drawdown m	-



Field Engineer: M Hadi

Remark: ....

Figure C25. Well completion log (by field geologist M. Hadi of DACAAR) for Observation well OBH2A.

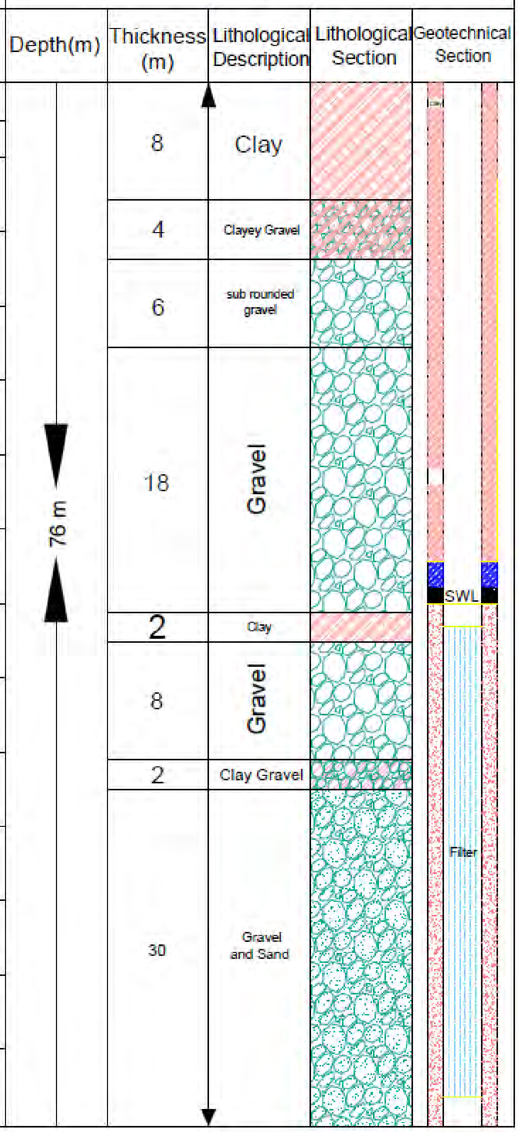
CAPACITY BUILDING AND INSTITUTIONAL IN THE FIELD HYDROGEOLOGY OF FARYAB PROVINCE

Project Name:NORPLAN
Date: 22/4/2015
LAT:35.92196
LON:64.74835
Scale:

Province:Faryab
District:Maimana
Village:Tokali khana
EC: PH:

S/No	Well Data	
1	Well ID	Second Observation Well for Well No2
2	Started Date	8/04/2015
	Completed Date	19/04/2015
3	Depth of Well(m)	76
4	Diameter of Well (inch)	10"
5	Type of pipe and Screen	PVC E Class
6	Diameter of pipe and Screen (inch)	6"
7	Interval of Screen(m)	(42-74)
8	Interval of Pipe (m)	(0-42) (74-76)
9	Length of pipe (m)	46
10	Size of screen slot (mm)	02
11	Length of Screen (m)	32
12	Static Water Level (m)	35.5
13	Size of gravel (mm)	(3 - 5) mm
14	Discharge lit/sec	-
15	Drawdown m	-

Well Lithologica log



Field Engineer: M Hadi

Remark: ....

Figure C26. Well completion log (by field geologist M. Hadi of DACAAR) for Observation well OBH2B.

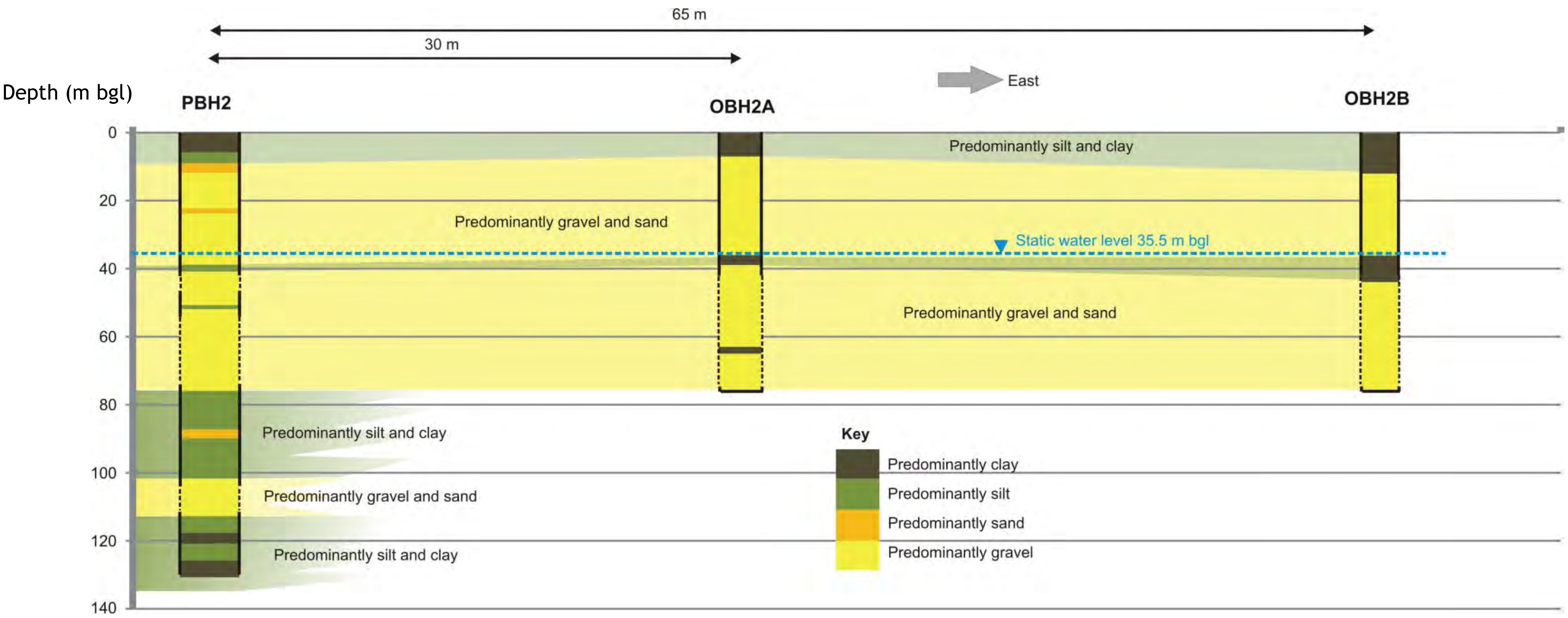


Figure C27. West-east cross-section through Wellfield 2.

Part D. Test Pumping

Prepared October 2015

Author: David Banks, based on information supplied from MRRD field teams.

D1 Pumping Test - Hydraulic Analysis

D1.1 Schedule

Production well PBH2 was test pumped in the period 31st May to 12th-June 2015. Manually-dipped water level readings were taken in PBH2 itself and in observation boreholes OBH2A and OBH2B during the test. The following schedule was utilised:

- 3 x 2 hrs step tests at constant rates of 3.1, 5.1 and 5.4 L/s, with 2 hr rest intervals between each step. All steps were carried out on 31st May 2015, between 0600 and 1800.
- 1 x 11 day constant rate test, commencing on 1st June 2015 at 0600 and running at 6.25 L/s until the pump was switched off at 0600 on 12th June 2015.
- Recovery was only monitored until noon on 12th June 2015.

D1.2 Results

The results of the test are provided in Section D3, but are summarised in the following diagram:

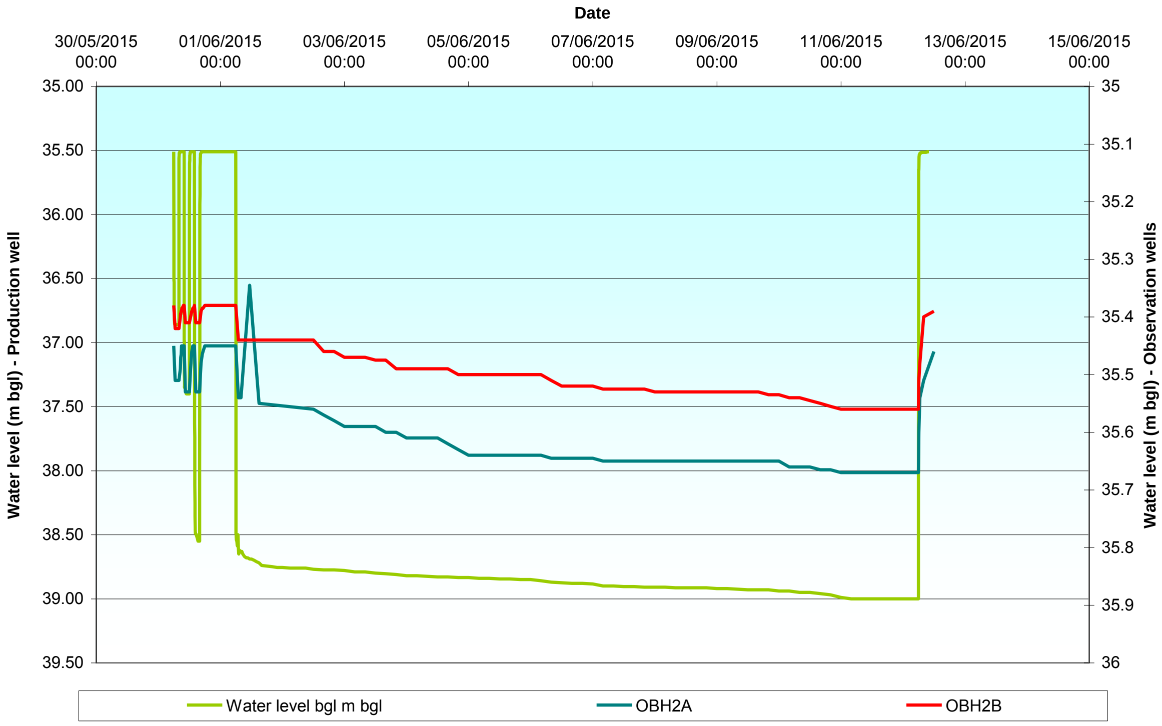


***Figure D1**. Schematic graph of water levels in PBH1 and OBH2A (blue) and OBH2B (red). m bgl = metres below ground level*

It will be seen that the bulk of the drawdown and recovery took place in the production well within the first few hours of the test, which may be an indicator of poor well efficiency (i.e. high well losses relative to aquifer losses).

D1.3 Step test analysis

The 2 hr drawdowns for each step of the step test can be combined with the 2 hr drawdown from the constant rate test as follows:

Step	Q	Q	2 hr drawdown (s)	Q/s	s/Q
	L/s	m^3/d	m	m^2/d	d/m^2
	0	0	0		
1	3.1	268	1.35	198	0.00680
2	5.1	441	1.89	233	0.00811
3	5.4	467	3.04	153	0.01981
Constant rate	6.25	540	3.12	173	0.01803

Table D1. Results of step testing (and 2 hr drawdown from constant rate test) on production borehole PBH2 - May/June 2015

It was found that recovery was complete by the end of each 2 hr interval between steps. Thus, the *Q* (discharge) versus drawdown (*s*) data can be plotted directly (Figure D2). The results do not fall neatly on a curve, suggesting that there may have been inaccuracies in measuring either discharge (most likely) or drawdown (less likely)

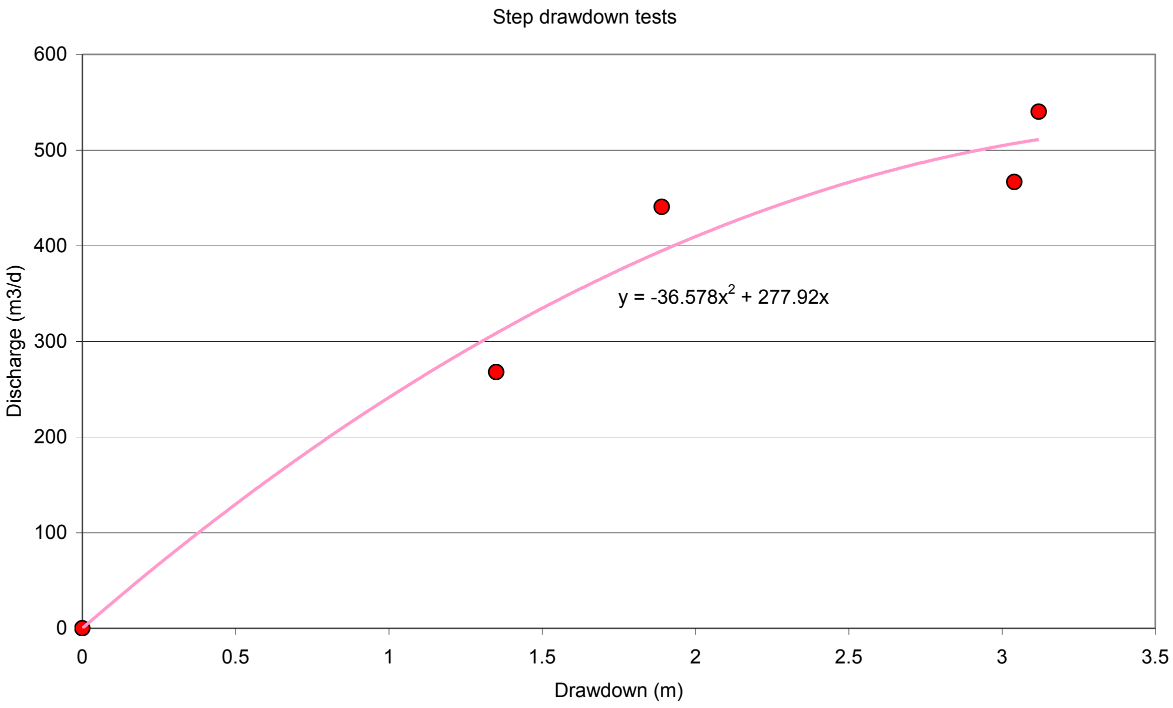


Figure D2. Plot of 2-hour drawdown versus discharge for step- and constant-rate testing of production borehole PBH2 - May/June 2015

An attempt to produce a Hantush-Bierschenk plot (Figure D3) of *s/Q* versus *Q* does not succeed in demonstrating any linearity and thus cannot be analysed (Bierschenk 1963, Hantush 1964).

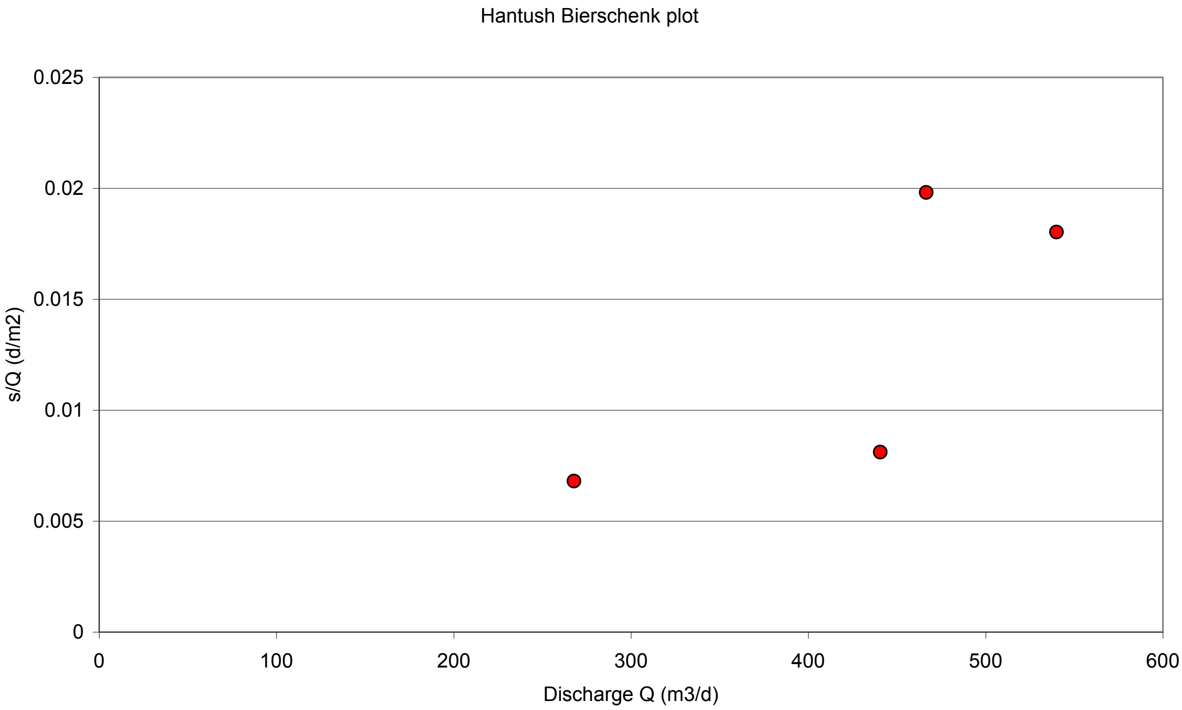


Figure D3. A Hantush-Bierschenk plot of s/Q versus discharge (Q) for 2-hour step tests and 2-hour data point from constant rate test - May/June 2015

Applying the Logan Approximation to the lowest (most hydraulically efficient) pumping rate allows us to make a first estimate of transmissivity (T), however:

$T = 1.22\ Q/s$ for efficient wells $T = 2Q/s$ for inefficient wells (Misstear *et al*. 2006)

leads us to a first estimate of transmissivity between 240 and 400 m^2/d.

D1.4 Constant rate test analysis

The data from the observation and production wells have been plotted on a Cooper-Jacob type plot (Figure D4; i.e. a plot of drawdown versus log time - Cooper & Jacob 1946). In the plot:

- Drawdown (s) = Dynamic water level - Static water level at pump start*

**(fully recovered from preceding step tests)*

- Time (t) = Time since pumps started (0600 on 1st June 2015)

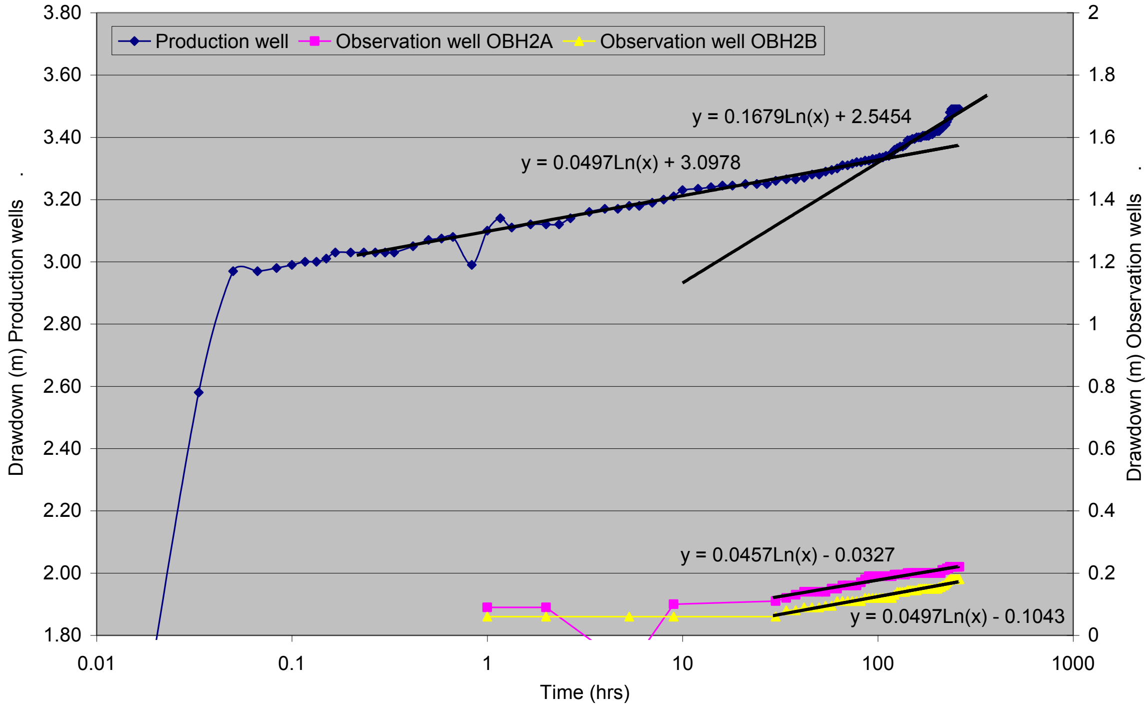


Figure D4. A plot of drawdown versus log(time since pump start) for the constant rate test of PBH2 in June 2015. *Data from the production borehole (left axis) and the two observation boreholes (right axis) are shown.*

Production Well PBH2

For the production well, the drawdown reaches a maximum value of around 3.5 m. The data between 0.1 and 110 hours following pump switch-on roughly fall on a straight line. A best fit straight line has been drawn through data between t = 1 hr and t = 110 hr using Excel and has been found to have the equation:

$s = 0.0497 \ln(t) + 3.0978$

According to Cooper-Jacob's log-linear approximation, the drawdown data should fit a line according to

$$s = \frac{Q}{4\pi T}\ln\left[\frac{2.25Tt}{r^2S}\right] = \frac{Q}{4\pi T}\ln[t] + \frac{Q}{4\pi T}\ln\left[\frac{2.25T}{r^2S}\right]$$

provided that $u = r^2S/4Tt$ is small. The definition of "small" is somewhat subjective. Some authors suggest that u should be <0.01, but Misstear et al. (2006) suggest u<0.05. This implies that $t > r^2S/0.2T$ for the analysed section of data.

- where S = dimensionless storage, Q = discharge = 6.25 L/s = 540 m^3/d and r = radius

Thus, $Q/4\pi T$ = 0.0497 m, and

T = transmissivity = 540 m^3/d / 4 / π / 0.0497 m = 865 m^3/d

We need to check that t is great enough for the Cooper-Jacob approximation to be valid:

$t > r^2S/0.2T$

The radius of the production borehole is 0.1 m; *S*, the dimensionless storage, is around 0.2 (see below) and T = 865 m^2/d. Thus:

$t > 1.2 \times 10^{-5}$ days = 2.8×10^{-4} hours for the Cooper-Jacob analysis to be valid. Our analysis is thus valid, as we have only used data where t > 1 day.

Observation Well OBH2A

For the observation borehole OBH2A, the drawdown reaches a maximum value of around 0.22 m. The data between 30 hours and the end of the test roughly fall on a straight line. A best fit straight line has been drawn through data between t = 30 hr and t = 258 hr using Excel and has been found to have the equation:

$s = 0.0457 \ln(t) - 0.03270$

Thus, $Q/4\pi T$ = 0.0457 m, and

T = transmissivity = 540 m^3/d / 4 / π / 0.0457 m = 940 m^3/d

Furthermore, by comparison with the Cooper-Jacob formula:

$$s = \frac{Q}{4\pi T}\ln\left[\frac{2.25Tt}{r^2 S}\right] = \frac{Q}{4\pi T}\ln[t] + \frac{Q}{4\pi T}\ln\left[\frac{2.25T}{r^2 S}\right]$$

when $s = 0$, $t = t_0$ and

$$t_0 = \frac{r^2 S}{2.25T}$$

In our case,

$s = 0 = 0.0457 \ln(t_0) - 0.03270$

$\ln(t_0)$ = 0.03270 m / 0.0457 m = 0.716

t_0 = 2.045 hrs (as hours are shown on the graph axis and used in Excel) = 0.0852 days

The observation borehole is located at a radial distance r = 30 m from the pumping well.

Thus, S = 0.0852 d x 2.25 x 940 m^2/d / 900 m^2 = 0.20

So **S = 20%,** which corresponds to an unconfined specific yield in a porous sand and gravel aquifer.

We need to check that t is great enough for the Cooper-Jacob approximation to be valid:

$t > r^2 S/0.2T$

The radial distance r = 30 m, S, the dimensionless storage, is around 0.2 and T = 940 m^2/d. Thus:

t > 0.96 days = 23 hours for the Cooper-Jacob analysis to be valid. We have only analysed data > 30 hours, thus our analysis is valid.

Observation Well OBH2B

For the observation borehole OBH2B, the drawdown reaches a maximum value of around 0.18 m. The data between 30 hours and the end of the test roughly fall on a straight line. A

best fit straight line has been drawn through data between t = 30 hr and t = 258 hr using Excel and has been found to have the equation:

$s = 0.0497 \ln(t) - 0.1043$

Thus, $Q/4\pi T = 0.0497$ m, and

T = transmissivity = 540 m^3/d / 4 / π / 0.0497 m = 865 m^3/d

The observation borehole is located at a radial distance r = 65 m from the pumping well.

$s = 0 = 0.0497 \ln(t_0) - 0.1043$

$\ln(t_0)$ = 0.1043 m / 0.0497 m = 2.099

t_0 = 8.155 hrs (as hours are shown on the graph axis and used in Excel) = 0.340 days

Thus, S = 0.340 d x 2.25 x 865 m^2/d / 4225 m^2 = 0.16

So **S = 16%,** which corresponds to an unconfined specific yield in a porous sand and gravel aquifer.

We need to check that t is great enough for the Cooper-Jacob approximation to be valid:

$t > r^2S/0.2T$

The radial distance r = 65 m, S, the dimensionless storage, is around 0.16 and T = 865 m^2/d. Thus:

t>3.9 days = 94 hours for the Cooper-Jacob analysis to be valid. We have analysed data > 30 hours, thus our analysis falls partly outside the validity of the Cooper-Jacob approximation. In fact, if repeat the analysis, using data from after 94 hrs, we obtain a value of

T = 701 m^2/d and S = 23%

D1.5 Significance of Late Data

In Figure D4, it will be seen that, after t = 110 hours, the slope of the drawdown vs. log(time) curve steepens dramatically. Several explanations are possible for this:

- an unrecorded increase in pumping rate (although there is no evidence of this in the observation boreholes).
- a dramatic unexplained decline in the production borehole efficiency
- some kind of low-permeability boundary being encountered by the expanding cone of depression of the production borehole.

If the low permeability boundary were linear, the slope of the line would approximately be expected to double in magnitude (Misstear *et al*. 2006). In fact, in Figure D4, the slope of the line approximately trebles in magnitude, suggesting that any low-permeability boundary is not merely linear, but partially surrounds the well field in a concave ('enclosure'-like) manner. The fact that the effect is not seen in the observation wells may imply that any such boundary is *not* to the east of PBH2.

Very roughly, the time it takes a hydraulic signal to reach a distance L is given by $L^2S/4T$ (Zimmerman 2003). If we assume that the hydraulic diffusivity T/S is 900 m^2/d / 0.2 = 4500 m^2/d, then a time of 110 hours (4.58 days) corresponds to a distance $\sqrt{(4 \times 4500\ m^2/d \times 4.58\ d)}$ = 287 m from the production borehole.

By examining the VES map of the base of the aquifer (Section B), we can see that the aquifer does indeed thin towards the west within a distance scale of around 300 m (Figure D5).

***Figure D5**. **Vertical electrical sounding locations in vicinity of borehole PBH2 (marked with an orange spot) showing inferred aquifer thickness (m)**. Blue colours show thick aquifer, yellow and orange show thin. The horizontal red line is a 300 m scale, illustrating that the aquifer thins to the west within 300 m of PBH2.*

D1.6 Summary

The pumping test results from all three monitoring points provide a consistent set of results:

- An apparent transmissivity of around 900 m^2/d
- A dimensionless storage of 16-20%, which corresponds with what would be expected for the specific yield of an unconfined sand and gravel aquifer.
- The transmissivity from Cooper-Jacob analysis of the long-term test is far greater than would have been predicted from the Logan Approximation applied to short term step test specific capacity data. This, together with the fact that the majority of drawdown and recovery occur within the first few hours of the test, is an indicator of very poor well efficiency (i.e. high well losses relative to aquifer losses).
- The steepening of the drawdown versus log(time) curve at 110 hours suggests a reduction in aquifer transmissivity at a distance of some 250 to 300 m from the production well. This ties in with results of the VES geophysical data.
- The pumping test has failed to demonstrate conclusively that a large abstraction can be sustainably derived from the aquifer - indeed, the test has demonstrated the presence of negative boundary conditions near to PBH2. A longer pumping test would be necessary to demonstrate sustainability, possibly coupled with testing of a second production borehole closer to the Maimana River.

D2 Pumping test - Water Chemistry

The pumped groundwater's electrical conductivity, temperature and pH were measured in the field by hand-held meters at regular intervals during the test pumping (Figure D6).

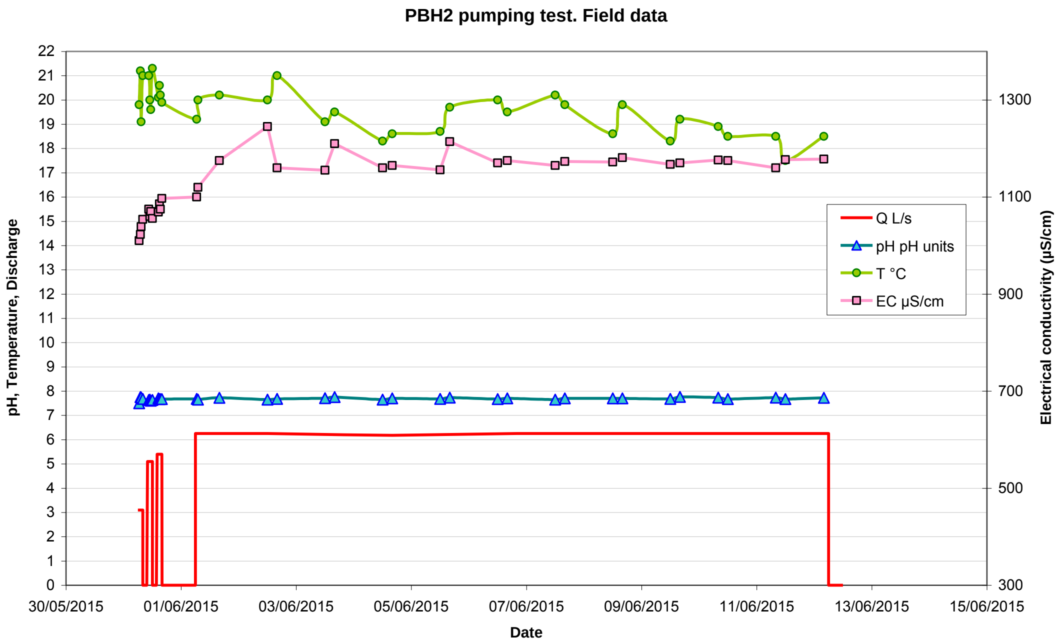


Figure D6. Rates of pumping and field determinations of pH, electrical conductivity (EC) and temperature of groundwater from PBH2, during pumping test.

The pH throughout the test was rather constant at 7.6 to 7.8. The electrical conductivity, on the other hand, rose from around 1010 µS/cm at the start of the step testing to 1245 µS/cm around 1 day into the constant rate test, and then remained at 1150 to 1200 µS/cm for the remainder of the test. The temperature of the pumped groundwater was initially around 20°C, which fell throughout the test to some 18-19°C by the end.

As regards sampling for chemical analysis, one groundwater sample was taken during the step testing of PBH2 on 31/5/15 (sample NOR-MM-01A). Six further samples were taken during the course of the constant-rate pumping test, as shown in Figure D7. These samples were labelled NOR-MM-01B to NOR-MM-06. Each sample comprised:

- One c. 15 ml aliquot of sample filtered in the field at 0.45 µm. This was delivered to British Geological Survey's analytical laboratory at Keyworth, UK and analysed for stable isotopes (^{2}H and ^{18}O) by mass spectrometry and (following in-flask laboratory acidification to remobilise sorbed metals) for a range of cations and trace elements by inductively coupled plasma mass spectrometry (ICP-MS),
- One 500 ml aliquot of unfiltered water. This was delivered to British Geological Survey's analytical laboratory at Keyworth, UK and analysed for anions by ion chromatography (IC) and for alkalinity by titration.

The samples were clear, colourless and non-turbid upon arrival in the United Kingdom.

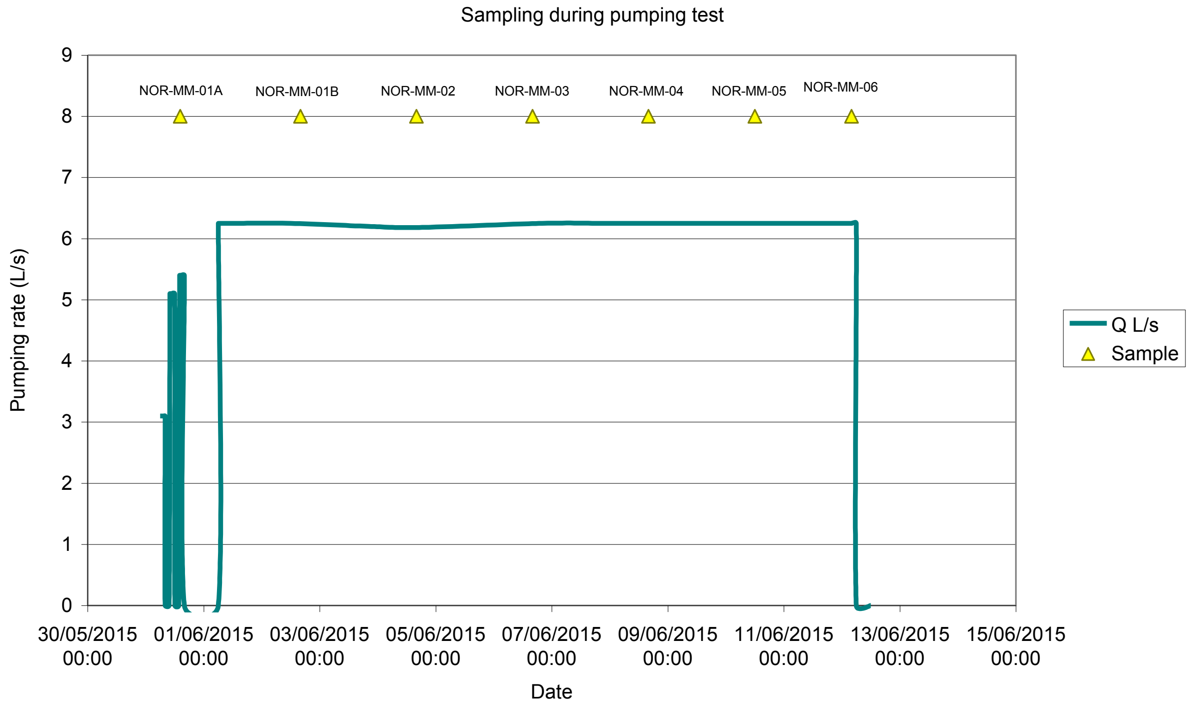


Figure D7. Rates of pumping during testing of Maimana production borehole PBH2, showing times of sampling.

Throughout the pumping test, the water had a Ca-Mg-(Na)-HCO3-(SO4-Cl) type, characteristic of the transition between the fresher Ca-Mg-HCO3 newly-recharged waters of the south of Faryab Province and the Na-SO4-Cl waters of the north (Banks 2014).

Apart from the initial salinity of the water being slightly less in the first (step test) sample, the composition and salinity of the water remains essentially unchanged throughout the test period (Figure D8 and D9). All ion balance errors were within ±2%, indicating extremely good analytical quality (Figure D10).

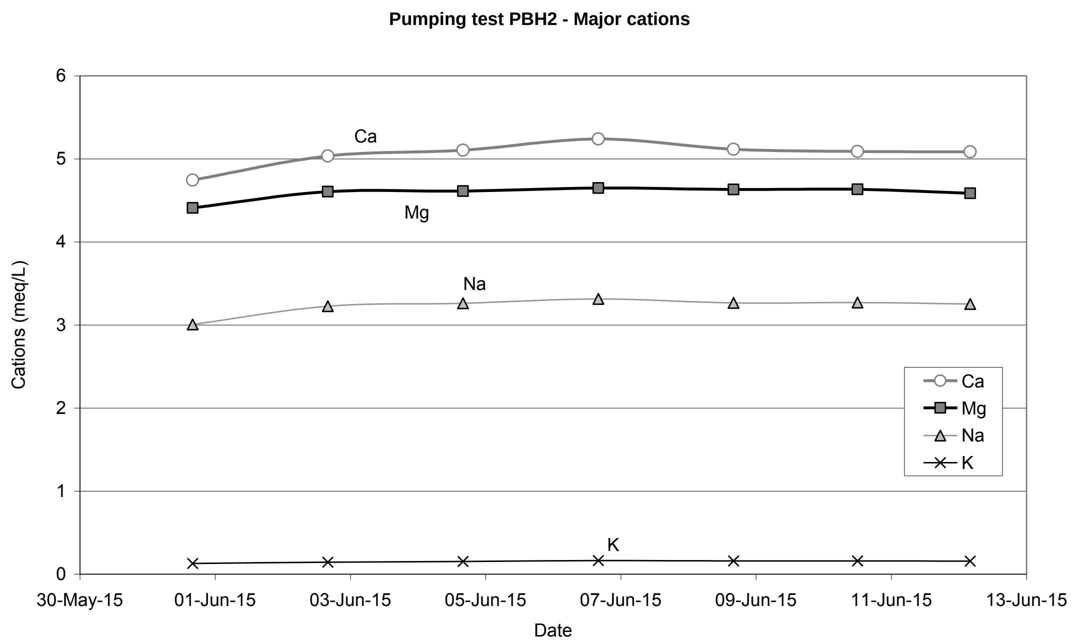


Figure D8. Major cation composition of the pumped groundwater from the PBH2 pumping test (meq/L).

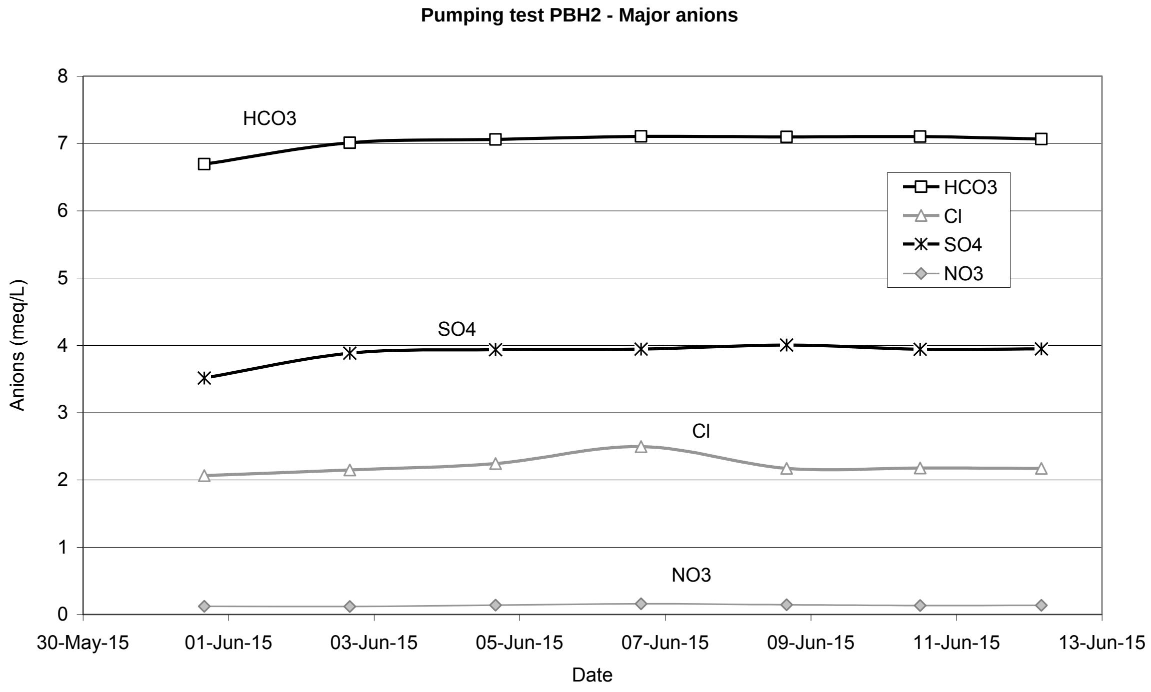


Figure D9. Major anion composition of the pumped groundwater from the PBH2 pumping test (meq/L).

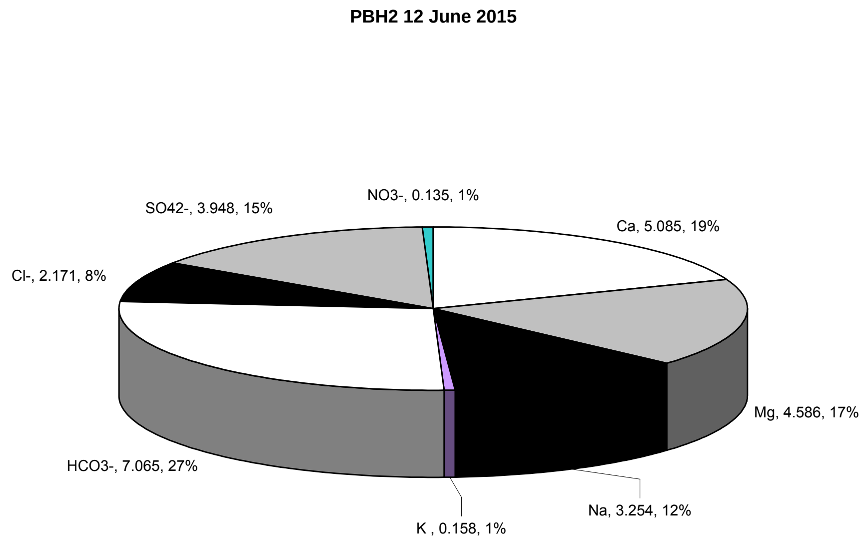


Figure D10. Major cation and anion composition of groundwater from PBH2 on 12th June 2015 (end of test), showing concentration of each component in meq/L and % of ion composition

The groundwater from well PBH2 appears to be of a wholesome quality in terms of inorganic chemistry. Nitrate concentrations are modest (8-9 mg/L), but not negligible, suggesting that there may be some source of diffuse nitrogen pollution in the groundwater catchment (agriculture or possibly latrines, etc.). Uranium concentrations are around 4 μg/L - still well below the WHO Provisional Guideline of 30 μg/L.

LIMS Code		13621-0001	13621-0002	13621-0003	13621-0004	13621-0005	13621-0006	13621-0007
Sample Code		NOR-MAI-01A	NOR-MAI-01B	NOR-MAI-02	NOR-MAI-03	NOR-MAI-04	NOR-MAI-05	NOR-MAI-06
Sample date		31-May-15	02/06/15	04/06/15	06/06/15	08/06/15	10/06/15	12/06/15
Time		Step test	16:00	16:00	16:00	16:00	12:00	04:00
TDS	mg l^{-1}	881	934	947	965	951	948	945
Ca	mg l^{-1}	95.1	101	102	105	103	102	102
Mg	mg l^{-1}	53.6	56.0	56.1	56.5	56.3	56.3	55.7
Na	mg l^{-1}	69.1	74.2	75.0	76.2	75.1	75.2	74.8
K	mg l^{-1}	5.03	5.62	6.00	6.35	6.23	6.20	6.17
HCO_3^-	mg l^{-1}	408	428	431	434	433	433	431
Cl^-	mg l^{-1}	73	76	80	88	77	77	77
SO_4^{2-}	mg l^{-1}	169	187	189	189	192	189	190
NO_3^-	mg l^{-1}	7.5	7.3	8.6	9.9	8.9	8.3	8.4
Cation Total	meq l^{-1}	12.4	13.1	13.2	13.4	13.2	13.2	13.2
Anion Total	meq l^{-1}	12.4	13.2	13.4	13.7	13.4	13.4	13.3
Balance	%	-0.23	-0.46	-0.70	-0.98	-0.65	-0.48	-0.63
Br^-	mg l^{-1}	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
HPO_4^{2-}	mg l^{-1}	1.0	2.1	0.6	<0.5	<0.5	<0.5	<0.5
F^-	mg l^{-1}	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Total P	mg l^{-1}	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total S	mg l^{-1}	59	65	67	67	66	66	66
Si	mg l^{-1}	6.04	6.10	6.24	6.12	6.13	6.21	6.00
Ba	µg l^{-1}	45.9	50.0	49.8	51.2	50.5	50.1	50.1
Sr	µg l^{-1}	2758	2898	2940	3002	2921	2941	2934
Mn	µg l^{-1}	1.1	1.6	0.7	3.6	0.3	2.1	0.8
Total Fe	µg l^{-1}	9	35	12	14	3	47	9
Li	µg l^{-1}	17	19	19	19	19	19	19
Be	µg l^{-1}	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	µg l^{-1}	158	163	161	164	163	161	160
Al	µg l^{-1}	6	20	8	14	2	32	8
Ti	µg l^{-1}	0.27	0.79	0.33	0.24	<0.05	1.37	0.34
V	µg l^{-1}	1.2	1.3	1.3	1.3	1.3	1.3	1.3
Cr	µg l^{-1}	1.39	1.83	1.30	1.24	1.27	1.37	1.30
Co	µg l^{-1}	0.02	0.03	0.02	0.05	0.02	0.04	0.02
Ni	µg l^{-1}	0.3	0.2	0.2	0.4	0.5	0.2	<0.1
Cu	µg l^{-1}	<0.4	1.2	<0.4	<0.4	<0.4	0.6	<0.4
Zn	µg l^{-1}	221	241	268	291	285	292	289
Ga	µg l^{-1}	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
As	µg l^{-1}	0.39	0.39	0.40	0.43	0.39	0.40	0.39
Se	µg l^{-1}	1.8	1.8	2.0	2.0	2.0	2.0	1.9
Rb	µg l^{-1}	1.32	1.42	1.46	1.53	1.46	1.51	1.48
Y	µg l^{-1}	0.034	0.060	0.034	0.065	0.026	0.073	0.041
Zr	µg l^{-1}	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nb	µg l^{-1}	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mo	µg l^{-1}	0.68	0.61	0.59	0.57	0.56	0.58	0.56
Ag	µg l^{-1}	<0.05	0.12	<0.05	<0.05	<0.05	<0.05	<0.05
Cd	µg l^{-1}	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sn	µg l^{-1}	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sb	µg l^{-1}	0.063	0.067	0.085	0.058	0.057	0.066	0.063
Cs	µg l^{-1}	0.011	0.012	0.012	0.012	0.013	0.014	0.012
La	µg l^{-1}	0.011	0.043	0.013	0.044	0.004	0.056	0.018
Ce	µg l^{-1}	0.022	0.077	0.026	0.079	0.005	0.098	0.032
Pr	µg l^{-1}	<0.002	0.009	0.002	0.009	<0.002	0.011	0.003
Nd	µg l^{-1}	<0.05	0.05	<0.05	<0.05	<0.05	0.07	<0.05
Sm	µg l^{-1}	0.003	0.009	<0.002	0.011	<0.002	0.013	0.005
Eu	µg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002
Gd	µg l^{-1}	0.002	0.008	0.002	0.009	<0.002	0.011	0.004
Tb	µg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dy	µg l^{-1}	<0.002	0.007	<0.002	0.007	<0.002	0.008	0.002
Ho	µg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Er	µg l^{-1}	<0.002	0.003	<0.002	0.004	<0.002	0.005	<0.002
Tm	µg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Yb	µg l^{-1}	<0.002	0.004	<0.002	0.003	<0.002	0.004	<0.002
Lu	µg l^{-1}	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Hf	$\mu g\ l^{-1}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ta	$\mu g\ l^{-1}$	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
W	$\mu g\ l^{-1}$	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tl	$\mu g\ l^{-1}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	$\mu g\ l^{-1}$	0.93	1.06	0.83	1.00	0.86	1.04	0.96
Th	$\mu g\ l^{-1}$	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
U	$\mu g\ l^{-1}$	3.80	4.08	4.09	4.11	4.10	4.07	4.07
δ18O	‰VSMOW	-8.3	-8.2	-8.2	-8.2	-8.2	-8.2	-8.2
δ2H	‰VSMOW	-52.1	-50.6	-50.2	-50.4	-50.3	-50.5	-50.2

***Table D2. Chemical analysis results for the six samples from well PBH2 during step and constant rate testing**, as analysed by the British Geological Survey, report no. 13621/1*

In terms of stable isotopes, when superimposed on the regional results taken from Banks (2014), the results from PBH2 cluster with the other groundwater results from Maimana, slightly below the local meteoric water line (Figure D11).

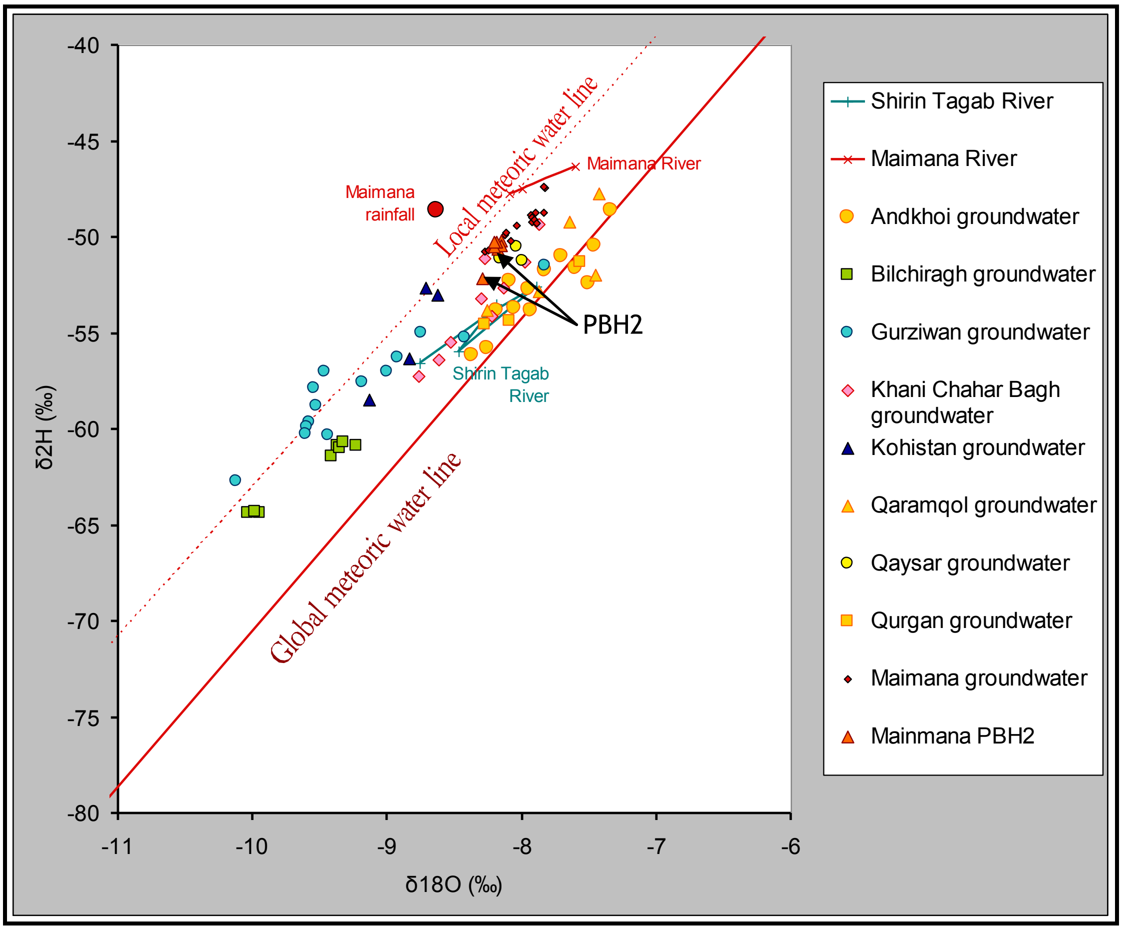


Figure D11. Stable isotope data for PBH2, superimposed upon the regional groundwater stable isotope diagram from Banks (2014).

D3 Pumping test - Raw Data

Date / Time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
31/05/2015 06:00	0	0	37.33	35.51	0.00	3.1	#N/A	#N/A	#N/A	35.45	0	35.38	0	
31/05/2015 06:01	60	0.0167	38.00	36.18	0.67	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:02	120	0.0333	38.25	36.43	0.92	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:03	180	0.0500	38.28	36.46	0.95	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:04	240	0.0667	38.30	36.48	0.97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:05	300	0.0833	38.33	36.51	1.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:06	360	0.1000	38.35	36.53	1.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:07	420	0.1167	38.39	36.57	1.06	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:08	480	0.1333	38.44	36.62	1.11	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:09	540	0.1500	38.48	36.66	1.15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:10	600	0.1667	38.55	36.73	1.22	3.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:12	720	0.2000	38.56	36.74	1.23	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:14	840	0.2333	38.64	36.82	1.31	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:16	960	0.2667	38.66	36.84	1.33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:18	1080	0.3000	38.67	36.85	1.34	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:20	1200	0.3333	38.67	36.85	1.34	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:25	1500	0.4167	38.68	36.86	1.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:30	1800	0.5000	38.68	36.86	1.35	#N/A	1010	7.5	19.8	35.51	0.06	35.42	0.04	
31/05/2015 06:35	2100	0.5833	38.68	36.86	1.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 06:40	2400	0.6667	38.68	36.86	1.35	3.1	#N/A	#N/A	#N/A	35.51	0.06	35.42	0.04	
31/05/2015 06:50	3000	0.8333	38.68	36.86	1.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 07:00	3600	1.0000	38.68	36.86	1.35	#N/A	1023	7,75	21.2	#N/A	#N/A	#N/A	#N/A	
31/05/2015 07:10	4200	1.1667	38.68	36.86	1.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 07:20	4800	1.3333	38.68	36.86	1.35	#N/A	1039	7.74	19.1	#N/A	#N/A	#N/A	#N/A	
31/05/2015 07:40	6000	1.6667	38.68	36.86	1.35	3.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:00	7200	2.0000	38.68	36.86	1.35	3.1	1054	7.68	21	35.51	0.06	35.42	0.04	
31/05/2015 08:01	60	0.0167	37.38	35.560	0.05	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:02	120	0.0333	37.36	35.540	0.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:03	180	0.0500	37.35	35.530	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:04	240	0.0667	37.35	35.530	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:05	300	0.0833	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:06	360	0.1000	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:07	420	0.1167	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:08	480	0.1333	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:09	540	0.1500	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	

Date / Time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
31/05/2015 08:10	600	0.1667	37.34	35.52	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:12	720	0.2000	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:14	840	0.2333	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:16	960	0.2667	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:18	1080	0.3000	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:20	1200	0.3333	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:25	1500	0.4167	37.33	35.512	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 08:30	1800	0.5000	37.33	35.512	0.00	#N/A	#N/A	#N/A	#N/A	35.49	0.04	35.40	0.02	
31/05/2015 08:35	2100	0.5833	37.33	35.512	0.00	#N/A	#N/A	#N/A	#N/A	35.48	0.03	35.395	0.015	
31/05/2015 08:40	2400	0.6667	37.33	35.511	0.00	#N/A	#N/A	#N/A	#N/A	35.47	0.02	35.395	0.015	
31/05/2015 08:50	3000	0.8333	37.33	35.511	0.00	#N/A	#N/A	#N/A	#N/A	35.465	0.015	35.39	0.01	
31/05/2015 09:00	3600	1.0000	37.33	35.511	0.00	#N/A	#N/A	#N/A	#N/A	35.45	0	35.39	0.01	
31/05/2015 09:10	4200	1.1667	37.33	35.511	0.00	#N/A	#N/A	#N/A	#N/A	35.45	0	35.385	0.005	
31/05/2015 09:20	4800	1.3333	37.33	35.51	0.00	#N/A	#N/A	#N/A	#N/A	35.45	0	35.385	0.005	
31/05/2015 09:40	6000	1.6667	37.33	35.51	0.00	0	#N/A	#N/A	#N/A	35.45	0	35.38	0	
31/05/2015 10:00	7200	2.0000	37.33	35.51	0.00	5.1	#N/A	#N/A	#N/A	35.45	0	35.38	0	
31/05/2015 10:01	60	0.0167	38.73	36.910	1.40	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:02	120	0.0333	38.80	36.980	1.47	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:03	180	0.0500	38.81	36.990	1.48	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:04	240	0.0667	38.81	36.990	1.48	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:05	300	0.0833	38.85	37.030	1.52	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:06	360	0.1000	39.01	37.190	1.68	5.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:07	420	0.1167	39.06	37.240	1.73	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:08	480	0.1333	39.11	37.290	1.78	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:09	540	0.1500	39.16	37.340	1.83	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:10	600	0.1667	39.17	37.350	1.84	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:12	720	0.2000	39.16	37.34	1.83	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:14	840	0.2333	39.16	37.34	1.83	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:16	960	0.2667	39.16	37.34	1.83	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:18	1080	0.3000	39.17	37.35	1.84	5.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:20	1200	0.3333	39.17	37.35	1.84	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:25	1500	0.4167	39.18	37.36	1.85	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:30	1800	0.5000	39.19	37.37	1.86	#N/A	1075	7.63	21	35.53	0.08	35.41	0.03	
31/05/2015 10:35	2100	0.5833	39.20	37.38	1.87	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:40	2400	0.6667	39.21	37.39	1.88	5.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 10:50	3000	0.8333	39.22	37.40	1.89	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 11:00	3600	1.0000	39.22	37.40	1.89	#N/A	1060	7.65	20	35.53	0.08	35.41	0.03	
31/05/2015 11:10	4200	1.1667	39.22	37.40	1.89	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 11:20	4800	1.3333	39.22	37.40	1.89	#N/A	1070	7.6	19.6	#N/A	#N/A	#N/A	#N/A	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
31/05/2015 11:40	6000	1.6667	39.22	37.40	1.89	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:00	7200	2.0000	39.22	37.40	1.89	5.1	1056	7.63	21.3	35.53	0.08	35.41	0.03	
31/05/2015 12:01	60	0.0167	38.64	36.820	1.31	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:02	120	0.0333	38.11	36.290	0.78	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:03	180	0.0500	37.76	35.940	0.43	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:04	240	0.0667	37.68	35.860	0.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:05	300	0.0833	37.53	35.710	0.20	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:06	360	0.1000	37.50	35.680	0.17	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:07	420	0.1167	37.45	35.630	0.12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:08	480	0.1333	37.42	35.600	0.09	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:09	540	0.1500	37.40	35.580	0.07	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:10	600	0.1667	37.38	35.56	0.05	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:12	720	0.2000	37.36	35.540	0.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:14	840	0.2333	37.35	35.530	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:16	960	0.2667	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:18	1080	0.3000	37.34	35.520	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:20	1200	0.3333	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:25	1500	0.4167	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:30	1800	0.5000	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.49	0.04	35.40	0.02	
31/05/2015 12:35	2100	0.5833	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:40	2400	0.6667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 12:50	3000	0.8333	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 13:00	3600	1.0000	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.46	0.01	35.39	0.01	
31/05/2015 13:10	4200	1.1667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.455	0.005	35.39	0.01	
31/05/2015 13:20	4800	1.3333	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.45	0	35.385	0.005	
31/05/2015 13:40	6000	1.6667	37.33	35.510	0.00	0	#N/A	#N/A	#N/A	35.45	0	35.385	0.005	
31/05/2015 14:00	7200	2.0000	37.33	35.510	0.00	5.4	#N/A	#N/A	#N/A	35.45	0	35.38	0	
31/05/2015 14:01	60	0.0167	39.22	37.40	1.89	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:02	120	0.0333	39.26	37.44	1.93	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:03	180	0.0500	39.30	37.48	1.97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:04	240	0.0667	39.39	37.57	2.06	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:05	300	0.0833	39.45	37.63	2.12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:06	360	0.1000	39.56	37.74	2.23	5.4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:07	420	0.1167	39.65	37.83	2.32	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:08	480	0.1333	39.72	37.90	2.39	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:09	540	0.1500	39.81	37.99	2.48	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:10	600	0.1667	39.93	38.11	2.60	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:12	720	0.2000	40.08	38.26	2.75	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:14	840	0.2333	40.18	38.36	2.85	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
31/05/2015 14:16	960	0.2667	40.27	38.45	2.94	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:18	1080	0.3000	40.28	38.46	2.95	5.4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:20	1200	0.3333	40.31	38.49	2.98	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:25	1500	0.4167	40.31	38.49	2.98	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:30	1800	0.5000	40.32	38.50	2.99	#N/A	1069	7.7	20.1	35.53	0.08	35.41	0.03	
31/05/2015 14:35	2100	0.5833	40.32	38.50	2.99	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:40	2400	0.6667	40.32	38.50	2.99	5.4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 14:50	3000	0.8333	40.33	38.51	3.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 15:00	3600	1.0000	40.34	38.52	3.01	#N/A	1086	7.67	20.6	35.53	0.08	35.41	0.03	
31/05/2015 15:10	4200	1.1667	40.35	38.53	3.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 15:20	4800	1.3333	40.37	38.55	3.04	#N/A	1075	7.67	20.2	#N/A	#N/A	#N/A	#N/A	
31/05/2015 15:40	6000	1.6667	40.37	38.55	3.04	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:00	7200	2.0000	40.37	38.55	3.04	5.4	1097	7.67	19.9	35.53	0.08	35.41	0.03	
31/05/2015 16:01	60	0.0167	39.77	37.950	2.44	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:02	120	0.0333	38.82	37.00	1.49	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:03	180	0.0500	38.54	36.720	1.21	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:04	240	0.0667	38.03	36.21	0.70	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:05	300	0.0833	37.83	36.01	0.50	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:06	360	0.1000	37.74	35.92	0.41	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:07	420	0.1167	37.66	35.84	0.33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:08	480	0.1333	37.58	35.760	0.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:09	540	0.1500	37.51	35.690	0.18	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:10	600	0.1667	37.45	35.63	0.12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:12	720	0.2000	37.41	35.590	0.08	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:14	840	0.2333	37.38	35.560	0.05	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:16	960	0.2667	37.37	35.550	0.04	#N/A	#N/A	#N/A	#N/A	35.50	0.05	35.40	0.02	
31/05/2015 16:18	1080	0.3000	37.36	35.540	0.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:20	1200	0.3333	37.35	35.530	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:25	1500	0.4167	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:30	1800	0.5000	37.34	35.520	0.01	#N/A	#N/A	#N/A	#N/A	35.48	0.03	35.39	0.01	
31/05/2015 16:35	2100	0.5833	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:40	2400	0.6667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 16:50	3000	0.8333	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 17:00	3600	1.0000	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.47	0.015	35.385	0.005	
31/05/2015 17:10	4200	1.1667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 17:20	4800	1.3333	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.46	0.01	35.385	0.005	
31/05/2015 17:40	6000	1.6667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
31/05/2015 18:00	7200	2.0000	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	35.45	0	35.38	0	
01/06/2015 06:00	0	0.0000	#N/A	#N/A	#N/A	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
01/06/2015 06:00	0	0.0000	37.33	35.510	0.00	6.25	#N/A	#N/A	#N/A	35.45	0	35.38	0	
01/06/2015 06:01	60	0.0167	38.80	36.980	1.47	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:02	120	0.0333	39.91	38.090	2.58	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:03	180	0.0500	40.30	38.480	2.97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:04	240	0.0667	40.30	38.480	2.97	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:05	300	0.0833	40.31	38.490	2.98	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:06	360	0.1000	40.32	38.500	2.99	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:07	420	0.1167	40.33	38.510	3.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:08	480	0.1333	40.33	38.510	3.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:09	540	0.1500	40.34	38.520	3.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:10	600	0.1667	40.36	38.540	3.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:12	720	0.2000	40.36	38.540	3.03	6.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:14	840	0.2333	40.36	38.540	3.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:16	960	0.2667	40.36	38.540	3.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:18	1080	0.3000	40.36	38.540	3.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:20	1200	0.3333	40.36	38.540	3.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:25	1500	0.4167	40.38	38.56	3.05	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:30	1800	0.5000	40.40	38.580	3.07	#N/A	1100	7.68	19.2	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:35	2100	0.5833	40.41	38.585	3.08	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:40	2400	0.6667	40.41	38.59	3.08	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 06:50	3000	0.8333	40.32	38.50	2.99	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 07:00	3600	1.0000	40.43	38.61	3.10	#N/A	1120	7.65	20	35.54	0.09	35.44	0.06	
01/06/2015 07:10	4200	1.1667	40.47	38.65	3.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 07:20	4800	1.3333	40.44	38.62	3.11	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 07:40	6000	1.6667	40.45	38.63	3.12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 08:00	7200	2.0000	40.45	38.63	3.12	#N/A	#N/A	#N/A	#N/A	35.54	0.09	35.44	0.06	
01/06/2015 08:20	8400	2.3333	40.45	38.63	3.12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 08:40	9600	2.6667	40.47	38.65	3.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 09:20	12000	3.3333	40.49	38.67	3.16	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 10:00	14400	4.0000	40.50	38.68	3.17	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 10:40	16800	4.6667	40.50	38.68	3.17	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 11:20	19200	5.3333	40.51	38.69	3.18	#N/A	#N/A	#N/A	#N/A	35.345	-0.105	35.44	0.06	
01/06/2015 12:00	21600	6.0000	40.51	38.69	3.18	6.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 13:00	25200	7.0000	40.52	38.70	3.19	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 14:00	28800	8.0000	40.53	38.71	3.20	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 15:00	32400	9.0000	40.54	38.72	3.21	#N/A	#N/A	#N/A	#N/A	35.55	0.1	35.44	0.06	
01/06/2015 16:00	36000	10.0000	40.56	38.74	3.23	#N/A	1175	7.72	20.2	#N/A	#N/A	#N/A	#N/A	
01/06/2015 18:00	43200	12.0000	40.57	38.745	3.24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
01/06/2015 20:00	50400	14.0000	40.57	38.75	3.24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
01/06/2015 22:00	57600	16.0000	40.58	38.755	3.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
02/06/2015 00:00	64800	18.0000	40.58	38.755	3.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
02/06/2015 03:00	75600	21.0000	40.58	38.76	3.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
02/06/2015 06:00	86400	24.0000	40.58	38.76	3.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
02/06/2015 09:00	97200	27.0000	40.58	38.76	3.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
02/06/2015 12:00	108000	30.0000	40.59	38.77	3.26	6.25	1245	7.65	20	35.56	0.11	35.44	0.06	
02/06/2015 16:00	122400	34.0000	40.60	38.775	3.27	#N/A	1160	7.68	21	35.57	0.12	35.46	0.08	NOR-MM-01B 15 ml filtered and 500 ml unfiltered
02/06/2015 20:00	136800	38.0000	40.60	38.775	3.27	#N/A	#N/A	#N/A	#N/A	35.58	0.13	35.46	0.08	
03/06/2015 00:00	151200	42.0000	40.60	38.78	3.27	#N/A	#N/A	#N/A	#N/A	35.59	0.14	35.47	0.09	
03/06/2015 04:00	165600	46.0000	40.61	38.79	3.28	#N/A	#N/A	#N/A	#N/A	35.59	0.14	35.47	0.09	
03/06/2015 08:00	180000	50.0000	40.61	38.79	3.28	#N/A	#N/A	#N/A	#N/A	35.59	0.14	35.47	0.09	
03/06/2015 12:00	194400	54.0000	40.62	38.80	3.29	#N/A	1155	7.71	19.1	35.59	0.14	35.475	0.095	
03/06/2015 16:00	208800	58.0000	40.63	38.805	3.30	#N/A	1210	7.75	19.5	35.60	0.15	35.475	0.095	
03/06/2015 20:00	223200	62.0000	40.63	38.81	3.30	6.2	#N/A	#N/A	#N/A	35.60	0.15	35.49	0.11	
04/06/2015 00:00	237600	66.0000	40.64	38.82	3.31	#N/A	#N/A	#N/A	#N/A	35.61	0.16	35.49	0.11	
04/06/2015 04:00	252000	70.0000	40.64	38.82	3.31	#N/A	#N/A	#N/A	#N/A	35.61	0.16	35.49	0.11	
04/06/2015 08:00	266400	74.0000	40.65	38.83	3.32	#N/A	#N/A	#N/A	#N/A	35.61	0.16	35.49	0.11	
04/06/2015 12:00	280800	78.0000	40.65	38.83	3.32	#N/A	1160	7.65	18.3	35.61	0.16	35.49	0.11	
04/06/2015 16:00	295200	82.0000	40.65	38.83	3.32	6.18	1165	7.7	18.6	35.62	0.17	35.49	0.11	NOR-MM-02 15 ml filtered and 500 ml unfiltered
04/06/2015 20:00	309600	86.0000	40.66	38.835	3.33	#N/A	#N/A	#N/A	#N/A	35.63	0.18	35.50	0.12	
05/06/2015 00:00	324000	90.0000	40.66	38.835	3.33	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
05/06/2015 04:00	338400	94.0000	40.66	38.84	3.33	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
05/06/2015 08:00	352800	98.0000	40.66	38.84	3.33	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
05/06/2015 12:00	367200	102.0000	40.67	38.845	3.34	#N/A	1156	7.68	18.7	35.64	0.19	35.50	0.12	
05/06/2015 16:00	381600	106.0000	40.67	38.845	3.34	#N/A	1214	7.73	19.7	35.64	0.19	35.50	0.12	
05/06/2015 20:00	396000	110.0000	40.67	38.85	3.34	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
06/06/2015 00:00	410400	114.0000	40.67	38.85	3.34	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
06/06/2015 04:00	424800	118.0000	40.68	38.86	3.35	#N/A	#N/A	#N/A	#N/A	35.64	0.19	35.50	0.12	
06/06/2015 08:00	439200	122.0000	40.69	38.87	3.36	#N/A	#N/A	#N/A	#N/A	35.645	0.195	35.51	0.13	
06/06/2015 12:00	453600	126.0000	40.70	38.875	3.37	#N/A	1170	7.67	20	35.645	0.195	35.52	0.14	
06/06/2015 16:00	468000	130.0000	40.70	38.88	3.37	#N/A	1175	7.7	19.5	35.645	0.195	35.52	0.14	NOR-MM-03 15 ml filtered and 500 ml unfiltered
06/06/2015 20:00	482400	134.0000	40.70	38.88	3.37	6.25	#N/A	#N/A	#N/A	35.645	0.195	35.52	0.14	
07/06/2015 00:00	496800	138.0000	40.71	38.885	3.38	#N/A	#N/A	#N/A	#N/A	35.645	0.195	35.52	0.14	
07/06/2015 04:00	511200	142.0000	40.72	38.90	3.39	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.525	0.145	
07/06/2015 08:00	525600	146.0000	40.72	38.90	3.39	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.525	0.145	
07/06/2015 12:00	540000	150.0000	40.73	38.905	3.40	#N/A	1165	7.65	20.2	35.65	0.2	35.525	0.145	
07/06/2015 16:00	554400	154.0000	40.73	38.905	3.40	#N/A	1173	7.7	19.8	35.65	0.2	35.525	0.145	
07/06/2015 20:00	568800	158.0000	40.73	38.91	3.40	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.525	0.145	
08/06/2015 00:00	583200	162.0000	40.73	38.91	3.40	6.25	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
08/06/2015 04:00	597600	166.0000	40.73	38.91	3.40	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
08/06/2015 08:00	612000	170.0000	40.74	38.915	3.41	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
08/06/2015 12:00	626400	174.0000	40.74	38.915	3.41	#N/A	1172	7.7	18.6	35.65	0.2	35.53	0.15	
08/06/2015 16:00	640800	178.0000	40.74	38.915	3.41	#N/A	1181	7.7	19.8	35.65	0.2	35.53	0.15	NOR-MM-04 15 ml filtered and 500 ml unfiltered
08/06/2015 20:00	655200	182.0000	40.74	38.915	3.41	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
09/06/2015 00:00	669600	186.0000	40.74	38.92	3.41	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
09/06/2015 04:00	684000	190.0000	40.74	38.92	3.41	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
09/06/2015 08:00	698400	194.0000	40.75	38.925	3.42	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
09/06/2015 12:00	712800	198.0000	40.75	38.93	3.42	#N/A	1167	7.68	18.3	35.65	0.2	35.53	0.15	
09/06/2015 16:00	727200	202.0000	40.75	38.93	3.42	6.25	1170	7.76	19.2	35.65	0.2	35.53	0.15	
09/06/2015 16:00	727200	202.0000	40.75	38.93	3.42	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.53	0.15	
09/06/2015 20:00	741600	206.0000	40.75	38.93	3.42	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.535	0.155	
10/06/2015 00:00	756000	210.0000	40.76	38.94	3.43	#N/A	#N/A	#N/A	#N/A	35.65	0.2	35.535	0.155	
10/06/2015 04:00	770400	214.0000	40.76	38.94	3.43	#N/A	#N/A	#N/A	#N/A	35.66	0.21	35.54	0.16	
10/06/2015 08:00	784800	218.0000	40.77	38.95	3.44	#N/A	1176	7.73	18.9	35.66	0.21	35.54	0.16	
10/06/2015 12:00	799200	222.0000	40.77	38.95	3.44	#N/A	1175	7.67	18.5	35.66	0.21	35.545	0.165	NOR-MM-05 15 ml filtered and 500 ml unfiltered
10/06/2015 16:00	813600	226.0000	40.78	38.96	3.45	#N/A	#N/A	#N/A	#N/A	35.665	0.215	35.55	0.17	
10/06/2015 20:00	828000	230.0000	40.79	38.97	3.46	#N/A	#N/A	#N/A	#N/A	35.665	0.215	35.555	0.175	
11/06/2015 00:00	842400	234.0000	40.81	38.99	3.48	#N/A	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
11/06/2015 04:00	856800	238.0000	40.82	39.00	3.49	#N/A	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
11/06/2015 08:00	871200	242.0000	40.82	39.00	3.49	#N/A	1160	7.73	18.5	35.67	0.22	35.56	0.18	
11/06/2015 12:00	885600	246.0000	40.82	39.00	3.49	#N/A	1177	7.67	17.5	35.67	0.22	35.56	0.18	
11/06/2015 16:00	900000	250.0000	40.82	39.00	3.49	#N/A	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
11/06/2015 20:00	914400	254.0000	40.82	39.00	3.49	#N/A	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
12/06/2015 00:00	928800	258.0000	40.82	39.00	3.49	#N/A	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
12/06/2015 04:00	943200	262.0000	40.82	39.00	3.49	6.25	1178	7.72	18.5	35.67	0.22	35.56	0.18	NOR-MM-06 15 ml filtered and 500 ml unfiltered
12/06/2015 06:00	0	0.0000	#N/A	#N/A	#N/A	6.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:00	0	0.0000	40.82	39.00	3.49	0	#N/A	#N/A	#N/A	35.67	0.22	35.56	0.18	
12/06/2015 06:01	60	0.0167	39.49	37.670	2.16	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:02	120	0.0333	38.33	36.51	1.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:03	180	0.0500	37.84	36.020	0.51	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:04	240	0.0667	37.57	35.75	0.24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:05	300	0.0833	37.52	35.70	0.19	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:06	360	0.1000	37.47	35.65	0.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:07	420	0.1167	37.47	35.65	0.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:08	480	0.1333	37.47	35.65	0.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:09	540	0.1500	37.47	35.65	0.14	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:10	600	0.1667	37.47	35.65	0.14	#N/A	#N/A	#N/A	#N/A	35.60	0.15	35.51	0.13	
12/06/2015 06:12	720	0.2000	37.37	35.550	0.04	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	

Date / time	Elapsed time		Water level PBH2		Drawdown	Discharge	EC	pH	Temp	OBH2A Water level		OBH2B Water level		Comments
	s	hr	m below datum	m bgl	m	L/s	µS/cm		°C	m below datum	m drawdown	m below datum	m drawdown	
12/06/2015 06:14	840	0.2333	37.37	35.550	0.04	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:16	960	0.2667	37.36	35.540	0.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:18	1080	0.3000	37.36	35.540	0.03	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:20	1200	0.3333	37.36	35.535	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:25	1500	0.4167	37.35	35.530	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:30	1800	0.5000	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	35.54	0.09	35.48	0.1	
12/06/2015 06:35	2100	0.5833	37.35	35.525	0.02	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:40	2400	0.6667	37.34	35.520	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 06:50	3000	0.8333	37.34	35.520	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 07:00	3600	1.0000	37.34	35.520	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 07:10	4200	1.1667	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 07:20	4800	1.3333	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 07:40	6000	1.6667	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 08:00	7200	2.0000	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	35.510	0.06	35.40	0.02	
12/06/2015 08:20	8400	2.3333	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 08:40	9600	2.6667	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 09:00	10800	3.0000	37.34	35.515	0.01	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 09:20	12000	3.3333	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 09:40	13200	3.6667	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 10:00	14400	4.0000	37.33	35.510	0.00	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 10:20	15600	4.3333				#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 10:40	16800	4.6667				#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 11:00	18000	5.0000				#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 11:20	19200	5.3333				#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 11:40	20400	5.6667				#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
12/06/2015 12:00	21600	6.0000				0	#N/A	#N/A	#N/A	35.460	0.01	35.39	0.01	
12/06/2015 12:20	22800	6.3333		35.55	after getting out the pump from well									

Table D3. Raw pumping test data, from testing of well PBH2, June 2015*. Step test pumping periods are shaded in green, constant rate test pumping is shaded in blue, recovery periods are unshaded. Yellow fields mark sampling for water chemistry. Red figures are artificially placed data solely for the purposes of plotting. bgl = below ground level; EC, pH, Temp. = field electrical conductivity, pH and temperature of pumped water.*

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D4 References

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