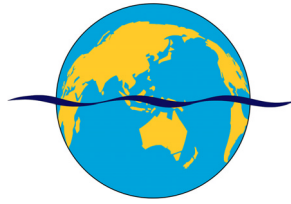


# Global Groundwater

Australian Bore Consultants Pty. Ltd. Hydrogeological Division  
ACN 077 734 153 ABN 66 077 734 153



PO Box 174  
Bassendean  
Western Australia  
6054

Meedo Station

Hydrogeological Report

for

Department of Agriculture

March, 2007

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**Hydrogeologist  
Global Groundwater**

P.O. Box 174  
Bassendean WA 6054  
Tel: + 61 8 9386 4725  
Fax: + 61 8 9386 1080

**Australian Bore Consultants Pty Ltd**Trading As: **Global Groundwater**

ACN 077 734 153 ABN 66 077 734 153

PO Box 174 Bassendean, Western Australia 6054

Telephone: 61 8 9386 4725 Facsimile: 61 8 9386 1080 E-mail: office@globalgw.com.au


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Document Status					
Version No.	Author	Reviewer	Approved for Issue		
			Name	Signature	Date
1	R. Nixon	D. Skidmore	R. Nixon		29/3/2007

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## 1 INTRODUCTION

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On 3 November 2003, the Cabinet of the Western Australian State Government approved the development of what has now become known as the Meedo and Brickhouse Horticulture Precincts. Cabinet also approved the establishment of a working group made up of the Departments of Agriculture and Food, Planning and Infrastructure, and Environment (now Water) to oversee the process and enable a commercial Expression of Interest (EoI) process to offer land and water for horticultural development.

The EoI needs to define soil and water availability. Water availability is defined by meeting the requirements of a 5C Groundwater Licence for a groundwater allocation including submission of a hydrogeological report estimating available groundwater resources. Global Groundwater was commissioned to undertake groundwater investigations by the now Department of Food and Agriculture under the "Carnarvon 2020 Initiative".

The provisional development scope at Meedo Station requires 4 GL of irrigable quality groundwater per year from Cretaceous and Permian aquifers.

This report presents an analysis of drilling results, including numerical modelling to simulate potential effects of abstracting the 4 GL/year for 20 years to meet the requirements of the horticultural development.

## 2 PREVIOUS WORK

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Thomson (2001), following on from work by Allen (1987) and Hocking et al (1987), indicated areas along the Wooramel River where the regional aquifer formed by the Birdrong Sandstone was potentially unconfined and possibly contained a significant resource of low salinity groundwater. A potential storage of 1200 GL with 0.3 GL/year renewable was indicated. Thomson (2001) also suggested that a larger resource of low salinity groundwater might occur in the Permian Moogooloo Sandstone, east of Meedo Station where a potential storage of 1338 GL with 3.9 GL/year renewable was indicated. In addition, Thomson (2001) outlined potential alluvial aquifers near the Wooramel River on Meedo Station (Figure 1) where it was considered that potential storage of 30 GL existed with 1.8 GL/year renewable.

Smolinski (2003) identified three soil resource areas on Meedo Station and one mainly on Towrana Station, crossing onto Pimbee Station that may be suitable for horticultural

development. Three of these are on the southern side of the Wooramel River, but the largest (6835 ha) is on the northern side (Figure 2).

Global Groundwater was appointed in 2003 to undertake preliminary field investigations to select drill sites within the areas where Thomson (2001) had identified prospective groundwater areas that were in association with the soil resources identified by Smolinski (2003) as being suitable for irrigation. These areas are on Meedo Station approximately 50 km east of the North West Coastal Highway and 140 km southwest of Carnarvon by air or 170 km by road (Figures 1 and 2). Preliminary field investigations in the 2003/2004 program included geophysical surveying of alluvial aquifers, down-hole videoing, air-lifting and groundwater sampling from existing bores. Results of the preliminary field investigations were presented in a brief letter report (Global Groundwater, 2003).

The geophysical program was designed to investigate potential alluvial aquifers near the Wooramel River on Meedo Station that Thomson (2001) had indicated might have had potential to provide water for an irrigation project. This enabled delineation of shallow, low salinity groundwater, but the resource was not large enough to provide sufficient water for the proposed horticultural project.

Global Groundwater (2003) also proposed a drilling and testing program, which was subsequently put out to tender (Cunningham, 2003). The drilling and testing program for investigation and production bores was undertaken in two stages in 2004 and 2005. Preliminary results and data were given by Global Groundwater (2004) and a comprehensive bore completion report was presented by Global Groundwater (2006). Bore locations are given in Figure 2 and a summary of bores drilled or assessed during the programs are presented in Tables 1, 2 and 3.

### 3 PROGRAM DESCRIPTION AND METHODOLOGY

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#### 3.1 DRILLING, BORE CONSTRUCTION AND TEST PUMPING

The methodology and details of the construction and test pumping was given in Global Groundwater (2006). A total of 20 bores were drilled during the 2004 and 2005 programs, with fourteen completed as monitoring bores and two as production bores. Movement of heavy vehicle drilling equipment was hampered by difficult access over dunes. Deep

watertables, large drilling fluid losses and swelling sub-surface clay often complicated drilling and bore construction. Bore development was also difficult due to deep watertables.

### 3.2 TEST PUMPING ANALYSIS

Data and analyses from the test pumping and waterlevel monitoring are given in Appendix A. Uncorrected test pumping data were presented in Global Groundwater (2006) and have been corrected for barometric pressure using information provided by the Bureau of Meteorology from Carnarvon and Shark Bay Airport weather stations. Barometric pressure at both stations were converted to equivalent water pressure, adjusted for salinity then multiplied by a barometric efficiency to obtain the best match with waterlevels recorded in bore M 4/05 (Figure 3). The change in water pressure from the start of monitoring was then applied to waterlevels measured during test pumping in bores M 11/04 and M12/04 and presented as "Corrected Drawdown" in the data sheets (Appendix A). Corrected drawdown is used in all test pumping data plots and calculations presented herein.

### 3.3 RESOURCE ESTIMATION

Interpretation of drilling and water chemistry data was used to determine the aquifer dimensions and potential recharge areas. Aquifer parameters were estimated by analysis of test pumping data from testing of production bores.

Hydrogeological conceptualisation of the aquifer enabled the generation a numerical model using the groundwater-modelling package Modflow 2000 (McDonald and Harbaugh, 1984). Simulations of a number of pumping scenarios were undertaken to provide preliminary estimates of the magnitude and extent of drawdown associated with groundwater abstraction at the site.

### 3.4 META DATA

Accuracy and other quantifying information relating to data collected during the 2004 and 2005 field programs is presented in Global Groundwater (2006). Metadata for the three numerical models are presented in Appendix B. The following salinity categories are used in this report –

- Fresh            0 to 500 mg/L TDS
- Marginal        500 to 1500 mg/L TDS
- Brackish        1500 to 3000 mg/L TDS
- Saline            Greater than 3000 mg/L TDS

## 4 SETTING

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### 4.1 PHYSIOGRAPHICAL SETTING

#### ***Climate***

The area has a Mediterranean – Semi Desert climate with hot dry summers and cool to mild wet winters. Rain falls mostly between March to August, but occasional cyclones and thunderstorms also provide significant rainfall in summer. The average annual rainfall for area is about 200 mm and potential annual evaporation is 2400 mm (Denman et al, 1985). The study area is within the Arid Pastoral Zone and the Carnarvon Biogeographic Region (Department of Environment, 2006).

#### ***Access***

Access to Meedo Station from the North West Coastal Highway is by unsealed road, which can be in good condition during dry conditions after grading, but deteriorates with movement of heavy vehicles and can be impassable after rain. River flows after rain in the catchment can wash out the crossing over the Wooramel River near Meedo homestead.

#### ***Geomorphology***

Denman et al (1985) and Hocking et al (1987) have previously described the geomorphology of the area. The landforms comprise the broad valley floor flood plain of the Wooramel River with Pleistocene to Holocene alluvium, playa and dune deposits and local calcrete associated with drainage lines. Analysis of palaeodrainages suggests that the river channel and flood plain in this area is a relatively young feature and that probably prior to the Miocene the river flowed to the sea further to the south (Denman et al, 1985).

#### ***Vegetation and Landuse***

The area has an open to dense Acacia shrub and chenopod steppe vegetation with tall Eucalyptus trees lining the major watercourses (Denman et al, 1985). The proposed borefield and horticultural development are within commercial sheep and goat grazing areas of the Meedo Pastoral Station that has been operating for a considerable period of time and this grazing will have had significant impact on the pre-existing native vegetation.

### 4.2 EXISTING BORES

Table 3 shows the details of the nineteen stock bores in the Meedo area. Based on their depth, fourteen of these bores source water from aquifers formed in the Cainozoic superficial

sediments. Three of the stock bores source water from the Mesozoic strata (McEwins Bore and Crystal Tank Bore are interpreted to source water from the Birdrong Sandstone and Callytharra Pool Bore in Pimbee Station to the east sources water from Permian formations). The Department of Environment and Conservation (DoE&C) manage Pimbee Station and have decommissioned all bores on the Station (including Callytharra Pool Bore) for vermin control. Two abandoned bores (Deep Bore and No 3 Bore) probably intersected the Birdrong Sandstone based on Department of Water (DoW) data.

## 5 HYDROGEOLOGY

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The geology of the region has been determined through exploration for hydrocarbons and groundwater as well as regional geological mapping. The hydrogeology of the region has been defined through drilling and testing for stock and community water supplies. Allen (1987) detailed much of the groundwater work undertaken in the region previously and his definition of the regional hydrogeology provides context to the results of the drilling and testing undertaken at Meedo for the current program.

The stratigraphic sequence of the area and interpreted aquifers are given in Table 4. The drilling details were presented in Global Groundwater (2006) and these have been compiled into east-west and north-south cross-sections (Enclosures 1 and 2 respectively).

### 5.1 GEOLOGICAL SEQUENCE

The target for the study was the Mesozoic sequence of the Gascoyne Sub Basin and Palaeozoic sequence of the Merlinleigh Sub Basin of the Carnarvon Basin. The Ajana Fault System described in Hocking et al (1987) juxtaposes Cretaceous Barrow Group sediments of the Gascoyne Sub Basin to the west against Permian Wooramel Group sediments of the Merlinleigh Sub Basin to the east.

Regional mapping (Hocking et al 1987), indicates two faults/lineaments within the Ajana Fault System traversing the Meedo area. The north-northwest trending fault shown by Hocking et al (1987) is possibly the same fault as that shown in the section of Enclosure 1. The northeast trending lineament shown by Hocking et al (1987) may be an intra-Permian fault. Some additional northwest trending faults were interpreted during this program and these are shown in the inset of Enclosures 1 and 2. The strata on both sides of the fault system are assumed to tilt gently to the west based on interpretation given by

Hocking et al (1987) but it is possible that the strata may be upturned in places by drag on faults.

The Mesozoic sequence in the western part of the study area consists of the Devonian Gneudna Formation underlying the Cretaceous Birdrong Sandstone, Muderong Shale Windalia Radiolarite and Gearle Siltstone (Enclosures 1 & 2). Cretaceous Toolonga Calcilutite may have been intersected near Barcoo Well in exploration bores M 9/04 and M 10/04 (Global Groundwater, 2006) but this unit does not extend much further east and was not intersected by bores drilled further east (Appendices B and C, Global Groundwater, 2006).

The Palaeozoic sequence in the eastern part of the study area is likely to include the Permian Moogooloo Sandstone and/or Keogh Formation. These strata are grouped as undifferentiated Permian Sediments in this report. Permian sediments outcrop further to the east in the bed of the Wooramel River (Denman et al, 1985).

Younger Cainozoic sediments form a relatively thin veneer covering most of the Mesozoic and Palaeozoic sequence present at Meedo. However, small outcrops of Windalia Radiolarite do occur in the bed of the Wooramel River as shown by Denman et al (1985) at McEwins Bore and about 3.5 km south of Top Mill Well. Giralia Calcarenite is interpreted to occur throughout much of the subsurface at Meedo based on drilling data (Global Groundwater, 2006). A ferruginous and siliceous duricrust, also occurs in the bed of the Wooramel River at Meedo along with consolidated to unconsolidated alluvial deposits. Clay, silt, sand and gravel occurs in the numerous clay pans that occur on Meedo. These are associated with major palaeodrainage deposits (Denman et al, 1985) which are up to about 4.5 km wide and broadly follow the present channel of the Wooramel River. Eolian sheet and dune sands cover most of the land surface at Meedo outside the bed of the Wooramel River and palaeodrainages.

## 5.2 AQUIFERS

The Cainozoic sediments can form minor shallow (superficial) aquifers and numerous stock and domestic bores and wells on Meedo exploit these.

The Gearle Siltstone can contain groundwater on the basis of normal circulation (air-rotary) drilling at the site of bore M 1/04. However, a number of stock bores that intersected Birdrong Sandstone (Table 3) would presumably have drilled through the Gearle Siltstone

without encountering sufficient supplies for stock. On this basis, aquifers within the Gearle Siltstone are regarded herein as minor, discontinuous and capable of only small supplies locally and are not considered further.

The Birdrong Sandstone and the Permian sediments form a large aquifer containing a substantial resource of low salinity groundwater.

The Gneudna Formation underlies the Birdrong Sandstone and was intersected during drilling (Global Groundwater, 2006). However, the potential of this unit was not a target of this investigation, due to higher salinity. These strata are considered to form the base of the aquifer in the Birdrong Sandstone at Meedo for this study.

### ***Superficial Aquifers***

Superficial aquifers are formed mostly in the alluvium and sands within the Giralia Calcarenite. Eolian sand may also contain groundwater in places. However, on Meedo, these aquifers are mostly thin and provide only small supplies for stock and domestic use. They are considered unlikely to be able to support or supplement horticultural developments in the area.

Areas where groundwater salinity in shallow aquifers is less than 1000 mg/L are generally restricted to close to the Wooramel River. Low salinity groundwater can occur in shallow aquifers further from the river where local recharge conditions are favourable but these are rare based on available stock bore salinity data (Table 3).

Geophysical surveying using an EM34 Electromagnetic Terrain Conductivity Meter was useful in locating areas where the shallow aquifers contained low salinity water along the Wooramel River near Barcoo Well (Global Groundwater, 2006).

Based on anecdotal advice, the alluvium may be thicker and form a more significant aquifer downstream of the Meedo homestead. The alluvium is also thicker along the river on Wooramel Station approximately 35 km west of Meedo where an alluvial/calcrete aquifer supports a horticultural development.

### ***Birdrong Sandstone***

The Birdrong Sandstone is between 41 m and 68 m thick in drill holes within the study area. It consists of fine to coarse-grained, weakly consolidated sandstone interbedded with siltstone and claystone. Sand sections of the formation are highly permeable.

Groundwater in the aquifer is confined by fine-grained sections of the formation or by fine-grained sediments in the overlying Gearle Siltstone, Windalia Radiolarite and Muderong Shale. These overlying formations also retard or prevent recharge to the Birdrong Sandstone from rainfall and river flow over most of the study area. The bulk of the recharge to the Birdrong Sandstone is therefore concluded to occur by through-flow from the Permian sediments to the east of the study area, which are hydraulically continuous with the Birdrong Sandstone within the study area. A smaller volume of local recharge may occur where the Wooramel River is coincident with geological faults, where upturning of sediment may occur.

The formation is completely saturated in the area of bore M 1/04 and McEwens Bore where the saturated thickness is 68 m. Saturated thickness decreases to the south. The formation is only partly saturated at bore M 3/04 where saturated thickness is 52 m and at bore M 12/04 where saturated thickness is 39 m. Waterlevels in the aquifer are between about 48 m and 73 m below ground level (bgl).

A large section of the formation within the study area contains fresh to marginal groundwater. The salinity of the groundwater generally increases with depth and to the north, south and west (Enclosures 1 and 2).

Yields from production bores completed in Birdrong Sandstone have been estimated from the testing to date at approximately 2000 m<sup>3</sup>/day. Water from this aquifer is fresh to brackish within the study area.

### ***Permian Sediments***

The Permian Wooramel Group sequence underlies the eastern part of the study area and comprises the Keogh Formation and/or Moogooloo Sandstone (Denman et al, 1985). In the study area, the strata consists mostly of medium to coarse grained sandstones with some silty and shaley horizons. The Permian sequence is thought to extend east and south to at least the sites of production bores BF 6/9 and BF 6/10 (Rockwater, 1982), which are located 32 km to the southeast of the study area (Figure 1).

Greater than 150 m of the Permian sequence is present on Meedo Station. The saturated thickness is at least 80 m. Waterlevels in the aquifer are between about 57 and 81 m bgl with the deepest levels occurring where the land surface is highest. Groundwater in the aquifer is unconfined in the upper parts but is confined by lower permeability units deeper within the sequence.

Groundwater in the Permian strata is fresh to saline in the study area and salinity increases with depth. As such, there is considerable stratification of different salinity groundwater in the Permian sequence (Enclosures 1 and 2).

The overall potentiometric gradient and interpreted groundwater contours (Enclosures 1 and 2) suggests that the bulk of recharge to the Permian strata occurs to the east of the study area. However, groundwater salinity and potentiometric head data indicate that some recharge to the Permian strata also occurs along the Wooramel River between bores M 7/04 and M 2/05. This recharge may be facilitated by upturning of sediments within the Permian sequence at faults associated with the Ajana Fault System.

Data from bores on Meedo indicate groundwater flows across the Ajana Fault System into the Birdrong Sandstone aquifer. The low salinity groundwater in bore M 3/04 is interpreted to be from throughflow from east of Meedo (Enclosures 1 and 2).

Available data supports the probability of a substantial area of fresh to marginal groundwater in the Permian sediments to the east of Meedo. However, the extents of the area are not well defined. Callytharra Pool Bore is located on Pimbee Station further to the east-southeast in an area broadly mapped as Moogooloo Sandstone by Thomson (2001). The bore is about 124 m deep and contains fresh water indicative of proximity to recharge. Saturated aquifer thickness intersected by the bore is possibly up to 60 m. Bores BF 6/9 and BF 6/10 are located approximately 26 km southeast of Callytharra Pool Bore in an area also broadly mapped as Moogooloo Sandstone by Thomson (2001). Bores BF 6/9 and BF 6/10 are capable of yielding around 850 m<sup>3</sup>/day of groundwater with salinity of 1100 ppm (Rockwater, 1982).

### **5.3 AQUIFER PARAMETERS**

Production bores M 11/04 and M 12/04 were subjected to controlled step and constant-rate test pumping. Comprehensive data from the two tests are presented in Global Groundwater (2006) and test pumping analysis sheets are given in Appendix A.

#### ***Bore M 11/04***

The step-test on bore M 11/04 was conducted at discharge rates up to 1414 m<sup>3</sup>/day. Waterlevel data obtained during the step-test are presented as a plot of drawdown versus time in Figure 4. The step-test results were analysed by the Hantush-Bierschenk method

(Hantush, 1964) to derive a well equation. The equation suggests that bore efficiency increases with increasing discharge rate suggesting that the bore was still undergoing development during the step-test. Correspondingly, well efficiency cannot be estimated from the step-test.

After reviewing the step-test results it was decided to pump bore M 11/04 at a discharge rate of 1337 m<sup>3</sup>/day during the constant-rate test. Waterlevels in bore 3/04 were also monitored during the constant-rate test on bore M 11/04. Monitored data are presented as a plot of drawdown versus time in Figure 5. Maximum drawdown by the end of the test was 4.495 m in bore M 11/04 and 1.128 m in bore M 3/04.

The drawdown curves were effectively a straight-line throughout the test that is a response indicative of confined aquifer conditions. Minor fluctuations in waterlevels from the trend are probably due to minor variations in discharge rate, possible errors in measurement bore development and/or small inaccuracies in correction of barometric effects.

Jacobs straight-line analysis (Cooper and Jacob, 1946) was conducted on data recorded during the later part of the test. The slope of the drawdown curves for bores M 11/04 and M 3/04 indicate transmissivity of 1407 and 905 m<sup>2</sup>/day, respectively. The average hydraulic conductivity calculated over the 50 m thickness of aquifer is therefore 28 and 18 m/day, respectively. This is within the range of hydraulic conductivity for coarse sand to gravel given by Heath (1982) and correlates well with the strata drilled.

A confined coefficient of storage of approximately  $9 \times 10^{-4}$  was calculated from the test pumping. A specific yield of 0.2 is assumed for calculations of groundwater storage. This specific yield is the same as that assigned to the Leederville Formation of the Perth Basin (Davidson, 1995), which is correlated with the Birdrong Sandstone of the Carnarvon Basin by Hocking et al (1987).

Analysis of the data using the method of Papadopoulos and Cooper (1967) indicates that storage in the casing did not affect the drawdown data used in the analysis. This is consistent with the appearance of the drawdown curves.

Recovery data from the test are given as a plot of residual drawdown versus the ratio of  $t/t'$  in Figure 6 and these indicate aquifer transmissivity of 1036 m<sup>2</sup>/day and therefore hydraulic conductivity is about 20 m/day. These values are similar to those derived from the constant-

rate test. The waterlevel was tending towards full recovery at the end of the monitored period of recovery suggesting testing did not deplete storage.

Field measured electrical conductivity (EC) decreased steadily from 1074  $\mu\text{S}/\text{cm}$  to approximately 965  $\mu\text{S}/\text{cm}$  during test pumping (Appendix A). However, laboratory measurements of 6 hourly samples showed EC increased from 1278 to 1280  $\mu\text{S}/\text{cm}$  during the test (Global Groundwater, 2006). This discrepancy is likely a result of drift in the field meter during the test and the data suggest groundwater salinity was effectively unchanged during test pumping.

### ***Bore M 12/04***

The step-test on bore M 12/04 was conducted at discharge rates up to 1204  $\text{m}^3/\text{day}$ . Waterlevel data obtained during the step-test are presented as a plot of drawdown versus time in Figure 7. Air in the discharge line and bore development during the test caused an erratic waterlevel response to pumping such that analyses to determine well efficiency could not be effectively undertaken.

After reviewing the step-test results it was decided to pump bore M 12/04 at a discharge rate of 1039  $\text{m}^3/\text{day}$  during the constant-rate test. Test data are presented as a plot of drawdown versus time in Figure 8. Maximum drawdown by the end of the test was 3.717 m in bore.

Rapid drawdown occurred in the production bore during the first minute of the test largely due to well loss. The overall trend of the remainder of the test is that of recovering waterlevels, which are likely a result of continued bore development and on this basis no further interpretation of the waterlevels is valid.

Recovery data are given as a plot of residual drawdown versus the ratio of  $t/t'$  in Figure 9. The slope of the residual drawdown curve indicates aquifer transmissivity is 1732  $\text{m}^2/\text{day}$  and therefore hydraulic conductivity of the screened interval is about 33  $\text{m}/\text{day}$ . These values are not supported by monitoring bore data, cannot be cross-referenced with parameters derived from the constant-rate test and are regarded as less accurate than parameters derived from testing of bore M 11/04. The residual drawdown data are inadequate to determine if the bore was tending towards full recovery at the end of the monitored period.

Field measured EC decreased significantly during the constant-rate test (3693 to 2283  $\mu\text{S}/\text{cm}$ , Appendix A), but these measurements were not supported by laboratory tested samples and are likely a result of field meter drift.

## 6 BORE CAPACITY

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Long-term drawdown in a bore can be predicted for various discharge rates by extrapolating a selected section of the drawdown curve recorded during test pumping. However, sustainable discharge rates may be lower than that thought possible if in the long-term the aquifer does not follow short-term trends on which the extrapolations are based. Further, interference from other pumping bores and declining waterlevels in the aquifer under conditions of reduced recharge will reduce the bore capacity. These potential factors have not been quantified or included in the estimated bore capacities given herein.

The discharge rate of a bore may also need to be reduced if groundwater salinity increases during longer term pumping from either upconing of deeper saline groundwater or migration of more saline groundwater from the peripheries of the aquifer. Adequate monitoring and assessment during bore operation is required to fully appraise these conditions.

The frequency and period of available monitoring bore data is insufficient to reliably determine average seasonal waterlevel fluctuations in the aquifer but the available data suggests that if seasonal fluctuations do occur, they are likely to be substantially less than 1 m. Nonetheless, the discharge rates recommended herein include a 3 m seasonal decline in aquifer waterlevels and this provides contingency for other undefined factors that may impact waterlevels in the aquifer.

### 6.1 BORE M 11/04

The later section of the constant rate test data (Figure 5) was used to extrapolate waterlevel trends to 180-days. Extrapolation of the drawdown curve suggests that production bore M 11/04 may be capable of a long-term discharge rate of 2160  $\text{m}^3/\text{day}$  (25 L/s). At this rate, the predicted long-term operational waterlevel in the bore would be approximately 69 m bgl including a 3 m seasonal waterlevel decline. This is below the top of the slotted interval.

The maximum waterlevel recorded during the test period was 63.258 m bgl, which is above the screen. The behaviour of the aquifer when the waterlevel falls below this depth has not been observed.

## **6.2 BORE M 12/04**

The long-term drawdown of the bore cannot be accurately determined due to drawdown during pumping being affected by bore development. However, on the basis of transmissivity and aquifer thickness being similar to bore M 11/04, then the capacity of bore M 12/04 is likely to be similar to that of bore M 11/04.

# **7 WATER QUALITY**

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Laboratory results of analyses on the quality of water from the bores are presented in Appendix E of Global Groundwater (2006).

## **7.1 GROUNDWATER SALINITY**

The spatial and vertical distribution of groundwater salinity is given on enclosures 1 and 2. The salinity of water sampled from bores is given in Tables 1, 2 & 3.

Groundwater in both the Birdrong Sandstone and Permian strata is fresh to saline over most of the study area. It is mostly fresh to marginal in the central part of the study area (Inset map, Enclosures 1 and 2), although brackish to saline groundwater occurs deeper in the aquifer within this central part. The body of groundwater with salinity less than 1000 mg/L extends west to bore M 4/05, north to bore M 8/05 and south to between bores M 7/05 and M 12/04. It is thickest in the area of bore M 3/04, where it occupies the entire saturated thickness of the aquifer (Enclosures 1 and 2).

Groundwater salinity increases to the north, south and west but low salinity groundwater extends east approximately 15.5 km, across the Ajana Fault System and is interpreted to be continuous to Callytharra Pool Bore. This bore is located on Pimbee Station, adjacent to the Wooramel River where recharge is likely to occur.

The thickness of fresh groundwater is less at bore M 3/05 and this is likely a result of groundwater increasing in salinity along groundwater flow to the west of Callytharra Pool Bore, before additional recharge from the Wooramel River is introduced west of bore M 3/04.

Once groundwater flow enters the confined Birdrong Sandstone west of the Ajana Fault System it is unlikely to receive further recharge and gradually increases in salinity down groundwater flow.

Salinity of groundwater in the aquifer increases with depth. This increasing trend is not apparent in bores M 3/04 and M 5/05 that were completed in Birdrong Sandstone based on down-hole conductivity data (Global Groundwater, 2006), but these bores were drilled using mud-rotary techniques and measurements of salinity with depth were not possible during drilling.

Groundwater in bores M 2/05 and M 3/05 is brackish based on the salinity of final samples. However, the bores are slotted deep in the profile and based on the results from the air-core drilling, a substantial thickness of strata containing low salinity groundwater occurs above the slotted intervals at the sites of these bores.

There was a slight decrease in groundwater salinity in water from bore M 11/04 after commencement of test pumping and this may be due to removal of high salinity drilling fluid (KCl) that was lost into the formation during drilling. This is supported by development observed during the step-test. However, overall groundwater salinity remained relatively stable throughout the tests on both production bores.

While salinity of the groundwater in the bulk of the central part of the study area is broadly suitable for irrigation, horticultural professionals should review the full set of water chemistry data presented herein to determine the suitability of the groundwater for a specific horticultural development.

## **7.2 HYDROCHEMISTRY**

Carbon dating was undertaken on water from bores M 1/05, M 4/05 and M 6/04 and Leaney (2006) interpreted this data. It is interpreted that groundwater age increases with depth and that there has been intermittent recharge to the aquifer in the area for the last 5400 years.

Concentrations of major ions in water from each bore have been plotted using a Piper trilinear diagram (Figure 10). The analysis on water from bore M 8/04 is not included in the assessment as the water is not considered representative of the Birdrong Sandstone aquifer at the site (Global Groundwater, 2006).

All waters are reasonably grouped, indicating similar chemistry, in a position on the diagram that indicates they are of the sodium chloride type. Variable depths in the aquifer from which water samples were obtained complicate the plot, as does local recharge, which adds younger water at different points along groundwater flow paths. Nonetheless, there is an overall, progressive increase in chloride content of the groundwater down flow path.

Interpretation of the data suggests recharge occurs closest to Callytharra Pool Bore and bore M 8/04. The position on the diagram of waters from bores M 5/05 and M 1/05 supports the potential for recharge along the Wooramel River between bores M 8/04 and M 2/05. The position on the diagram of water from bore M 4/05 supports possible recharge about 3 km up gradient of bore M 8/05 where the bed of the Wooramel River corresponds to the position of interpreted faults.

Bores M 2/05 and M 3/05 are slotted against deep sections of the aquifer where older water occurs and this causes them to plot in the high chloride area of the diagram. However, a thick section of younger, low salinity groundwater occurs above the slots at both these sites. Similarly, bore M 6/04 also has slots set against deeper sections of the aquifer and as such water from it plots in a higher chloride area on the diagram than water from adjacent bore M 7/04.

Water from bores M 12/04, M 11/04 and M 7/05 plot on the diagram farthest along flow path and this is consistent with the plot of potentiometric contours for the aquifer.

## 8 GROUNDWATER RESOURCES

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A large volume of groundwater is stored in the Birdrong Sandstone and Permian sediments within the study area. The volume of groundwater available from the shallow aquifers is low and is not included in resource calculations.

### 8.1 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual model is of an aquifer formed in the Birdrong Sandstone and Permian sediments. The aquifer is regarded as continuous across the Ajana Fault System such that the Birdrong Sandstone is in hydraulic connection with saturated Permian sediments to the east.

Groundwater in the Birdrong Sandstone is confined by finer grained units that overly the sandstone. Groundwater in the Permian sediments is unconfined in the upper parts but is confined by lower permeability units deeper within the sequence.

The top of the aquifer is the top of the Birdrong Sandstone, where it is fully saturated, or the watertable in the Permian sediments and areas of Birdrong Sandstone where they are not fully saturated. The base of the aquifer in the west of the model area is the base of the Birdrong Sandstone. The underlying Gnedna Formation is also an aquifer but contains higher salinity groundwater and has not been considered for resource calculations. The base of the aquifer in the east of the model area is assumed to be a similar elevation to that of the base of the Birdrong Sandstone for resource calculation purposes.

Groundwater is recharged to the east and enters the model area mostly by throughflow from east to west. While some recharge within the model area likely occurs by infiltration from the Wooramel River through strata potentially upturned by the Ajana Fault System, this recharge is not quantified in the numerical model. Groundwater leaves the area by outflow through the Birdrong Sandstone to the west.

Groundwater salinity increases along the flow path and with depth. Groundwater salinity increases to the north and south.

### ***Aquifer Thickness***

The Birdrong Sandstone ranges in thickness from 41 to 68 m. The average thickness of the formation in seven bores interpreted to have intersected the full thickness of the formation in the study area (Global Groundwater, 2006) is 57 m. The Permian sequence to the east is substantially thicker. However, the conceptual model regards its thickness to be similar to that of the Birdrong Sandstone.

### ***Groundwater Storage***

Storage of groundwater a) less than 1000 ppm and b) between 1000 and 1500 ppm has been calculated from interpreted sections (Enclosures 1 and 2) using an inverted triangular shaped prism oriented east-west as the simplified aquifer shape.

- a) If it is assumed that the Birdrong and Permian sandstone aquifers:
- have 20% porosity,
  - contain groundwater with salinity less than 1000 ppm over an average thickness of 25 m across a 19 km east-west aquifer section (Enclosure 1) and,

- that this section extends north-south over a width of 10 km (Enclosure 2),  
then storage of groundwater with salinity less than 1000 ppm is 950 GL  
( $1.9 \times 10^8 \text{ m}^2 \times 25 \text{ m}$ ).
- b) If it is assumed that the Birdrong and Permian sandstone aquifers:
- have 20% porosity,
  - contain groundwater with salinity between 1000 and 1500 ppm over an average thickness of 10 m across a 21 km east-west aquifer section (Enclosure 1),
  - and that this section extends north-south over a width of 15 km (Enclosure 2),  
then storage of groundwater with salinity between 1000 and 1500 ppm is 630 GL  
( $3.15 \times 10^8 \text{ m}^2 \times 10 \text{ m}$ ).

### ***Groundwater Throughflow***

The Darcy equation ( $Q=kiA$ ) was applied to the north-south cross section between bores M 1/04 and M 12/04:

- Area (A) = 50 m x 13 960 m,
- $k = 15$ ,
- Hydraulic gradient (i) = 1 m head difference over 5500 m (from contours in the Birdrong)

The Darcy equation suggests throughflow (Q) of 1904 m<sup>3</sup>/day (0.70 GL/year) of low salinity groundwater passes through the entire saturated thickness of the aquifer section between bores M 1/04 and M 12/04.

### ***Groundwater Recharge***

Interpreted potentiometric contours (Enclosures 1 and 2) indicate recharge to the aquifer is largely to the east of Meedo Station and to a lesser extent from the Wooramel River on Meedo.

Carbon dating analyses of groundwater was also undertaken to assess recharge. Results of the carbon dating of water from bores M6/04, M 1/05 and M 4/05 (Leaney, 2006) indicate that groundwater at the watertable is probably less than 1000 years old but that water deeper in the aquifer is possibly 5400 years old. Average recharge rates between 1.5 and 3.0 mm per year (equivalent to approximately 0.75 to 1.5% of average annual rainfall) were considered possible based on these ages and assuming vertical recharge from a uniformly

distributed spatial source. However, recharge of this type seems less likely than recharge by seepage of water from river flows and so the validity of the method in calculating recharge is questionable. Nonetheless, the carbon dating results support the thesis of some recharge occurring locally.

In equilibrium (steady state) conditions, in the absence of pumping and assuming no other gains or losses, groundwater throughflow equals groundwater input or recharge. Therefore throughflow can be used to approximate groundwater recharge to the aquifer as a whole. Groundwater in the Birdrong Sandstone is confined, the watertable in the Permian sediments is deep and unlikely to be affected by evapotranspiration and only a small number of stock bores draw an insignificant volume of water from the aquifer at Meedo. On this basis, throughflow at Meedo will approximate recharge to the aquifer east of the section between bores M 1/04 to M 12/04.

Most of the calculated groundwater throughflow of 0.70 GL/year is interpreted to be from recharge east of the study area with a smaller amount likely to occur from more local recharge along specific sections of the Wooramel River on Meedo.

### ***Groundwater Movement and Discharge***

Regional groundwater flow in the Birdrong Sandstone is from east to west (Allen, 1987). However, potentiometric contours indicate that in the study area groundwater flow is mostly to the west and southwest. This is likely a result of groundwater recharge from the Wooramel River mainly on Pimbee Station resulting in slight mounding of groundwater that dissipates to the west.

Discharge from the Birdrong Sandstone occurs offshore where groundwater discharge occurs naturally. Groundwater discharge from the Birdrong Sandstone also occurs from pumping or free flowing (uncapped) artesian bores. Overall hydrostatic pressures in the aquifer are increasing due to capping of numerous artesian bores that were previously flowing under the Carnarvon Artesian Basin Rehabilitation Project, which is a component of the Gascoyne Murchison Strategy. Nonetheless, this is not likely to have a significant effect on waterlevels in the study area.

## **8.2 NUMERICAL MODEL**

A numerical model was constructed using the groundwater-modelling package Modflow 2000, developed by the United States Geological Survey (McDonald and Harbaugh, 1984).

Three simulations (Models 1, 2 and 3) were run using the parameters presented in Appendix B.

### ***Model Discretisation***

The extents of the model are 270 000 to 310 000 E and 7140 000N to 7170 000 N (MGA94 zone 50). The east and west extents of the model are approximately 20 km from bore M11/04. The north and south extents of the model are approximately 15 km from bore M11/04.

The east and west model boundaries are constant head boundaries set to the interpreted heads from the cross sections (Enclosures 1 and 2). The north and south model boundaries are general head boundaries with hydraulic conductivity of the adjacent cells.

The model has two layers. Layer 1 incorporates formations overlying the Birdrong Sandstone in the west of the study area as well as upper sections of Permian strata in the east of the study area. Layer 2 incorporates the Birdrong Sandstone in the west of the study area and lower sections of Permian strata in the east of the study area.

The top of layer 1 was set to the ground surface. The base of layer 1 was set to the depth of the top of the Birdrong Sandstone in the west. The base of layer 1 was set to approximately 50 m AHD in areas of Permian strata to the east as this elevation was below the potentiometric heads in the aquifer and merged well with the Birdrong Sandstone. The base of Layer 2 was set to the base of the Birdrong Sandstone in the west and approximately 20 m AHD in areas of Permian strata to the east. This created unconfined aquifer between 21 and 35 m thick in the Permian strata above an approximately 30 m thick confined aquifer. Although the Permian strata extend deeper than this, the modelled thickness for the Permian strata approximates that of the adjacent Birdrong Sandstone.

Layer 1, west of the Ajana Fault System is inactive to assist model convergence, which is appropriate as these strata are confining beds. Both layers were classified as Type 3 aquifers (confined/unconfined with variable storage and transmissivity as determined by the hydraulic conductivity and head in the cell).

A storage coefficient ( $S_s$ ) of  $9 \times 10^{-4}$  from the test pumping was used in the models. Specific yield ( $S_y$ ) of 0.2 was also applied. The  $S_s$  is used when the cells are fully saturated to simulate confined conditions and  $S_y$  is used once the head in a cell falls beneath the top of that cell to simulate unconfined conditions. Hydraulic conductivity in the model was initially

set a values indicated by test pumping and those indicative of the strata, then was varied to achieve model calibration.

### ***Steady State Calibration***

Initially hydraulic conductivity (k) in Model 1 was adjusted to achieve steady state heads (ie without pumping) that matched those presented in the cross sections. Steady state calibration was achieved using a k of 15 m/day in the Birdrong Sandstone and a k of 3 m/day in the Permian sediments. Successful calibration was assumed with modelled waterlevels in most bores within 1 m of observed heads (Appendix B).

Groundwater throughflow under steady state condition was calculated in Model 1 using the zone budget function. A 1 km wide zone was established north to south between bores M 1/04 and M 12/04. Under steady state conditions the model calculates groundwater throughflow between bores M 1/04 and M 12/04 is that 1574 m<sup>3</sup>/day (0.57 GL/year).

Throughflow calculated by the model is similar but slightly lower than throughflow of 1904 m<sup>3</sup>/day (0.70 GL/year) calculated for the entire saturated thickness of the aquifer using the Darcy equation. The lower throughflow calculated by the model likely relates to the variable aquifer thickness in the model compared to the simplified dimensions assumed for the calculation using the Darcy equation.

### ***Transient Calibration***

Model 2 was run in transient state to simulate 24-hour test pumping in bore M 11/04. The model predicted greater drawdown in bore M 3/04 than that actually observed during the test. This is consistent with lower hydraulic conductivity used in the model than that derived from test pumping. It was determined that the model sufficiently simulated the test pumping.

### ***Predictive Modelling***

Finally Model 3 was used to simulate pumping from a nominal borefield containing 5 bores including bore M 11/04. The modelled bores were located in a single line with one model bore approximately 700 m to the west of bore M 11/04 and the remainder approximately 1000, 2000 and 3000 m east of bore M 11/04, respectively. This locates the potential borefield in an area where the Birdrong Sandstone contains groundwater with salinity less than 1000 ppm over a significant saturated thickness.

Pumping was simulated for 7300 days (20 years) at a discharge rate of 2160 m<sup>3</sup>/day for each bore for a combined total of 3.94 GL/year to approximate the proposed development

requirement of 4 GL/year. Lines of 'particles' were placed on the west side of the Ajana Fault, which is the eastern edge of simulated Birdrong Sandstone aquifer and along a north south line through bore M 4/05. This was undertaken to assess the potential for groundwater with higher salinity on the periphery of the model area to move inwards toward the modelled production bores.

Simulated potentiometric heads from pumping over 20 years and particle flow lines are given in Figure 11. The length of the modelled particle flow lines represent the distance over which the groundwater is predicted to move at that point in the aquifer. Particle flow lines are longest (793 m) close to production bores where steeper hydraulic gradients are induced but these originate in areas of low salinity groundwater.

Simulated pumping diverts particle flow lines from the periphery of the aquifer towards the production bores by approximately 90 m at the site of bore M 1/04 and approximately 145 m at the site of bore M 12/04. Natural groundwater flow direction is reversed over a distance of greater than 20 km west of the bores. However, the maximum distance higher salinity groundwater is predicted to move from the west is 70 m.

Overall, the modelled potentiometric heads indicates that groundwater storage dominates the impacts of simulated pumping. Because of this, borefield configuration is less critical. The modelled potentiometric heads suggest that in the absence of upconing of deeper groundwater, the quality of groundwater produced by a production bore in the aquifer will be determined by the groundwater stored within about a 1 km radius of that bore over the 20 year period.

Modelled drawdown is shown in Figure 12. Simulated pumping for 20 years creates a maximum of about 8 m drawdown in bore M 3/04, which is 12 m from production bore M 11/04. The area where simulated drawdown is greater than 1 m is contained in an area with a maximum radius of about 7 km from bore M 11/04 and does extend outside Meedo station.

## 9 ASSESSMENT OF POTENTIAL IMPACTS

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In terms of the proposed development:

1. Pumping for 20 years at 4 GL/year utilises about 8% of calculated storage of groundwater with salinity less than 1000 mg/L or about 5% of groundwater with salinity less than 1500 mg/L.
2. Calculated groundwater throughflow of lower salinity water at Meedo may be indicative of recharge to the aquifer and is estimated at 0.57 GL to 0.70 GL/year, from numerical modelling and the Darcy equation, respectively.
3. Simulated pumping for 20 years at 4 GL/year modifies groundwater flow, but not sufficiently to cause an influx of higher salinity groundwater from the aquifer peripheries to the production bores.

### 9.1 EXISTING GROUNDWATER USERS

Existing use of groundwater from the combined aquifer of the Birdrong Sandstone and Permian sediments within the area significantly influenced by the proposed development is restricted to two stock bores (Crystal Tank Bore and McEwins Bore, Table 3, Figure 12). Potential impact on the low abstraction of water from these bores for stock could be offset simply using water from the horticultural development and can be addressed in licensing. The remaining stock bores in the area source groundwater from shallow aquifers not predicted to be affected by pumping in the lower, confined aquifer.

Modelling indicates a drop in potentiometric heads of less than 1 m may extend outside the model area but only in the Birdrong Sandstone. On this basis no appreciable impact is predicted on other bores including artesian bores screened in the Birdrong Sandstone aquifer.

No change in the quality of water from existing bores is predicted from modelling of the proposed extraction for the horticultural development.

### 9.2 ENVIRONMENTAL IMPACTS

The predicted area of influence of pumping occurs mostly within the Meedo pastoral lease area where for many years the land has been used only for commercial grazing of sheep and goats. Commercial stock grazing continues today and the grazing will have significantly

impacted the natural vegetation. There are no gazetted or known groundwater dependent areas of environmental significance known to occur within the projected area of influence of pumping.

The regional watertable in the Birdrong and Permian sediments occurs at depths of about 48 m or greater and as such the native vegetation in the area is not dependent on it. Some areas of native vegetation that depend on shallow aquifers may occur (for example vegetation along the Wooramel River). However, groundwater in these aquifers is perched on substantial thicknesses of low permeability strata and is not connected to the regional groundwater flow system of the aquifer formed in the Birdrong Sandstone and Permian sediments. On this basis, it is predicted that the shallow aquifers and any groundwater dependant ecosystems that utilise the shallow aquifers will not be affected by pumping from the regional aquifer. Correspondingly, no environmental impacts of significance are predicted from the proposed abstraction for the horticultural development.

## 10 CONCLUSIONS

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The Department of Agriculture and Food propose to offer for EoI a 400 Ha land and water package alongside the Wooramel River in the area of Meedo Station. Approximately 4 GL/year of groundwater with salinity less than 1500 mg/L is required for the development.

A groundwater resource likely capable of supplying 4 GL/year of low salinity groundwater has been identified close to the soil resource set aside for the development. The aquifer is formed by groundwater stored within the Cretaceous Birdrong Sandstone and Permian sediments at the east end of Meedo Station, crossing into Pimbee Station to the east of Meedo. Groundwater in the aquifer is deep with depth to water in bores ranging from about 48 to 81 m bgl. This in conjunction with swelling shales above the aquifer and drilling fluid losses complicates drilling. The deepest waterlevels occur where surface elevation is highest.

Groundwater in the aquifer is confined over most of the area but is regarded as unconfined in the east where recharge mostly occurs. Interpretation of potentiometric contours and hydrochemistry suggest some recharge also occurs on Meedo possibly where the Wooramel River is coincident on geological faults.

Groundwater flows from the east, mostly to the west and southwest across Meedo. Annual groundwater throughflow estimates of between 0.57 and 0.70 GL have been generated using numerical modeling of the aquifer and the Darcy equation, respectively. Storage of groundwater in the aquifer with salinity less than 1000 mg/L has been calculated to be in the order of 950 GL and storage with salinity of 1000 to 1500 mg/L in the order of 630 GL.

Numerical modelling of the aquifer predicts that extraction of 4 GL per year over a 20 year period would result in maximum drawdown in the aquifer of about 8 m. The area of drawdown greater than 1 m is predicted to extend a maximum of about 8 km from a potential borefield located centrally over the area of aquifer containing low salinity groundwater. The abstraction would be drawn mostly from storage.

Aquifer storage is very large and it is estimated only 5% of the available groundwater storage with less than 1500 ppm would be extracted after pumping at 4 GL/year for 20 years. Correspondingly, the impact of abstraction over the 20-year period is small. Further, the ratio of groundwater storage to the required abstraction provides a large buffer such that unexpected changes in groundwater levels and quality should be slow providing sufficient time for contingencies to be put in place.

Pumping for the development will likely impact the waterlevel in two stock bores in the area. However, the potential loss or reduction in yield from these bores could be offset by providing water from the horticultural development. Pumping is predicted to have negligible impact on groundwater quality.

Land within the area predicted to be affected by pumping has been used extensively for commercial grazing and is therefore likely to be degraded. Pumping is predicted to have no impact on potential groundwater dependent ecosystems, which will be dependent on groundwater contained in shallow aquifers, perched above the deeper regional aquifer of the Birdrong Sandstone and Permian sediments.

## 11 RECOMMENDATIONS

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1. The developer that emerges as the preferred proponent through the EoI process should lodge a groundwater licence application that is consistent with the Carnarvon Basin Management Plan.

2. The successful developer should generate an operating strategy setting out borefield configuration, pumping regimes and required monitoring and assessment, prior to borefield development.
3. The current numerical model should be utilised to predict the potential impact of the borefield proposed by the developer, which may have alternate configuration to that detailed herein. Alternative configurations and pumping regimes are unlikely to significantly change the impacts of pumping, but should be formalised as part of an operating strategy.

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**Table 1. Summary of 2004 Bores**

Bore Name	GGID <sup>A</sup>	MGA 94 Coordinates <sup>B</sup> Zone 50 GDA94		Drill Depth (m)	Case Material	Case ID NB (mm)	Slots (m bgl)		Screened Strata	Salinity TDS (mg/L) <sup>D</sup>	SWL <sup>G</sup>	SWL <sup>G</sup>	Comments
		N	E				From	To			(m bgl)	(m AHD)	
M 1/04	793	7163226.56	289671.06	174	PVC	50	149.815	173.815	Gnuedna	2000	48.240	71.182	Monitoring bore
M 2/04	794	7163226.55	289668.75	93	PVC	50	69.785	90.785	Birdrong	1300	48.150	71.277	Monitoring bore
M 3/04	795	7155798.24	289732.35	117	PVC	50	60.240	104.240	Birdrong	672 <sup>E</sup>	58.735	70.780	Monitoring bore
M 4/04	796	7158866.20	298461.00	66	PVC	50	55.067	61.082	Permian	-	Dry	Dry	Monitoring bore
M 5/04	797	7158880.30	298437.70	119	-	-	-	-	-	-	-	-	Lost bore
M 6/04	798	7158881.39	298433.66	150	PVC	50	119.525	149.467	Permian	1400	69.430	75.112	Monitoring bore
M 7/04	799	7158881.39	298433.87	150	PVC	50	71.482	101.357	Permian	830	70.260	74.259	Monitoring bore
M 8/04	800	7159382.21	298446.33	120	PVC	50	60.035	108.155	Permian	380	80.647	74.563	Monitoring bore
M 9/04 <sup>C</sup>	72851	7156558.50	270407.10	30	-	-	-	-	-	200 <sup>F</sup>	-	-	Investigation bore, backfilled and abandoned
M 10/04 <sup>C</sup>	72852	7156577.40	270798.40	24	-	-	-	-	-	500 <sup>F</sup>	-	-	Investigation bore, backfilled and abandoned
M 11/04	801	7155785.45	289730.99	120	PVC	150	65.599	107.819	Birdrong	672	58.470	70.768	Production bore
M 12/04	802	7149324.24	289182.39	111.5	PVC	150	59.315	111.084	Birdrong	2830	72.417	69.863	Production bore

## Notes.

- A Global Groundwater's Groundwater Information Database Identification Number (GGID).
- B Coordinates derived by Real Time Kinematic (RTK) GPS measurement (apart from bores M 9/04 and M10/04) position error 0.004 to 0.013 m. See metadata section of Global Groundwater (2006).
- C Coordinates for these bores derived by GPS measurement, estimated position error 4 m. See metadata section of Global Groundwater (2006).
- D Laboratory tested salinity of samples obtained in 2005 after purging of bores or 24-hour test pumping unless otherwise noted.
- E Salinity assumed the same as for bore M 11/04.
- F Field salinity of muddy slurry obtained during air-core drilling.
- G Static waterlevels recorded September/October 2005.

**Table 2. Summary of 2005 Bores**

Bore Name	GGID <sup>A</sup>	MGA 94 Coordinates <sup>B</sup> Zone 50 GDA94		Drill Depth (m)	Case Material	Case ID NB (mm)	Slots (m bgl)		Screened Strata	Salinity TDS (mg/L) <sup>D</sup>	SWL <sup>F</sup> (m bgl)	SWL <sup>F</sup> (m AHD)	Comments
		N	E				From	To					
M 1/05	835	7158415.42	292833.229	101	PVC	50	76.791	82.942	Permian	700	57.075	71.448	Monitoring bore, drilled to 101 m, collapsed to 84 m.
M 2/05	836	7155987.30	296741.402	120	PVC	50	113.267	119.31	Permian	2000	64.640	71.834	Monitoring bore
M 3/05	837	7155957.56	297925.747	120	PVC	50	77.789 114.101	83.829 120.129	Permian	2000	64.773	72.210	Monitoring bore
M 4/05	838	7155675.99	285819.246	114	PVC	50	58.434 82.566	70.490 88.594	Muderong/ Birdrong	1100	57.192	70.636	Monitoring bore, drilled to 114 m, collapsed to 96 m.
M 5/05	839	7152048.76	293632.298	106	PVC	50	77.610	99.752	Birdrong	2400	73.572	71.173	Monitoring bore
M 6/05 <sup>C</sup>	841	7158430.3	292824.400	122	-	-	-	-	-	625 <sup>E</sup>	-	-	Lost bore, not cased due to binding of unconsolidated sands.
M 7/05	840	7153995.09	290719.714	108	PVC	50	58.966	64.984	Birdrong	640	55.662	70.846	Monitoring bore, drilled to 108 m, collapsed to 66 m.
M 8/05	842	7159843.20	289023.421	112	PVC	50	52.794	64.850	Muderong	2200	63.525	70.800	Monitoring bore, drilled to 112 m, collapsed to 65 m.

## Notes.

- A Global Groundwaters Groundwater Information Database Identification Number (GGID).
- B Coordinates derived by Real Time Kinematic (RTK) GPS measurement (apart from bore M 6/04) position error 0.004 to 0.015 m. See metadata section of Global Groundwater (2006).
- C Coordinates for this bore derived by GPS measurement, estimated position error 3 m. See metadata section of Global Groundwater (2006).
- D Laboratory tested salinity of samples obtained in 2005 after purging of bores unless otherwise noted.
- E Field salinity measured recorded during drilling. May be inaccurate by up to 400 ppm too low.
- F Static waterlevels recorded September 2005

**Table 3. Summary of Stock Bores**

Bore Name <sup>A</sup>	WGS 84 Coordinates <sup>B</sup>		Depth <sup>C</sup> (m bgl)	TOC <sup>C</sup> (m agl)	SWL <sup>C</sup> bTOC	Interpreted Screened Aquifer	Salinity (mg/L) <sup>D</sup>	Comments
	Latitude	Longitude						
Weaner Well 66	-25.655945	114.644446	17.40		13.70	Alluvial	827	Fitted with Southern Cross mill
Autos Well 80	-25.616669	114.673897	24.73	0.50	19.85		448	
Doukers Bore 50	-25.624798	114.739259	26.0?	0.25	7.27		2970	145mm ID PVC depth may be pump
Mundillya Bore 90	-25.627584	114.808303					2480	5" OD steel casing
McEwins Bore	-25.632282	114.898239				Birdrong Sandstone	801	5" OD steel casing, diesel pump, signed McEwins Bore 178
Calcrete Well	-25.633284	114.905839	21.75		21.70	Alluvial	465	Named by Global Groundwater (Abandoned)
Barcoo Well	-25.690594	114.717068	15.80	0.75	13.10	Alluvial	530	
House Well 43	-25.662205	114.626377	13.30	0.10	11.20	Alluvial	1470	
Alstons Bore	-25.682159	114.639627	16.45		10.80	Alluvial	5110	145mm ID PVC casing, collapsed.
Alstons Well	-25.681907	114.639682	23.50	0.40	15.90		1630	
Wandi Well	-25.723725	114.797372	14.00	0.13	13.10	Alluvial	1610	Cement lined well less than 1m in diam.
CRA Bore	-25.679045	114.834545	14.00	0.70	13.10	Open in alluvial	1060	194mm ID PVC, grout below 13m, 112mAHD
Yabidda Well	-25.733006	114.689765	26.80	0.50	23.30	Aeolian/alluvial sand	800	4 post Mill "The Aermotor" Chicago
Camel Well	-25.757411	114.798768	19.50	0.60	17.20		1760	5 foot well liner, 14ft windmill
Top Mill Well	-25.659540	114.93040		0.00	11.95	Alluvial	327	Signed Top Well 60, indicating pump @ 18m
Crystal Tank Bore	-25.700454	114.943112		0.33		Birdrong Sandstone	338	Equipped with windmill. gl 134mAHD
Deep Bore	-25.767646	114.941191	>62.00		>62.00	Birdrong Sandstone		Abandoned. Drilled prior to 1977 using rotary percussion methods. Data from DoW database.
Meedo No.3 Bore	-25.796600	114.894278	83.00		73.60	?Birdrong Sandstone		Abandoned. Drilled 30 June 1929. Data from DoW database.
Callytharra Pool Bore	-25.683600	115.057620	126.10	0.295	63.85	Moogooloo / Permian	410-430	Pump removed by DoE&C gl 149mAHD

Notes. • TOC Top of Casing

• A Number following bore name is number shown on sign at bore likely to be pump depth (ft).

• B Coordinates are derived by GPS measurement, (error up to 30m).

• C Field readings June 2003.

• D Field tested salinity of bailed samples.

**Table 4. Stratigraphic Sequence** (Modified After Denman et al (1987) and Hocking et al (1987))

Age	Group/Formation	Maximum Thickness (m) <sup>A</sup>	Lithology / Remarks
<b>CAINOZOIC</b>			
Quaternary	Superficial Deposits	12 <sup>B</sup>	Aeolian sand and gravel, alluvial and aeolian clay and silt. Minor unconfined aquifer containing fresh to brackish groundwater.
Miocene	Duricrust	c	Ferruginous and siliceous duricrust, laterite and silcrete.
Eocene	Giralia Calcarenite	10(11 <sup>B</sup> )	Glauconitic, bioclastic limestone and calcarenite, shallow marine. Can contain sand at Meedo and forms minor shallow aquifers with fresh to marginal groundwater near the Wooramel River.
<b>MESOZOIC</b>			
Cretaceous	Toolonga Calcilutite	100(?)	Friable calcilutite and calcisiltite, minor chert, commonly porcellanised. Marine
	Gearle Siltstone	90 (24 <sup>B</sup> )	Siltstone and claystone, locally bentonitic. Marine. Minor local aquifers possible.
	Windalia Radiolarite	50 (30 <sup>B</sup> )	Interbedded radiolaria rich black chert, siltstone and minor shale, porcellanised. Marine shelf.
	Muderong Shale	20 (42 <sup>B</sup> )	Fine grained glauconitic shale and argillaceous siltstone. Marine.
	Birdrong Sandstone	35 (68 <sup>B</sup> )	Medium grained quartz sandstone, shallow marine.
<b>PALAEOZOIC</b>			
Permian	Keogh Formation	50	Siltstone and sandstone, minor claystone, shallow marine to estuarine.
	Moogooloo Sandstone	118	Fine grained silty sandstone and medium to very coarse grained and pebbly sandstone (feldspathic/lithic arenite). Estuarine – shallow marine
	Callytharra Formation	244	Calcareous siltstone and calcarenite, fossiliferous. Marine
	Carrandiby Formation	72	Fine grained siltstone, sandstone, some limestone. Marine.
Permian - Carboniferous	Lyons Group	>1500	Glacigene feldspathic arenite, quartz wacke, shale and tillite. Marine and continental
Devonian (Frasnian)	Gneudna Formation	>300	Limestone, sandstone and siltstone, probably non porous
<b>ARCHAEAN</b>			
			Gneiss, coarse to fine grained.

Major aquifer in Birdrong Sandstone and Permian sediments  
 Mostly confining beds above Birdrong Sandstone

- A Maximum onshore thickness from Denman et al (1987) and Hocking et al (1987).  
 B Maximum thickness encountered in bores in the Meedo area (Global Groundwater, 2006)  
 C Undifferentiated in drill holes (Global Groundwater, 2006)

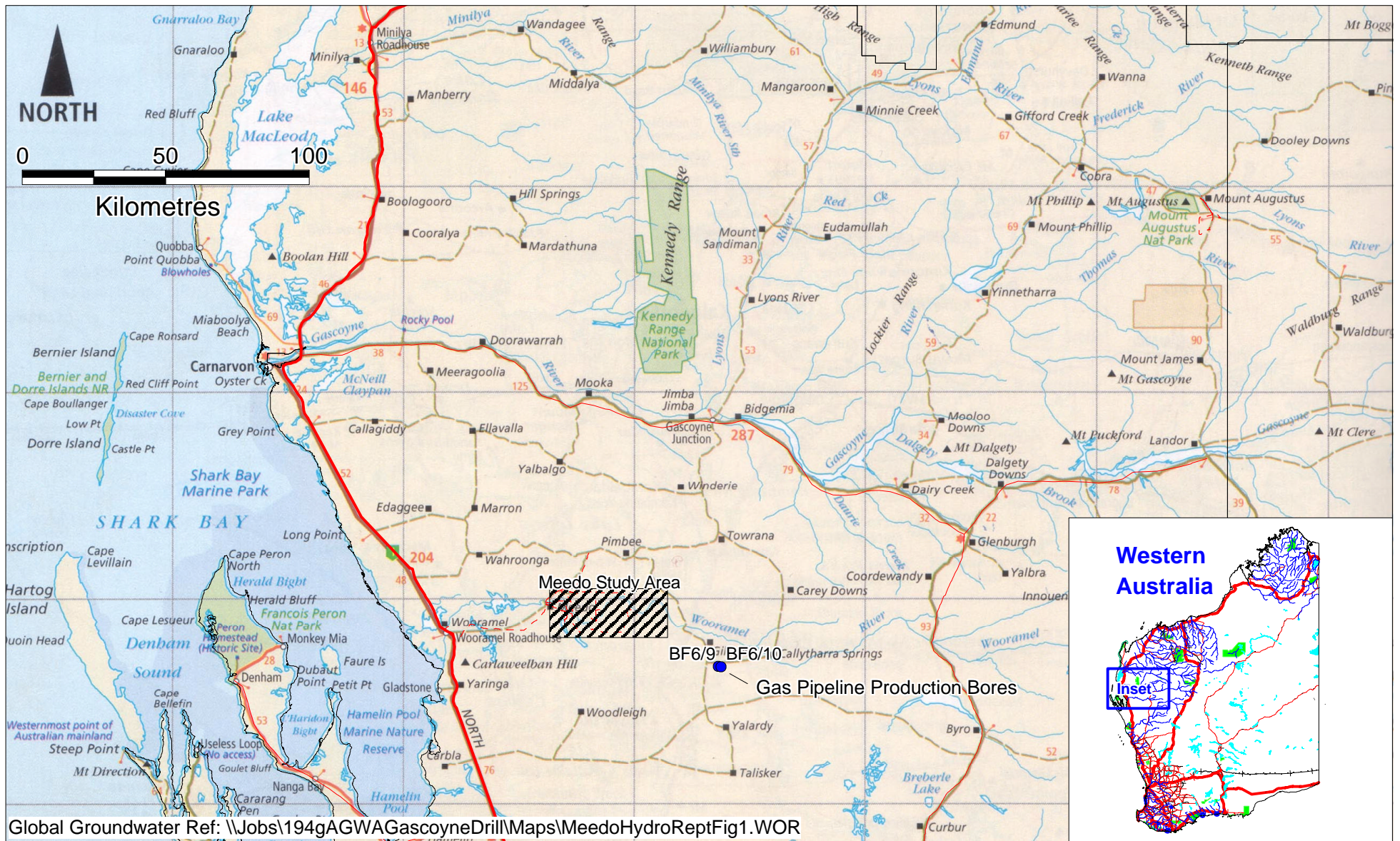


Figure 1 Regional Location

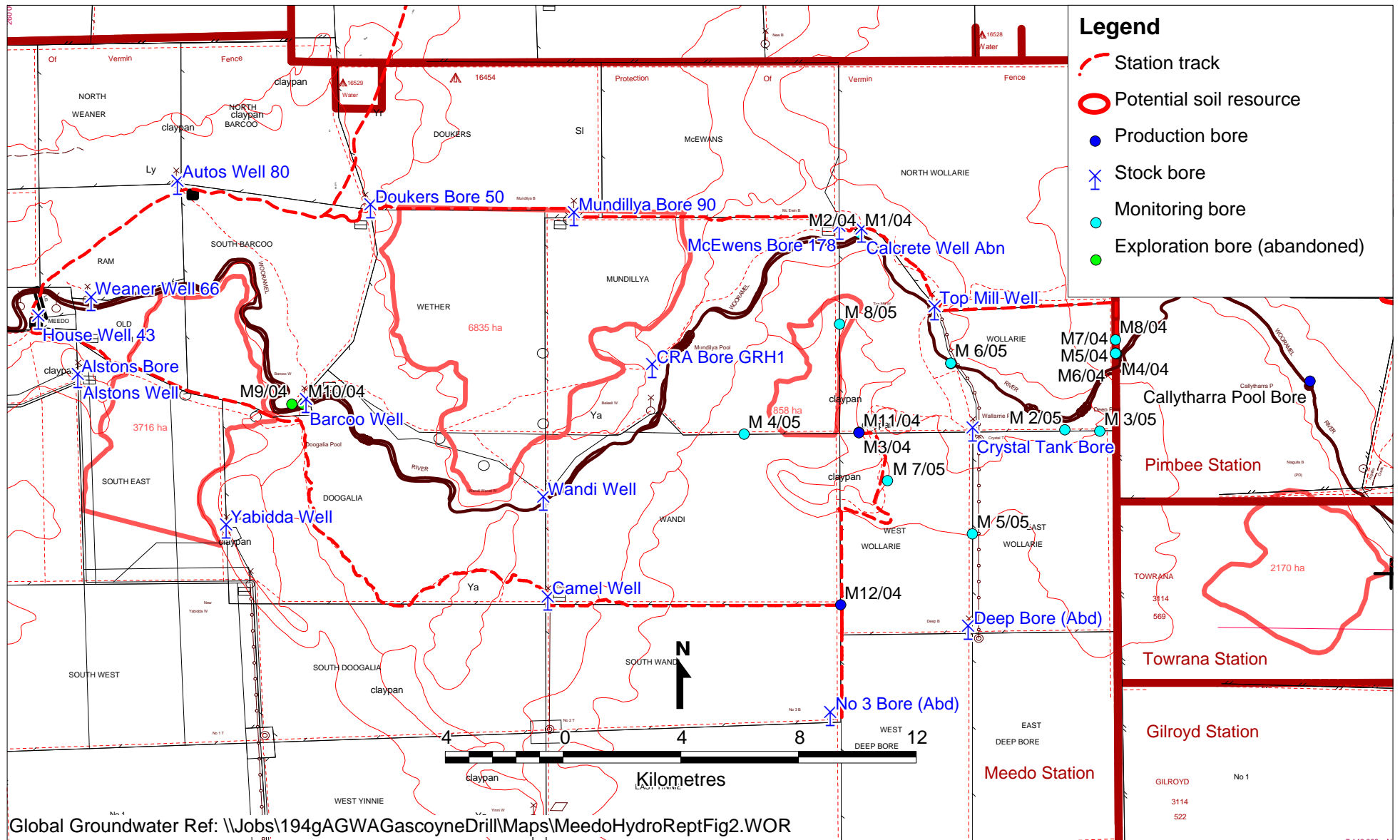


Figure 2. Meedo Bore and Soil Resource Locations

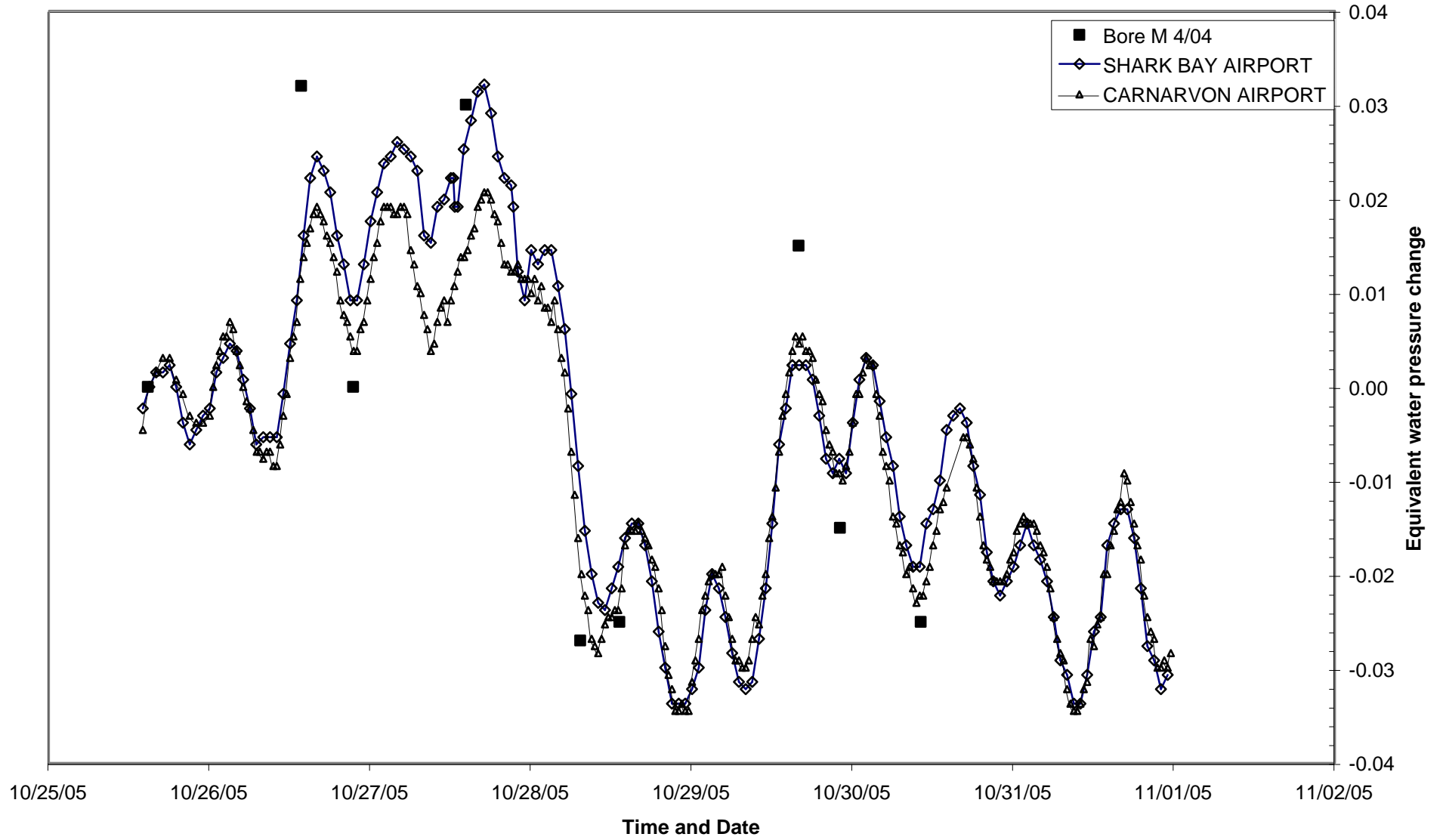


Figure 3. Environmental Correction of Potentiometric Heads

### Step Test Bore M 11/04

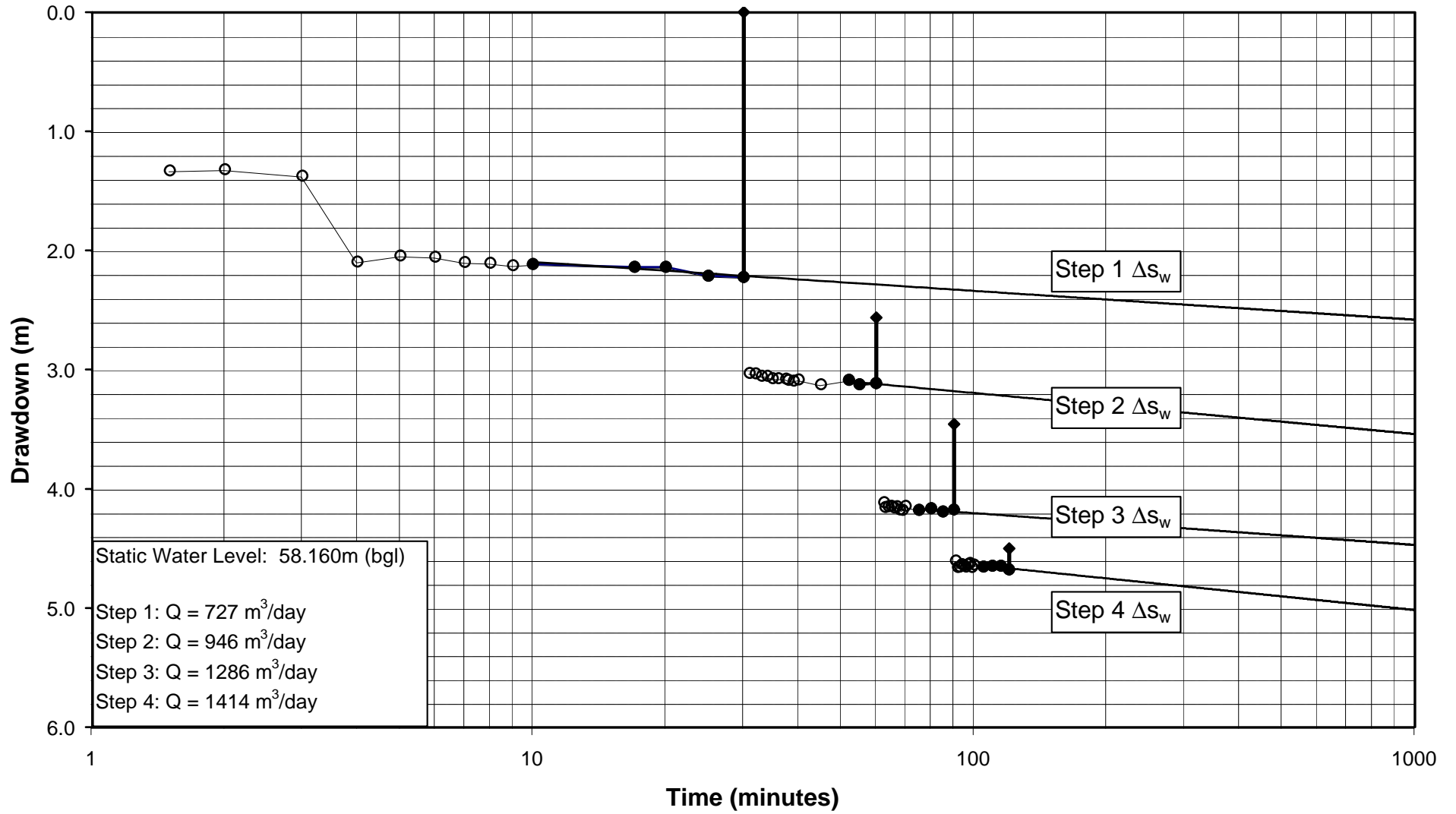


Figure 4.

### Constant Rate Test Bore M 11/04

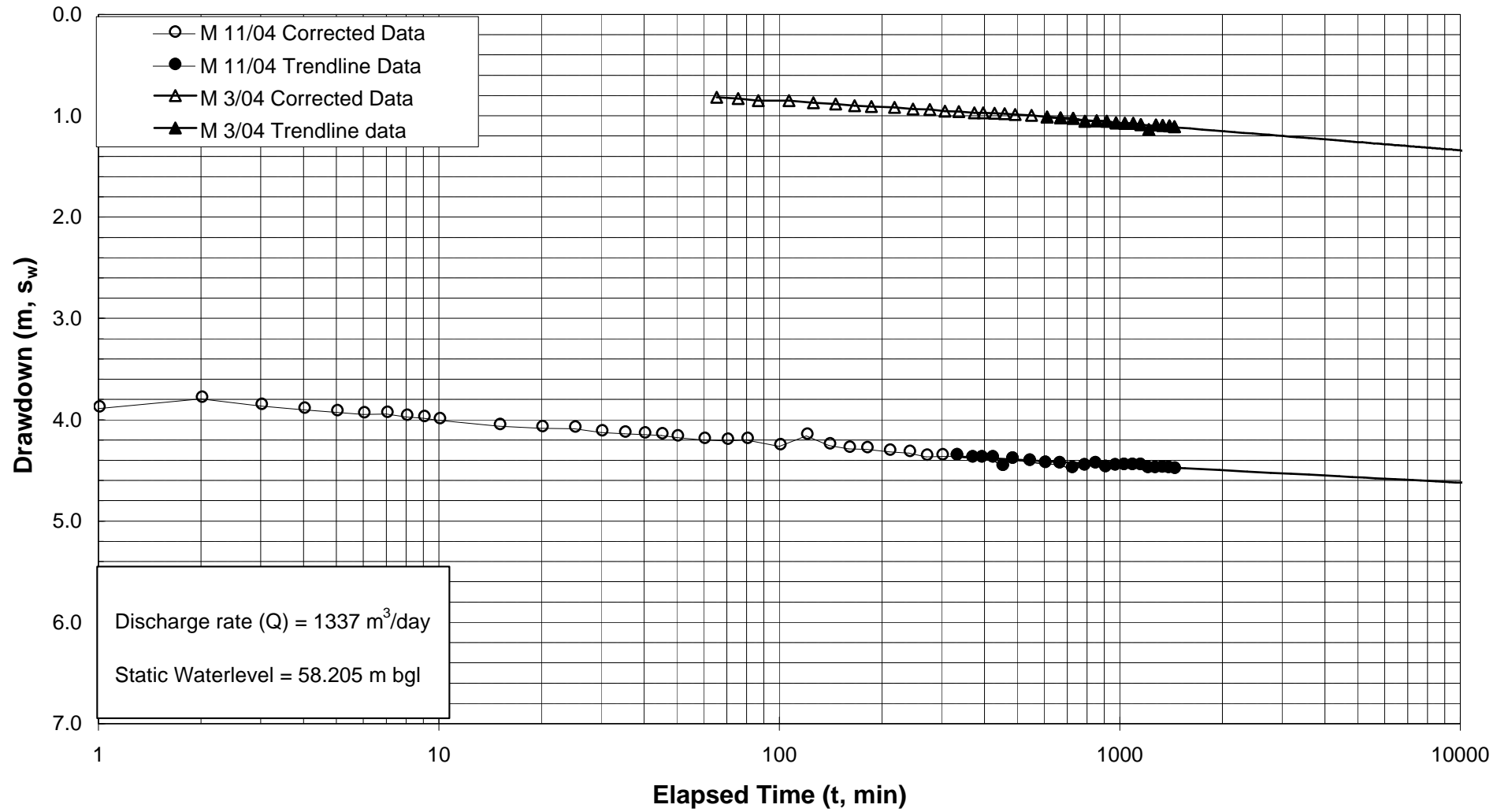


Figure 5.

### Residual Drawdown Bore M 11/04

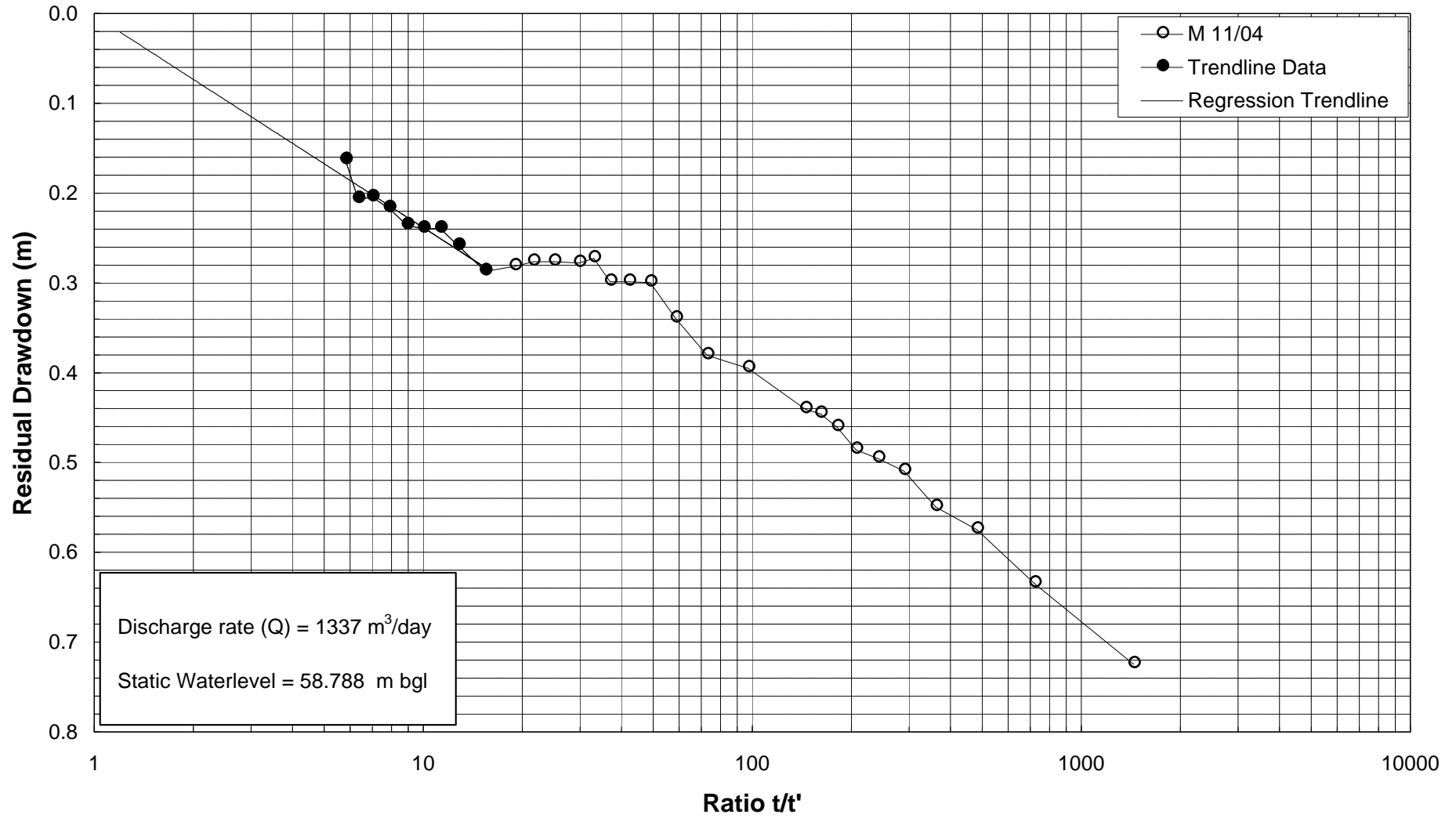


Figure 6.

### Step Test Bore M 12/04

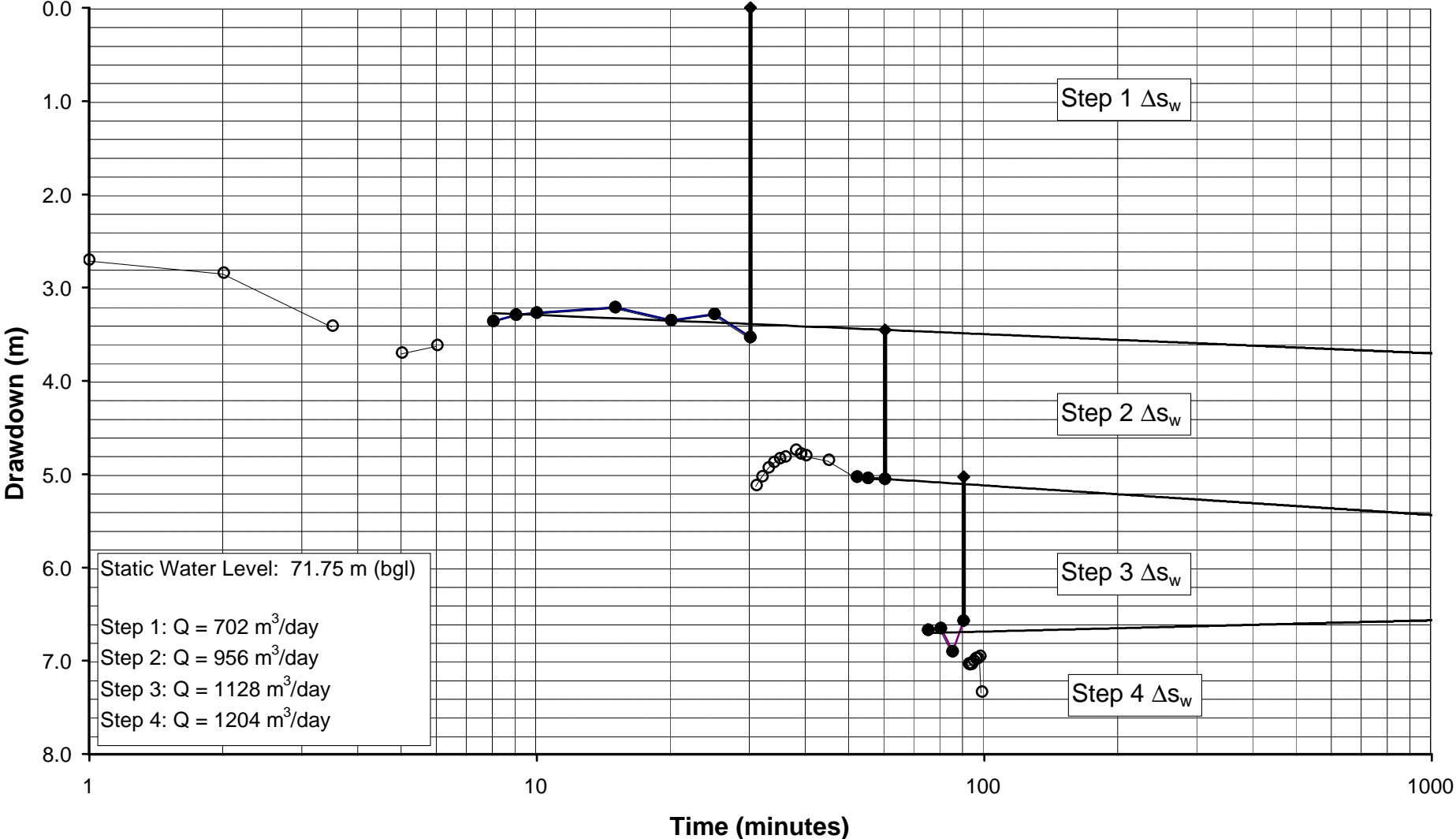


Figure 7.

### Constant Rate Test Bore M 12/04

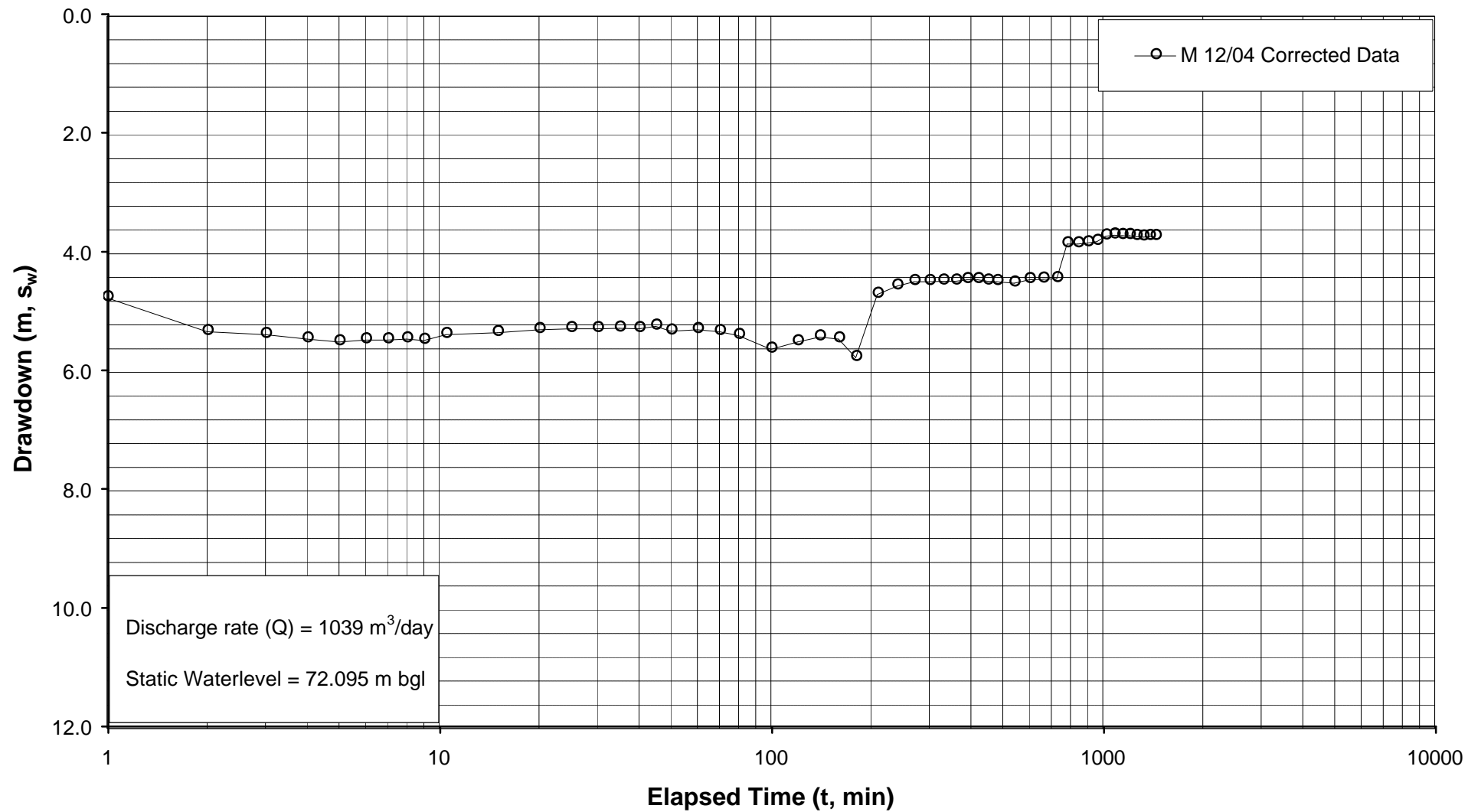


Figure 8.

### Residual Drawdown Bore M 12/04

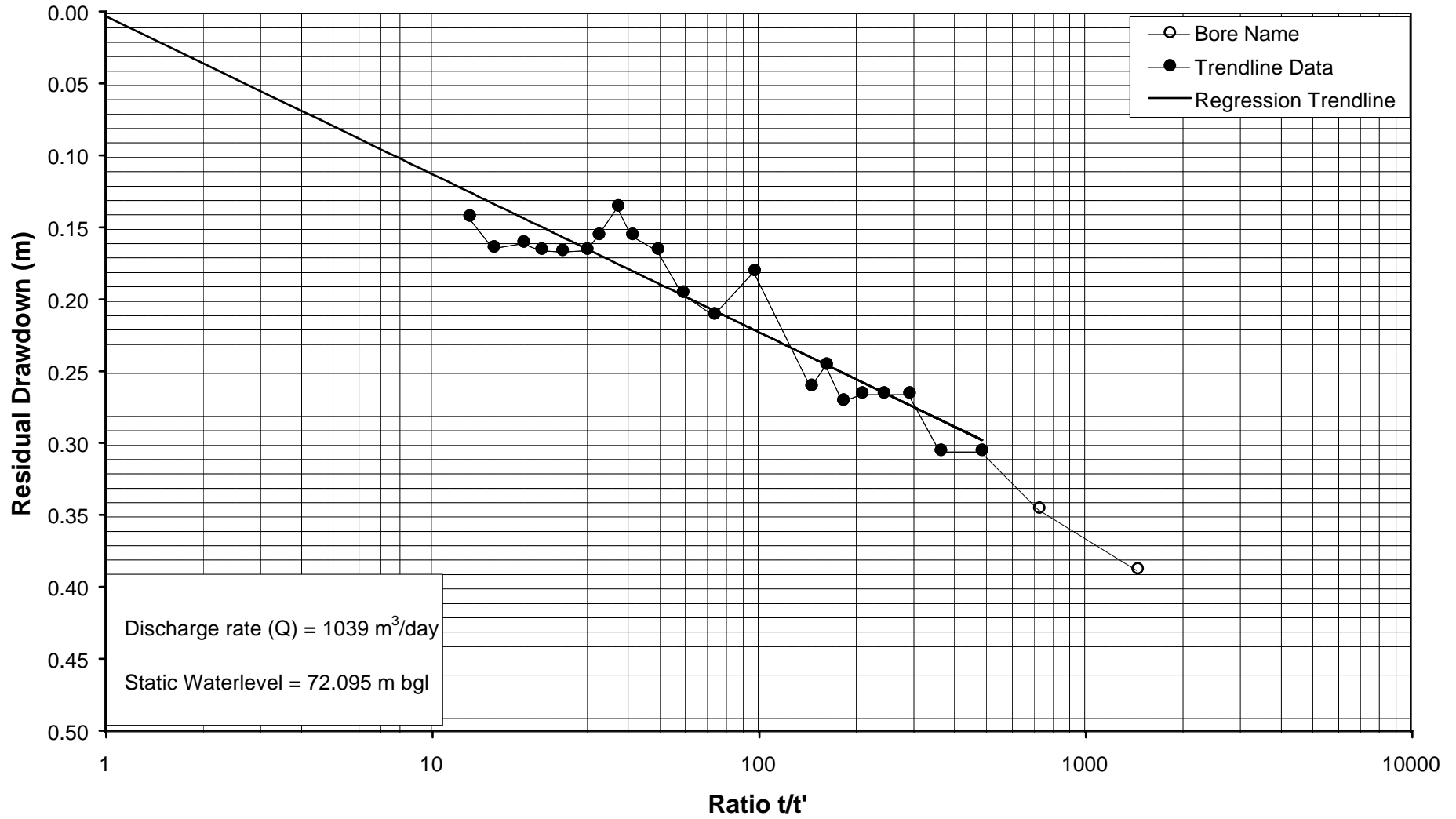
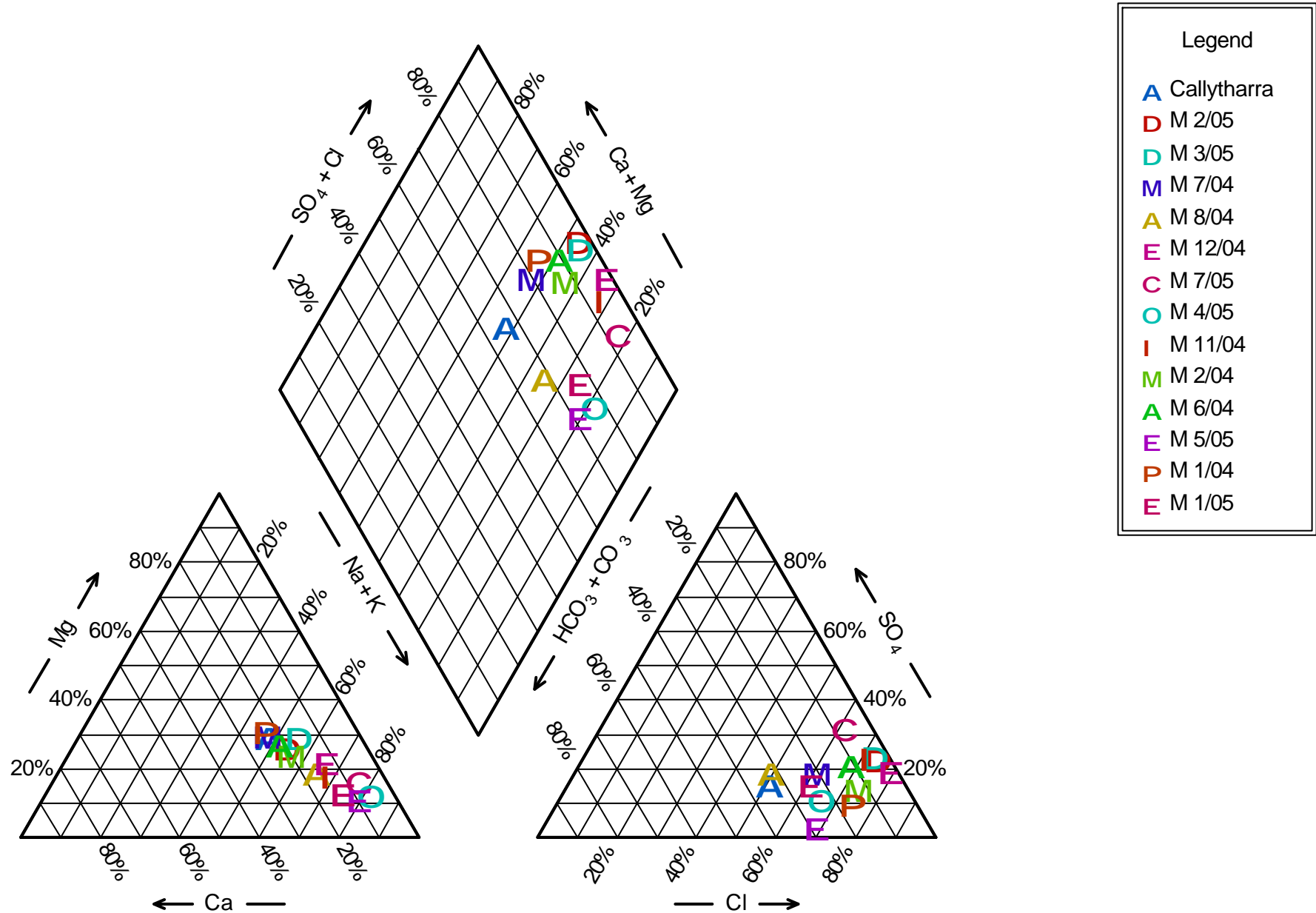


Figure 9.

Figure 10. Piper Trilinear Diagram



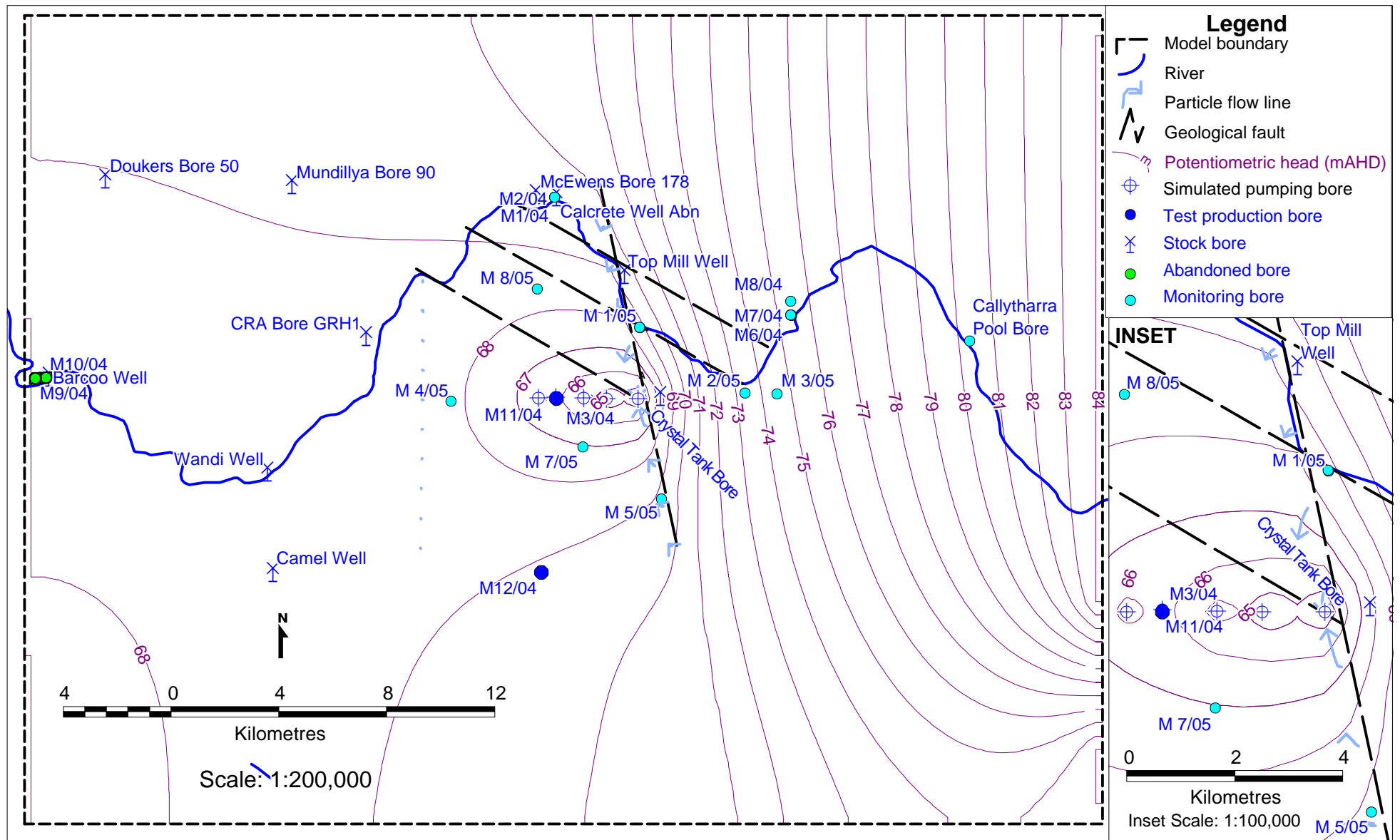
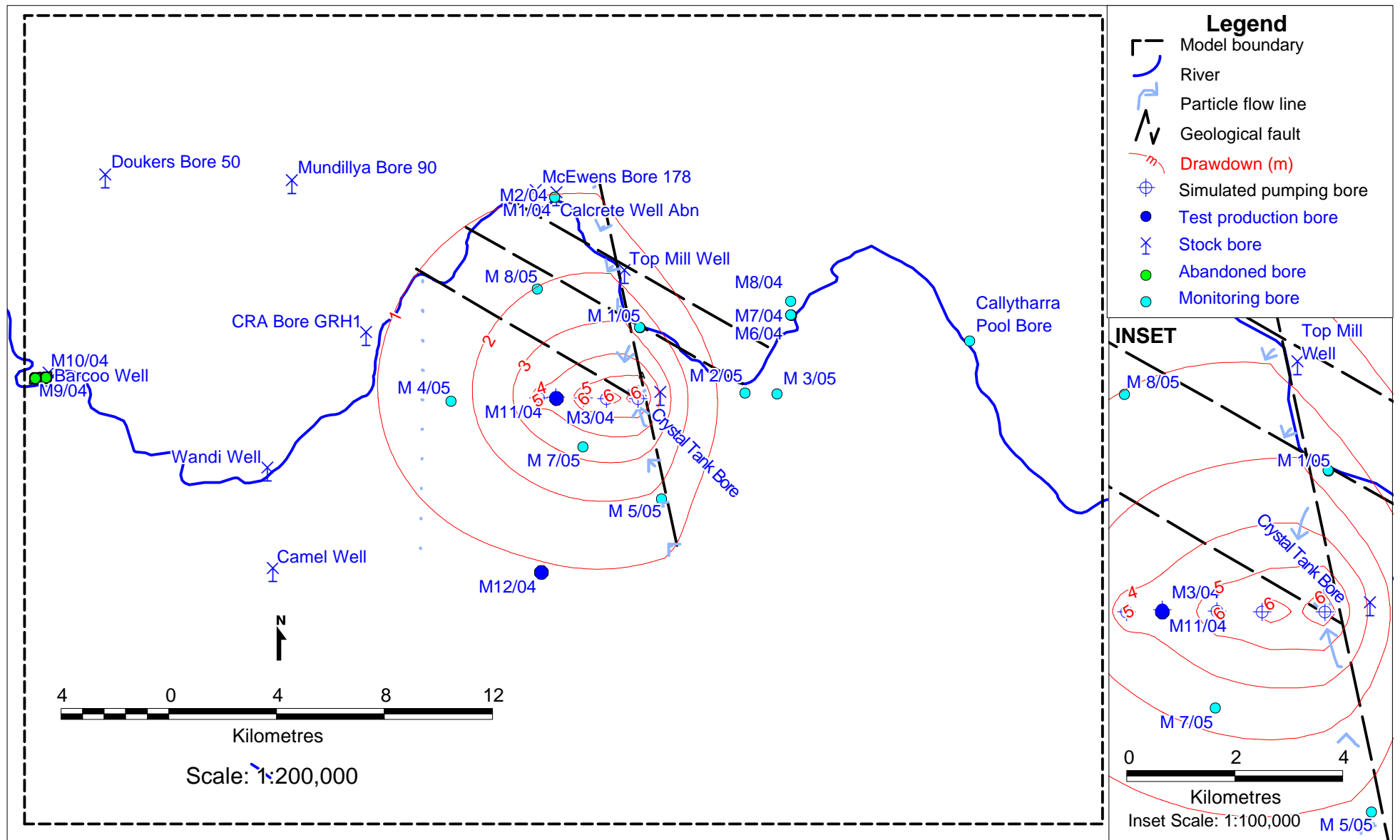


Figure 11. Modelled Potentiometric Contours (20 years pumping at 4 GL/yr)



Global Groundwater Reference: \\194g\\MeedoModelIDD20yrs.WOR

Figure 12. Modelled Drawdown (20 years pumping at 4 GL/yr)

## Appendix A

### Test Pumping Data and Analysis Sheets

#### ***Bore M 11/04***

- Step-Test Data Sheet
- Step-Test Pumping Analysis Sheet
- Constant-Rate Test – Data Sheet
- Recovery – Data Sheet
- Test Pumping Analysis Sheet

#### ***Bore M 12/04***

- Step-Test Data Sheet
- Constant-Rate Test – Data Sheet
- Recovery – Data Sheet
- Test Pumping Analysis Sheet

# GLOBAL GROUNDWATER

## Step Test Data Sheet

Date :	<input type="text" value="25-Oct-05"/>	Supervisor :	<input type="text" value="G Watkins"/>	Pumped Bore:	<input type="text" value="M 11/04"/>
Job No :	<input type="text" value="194g"/>	Operator:	<input type="text" value="D Lang"/>	Measurements on Bore:	<input type="text" value="M 11/04"/>
Client :	<input type="text" value="Dep. Agriculture WA"/>	Distance to Pumped Bore (m):	<input type="text" value="0"/>		
Contractor:	<input type="text" value="K S Black and Co"/>				

SWL (mbMP):	<input type="text" value="59.057"/>	SWL (mbgl):	<input type="text" value="58.160"/>	Pump Inlet (mbmp):	<input type="text" value="81.5"/>
MP (maToC):	<input type="text" value="0.587"/>	Start Time:	<input type="text" value="25/10/2005 15:55"/>	Available Drawdown (m):	<input type="text" value="22.4"/>
ToC (magl):	<input type="text" value="0.310"/>	End Time:	<input type="text" value="25/10/2005 17:55"/>	Discharge Location:	<input type="text" value="40m North"/>
Pump :	<input type="text" value="S Cross LAD 13s"/>			Bore Internal Diam. (mm):	<input type="text" value="150.0"/>

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC = Top of Casing (Bore)

STEP	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Remarks
6" Weir with 4" orifice @ 4"			<b>727 (m<sup>3</sup>/d)</b>		<b>8.41 (L/s)</b>
<b>1</b>	15:56:30	1.5	60.385	1.328	
	15:57:00	2	60.375	1.318	
	15:58:00	3	60.430	1.373	
	15:59:00	4	61.150	2.093	
	16:00:00	5	61.100	2.043	
	16:01:00	6	61.110	2.053	
	16:02:00	7	61.155	2.098	
	16:03:00	8	61.160	2.103	
	16:04:00	9	61.180	2.123	
	16:05:00	10	61.170	2.113	
	16:12:00	17	61.195	2.138	
	16:15:00	20	61.195	2.138	Water temp 32 deg
	16:20:00	25	61.270	2.213	EC 1074 uS/cm
16:25:00	30	61.280	2.223		
6" Weir with 4" orifice @ 7"			<b>946 (m<sup>3</sup>/d)</b>		<b>10.95 (L/s)</b>
<b>2</b>	16:26:00	31	62.085	3.028	
	16:27:00	32	62.090	3.033	
	16:28:00	33	62.110	3.053	
	16:29:00	34	62.110	3.053	
	16:30:00	35	62.130	3.073	
	16:31:00	36	62.130	3.073	
	16:32:30	37.5	62.135	3.078	
	16:33:00	38	62.145	3.088	
	16:34:00	39	62.150	3.093	
	16:35:00	40	62.140	3.083	
	16:40:00	45	62.180	3.123	
	16:47:00	52	62.145	3.088	Water temp 32 deg
	16:50:00	55	62.180	3.123	EC 1076 uS/cm
	16:55:00	60	62.170	3.113	

# GLOBAL GROUNDWATER

## Step Test Data Sheet

Date:	<input type="text" value="25-Oct-05"/>	Supervisor:	<input type="text" value="G Watkins"/>	Pumped Bore:	<input type="text" value="M 11/04"/>
Job No:	<input type="text" value="194g"/>	Operator:	<input type="text" value="D Lang"/>	Measurements on Bore:	<input type="text" value="M 11/04"/>
Client:	<input type="text" value="Dep. Agriculture WA"/>		Distance to Pumped Bore (m):	<input type="text" value="0"/>	
Contractor:	<input type="text" value="K S Black and Co"/>				

SWL (mbMP):	<input type="text" value="59.057"/>	SWL (mbgl):	<input type="text" value="58.160"/>	Pump Inlet (mbmp):	<input type="text" value="81.5"/>
MP (maToC):	<input type="text" value="0.587"/>	Start Time:	<input type="text" value="25/10/2005 15:55"/>	Available Drawdown (m):	<input type="text" value="22.4"/>
ToC (magl):	<input type="text" value="0.310"/>	End Time:	<input type="text" value="25/10/2005 17:55"/>	Discharge Location:	<input type="text" value="40m North"/>
Pump:	<input type="text" value="S Cross LAD 13s"/>			Bore Internal Diam. (mm):	<input type="text" value="150.0"/>

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC = Top of Casing (Bore)

STEP	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Remarks
6" Weir with 4" orifice @ 13"			1286 (m <sup>3</sup> /d)		14.89 (L/s)
<b>3</b>	16:56:00	61			
	16:57:30	62.5	63.170	4.113	
	16:58:00	63	63.210	4.153	
	16:59:00	64	63.205	4.148	
	17:00:00	65	63.202	4.145	
	17:01:00	66	63.215	4.158	
	17:02:00	67	63.205	4.148	
	17:03:00	68	63.230	4.173	
	17:04:00	69	63.235	4.178	
	17:05:00	70	63.200	4.143	
	17:10:00	75	63.235	4.178	
	17:15:00	80	63.220	4.163	Water temp 31.5 deg
17:20:00	85	63.250	4.193	EC 1063 uS/cm	
17:25:00	90	63.230	4.173		
6" Weir with 4" orifice @ 16"			1414 (m <sup>3</sup> /d)		16.37 (L/s)
<b>4</b>	17:26:00	91	63.660	4.603	
	17:27:00	92	63.715	4.658	
	17:28:00	93	63.710	4.653	
	17:29:00	94	63.690	4.633	
	17:30:00	95	63.700	4.643	
	17:31:00	96	63.710	4.653	
	17:32:00	97	63.690	4.633	
	17:33:00	98	63.680	4.623	
	17:34:00	99	63.715	4.658	
	17:35:00	100	63.695	4.638	
	17:40:00	105	63.710	4.653	
	17:45:00	110	63.705	4.648	Water temp 32 deg
17:50:00	115	63.705	4.648	EC 1051 uS/cm	
17:55:00	120	63.735	4.678		

# GLOBAL GROUNDWATER

## Step Test Pumping Analysis Sheet

Job No.:	<u>194g</u>	Pumped Bore:	<u>M 11/04</u>
Client.:	<u>Dep. Agriculture WA</u>	Calculations for Bore:	<u>M 11/04</u>
Screens (mbgl):	<u>65.599</u> to <u>107.819</u>	Bore Diameter (mm):	<u>150.0</u>
Step Test Start:	<u>25-Oct-05 15:55</u>	Bore Radius r (m):	<u>0.075</u>
Step Test End:	<u>25-Oct-05 17:55</u>	SWL (mbgl):	<u>58.160</u>
Duration (hours):	<u>2.0</u>		

Method of Analysis:	<b><u>Hantush-Bierschenk Method</u></b>		
Regression Equation Step 1:	$s_w =$	<u>0.105</u>	$\ln(t) +$ <u>2.1321</u>
Regression Equation Step 2:	$s_w =$	<u>0.1497</u>	$\ln(t) +$ <u>2.7835</u>
Regression Equation Step 3:	$s_w =$	<u>0.1161</u>	$\ln(t) +$ <u>3.9466</u>

Note: See drawdown plot for lines of best fit represented by the above equations.

For well efficiency, theoretical (s) drawdown can be predicted from the slope and intercept of the curve derived from the plot of Q versus s/Q and then compared with the actual drawdown recorded during the constant rate test.

The curve has the equation  $s/Q=B+CQ$  where B is the intercept and C is the slope. Rearranging the equation  $s=bQ+CQ^2$ . Where s (total drawdown) is made up of drawdown due to laminar flow (BQ) regarded as being mostly due to the aquifer and drawdown due to turbulent flow ( $CQ^2$ ), regarded as mostly due to well losses.

From the Step Test the Following are derived

Step	Δs <sub>w</sub> for each step	ΣΔ(s <sub>w</sub> )	Q	ΣΔ(s <sub>w</sub> )/Q	Intercept (B)	Slope (C)
1	2.22	2.22	726.62	0.0031	0.004	-6.689E-07
2	0.55	2.77	946.08	0.0029		
3	0.72	3.49	1286.50	0.0027		
4	0.18	3.67	1414.37	0.0026		

**Therefore the characteristic curve for the bore ( $s=BQ+CQ^2$ ) is;**

$$s = \underline{0.0036} Q + \underline{-6.6886E-07} Q^2$$

and after pumping for 30 minutes at 1337 m<sup>3</sup>/day

Predicted drawdown due to laminar flow (BQ) = 4.752 m or 134% of the total.

Predicted drawdown due to turbulent flow (CQ) = -1.195 m or -34% of the total.

Total predicted drawdown = 3.557 m

Actual 30-min drawdown during constant rate test = 4.126 m

### **Comments**

The bore characteristic curve indicates that the bore was undergoing development during the step-test and so can't be used to estimate bore efficiency. Nonetheless, well losses are likely to be low when pumping within the step test range of rates.

## GLOBAL GROUNDWATER

<b>Constant Rate Test - Data Sheet</b>						
Test Start:	26-Oct-05 07:45		Test End:	27-Oct-05 07:45		
Job No.:	194g		Pumped Bore:	M 11/04		
Client.:	Dep. Agriculture WA		Measurements on Bore:	M 11/04		
Contractor:	K S Black and Co		Supervisor:	G Watkins		
SWL (mbMP):	59.102		Pump Inlet (mbmp):	81.5		
MP (maTOC):	0.587		Available Drawdown (m):	22.4		
TOC (magl):	0.310		Discharge Dist. & Direction:	40m North		
SWL (mbgl):	58.205		Bore Internal Diameter (mm):	150		
Pump Used:	S Cross LAD 13s	Flow (L/s):	15.47	Flow (m <sup>3</sup> /day):	1337	
Flow device:	QA calibrated 6" Weir with 4" orifice @ 14" manometer height.					
Start Time:	7:45:00	End Time:	7:45:00	Number of other Bores Monitored:	1	
SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level MP = Measuring point      magl = Metres above ground level      ToC= Top of Casing (Bore)						
Date	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Corrected Drawdown (m)	Comments
26-Oct-05	7:46:00	1.0	63.000	3.898	3.890	
26-Oct-05	7:47:00	2.0	62.905	3.803	3.796	
26-Oct-05	7:48:00	3.0	62.975	3.873	3.866	
26-Oct-05	7:49:00	4.0	63.010	3.908	3.901	
26-Oct-05	7:50:00	5.0	63.035	3.933	3.926	
26-Oct-05	7:51:00	6.0	63.060	3.958	3.950	
26-Oct-05	7:52:00	7.0	63.055	3.953	3.945	
26-Oct-05	7:53:00	8.0	63.085	3.983	3.975	
26-Oct-05	7:54:00	9.0	63.095	3.993	3.985	
26-Oct-05	7:55:00	10.0	63.115	4.013	4.005	
26-Oct-05	8:00:00	15.0	63.175	4.073	4.065	EC 1050 uS/cm
26-Oct-05	8:05:00	20.0	63.195	4.093	4.085	
26-Oct-05	8:10:00	25.0	63.200	4.098	4.090	
26-Oct-05	8:15:00	30.0	63.235	4.133	4.126	
26-Oct-05	8:20:00	35.0	63.250	4.148	4.141	
26-Oct-05	8:25:00	40.0	63.255	4.153	4.146	
26-Oct-05	8:30:00	45.0	63.265	4.163	4.156	EC 1048 uS/cm
26-Oct-05	8:35:00	50.0	63.285	4.183	4.176	
26-Oct-05	8:45:00	60.0	63.310	4.208	4.201	
26-Oct-05	8:55:00	70.0	63.320	4.218	4.211	
26-Oct-05	9:05:00	80.0	63.310	4.208	4.201	EC 1044 uS/cm
26-Oct-05	9:25:00	100.0	63.375	4.273	4.264	
26-Oct-05	9:45:00	120.0	63.270	4.168	4.160	EC 1022 uS/cm
26-Oct-05	10:05:00	140.0	63.365	4.263	4.254	EC 1024 uS/cm
26-Oct-05	10:25:00	160.0	63.395	4.293	4.287	
26-Oct-05	10:45:00	180.0	63.400	4.298	4.293	EC 1028 uS/cm
26-Oct-05	11:15:00	210.0	63.420	4.318	4.316	EC 1026 uS/cm
26-Oct-05	11:45:00	240.0	63.430	4.328	4.329	EC 1019 uS/cm
26-Oct-05	12:15:00	270.0	63.465	4.363	4.367	EC 1023 uS/cm
26-Oct-05	12:45:00	300.0	63.460	4.358	4.364	EC 1007 uS/cm
26-Oct-05	13:15:00	330.0	63.455	4.353	4.362	EC 991 uS/cm
26-Oct-05	13:52:00	367.0	63.475	4.373	4.385	EC 973 uS/cm
26-Oct-05	14:15:00	390.0	63.470	4.368	4.382	EC 994 uS/cm

## GLOBAL GROUNDWATER

<b>Constant Rate Test - Data Sheet</b>						
Test Start:	26-Oct-05 07:45		Test End:	27-Oct-05 07:45		
Job No.:	194g		Pumped Bore:	M 11/04		
Client.:	Dep. Agriculture WA		Measurements on Bore:	M 11/04		
Contractor:	K S Black and Co		Supervisor:	G Watkins		
SWL (mbMP):	59.102		Pump Inlet (mbmp):	81.5		
MP (maTOC):	0.587		Available Drawdown (m):	22.4		
TOC (magl):	0.310		Discharge Dist. & Direction:	40m North		
SWL (mbgl):	58.205		Bore Internal Diameter (mm):	150		
Pump Used:	S Cross LAD 13s	Flow (L/s):	15.47	Flow (m <sup>3</sup> /day):	1337	
Flow device:	QA calibrated 6" Weir with 4" orifice @ 14" manometer height.					
Start Time:	7:45:00	End Time:	7:45:00	Number of other Bores Monitored:	1	
SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level MP = Measuring point          magl = Metres above ground level          ToC= Top of Casing (Bore)						
Date	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Corrected Drawdown (m)	Comments
26-Oct-05	14:45:00	420.0	63.470	4.368	4.384	EC 989 uS/cm
26-Oct-05	15:15:00	450.0	63.550	4.448	4.465	EC 997 us/cm
26-Oct-05	15:45:00	480.0	63.480	4.378	4.396	EC 992 uS/cm
26-Oct-05	16:45:00	540.0	63.500	4.398	4.415	EC 984 uS/cm
26-Oct-05	17:45:00	600.0	63.525	4.423	4.438	EC 974 uS/cm
26-Oct-05	18:45:00	660.0	63.530	4.428	4.440	EC 972 uS/cm
26-Oct-05	19:45:00	720.0	63.580	4.478	4.485	EC 979 uS/cm
26-Oct-05	20:45:00	780.0	63.560	4.458	4.463	EC 967 uS/cm
26-Oct-05	21:45:00	840.0	63.540	4.438	4.441	EC 962 uS/cm
26-Oct-05	22:45:00	900.0	63.575	4.473	4.480	EC 965 uS/cm
26-Oct-05	23:45:00	960.0	63.555	4.453	4.464	EC 966 uS/cm
27-Oct-05	0:45:00	1020.0	63.545	4.443	4.458	EC 967 uS/cm
27-Oct-05	1:45:00	1080.0	63.540	4.438	4.457	EC 973 uS/cm
27-Oct-05	2:45:00	1140.0	63.540	4.438	4.457	EC 965 uS/cm
27-Oct-05	3:45:00	1200.0	63.570	4.468	4.486	EC 964 uS/cm
27-Oct-05	4:45:00	1260.0	63.570	4.468	4.487	EC 967 uS/cm
27-Oct-05	5:45:00	1320.0	63.570	4.468	4.482	EC 965 uS/cm
27-Oct-05	6:45:00	1380.0	63.580	4.478	4.488	EC 964 uS/cm
27-Oct-05	7:45:00	1440.0	63.590	4.488	4.495	EC 967 uS/cm

## GLOBAL GROUNDWATER

Monitoring Bore - Data Sheet											
Date: <input type="text" value="26-Oct-05 07:45"/>		Job No.: <input type="text" value="194g"/>		Client: <input type="text" value="Dep. Agriculture WA"/>		Test Start: <input type="text" value="26-Oct-05 07:45"/>		Production Bore Pumped: <input type="text" value="M 11/04"/>			
Measurements on Bore: <input type="text" value="M 3/04"/>						Measurements on Bore: <input type="text" value="M 4/04"/>					
Distance from Pumped Bore (m): <input type="text" value="12"/>						Distance From Pumped Bore (m) <input type="text" value="3910"/>					
SWL (mbMP): <input type="text" value="59.322"/>			MP (magl): <input type="text" value="0.570"/>			SWL (mbmp): <input type="text" value="57.945"/>			MP (magl): <input type="text" value="0.808"/>		
SWL (mbgl): <input type="text" value="58.752"/>			Bore Diam. (mm): <input type="text" value="50"/>			SWL (mbgl): <input type="text" value="57.137"/>			Bore Diam. (mm): <input type="text" value="50"/>		
SWL Measured on: <input type="text" value="26-Oct-05 07:45"/>						SWL Measured on: <input type="text" value="25-Oct-05 14:45"/>					
SWL = Static water level				mbMP = Metres below measuring point				mbgl = Metres below ground level			
MP = Measuring point				magl = Metres above ground level				ToC= Top of Casing (Bore)			
Date	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Corrected Drawdown (m)	Date	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Corrected Drawdown (m)
26-Oct-05	8:50:00	65.00	60.165	0.843	0.836	26-Oct-05	13:40:00	355.0	57.913	-0.032	-0.021
26-Oct-05	9:00:00	75.00	60.180	0.858	0.851	26-Oct-05	21:25:00	820.0	57.945	0.000	0.004
26-Oct-05	9:11:00	86.00	60.200	0.878	0.870	27-Oct-05	14:15:00	1830.0	57.915	-0.030	-0.016
26-Oct-05	9:31:00	106.00	60.200	0.878	0.869	28-Oct-05	7:20:00	2855.0	57.972	0.027	0.007
26-Oct-05	9:50:00	125.00	60.220	0.898	0.890	28-Oct-05	13:10:00	3205.0	57.970	0.025	0.001
26-Oct-05	10:10:00	145.00	60.235	0.913	0.904	29-Oct-05	15:55:00	4810.0	57.930	-0.015	-0.010
26-Oct-05	10:30:00	165.00	60.250	0.928	0.922	29-Oct-05	22:05:00	5180.0	57.960	0.015	0.006
26-Oct-05	10:50:00	185.00	60.255	0.933	0.930	30-Oct-05	10:10:00	5905.0	57.970	0.025	0.003
26-Oct-05	11:21:00	216.00	60.260	0.938	0.937						
26-Oct-05	11:50:00	245.00	60.275	0.953	0.956						
26-Oct-05	12:19:00	274.00	60.275	0.953	0.958						
26-Oct-05	12:49:00	304.00	60.290	0.968	0.975						
26-Oct-05	13:19:00	334.00	60.290	0.968	0.979						
26-Oct-05	13:56:00	371.00	60.300	0.978	0.991						
26-Oct-05	14:19:00	394.00	60.300	0.978	0.993						
27-Oct-05	14:50:00	425.00	60.300	0.978	0.995						
27-Oct-05	15:20:00	455.00	60.305	0.983	1.001						
28-Oct-05	15:54:00	489.00	60.310	0.988	1.007						
26-Oct-05	16:51:00	546.00	60.320	0.998	1.015						
26-Oct-05	17:51:00	606.00	60.340	1.018	1.033						
26-Oct-05	18:50:00	665.00	60.350	1.028	1.040						
26-Oct-05	19:49:00	724.00	60.360	1.038	1.045						
26-Oct-05	20:49:00	784.00	60.390	1.068	1.073						
26-Oct-05	21:54:00	849.00	60.390	1.068	1.071						
26-Oct-05	22:53:00	908.00	60.390	1.068	1.075						
26-Oct-05	23:51:00	966.00	60.400	1.078	1.089						
27-Oct-05	0:50:00	1025.00	60.400	1.078	1.093						
27-Oct-05	1:50:00	1085.00	60.400	1.078	1.097						
27-Oct-05	2:49:00	1144.00	60.410	1.088	1.107						
27-Oct-05	3:51:00	1206.00	60.460	1.138	1.156						
27-Oct-05	4:50:00	1265.00	60.415	1.093	1.112						
27-Oct-05	5:49:00	1324.00	60.425	1.103	1.117						
27-Oct-05	6:50:00	1385.00	60.430	1.108	1.118						
27-Oct-05	7:38:00	1433.00	60.440	1.118	1.128						
27-Oct-05	8:03:00	1458.00	59.700	0.378	Note A						
27-Oct-05	8:08:00	1463.00	59.680	0.358	Note A						
27-Oct-05	8:13:00	1468.00	59.660	0.338	Note A						
27-Oct-05	8:18:00	1473.00	59.645	0.323	Note A						
27-Oct-05	8:23:00	1478.00	59.635	0.313	Note A						
27-Oct-05	8:28:00	1483.00	59.625	0.303	Note A						
27-Oct-05	8:33:00	1488.00	59.620	0.298	Note A						
27-Oct-05	8:38:00	1493.00	59.610	0.288	Note A						
27-Oct-05	8:49:00	1504.00	59.595	0.273	Note A						
27-Oct-05	8:58:00	1513.00	59.585	0.263	Note A						
27-Oct-05	9:09:00	1524.00	59.580	0.258	Note A						
27-Oct-05	9:30:00	1545.00	59.560	0.238	Note A						
27-Oct-05	9:51:00	1566.00	59.545	0.223	Note A						
27-Oct-05	10:09:00	1584.00	59.535	0.213	Note A						
27-Oct-05	10:30:00	1605.00	59.515	0.193	Note A						
27-Oct-05	10:51:00	1626.00	59.500	0.178	Note A						
27-Oct-05	11:19:00	1654.00	59.490	0.168	Note A						
27-Oct-05	11:49:00	1684.00	59.480	0.158	Note A						
27-Oct-05	12:20:00	1715.00	59.460	0.138	Note A						
27-Oct-05	12:47:00	1742.00	59.415	0.093	Note A						

A. Recovery data for bore M 3/04 not corrected for barometric effects.

## GLOBAL GROUNDWATER

### Recovery - Data Sheet

Test Start:	26-Oct-05 07:45	Test End:	27-Oct-05 07:45
Job No.:	194g	Pumped Bore:	M 11/04
Client.:	Dep. Agriculture WA	Measurements on Bore:	M 11/04
Contractor:	K S Black and Co	Supervisor:	G Watkins
SWL (mbMP):	59.102	Preceding Constant Rate Test Flow (m <sup>3</sup> /day):	1337
MP (maTOC):	0.587	(L/s):	15.47
TOC (magl):	0.310	Pump Start Time:	7:45:00
SWL (mbgl):	58.205	Pump Stop Time:	7:45:00
		Number of other Bores Monitored:	1

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC= Top of Casing (Bore)

Date	Time (Hr:Min:Sec)	Time Since Pumping Stopped (t') (Min)	Ratio t/t'	Water Level	Residual Drawdown (m)	Corrected Residual Drawdown (m)	Calculated Recovery (m)	Remarks
27-Oct-05	7:46:00	1.00	1441.00	59.820	0.718	0.725	3.771	
27-Oct-05	7:47:00	2.00	721.00	59.730	0.628	0.635	3.861	
27-Oct-05	7:48:00	3.00	481.00	59.670	0.568	0.575	3.921	
27-Oct-05	7:49:00	4.00	361.00	59.645	0.543	0.550	3.946	
27-Oct-05	7:50:00	5.00	289.00	59.605	0.503	0.510	3.986	
27-Oct-05	7:51:00	6.00	241.00	59.590	0.488	0.496	4.000	
27-Oct-05	7:52:00	7.00	206.71	59.580	0.478	0.486	4.010	
27-Oct-05	7:53:00	8.00	181.00	59.555	0.453	0.461	4.035	
27-Oct-05	7:54:00	9.00	161.00	59.540	0.438	0.446	4.050	
27-Oct-05	7:55:00	10.00	145.00	59.535	0.433	0.441	4.055	
27-Oct-05	8:00:00	15.00	97.00	59.490	0.388	0.395	4.101	
27-Oct-05	8:05:00	20.00	73.00	59.475	0.373	0.381	4.116	
27-Oct-05	8:10:00	25.00	58.60	59.435	0.333	0.340	4.157	
27-Oct-05	8:15:00	30.00	49.00	59.395	0.293	0.300	4.197	
27-Oct-05	8:20:00	35.00	42.14	59.395	0.293	0.299	4.198	
27-Oct-05	8:25:00	40.00	37.00	59.395	0.293	0.299	4.199	
27-Oct-05	8:30:00	45.00	33.00	59.370	0.268	0.273	4.225	
27-Oct-05	8:35:00	50.00	29.80	59.375	0.273	0.278	4.220	
27-Oct-05	8:45:00	60.00	25.00	59.375	0.273	0.277	4.222	
27-Oct-05	8:55:00	70.00	21.57	59.375	0.273	0.276	4.222	
27-Oct-05	9:05:00	80.00	19.00	59.380	0.278	0.281	4.218	
27-Oct-05	9:25:00	100.00	15.40	59.385	0.283	0.287	4.213	
27-Oct-05	9:47:00	122.00	12.80	59.355	0.253	0.259	4.243	
27-Oct-05	10:05:00	140.00	11.29	59.335	0.233	0.240	4.263	
27-Oct-05	10:25:00	160.00	10.00	59.335	0.233	0.240	4.263	
27-Oct-05	10:47:00	182.00	8.91	59.330	0.228	0.236	4.268	
27-Oct-05	11:15:00	210.00	7.86	59.310	0.208	0.217	4.289	
27-Oct-05	11:45:00	240.00	7.00	59.300	0.198	0.205	4.302	
27-Oct-05	12:15:00	270.00	6.33	59.300	0.198	0.207	4.301	
27-Oct-05	12:45:00	300.00	5.80	59.255	0.153	0.163	4.346	

# GLOBAL GROUNDWATER

## Test Pumping Analysis Sheet

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Job No.:	<u>194g</u>	Pumped Bore:	<u>M 11/04</u>		
Client.:	<u>Dep. Agriculture WA</u>	Calculations for Bore:	<u>M 11/04</u>		
Screens (mbgl):	<u>65.599</u>	to	<u>107.819</u>	Bore Diameter (mm):	<u>150</u>
Test Start:	<u>26-Oct-05 07:45</u>	Bore Radius r (m):	<u>0.075</u>		
Test End:	<u>27-Oct-05 07:45</u>	Discharge Rate Q (m <sup>3</sup> /day) :	<u>1337</u>		
Duration (hours):	<u>24.0</u>	SWL (mbgl):	<u>58.205</u>		

---

Method of Analysis: Jacobs Straight Line Regression

### Production Bore M11/04

Drawdown Regression Equation:  $s_w =$  0.0755  $\ln(t) +$  3.9461

Curve Section Used: Start time (min) = 330 End time (min) = 1440

### Monitoring Bore M3/04

Drawdown Regression Equation:  $s_w =$  0.1174  $\ln(t) +$  0.2801

Curve Section Used: Start time (min) = 606 End time (min) = 1433

### **Aquifer Parameters**

Aquifer Transmissivity (T) =  $2.3Q/4\pi\Delta s$  and Hydraulic Conductivity (k) = T/b

The interpreted thickness of the aquifer is = 50.00 m

### Production Bore M11/04

The slope of the selected curve section ( $\Delta s$ ) = 0.17 m

Therefore Transmissivity = 1407 m<sup>2</sup>/day and Hydraulic Conductivity = 28 m/day

### Monitoring Bore M3/04

The slope of the selected curve section ( $\Delta s$ ) = 0.27 m

Therefore Transmissivity = 905 m<sup>2</sup>/day and Hydraulic Conductivity = 18 m/day

Storage Coefficient (S) =  $2.25Tt_0/r^2$  where -

-  $t_0$  is time in days when drawdown extrapolates to 0m and

- r is the distance from pumped bore (m)

By re-ordering the monitoring bore drawdown regression equation above and if  $s_w = 0$ ,

then  $t_0 =$  0.000064 and S = 0.0009

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# GLOBAL GROUNDWATER

## Test Pumping Analysis Sheet

Job No.: 194g Pumped Bore: M 11/04

Client: Dep. Agriculture WA Calculations for Bore: M 11/04

Method of Analysis:     This Recovery - Straight Line Regression    

Residual Drawdown Regression Equation:  $s_w =$  0.1026  $\ln(t) +$  0.0022

Curve Section Used: Start point (t/t') = 15.40 End point t/t' (min) = 5.80

### Aquifer Parameters From Residual Drawdown

Aquifer Transmissivity (T) =  $2.3Q/4\pi\Delta s$  and Hydraulic Conductivity (k) = T/b

The slope of the selected curve section ( $\Delta s'$ ) = 0.24 m

Therefore Transmissivity = 1036 m<sup>2</sup>/day and Hydraulic Conductivity = 21 m/day

Aquifer parameters are in reasonable agreement with those derived from the drawdown curve. Residual drawdown was 0 m when t/t' was about 1 indicating that the bore was tending towards full recovery

### Casing Storage Effects

The method of Papadopoulos and Cooper (1967) ( $t > 25r^2/T$ ) was used to determine the time at which casing storage ceased to affect the waterlevels in the bore.

Casing storage effects cease after 0.1 minutes.

### Recommended Bore Discharge Rate and Pump Depth Setting

Extrapolation Period: 180 Days or 259200 minutes

The 180 Day Extrapolated Drawdown (s) = 4.89 m

And the 180 Day Specific Capacity (Q/s) at the tested rate = 273.49 m<sup>3</sup>/day/m

Using long-term extrapolated specific capacity, drawdown can be predicted for various discharge rates.

Long term drawdown @ 2160 m<sup>3</sup>/day = 8 m

If seasonal decline in aquifer waterlevel of 3 m was allowed for, then the long-term

predicted waterlevel would be 69 m bgl.

**The maximum recommended constant (24 hour) discharge rate for the bore is 2160 m<sup>3</sup>/day**

### Comments

The maximum waterlevel recorded during the test period was approximately 63.258 mbgl which is above the screen. The behaviour of the aquifer when the waterlevel falls below this depth has not been observed. Further, the predicted waterlevel is below the top of the screen and the transmissivity decreases as the waterlevel falls below the top of the screen. Irrespective of the recommended discharge rate, the predictions are based on only short-term pumping and longer-term monitoring of waterlevels is required to track actual aquifer behaviour.

# GLOBAL GROUNDWATER

## Step Test Data Sheet

Date:	<input type="text" value="28-Oct-05"/>	Supervisor:	<input type="text" value="G Watkins"/>	Pumped Bore:	<input type="text" value="M 12/04"/>
Job No:	<input type="text" value="194g"/>	Operator:	<input type="text" value="D Lang"/>	Measurements on Bore:	<input type="text" value="M 12/04"/>
Client:	<input type="text" value="Dep. Agriculture WA"/>	Distance to Pumped Bore (m):	<input type="text" value="0"/>		
Contractor:	<input type="text" value="K S Black and Co"/>	GGW ID:	<input type="text" value="802"/>	Tagged Depth (m bTOC):	
SWL (mbMP):	<input type="text" value="72.500"/>	SWL (mbgl):	<input type="text" value="71.750"/>	Pump Inlet (mbmp):	<input type="text" value="81.5"/>
MP (maToC):	<input type="text" value="0.292"/>	Start Time:	<input type="text" value="28/10/2005 15:45"/>	Available Drawdown (m):	<input type="text" value="9.0"/>
ToC (magl):	<input type="text" value="0.458"/>	End Time:	<input type="text" value="28/10/2005 17:45"/>	Discharge Location:	<input type="text" value="40m North"/>
		Pump:	<input type="text" value="S Cross LAD 13s"/>	Bore Internal Diam. (mm):	<input type="text" value="150.0"/>

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC = Top of Casing (Bore)

STEP	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Remarks
6" Weir with 3" orifice @ 15" manometer height			702 (m <sup>3</sup> /d)		8.12 (L/s)
<b>1</b>	15:46:00	1	75.200	2.700	
	15:47:00	2	75.340	2.840	
	15:48:30	3.5	75.910	3.410	
	15:49:00	4			
	15:50:00	5	76.200	3.700	
	15:51:00	6	76.115	3.615	Flow rate problems - very gassy
	15:52:00	7			
	15:53:00	8	75.860	3.360	
	15:54:00	9	75.790	3.290	
	15:55:00	10	75.770	3.270	
	16:00:00	15	75.710	3.210	
	16:05:00	20	75.850	3.350	Water temp 31 deg
	16:10:00	25	75.785	3.285	EC 2780 uS/cm
16:15:00	30	76.030	3.530		
6" Weir with 3" orifice @ 27" manometer height			956 (m <sup>3</sup> /d)		11.07 (L/s)
<b>2</b>	16:16:00	31	77.620	5.120	
	16:17:00	32	77.525	5.025	Gas increasing
	16:18:00	33	77.430	4.930	
	16:19:00	34	77.370	4.870	
	16:20:00	35	77.330	4.830	
	16:21:00	36	77.310	4.810	
	16:22:00	37			
	16:23:00	38	77.240	4.740	
	16:24:00	39	77.280	4.780	
	16:25:00	40	77.300	4.800	
	16:30:00	45	77.350	4.850	
	16:37:00	52	77.530	5.030	Water temp 29.9 deg
	16:40:00	55	77.540	5.040	EC 3317 uS/cm
16:45:00	60	77.550	5.050		

# GLOBAL GROUNDWATER

## Step Test Data Sheet

Date:	<b>28-Oct-05</b>	Supervisor:	<b>G Watkins</b>	Pumped Bore:	<b>M 12/04</b>
Job No:	<b>194g</b>	Operator:	<b>D Lang</b>	Measurements on Bore:	<b>M 12/04</b>
Client:	<b>Dep. Agriculture WA</b>	Distance to Pumped Bore (m):	<b>0</b>		
Contractor:	<b>K S Black and Co</b>	GGW ID:	<b>802</b>	Tagged Depth (m bTOC):	
SWL (mbMP):	<b>72.500</b>	SWL (mbgl):	<b>71.750</b>	Pump Inlet (mbmp):	<b>81.5</b>
MP (maToC):	<b>0.292</b>	Start Time:	<b>28/10/2005 15:45</b>	Available Drawdown (m):	<b>9.0</b>
ToC (magl):	<b>0.458</b>	End Time:	<b>28/10/2005 17:45</b>	Discharge Location:	<b>40m North</b>
		Pump:	<b>S Cross LAD 13s</b>	Bore Internal Diam. (mm):	<b>150.0</b>

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC = Top of Casing (Bore)

STEP	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Remarks
6" Weir with 3" orifice @ 38" manometer height				1128 (m <sup>3</sup> /d)	13.05 (L/s)
<b>3</b>	16:46:00	61			
	16:47:00	62			Gas improved
	16:48:00	63	79.250	6.750	
	16:49:00	64			
	16:50:00	65	79.250	6.750	
	16:51:00	66	79.230	6.730	
	16:52:00	67	79.330	6.830	
	16:53:00	68	79.175	6.675	Flow adjusted
	16:54:00	69	79.220	6.720	
	16:55:00	70	79.290	6.790	
	17:00:00	75	79.170	6.670	
	17:05:00	80	79.150	6.650	Water temp 28.8 deg
17:10:00	85	79.400	6.900	EC 3350 uS/cm	
17:15:00	90	79.070	6.570		
6" Weir with 3" orifice @ 44" manometer height				1204 (m <sup>3</sup> /d)	13.94 (L/s)
<b>4</b>	17:16:00	91			
	17:17:30	92.5	79.530	7.030	
	17:18:00	93	79.540	7.040	
	17:19:00	94	79.535	7.035	
	17:20:00	95	79.500	7.000	
	17:21:00	96	79.470	6.970	
	17:22:00	97	79.470	6.970	
	17:23:00	98	79.450	6.950	Water temp 29.2 deg
	17:24:00	99	79.831	7.331	EC 3284 uS/cm
	17:25:00	100			Test ended at 100 minutes when WL
	17:30:00	105			intersected pump inlet.
	17:35:00	110			
17:40:00	115				
17:45:00	120				

## GLOBAL GROUNDWATER

<b>Constant Rate Test - Data Sheet</b>						
Test Start:	29-Oct-05 07:30		Test End:	30-Oct-05 07:30		
Job No.:	194g	GGW Bore ID:	802	Pumped Bore:	M 12/04	
Client.:	Dep. Agriculture WA		Tagged depth (m bTOC):	NA		
Contractor:	K S Black and Co		Supervisor:	G Watkins		
SWL (mbMP):	72.845		Pump Inlet (mbmp):	81.50		
MP (maTOC):	0.292		Available Drawdown (m):	8.65		
TOC (magl):	0.458		Discharge Dist. & Direction:	40m North		
SWL (mbgl):	72.095		Bore Internal Diameter (mm):	150		
Pump Used:	S Cross LAD 13s	Flow (L/s):	12.03	Flow (m <sup>3</sup> /day):	1039	
Flow device:	QA calibrated 6" Weir with 3" orifice @ 32" manometer height.					
Start Time:	7:30:00	End Time:	7:30:00	Number of other Bores Monitored:	0	
SWL = Static water level		mbMP = Metres below measuring point		mbgl = Metres below ground level		
MP = Measuring point		magl = Metres above ground level		ToC= Top of Casing (Bore)		
Date	Time (Hr:Min:Sec)	Elapsed Time (Min)	Water Level (m)	Drawdown (m)	Corrected Drawdown (m)	Comments
29-Oct-05	7:31:00	1.0	77.620	4.775	4.745	
29-Oct-05	7:32:00	2.0	78.190	5.345	5.315	
29-Oct-05	7:33:00	3.0	78.240	5.395	5.365	
29-Oct-05	7:34:00	4.0	78.315	5.470	5.440	
29-Oct-05	7:35:00	5.0	78.360	5.515	5.485	
29-Oct-05	7:36:00	6.0	78.330	5.485	5.455	EC 3693 uS/cm
29-Oct-05	7:37:00	7.0	78.330	5.485	5.455	
29-Oct-05	7:38:00	8.0	78.310	5.465	5.435	
29-Oct-05	7:39:00	9.0	78.335	5.490	5.460	
29-Oct-05	7:40:30	10.5	78.240	5.395	5.365	
29-Oct-05	7:45:00	15.0	78.210	5.365	5.335	
29-Oct-05	7:50:00	20.0	78.155	5.310	5.280	
29-Oct-05	7:55:00	25.0	78.140	5.295	5.265	
29-Oct-05	8:00:00	30.0	78.140	5.295	5.265	EC 3602 uS/cm
29-Oct-05	8:05:00	35.0	78.135	5.290	5.260	
29-Oct-05	8:10:00	40.0	78.140	5.295	5.265	
29-Oct-05	8:15:00	45.0	78.100	5.255	5.225	
29-Oct-05	8:20:00	50.0	78.180	5.335	5.305	
29-Oct-05	8:30:00	60.0	78.155	5.310	5.281	EC 3558 uS/cm
29-Oct-05	8:40:00	70.0	78.190	5.345	5.317	
29-Oct-05	8:50:00	80.0	78.250	5.405	5.378	
29-Oct-05	9:10:00	100.0	78.480	5.635	5.608	
29-Oct-05	9:30:00	120.0	78.360	5.515	5.489	
29-Oct-05	9:50:00	140.0	78.280	5.435	5.410	
29-Oct-05	10:10:00	160.0	78.310	5.465	5.440	
29-Oct-05	10:30:00	180.0	78.620	5.775	5.753	
29-Oct-05	10:59:00	209.0	77.550	4.705	4.685	
29-Oct-05	11:30:00	240.0	77.410	4.565	4.549	
29-Oct-05	12:00:00	270.0	77.335	4.490	4.476	EC 3206 uS/cm
29-Oct-05	12:30:00	300.0	77.325	4.480	4.469	EC 2784 uS/cm
29-Oct-05	13:00:00	330.0	77.315	4.470	4.463	EC 3019 uS/cm
29-Oct-05	13:30:00	360.0	77.310	4.465	4.462	EC 2950 uS/cm
29-Oct-05	14:00:00	390.0	77.290	4.445	4.444	EC 2902 uS/cm



## GLOBAL GROUNDWATER

### Recovery - Data Sheet

Test Start: <input type="text" value="29-Oct-05 07:30"/>	Test End: <input type="text" value="30-Oct-05 07:30"/>
Job No.: <input type="text" value="194g"/>	Pumped Bore: <input type="text" value="M 12/04"/>
Client.: <input type="text" value="Dep. Agriculture WA"/>	Tagged Depth (m bTOC): <input type="text" value="0"/>
Contractor: <input type="text" value="K S Black and Co"/>	Supervisor: <input type="text" value="G Watkins"/>
SWL (mbMP): <input type="text" value="72.845"/>	Preceding Constant Rate Test Flow (m <sup>3</sup> /day): <input type="text" value="1039"/>
MP (maTOC): <input type="text" value="0.292"/>	(L/s): <input type="text" value="12.03"/>
TOC (magl): <input type="text" value="0.458"/>	Pump Start Time: <input type="text" value="7:30:00"/>
SWL (mbgl): <input type="text" value="72.095"/>	Pump Stop Time: <input type="text" value="7:30:00"/>
Number of other Bores Monitored: <input type="text" value="0"/>	

SWL = Static water level      mbMP = Metres below measuring point      mbgl = Metres below ground level  
 MP = Measuring point      magl = Metres above ground level      ToC= Top of Casing (Bore)

Date	Time (Hr:Min:Sec)	Time Since Pumping Stopped (t') (Min)	Ratio t/t' (m)	Water Level	Residual Drawdown (m)	Corrected Residual Drawdown (m)	Calculated Recovery (m)	Remarks
30-Oct-05	7:31:00	1.00	1441.00	73.250	0.405	0.387		
30-Oct-05	7:32:00	2.00	721.00	73.210	0.365	0.345		
30-Oct-05	7:33:00	3.00	481.00	73.170	0.325	0.305		
30-Oct-05	7:34:00	4.00	361.00	73.170	0.325	0.305		
30-Oct-05	7:35:00	5.00	289.00	73.130	0.285	0.265		
30-Oct-05	7:36:00	6.00	241.00	73.130	0.285	0.265		
30-Oct-05	7:37:00	7.00	206.71	73.130	0.285	0.265		
30-Oct-05	7:38:00	8.00	181.00	73.135	0.290	0.270		
30-Oct-05	7:39:00	9.00	161.00	73.110	0.265	0.245		
30-Oct-05	7:40:00	10.00	145.00	73.125	0.280	0.260		
30-Oct-05	7:45:00	15.00	97.00	73.045	0.200	0.180		
30-Oct-05	7:50:00	20.00	73.00	73.075	0.230	0.210		
30-Oct-05	7:55:00	25.00	58.60	73.060	0.215	0.195		
30-Oct-05	8:00:00	30.00	49.00	73.030	0.185	0.165		
30-Oct-05	8:06:00	36.00	41.00	73.020	0.175	0.155		
30-Oct-05	8:10:00	40.00	37.00	73.000	0.155	0.135		
30-Oct-05	8:16:00	46.00	32.30	73.020	0.175	0.155		
30-Oct-05	8:20:00	50.00	29.80	73.030	0.185	0.165		
30-Oct-05	8:30:00	60.00	25.00	73.030	0.185	0.166		
30-Oct-05	8:40:00	70.00	21.57	73.030	0.185	0.165		
30-Oct-05	8:50:00	80.00	19.00	73.025	0.180	0.160		
30-Oct-05	9:10:00	100.00	15.40	73.030	0.185	0.163		
30-Oct-05	9:30:00	120.00	13.00	73.010	0.165	0.142		Pump pulled
30-Oct-05	11:38:00	248.00	6.81	72.665	-0.180			

# GLOBAL GROUNDWATER

## Test Pumping Analysis Sheet

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Job No.:	<u>194g</u>	Pumped Bore:	<u>M 12/04</u>		
Client.:	<u>Dep. Agriculture WA</u>	Calculations for Bore:	<u>M 12/04</u>		
Screens (mbgl):	<u>59.315</u>	to	<u>111.084</u>	Bore Diameter (mm):	<u>150</u>
Test Start:	<u>29-Oct-05 07:30</u>	Bore Radius r (m):	<u>0.075</u>		
Test End:	<u>30-Oct-05 07:30</u>	Discharge Rate Q (m <sup>3</sup> /day) :	<u>1039</u>		
Duration (hours):	<u>24.0</u>	SWL (mbgl):	<u>72.095</u>		

---

Aquifer parameters can't be calculated from the constant rate test as the bore was undergoing development.

The interpreted thickness of the aquifer is = 38.67 m

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### **Comments**

The bore was undergoing development throughout the constant-rate test and so a recommended long-term discharge rate can't be calculated. However it is likely that the bore can sustain the rate than that at which is was pumped (1039 m<sup>3</sup>/day). This would need to be confirmed by further pumping and waterlevel monitoring. The maximum waterlevel recorded during the test period was approximately 78 m and therefore the behaviour of the aquifer when the waterlevel falls below this has not been observed. A low flow cut-out switch is required to protect the pump motor should waterlevels fall lower than predicted.

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## **Appendix B**

### **Numerical Model Meta Data**

- MODEL PARAMETERS Meedo 1
- MODEL PARAMETERS Meedo 2
- MODEL PARAMETERS Meedo 3

## MODEL PARAMETERS Meedo 1

This model is used to generate potentiometric heads, with estimated hydraulic parameters refined to calibrate the model and through-flow. Steady state heads output from this file are used as start of transient simulations.

### Overlays

Faults.dxf in \\Model\Meedo\ – Source: \\Maps\SatInterpFaults.tab

Fence.dxf in \\Model\Meedo\ – Source: \\Maps\meedo\_Edited\_Roads.tab

River.dxf in \\Model\Meedo\ – Source: Map\_Archive\GeoScience250kTopo\SG5005\g5005d\_1.tab

Saved copy of Table in GDA94 projection, then exported to DXF and imported into VMODFLOW.

### Model start data

1/1/2004

### ID

Model name Meedo.vmf

### Grid

Based on GDA94 Zone 50 Coordinates

Length unit = m

Hydraulic Conductivity unit = m/d

Time unit = day

Pumping unit = m<sup>3</sup>/d

Recharge unit = mm/yr

Number of Columns = 101 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min X = 270000

Max X = 310000

Number of Rows = 100 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min Y = 7140000

Max Y = 7170000

Number of Layers = 2

### Layer Surface

Source: \\140gGDC\_IrrigationInvestigation\AgData\AG\_DEM\_MEEDO.ERS

Resized to 275 x 232 (order of magnitude reduction), source is GDA94 zone 50 so exported to surfer ASCII grid (VMF\Surface.GRD) and imported into model as surface (see Figure 1).

### Base of Layers

There are three interpreted NN-E faults and one N-S fault in layer 1+2, which are located in the middle of the model (see Figure 2). Only the N-S fault is incorporated in the model as it is the boundary between the Birdrong and Permian Sediments, which are represented by different hydraulic properties.

Base of Layer 1 was imported from BaseL1\_polyline.dbf, BaseL1\_polyline.shx, and BaseL1\_polyline.shp in VMF\BaseL1\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls and from Meedo Bore Completion Report. Base of L1 west of the N-S fault is based on the top of the Birdrong and east of N-S fault was set between 47-63m AHD. The contours were drawn by hand in Mapinfo, then exported as ESRI Shapefile in GDA94 zone 50. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

Base of Layer 2 was imported from BaseL2\_polyline.dbf, BaseL2\_polyline.shx, and BaseL2\_polyline.shp in VMF\BaseL2\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls from Meedo Bore Completion Report. The contours were drawn by hand in Mapinfo, then exported as ESRI Shapefile in GDA94. West of the N-S fault the base of

Layer 2 is the base of the Birdrong and east N-S fault it is approximately 20mAHD to match the adjacent Birdrong thickness. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

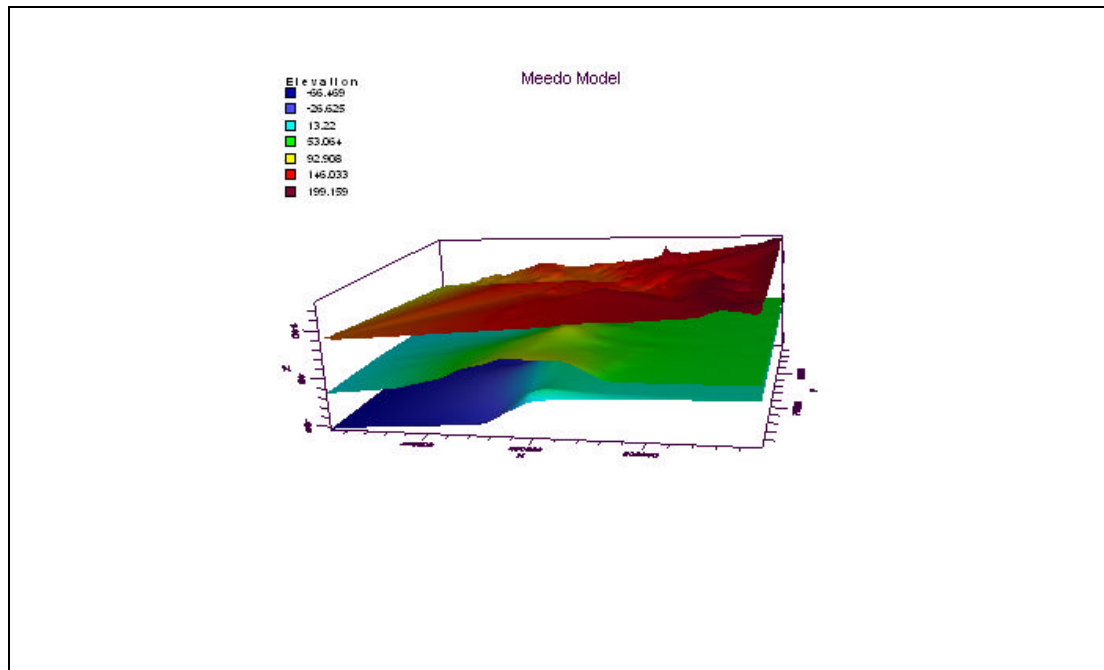


Figure 1: 3D-View of Ground Surface, Bottom of Layer 1 and Layer 2

#### Inactive flow cells

Layer 1, west of N-S fault cells are inactive (light blue in Figure 2).

#### Properties

West of N-S fault

Code 1  $K_x = 0.1\text{m/d}$ ,  $K_z = 0.01\text{m/d}$ , applied to layer 1

Code 2  $K_x = 15\text{m/d}$ ,  $K_z = 1.5\text{m/d}$ , applied to layer 2

East of N-S fault

Code 3  $K_x = 3\text{m/d}$ ,  $K_z = 0.3\text{m/d}$ , applied to Layer 1+2

$S_s = 9 \times 10^{-4}$ ,  $S_y = 0.2$  applied to Layer 1+2

#### Observation Bores

M2/04, M3/04, M6/04, M7/04, M8/04, M11/04, M12/04, M1/05, M2/05, M3/04, M5/05, M7/05 were used as observation bores. M8/05 omitted due to not in Birdrong. Source

\\194gAGWAGascoyneDrill\PostSurvey&SampleBoreDetails.xls, Time = 660 days. Head m AHD Sep05.

#### Pumping Bores

Model to calibrate against test pumping data source

\\194gAGWAGascoyneDrill\TestPumpM11\_04.xls. M11/04 coordinates, screen etc from bore completion report.

Stop time 7300 days (20yrs). Start Time Head and Stop Time Head based on initial heads in \\Model\Meedo\L2\_WL\_AHD.GRD. West boundary a line from E 270000/N 7170000 to E 270000/N 7140000, east boundary a line from E 310000/N 7170000 to E 310000/N 7170000, applied to layer 2. In layer1, only east boundary (west of fault is inactive) assigned (brown colour in Figure 2).

#### General Head Boundary

Stop time 7300days, applied to layer 1+2. Layer 2 north boundary a line from E 270000/N 7170000 to E 310000/N 7170000, and south a line from E 270000/N 7140000 to 310000/N 7140000. Horizontal

hydraulic conductivity west of fault  $K=15\text{m/d}$  (Birdrong), east of fault  $K=3\text{m/d}$  (Permian). In layer 1 GHB only applied to cells east of fault (green colour in Figure 2)

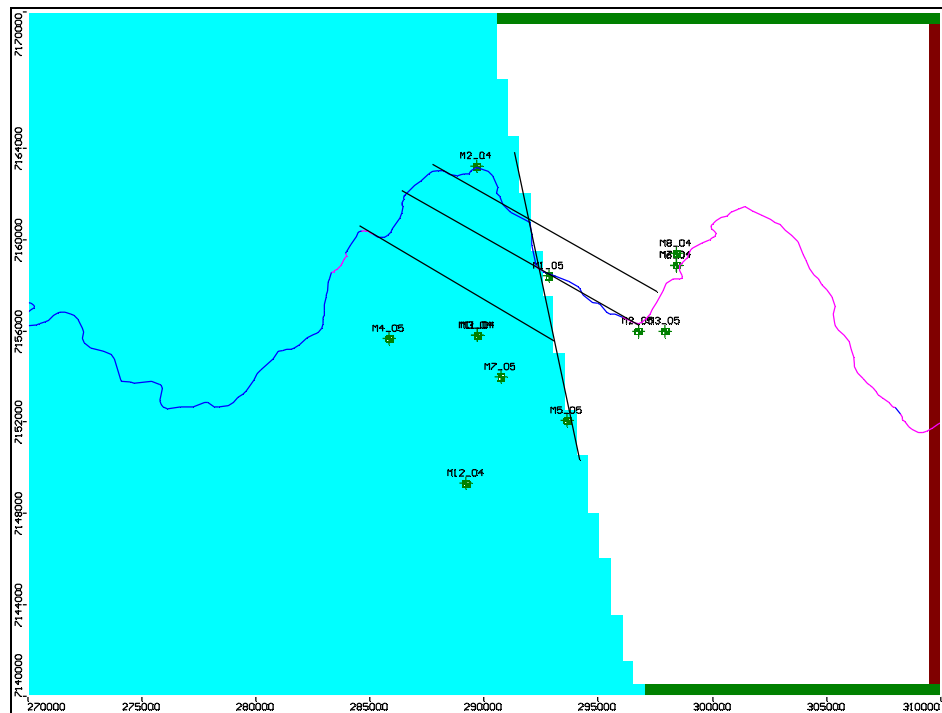


Figure 2 Boundary Conditions

### Initial Head

Layer 1 = Layer 2

### Layer 2 (Birdrong - Permian)

Layer 2 heads = L2\_WL\_AHD.GRD in \\Model\Meedo\L2\_WL\_AHD.GRD from MeedoWL\_ContAHD\_GDA94.TAB. MapInfo table

\\194gAGWAGascoyneDrill\Maps\MeedoWL\_ContAHD (GDA94.TAB) exported to txt file then opened in XL, edited and exported to XL 4.0 Worksheet. Then grided in Surfer, resized 60 rows x 80 columns and saved as binary Surfer Grid. Since the model domain was bigger than the data source domain, artificial values were created in the NW, SW, NE, and NW corner of the model.

### Zone Budget

Zone 1: Whole model domain

Zone 2: Layer 2, area between bore M2/04 and M12/04, 1km wide.

### Time

Steady State

### Layer type

Layer 1 - Type 3 Confined/Unconfined variable S, T.

Layer 2 - Type 3 Confined/Unconfined variable S, T

### Calibration

The output data are saved in \\Output\CalcHeadvsObsHead.JPG

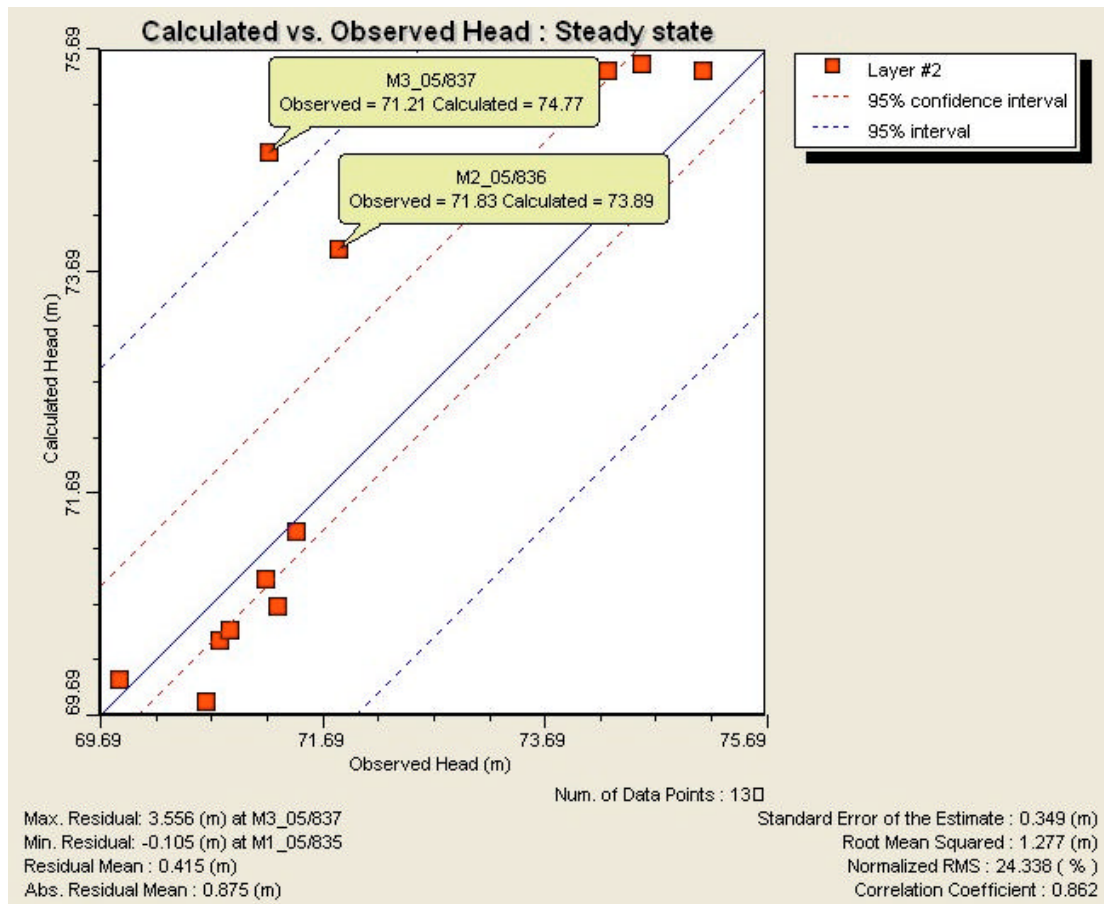


Figure 3: Calculated Heads versus Observed Heads

Calculated heads versus Observed heads: Except of M3/05 and M2/05, all of the calculated heads are within the 95% confidence interval and 95% interval respectively. Calculated and observed heads of M3/05 and M2/05 differ between 2.50m and 2m.

The through flow in zone 2 is 1574m<sup>3</sup>/d, which is 400m<sup>3</sup>/day less than the results of the calculation with the Darcy formula  $Q=kiA$  (Area = 50mx14000m,  $k = 15$ ,  $i = 1\text{m head} / 5500\text{m}$  (from contours) = 1909m<sup>3</sup>/day).

## MODEL PARAMETERS Meedo 2

This model is used to calibrate hydraulic parameters and through-flow against test pumping data.

### Overlays

Faults.dxf in \\Model\Meedo\ – Source: \\Maps\SatInterpFaults.tab

Fence.dxf in \\Model\Meedo\ – Source: \\Maps\meedo\_Edited\_Roads.tab

River.dxf in \\Model\Meedo\ – Source: Map\_Archive\GeoScience250kTopo\SG5005\g5005d\_1.tab

Saved copy of tables in GDA94 projection, then exported to DXF and imported into VMODFLOW.

### Model start data

1/1/2004

### ID

Model name Meedo2.vmf

### Grid

Based on GDA94 Zone 50 Coordinates

Length unit = m

Hydraulic Conductivity unit = m/d

Time unit = day

Pumping unit = m<sup>3</sup>/d

Recharge unit = mm/yr

Number of Columns = 101 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min X = 270000

Max X = 310000

Number of Rows = 100 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min Y = 7140000

Max Y = 7170000

Number of Layers = 2

### Layer Surface

Source: \\140gGDC\_IrrigationInvestigation\AgData\AG\_DEM\_MEEDO.ERS

Resized to 275 x 232 (order of magnitude reduction), source is GDA94 zone 50 so exported to surfer ASCII grid (VMF\Surface.GRD) and imported into model as surface (see Figure 1).

### Base of Layers

There are three interpreted NN-E faults and one N-S fault in layer 1+2, which are located in the middle of the model (see Figure 2). Only the N-S fault is incorporated in the model as it is the boundary between the Birdrong and Permian Sediments, which are represented by different hydraulic properties.

Base of Layer 1 was imported from BaseL1\_polyline.dbf, BaseL1\_polyline.shx, and BaseL1\_polyline.shp in VMF\BaseL1\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls and from Meedo Bore Completion Report. Base of L1 west of the N-S fault is based on the top of the Birdrong and east of N-S fault was set between 47-63m AHD. The contours were drawn by hand in Mapinfo, then exported as ESRI Shapefile in GDA94 zone 50. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

Base of Layer 2 was imported from BaseL2\_polyline.dbf, BaseL2\_polyline.shx, and BaseL2\_polyline.shp in VMF\BaseL2\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls from Meedo Bore Completion Report. The contours were drawn by hand in Mapinfo, then exported as ESRI Shapefile in GDA94. West of the N-S fault the base of Layer 2 is the base of the Birdrong and east N-S fault it is approximately 20m AHD to match the

adjacent Birdrong thickness. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

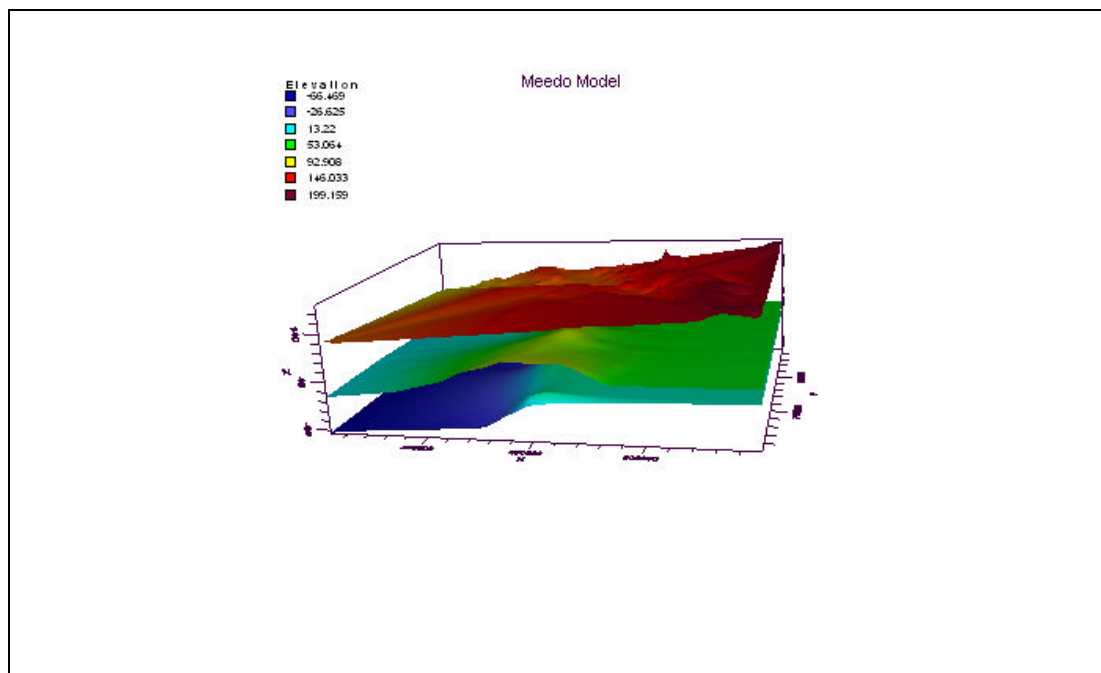


Figure 1: 3D-View of Ground Surface, Bottom of Layer 1 and Layer 2

#### Inactive flow cells

Layer 1, west of N-S fault cells are inactive (light blue in Figure 2).

#### Properties

West of N-S fault

Code 1  $K_x = 0.1\text{m/d}$ ,  $K_z = 0.01\text{m/d}$ , applied to layer 1

Code 2  $K_x = 15\text{m/d}$ ,  $K_z = 1.5\text{m/d}$ , applied to layer 2

East of N-S fault

Code 3  $K_x = 3\text{m/d}$ ,  $K_z = 0.3\text{m/d}$ , applied to Layer 1+2

$S_s = 9 \times 10^{-4}$ ,  $S_y = 0.2$  applied to Layer 1+2

#### Observation Bores

Heads in M3/04 during pumping test in M11/04 were imported from ObsM3\_04PumpM11\_4.xls after being converted to AHD from source data in \\194gAGWAGascoyneDrill\TestPumpM11\_04.xls.

#### Pumping Bores

Test pumping data source from \\194gAGWAGascoyneDrill\TestPumpM11\_04.xls. M11/04 coordinates, screen etc from bore completion report. Bore M11-04 pumped for 24hrs (1 day) at a rate of 1337m<sup>3</sup>/d; calibration against heads in M3/04. Model starts pumping at day 0 not at day 664.32 (Model start 01.01.2004, pump test 26.10.2005=664.32 days later).

#### Constant Head Boundary

Stop time 7300 days (20yrs). Start Time Head and Stop Time Head based on initial heads in Model\Meedo\L2\_WL\_AHD.GRD. West boundary a line from E 270000/N 7170000 to E 270000/N 7140000, east boundary a line from E 310000/N 7170000 to E 310000/N 7170000, applied to layer 2. In layer1, only east boundary (west of fault is inactive) assigned (brown colour in Figure 2).

#### General Head Boundary

Stop time 7300days, applied to layer 1+2. Layer 2 north boundary a line from E 270000/N 7170000 to E 310000/N 7170000, and south a line from E 270000/N 7140000 to 310000/N 7140000. Horizontal hydraulic conductivity west of fault  $K=15\text{m/d}$  (Birdrong), east of fault  $K=3\text{m/d}$  (Permian). In layer 1 GHB only applied to cells east of fault (green colour in Figure 2)

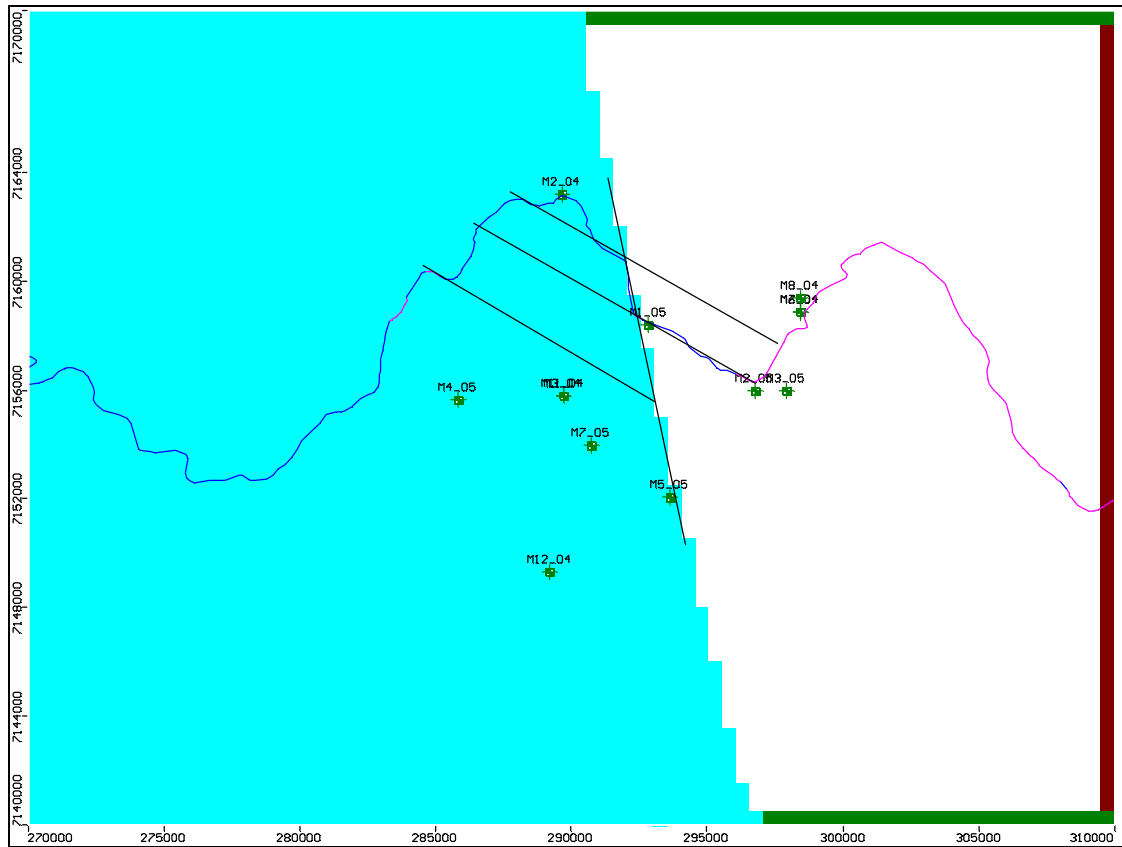


Figure 2 Boundary Conditions

Model boundaries and inactive flow cells (light blue: inactive flow cells, green: General Head Boundary, brown: Constant Head Boundary)

### Initial Head

Initial heads from steady state model Meedo 1.

### Zone Budget

Zone 1: Whole model domain

Zone 2: Layer 2, area between bore M2/04 and M12/04, 1km wide.

### Time

Transient

### Layer type

Layer 1 - Type 3 Confined/Unconfined variable S, T.

Layer 2 - Type 3 Confined/Unconfined variable S, T

## Calibration

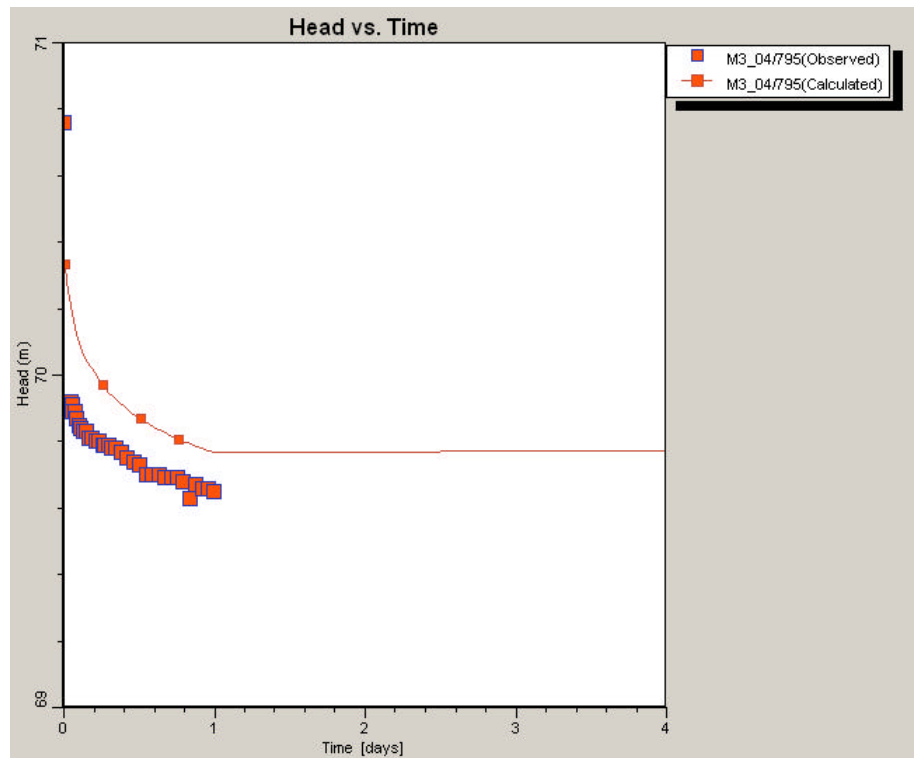


Figure 3 Heads versus Time  $K=15\text{m/d}$ ,  $S_s = 9 \cdot 10^{-4}$   $S_y = 0.20$ .

Meedo2 was then run with  $K=18\text{m/d}$  (Figure 4) for the Birdrong Formation (calculated from pumping test data) to estimate the effects compared to  $K=15\text{m/d}$ .

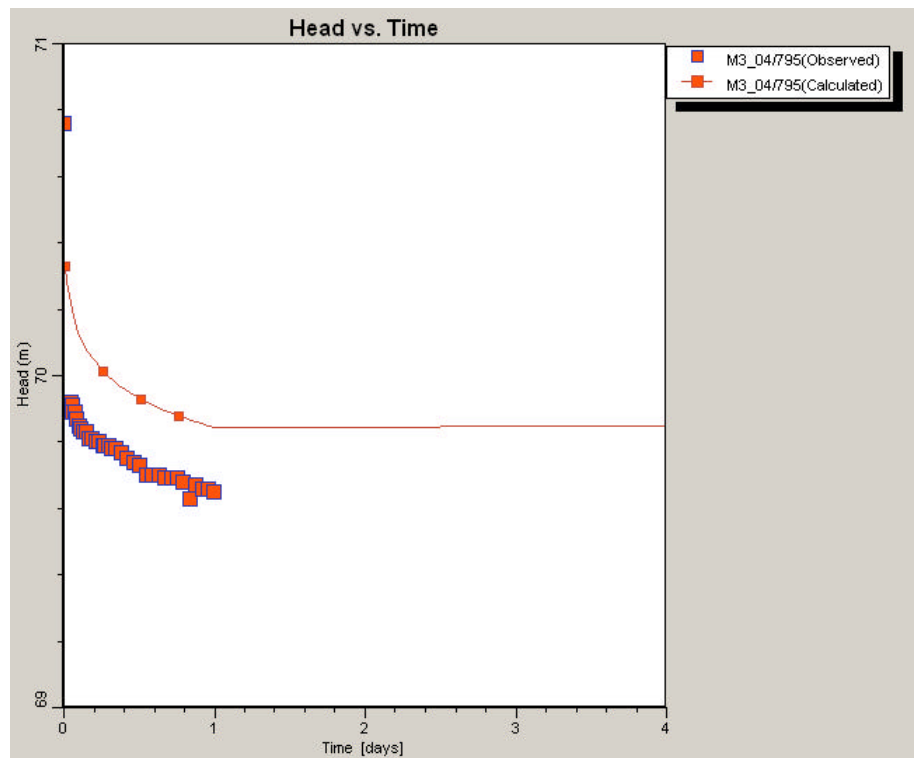


Figure 4 Heads versus Time  $K=18\text{m/d}$ ,  $S_s = 9 \cdot 10^{-4}$   $S_y = 0.20$ .

The calculated heads versus observed heads using  $K=18\text{m/d}$  do not match as well as in  $15\text{ m/d}$ . Therefore the testpumping derived hydraulic conductivity of  $K=18\text{m/d}$  for the Birdrong Formation

seems to be too high. The model was rerun with  $K=12$  in the Birdrong (Figure 5), which provides a better match to the testpumping data.

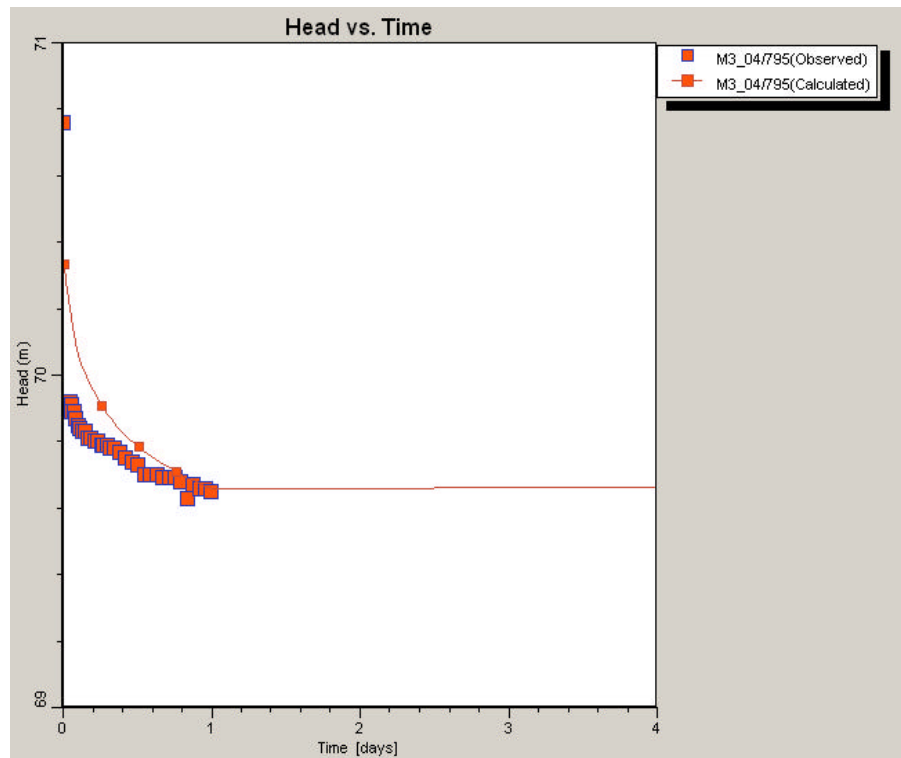


Figure 5: Heads versus Time  $K=12\text{m/d}$ ,  $S_s = 9 \times 10^{-4}$ ,  $S_y = 0.20$ .

The model was also sensitive to changes in  $S_y$ . The best match of calibrated to observed heads is with  $K=15$  and storage of  $S_s = 9 \times 10^{-4}$ ,  $S_y = 0.10$  (Figure 6).

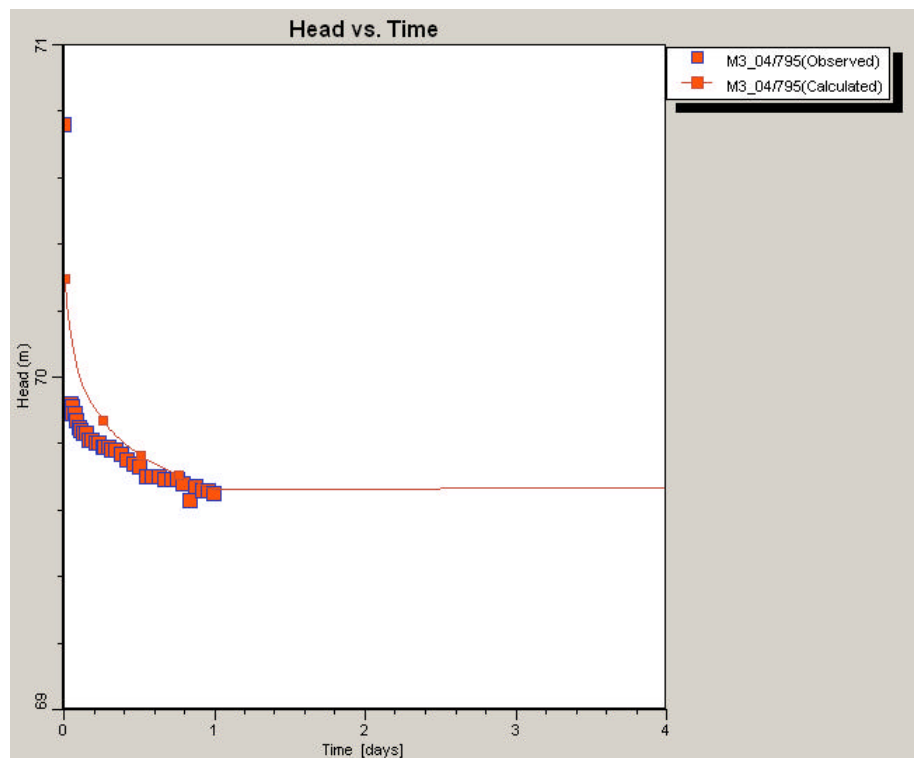


Figure 6: Heads versus Time  $K=15\text{m/d}$ ,  $S_s = 9 \times 10^{-4}$ ,  $S_y = 0.1$ .

The model was less sensitive to changes in  $S_s$ .  $K=15$  and storage of  $S_s = 6.5 \times 10^{-5}$ ,  $S_y = 0.20$  (Figure 7).

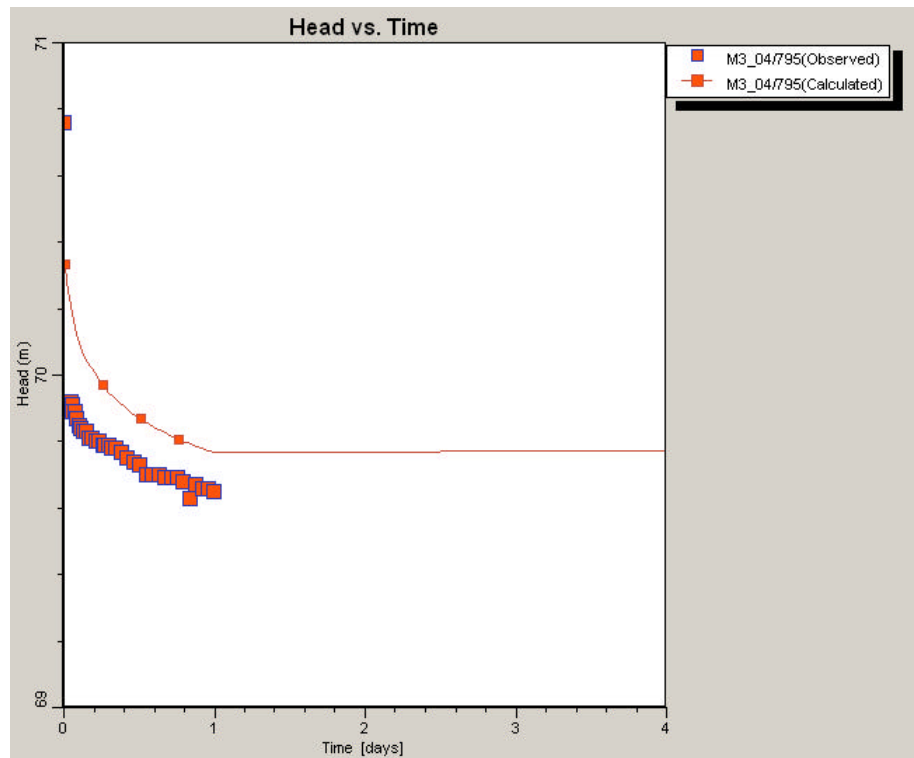


Figure 7: Heads versus Time  $K=15\text{m/d}$  ,  $S_s = 6.5 \cdot 10^{-5}$   $S_y = 0.20$ .

### Summary

Meedo 1 calibrated to  $k=15$ .

Meedo 2 calibration to  $K=15$  and  $S_s = 9 \cdot 10^{-4}$ ,  $S_y = 0.20$  in Meedo 2 is acceptable.

Meedo 2 calibration to  $K=15$  and  $S_s = 9 \cdot 10^{-4}$ ,  $S_y = 0.10$  in Meedo 2 is better, but test pumping indicates confined response to pumping, where model using unconfined storage due to waterlevel being beneath the top of the cells. With longer term pumping contribution from drainage of pore space will likely increase so the  $S_y = 0.2$  is maintained in Meedo 3 along with  $S_s = 9 \cdot 10^{-4}$  (derived from test pumping) for the Birdrong Formation. Hydraulic conductivity is also likely better calibrated to steady state conditions across the model rather than short test where this effect can be overcome by changing storage parameters so  $k = 15$  is used in Meedo 3.

## MODEL PARAMETERS Meedo 3

The model is used to estimate the effects on the aquifer and on through flow by pumping five bores for 20yrs at a rate of 25l/s (2160m<sup>3</sup>/d). Particles are placed along the Ajana fault to estimate movement of water and salinity migration.

### Overlays

Faults.dxf in \\Model\Meedo\ – Source: \\Maps\SatInterpFaults.tab

Fence.dxf in \\Model\Meedo\ – Source: \\Maps\meedo\_Edited\_Roads.tab

River.dxf in \\Model\Meedo\ – Source: Map\_Archive\GeoScience250kTopo\SG5005\g5005d\_1.tab

Saved copy of Table in GDA94 projection, then exported to DXF and imported into VMODFLOW.

### Model start data

1/1/2004

### ID

Model name Meedo3.vmf

### Grid

Based on GDA94 Zone 50 Coordinates

Length unit = m

Hydraulic Conductivity unit = m/d

Time unit = day

Pumping unit = m<sup>3</sup>/d

Recharge unit = mm/yr

Number of Columns = 101 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min X = 270000

Max X = 310000

Number of Rows = 100 (mostly 500x500m; Grid refined around pumping bore M11/04 and Observation bore M3/04. Smallest cells: 2x2m (bores and adjacent cells)

Min Y = 7140000

Max Y = 7170000

Number of Layers = 2

### Layer Surface

Source: \\140gGDC\_IrrigationInvestigation\AgData\AG\_DEM\_MEEDO.ERS

Resized to 275 x 232 (order of magnitude reduction), source is GDA94 zone 50 so exported to surfer ASCII grid (VMF\Surface.GRD) and imported into model as surface (see Figure 1).

### Base of Layer

There are three interpreted NN-E faults and one N-S fault in layer 1+2, which are located in the middle of the model (see Figure 2). Only the N-S fault is incorporated in the model as it is the boundary between the Birdrong and Permian Sediments, which are represented by different hydraulic properties.

Base of Layer 1 was imported from BaseL1\_polyline.dbf, BaseL1\_polyline.shx, and BaseL1\_polyline.shp in VMF\BaseL1\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls and from Meedo Bore Completion Report. Base of L1 west of the N-S fault is based on the top of the Birdrong and east of N-S fault was set between 47-63m AHD. The contours were drawn by hand in Mapinfo, then exported as ESRI Shapefile in GDA94 zone 50. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

Base of Layer 2 was imported from BaseL2\_polyline.dbf, BaseL2\_polyline.shx, and BaseL2\_polyline.shp in VMF\BaseL2\_polyline.dbf. Data derived from PostSurvey&SampleBoreDetails.xls from Meedo Bore Completion Report. The contours were drawn

by hand in Mapinfo, then exported as ESRI Shapefile in GDA94. West of the N-S fault the base of Layer 2 is the base of the Birdrong and east N-S fault it is approximately 20mAHD to match the adjacent Birdrong thickness. Base was imported into model with minimum thickness of layer 1 set at 1m (see Figure 1).

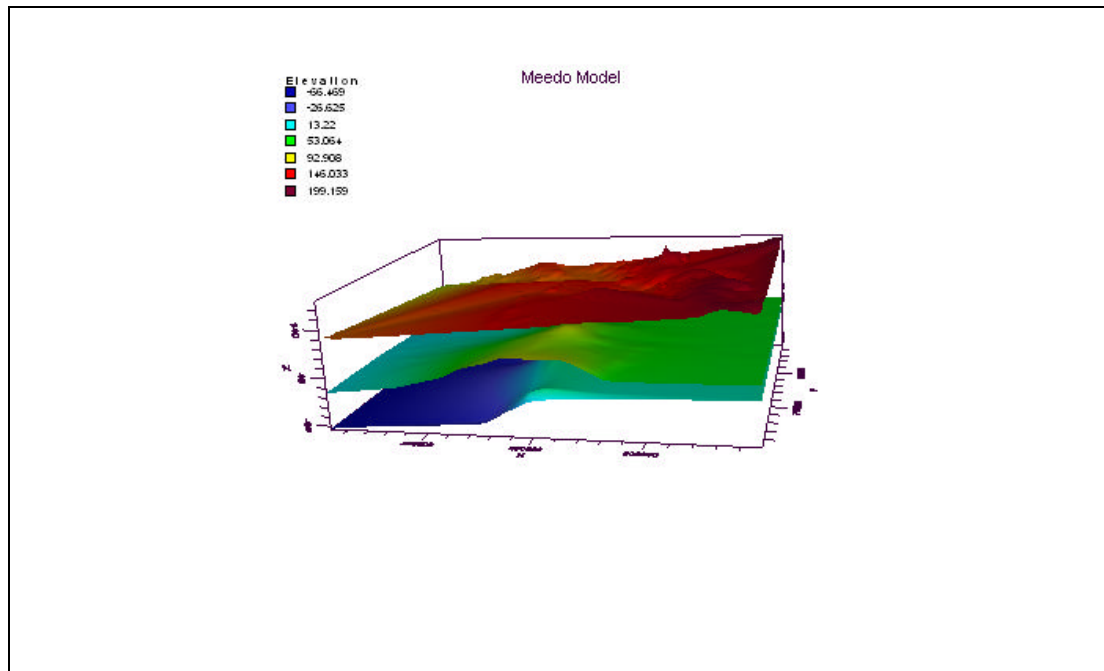


Figure 1: 3D-View of Ground Surface, Bottom of Layer 1 and Layer 2

**Inactive flow cells**

Layer 1, west of N-S fault cells are inactive (light blue in Figure 2).

**Properties**

West of N-S fault

Code 1  $K_x = 0.1\text{m/d}$ ,  $K_z = 0.01\text{m/d}$ , applied to layer 1

Code 2  $K_x = 15\text{m/d}$ ,  $K_z = 1.5\text{m/d}$ , applied to layer 2

East of N-S fault

Code 3  $K_x = 3\text{m/d}$ ,  $K_z = 0.3\text{m/d}$ , applied to Layer 1+2

$S_s = 9 \times 10^{-4}$ ,  $S_y = 0.2$  applied to Layer 1+2

**Observation bores**

Not needed

**Pumping bores**

M11/04 and four additional pumps (PB2W, PB3E, PB4E, PB5E) were placed in a single line +/-700m to the west and between +/-1000m and 3000m to the east @ roughly 700-1000m spacing. Coordinates of the pumps are in \\PumpsNEW.xls and in \\PumpsNEW.TAB. The pumps are pumping for 20yrs at a rate of 25l/s (2160m3/d). Particles are placed along the fault for particle tracking. Birdrong  $K=15\text{m/d}$ .

**Constant Head Boundary**

Stop time 7300 days (20yrs). Start Time Head and Stop Time Head based on initial heads in Model\Meedo\L2\_WL\_AHD.GRD. West boundary a line from E 270000/N 7170000 to E 270000/N 7140000, east boundary a line from E 310000/N 7170000 to E 310000/N 7170000, applied to layer 2. In layer1, only east boundary (west of fault is inactive) assigned (brown colour in Figure 2).

**General Head Boundary**

Stop time 7300days, applied to layer 1+2. Layer 2 north boundary a line from E 270000/N 7170000 to E 310000/N 7170000, and south a line from E 270000/N 7140000 to 310000/N 7140000. Horizontal

hydraulic conductivity west of fault  $K=15\text{m/d}$  (Birdrong), east of fault  $K=3\text{m/d}$  (Permian). In layer 1 GHB only applied to cells east of fault (green colour in Figure 2)

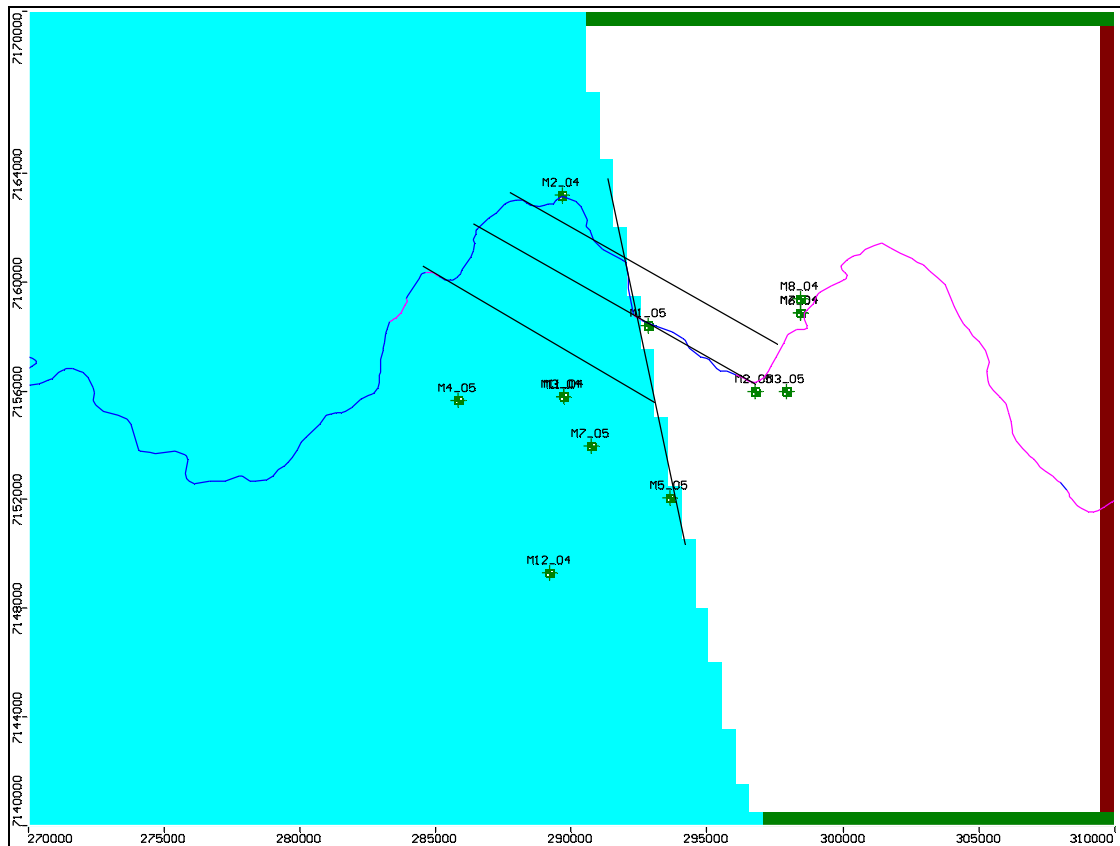


Figure 2 Boundary Conditions

### Initial Head

Initial heads from steady state model Meedo 1.

### Zone Budget

Zone 1: Whole model domain

Zone 2: Layer 2, area between bore M2/04 and M12/04, 1km wide.

### Time

Transient

### Layer Type

Layer 1 - Type 3 Confined/Unconfined variable S, T.

Layer 2 - Type 3 Confined/Unconfined variable S, T

### Results

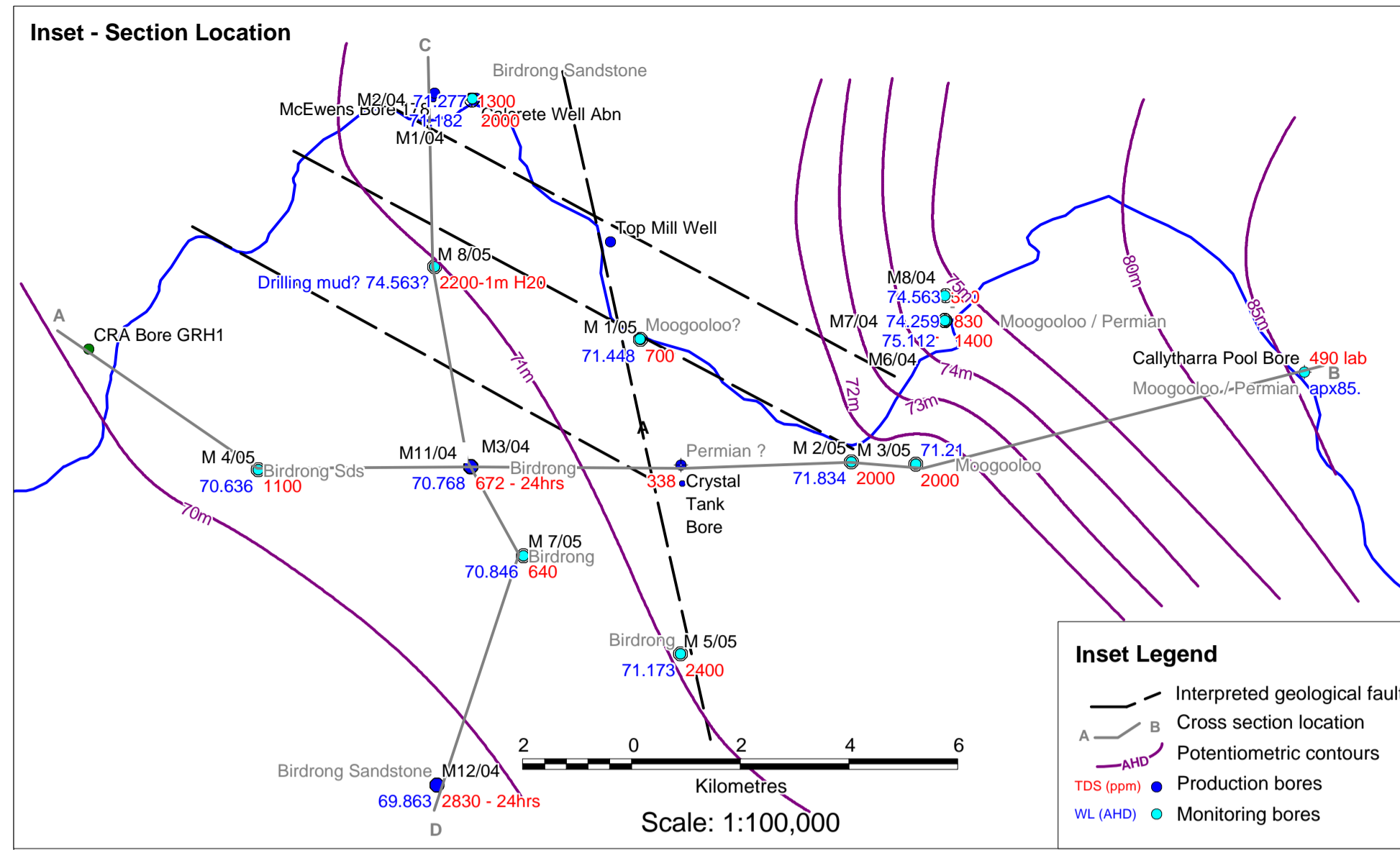
Output data saved in:

\\Output\DrawdownL2\_20yrs.shp = Drawdown in Layer 2 after 20yrs

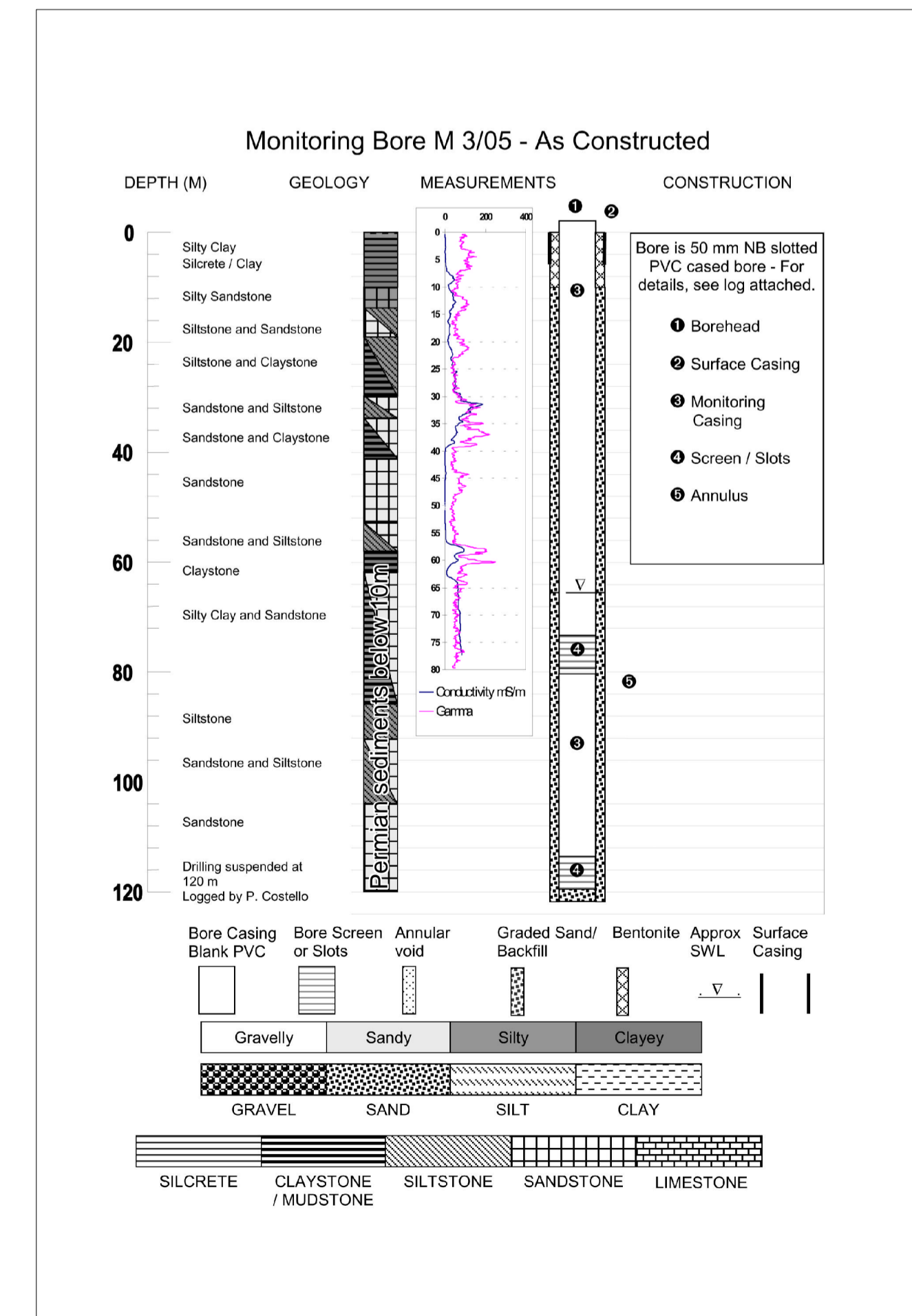
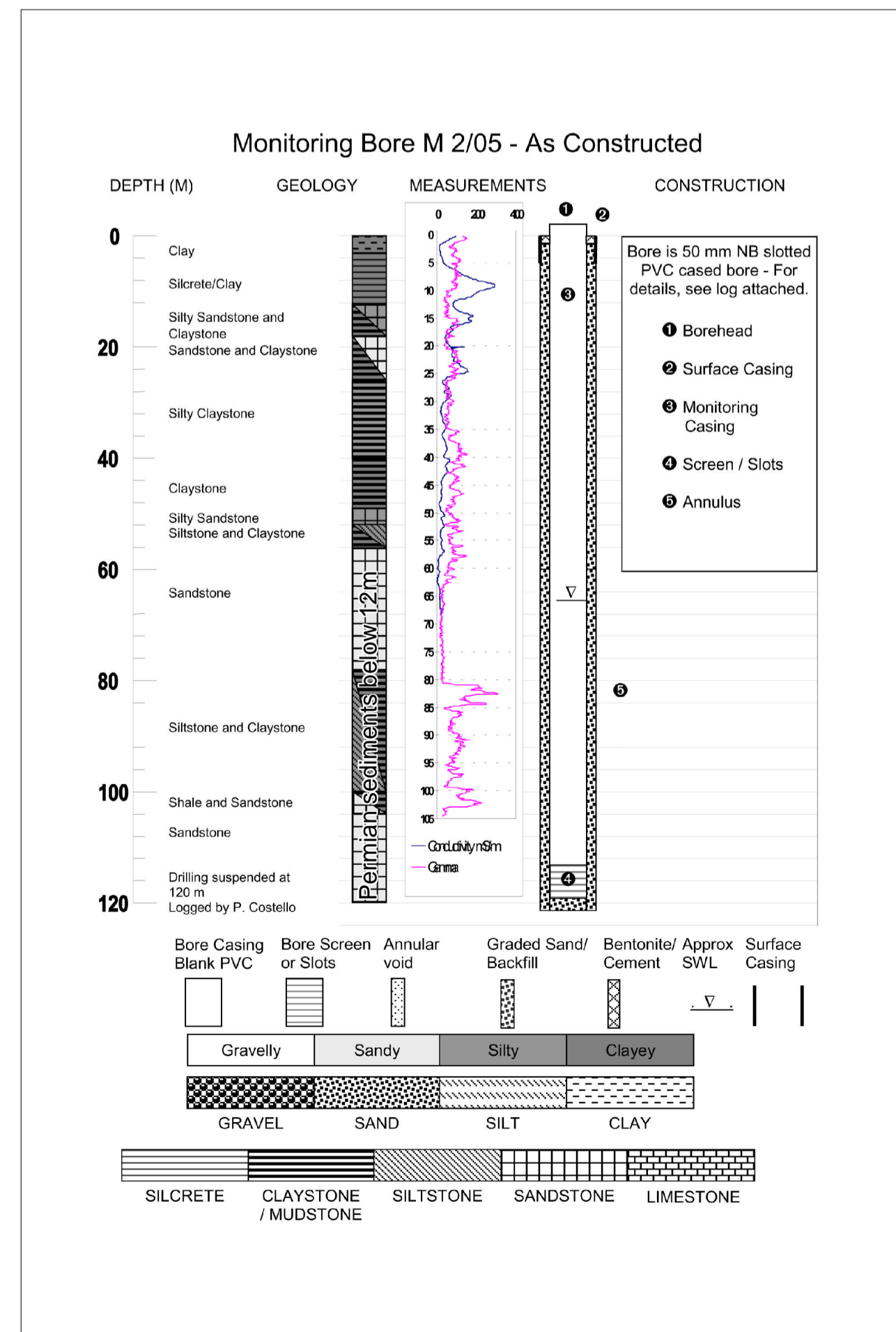
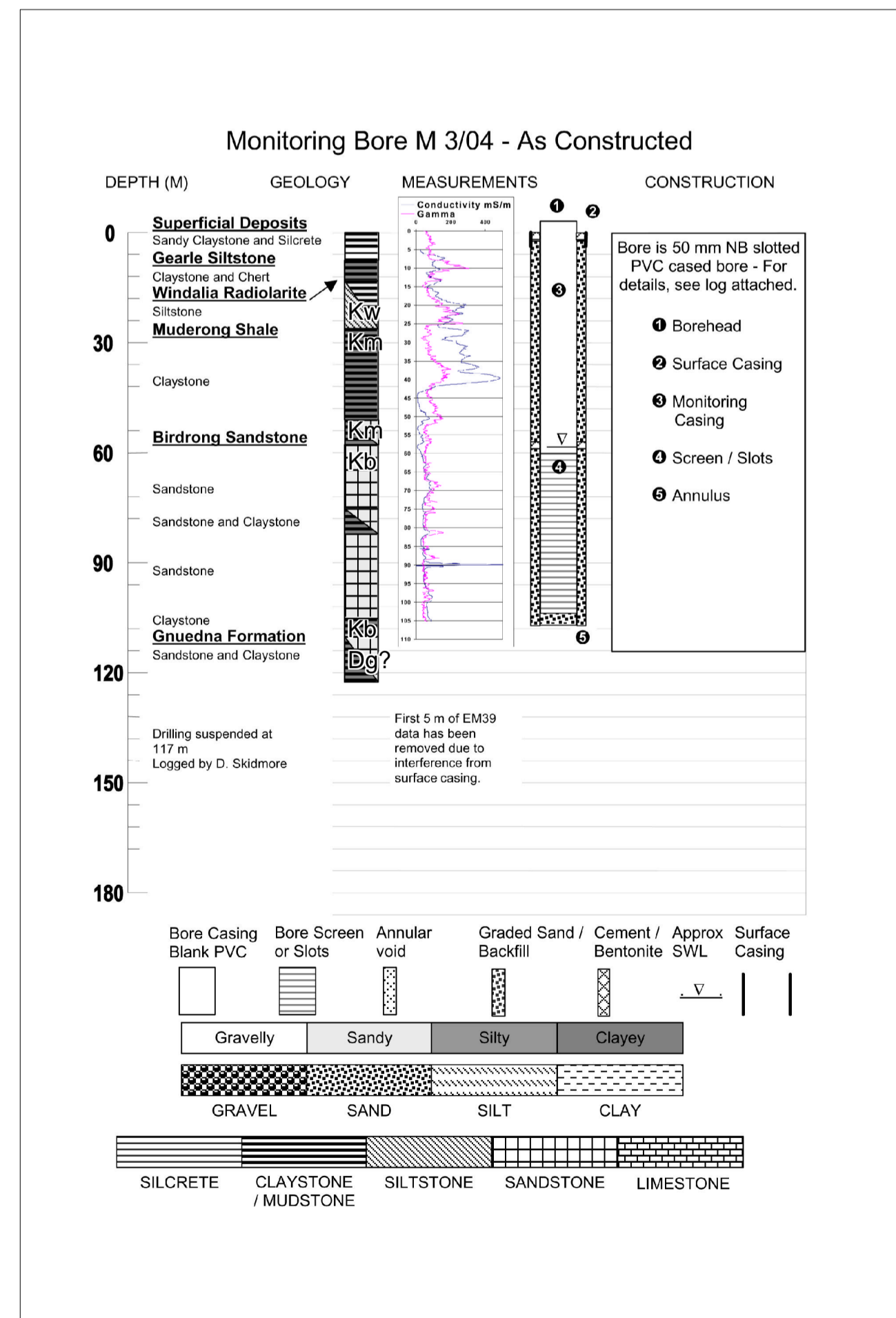
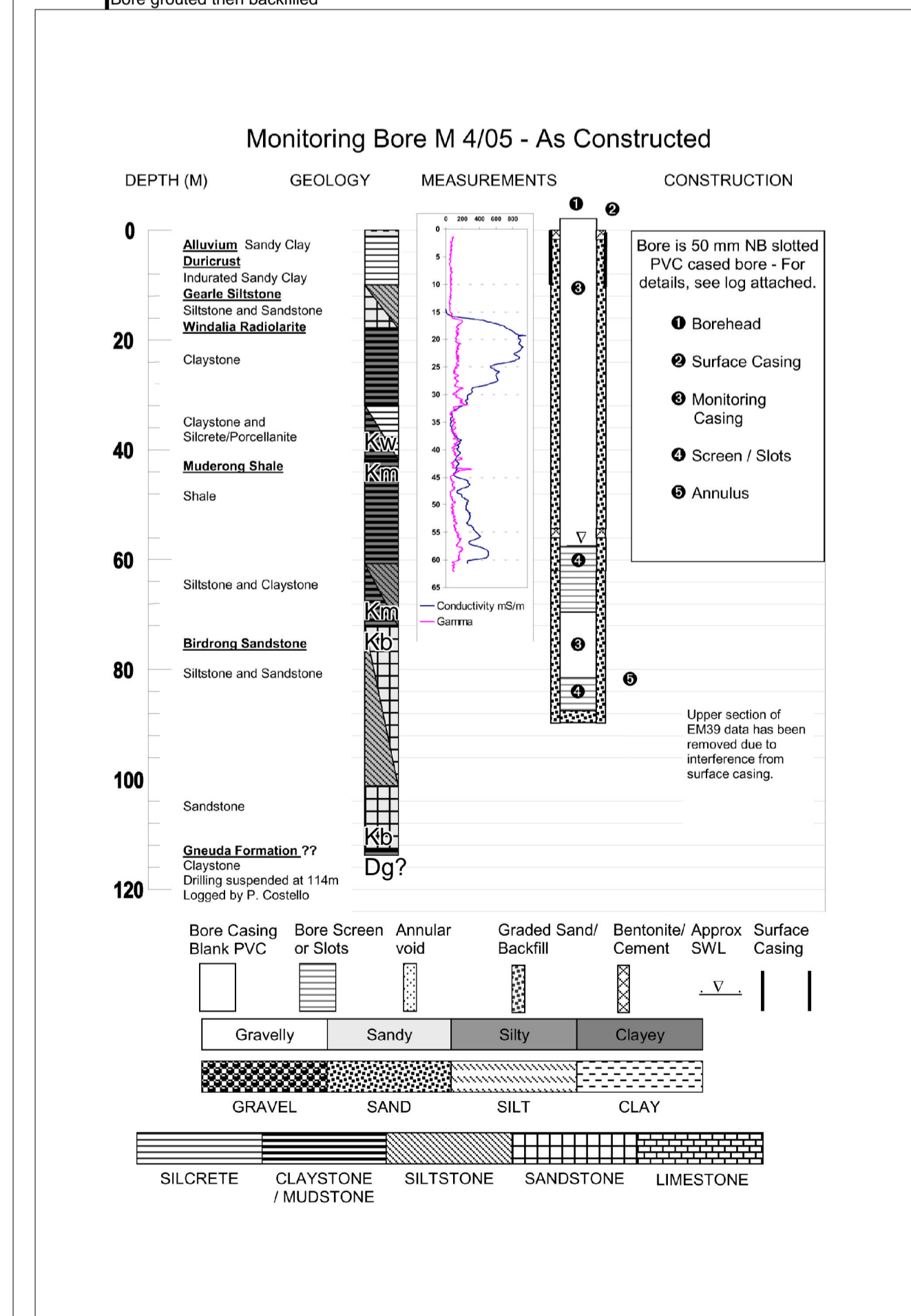
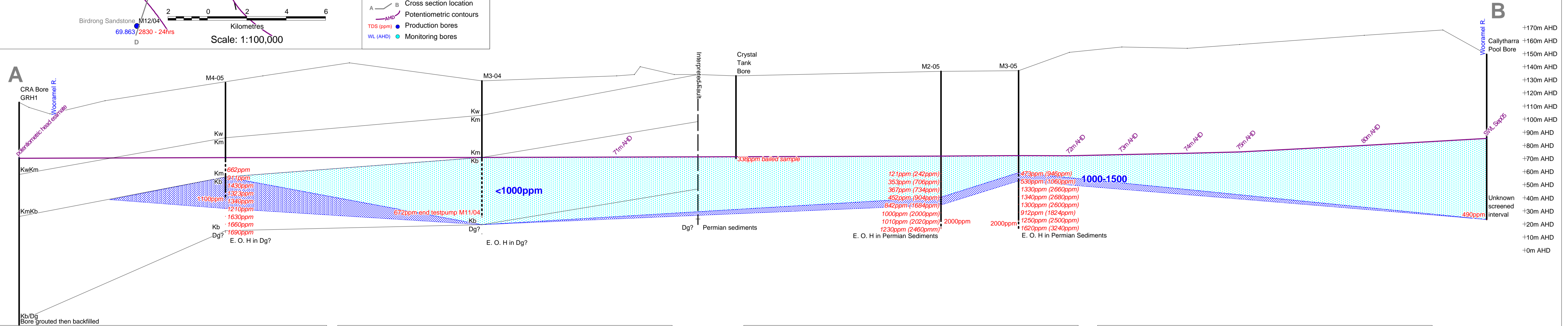
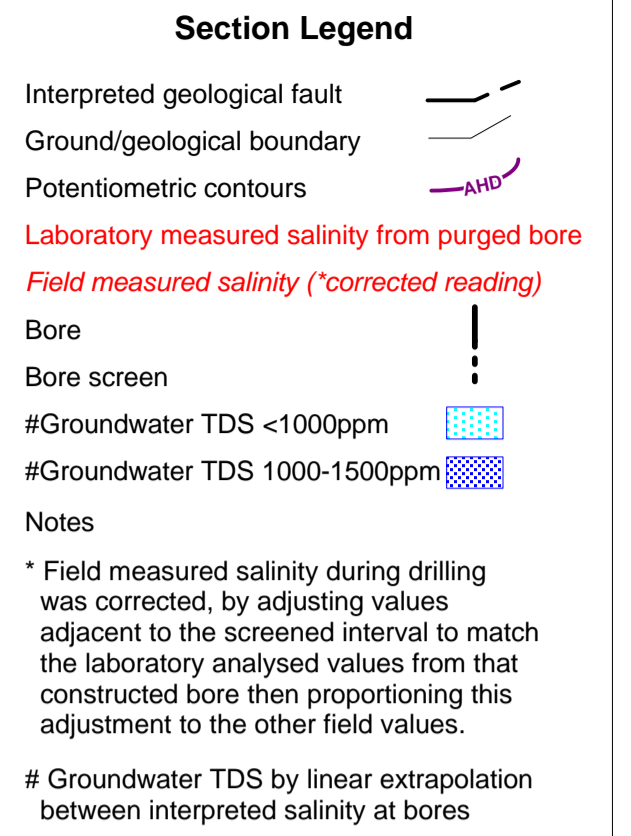
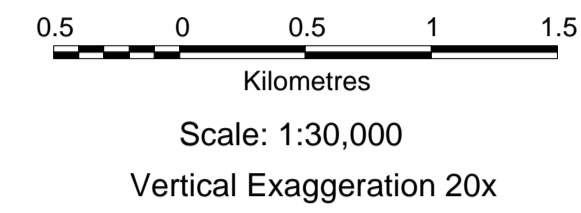
\\Output\HeadsL2\_20yrs.shp = Potentiometric heads in Layer 2 after 20yrs

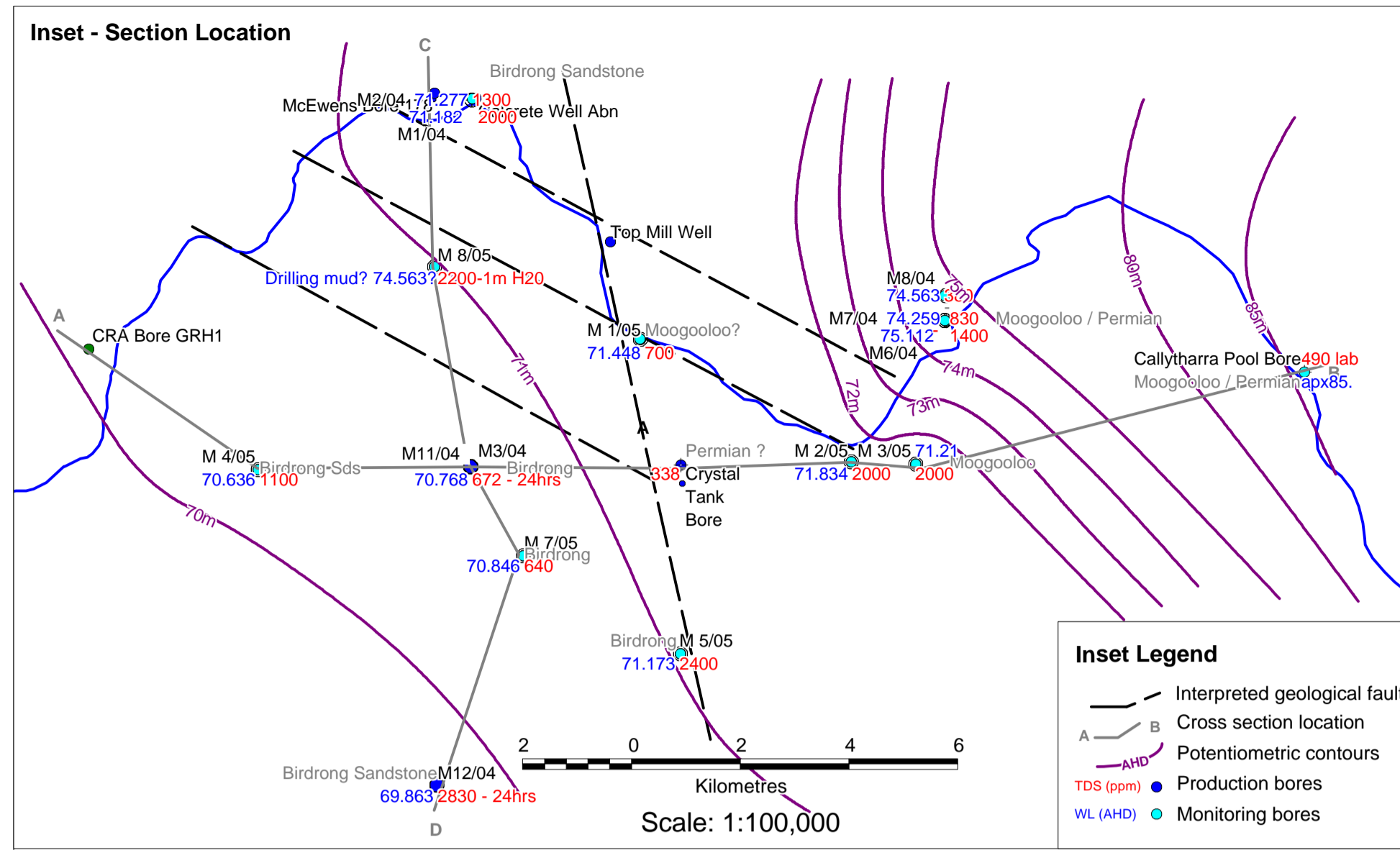
\\Output\PathlinesL2\_20yrs.tim.pth.shp = Flow path in Layer 2 over 20yrs

\\Output\PathlinesL2\_20yrs.tim.tim.shp = Flow path in Layer 2 over 20yrs with a point at each time step.

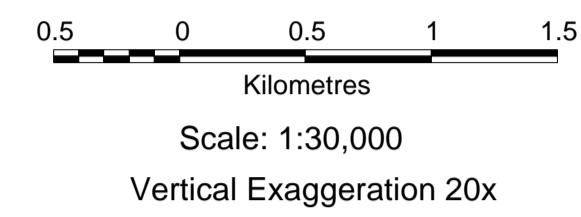


## Meedo East-West Section



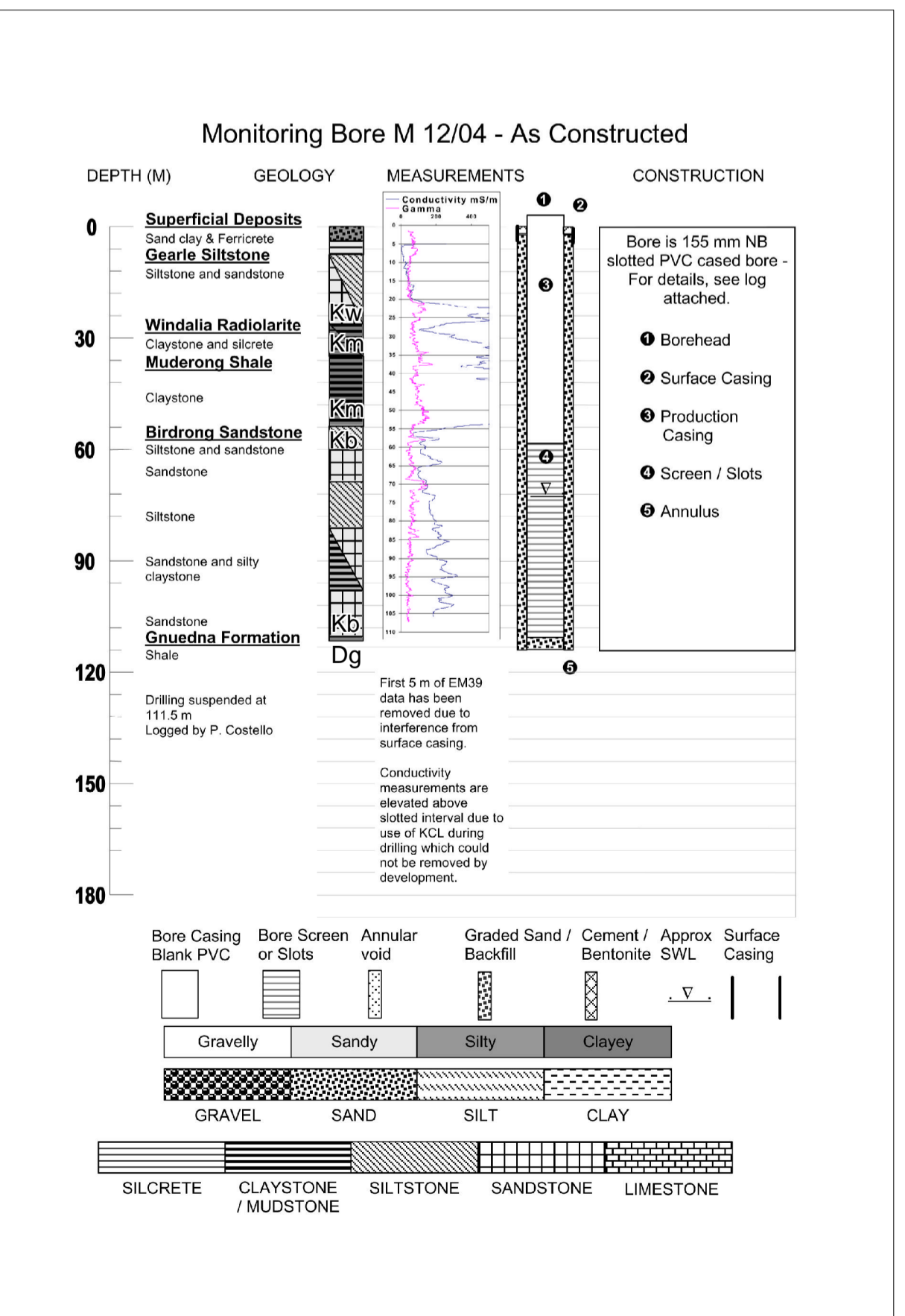
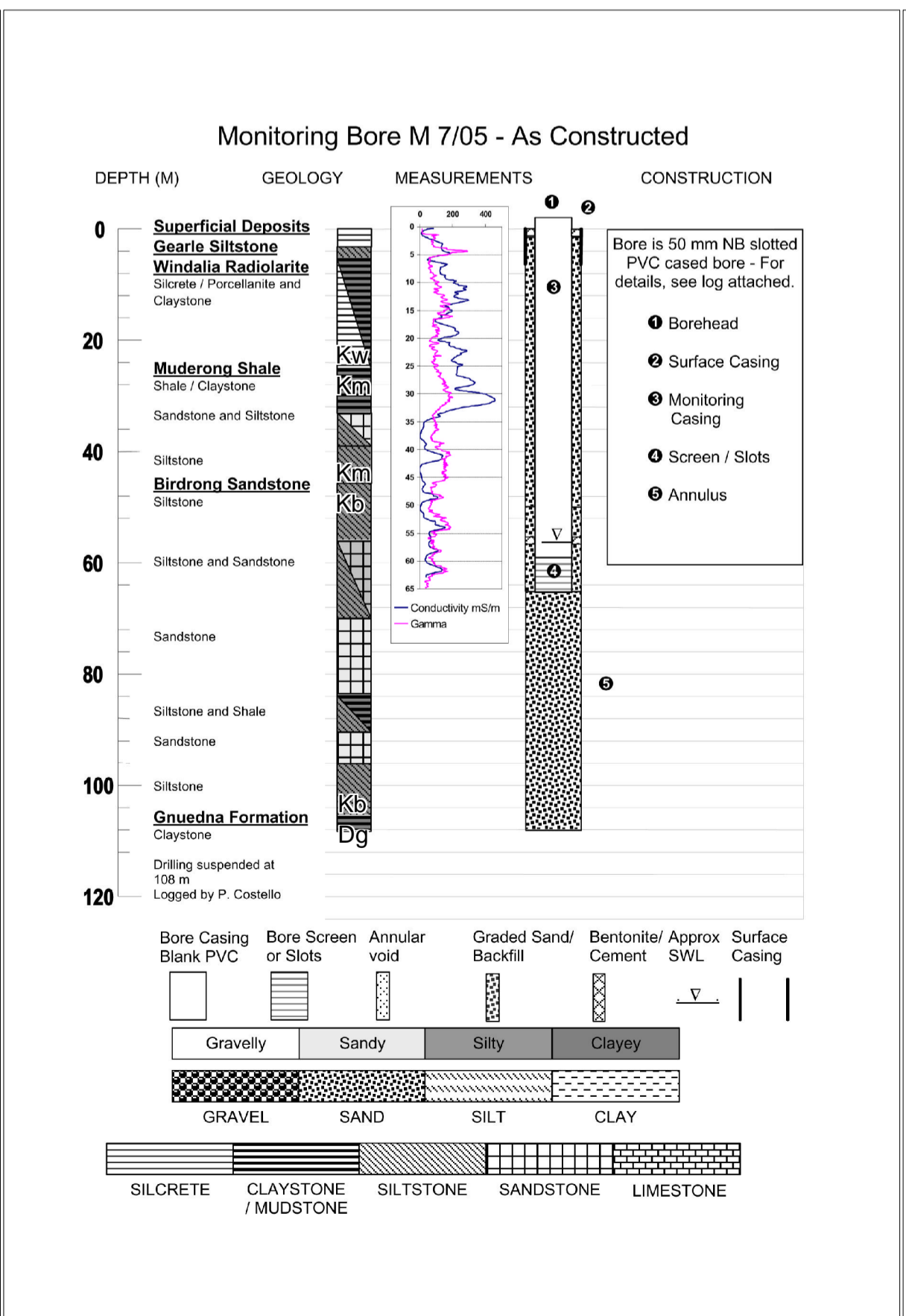
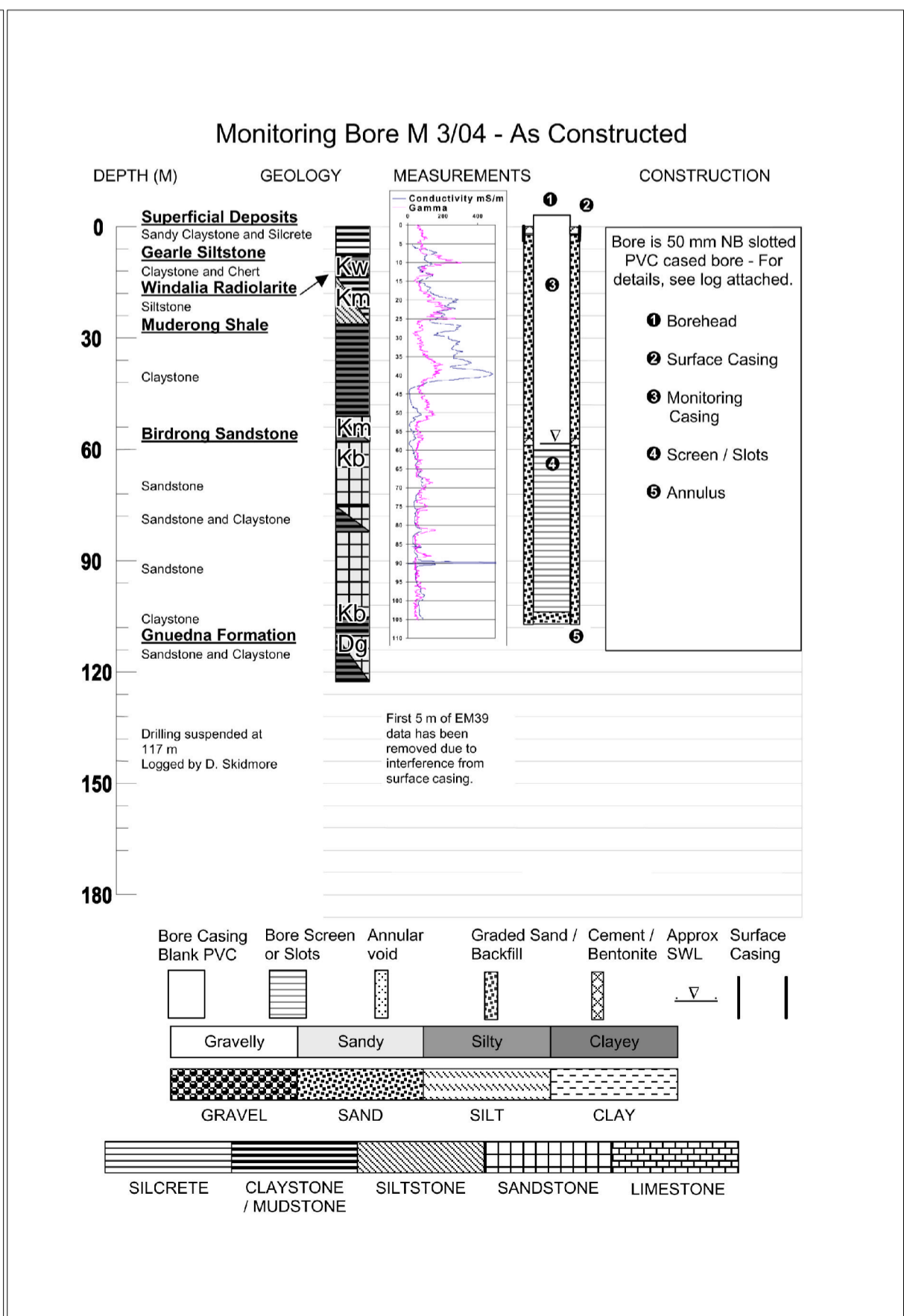
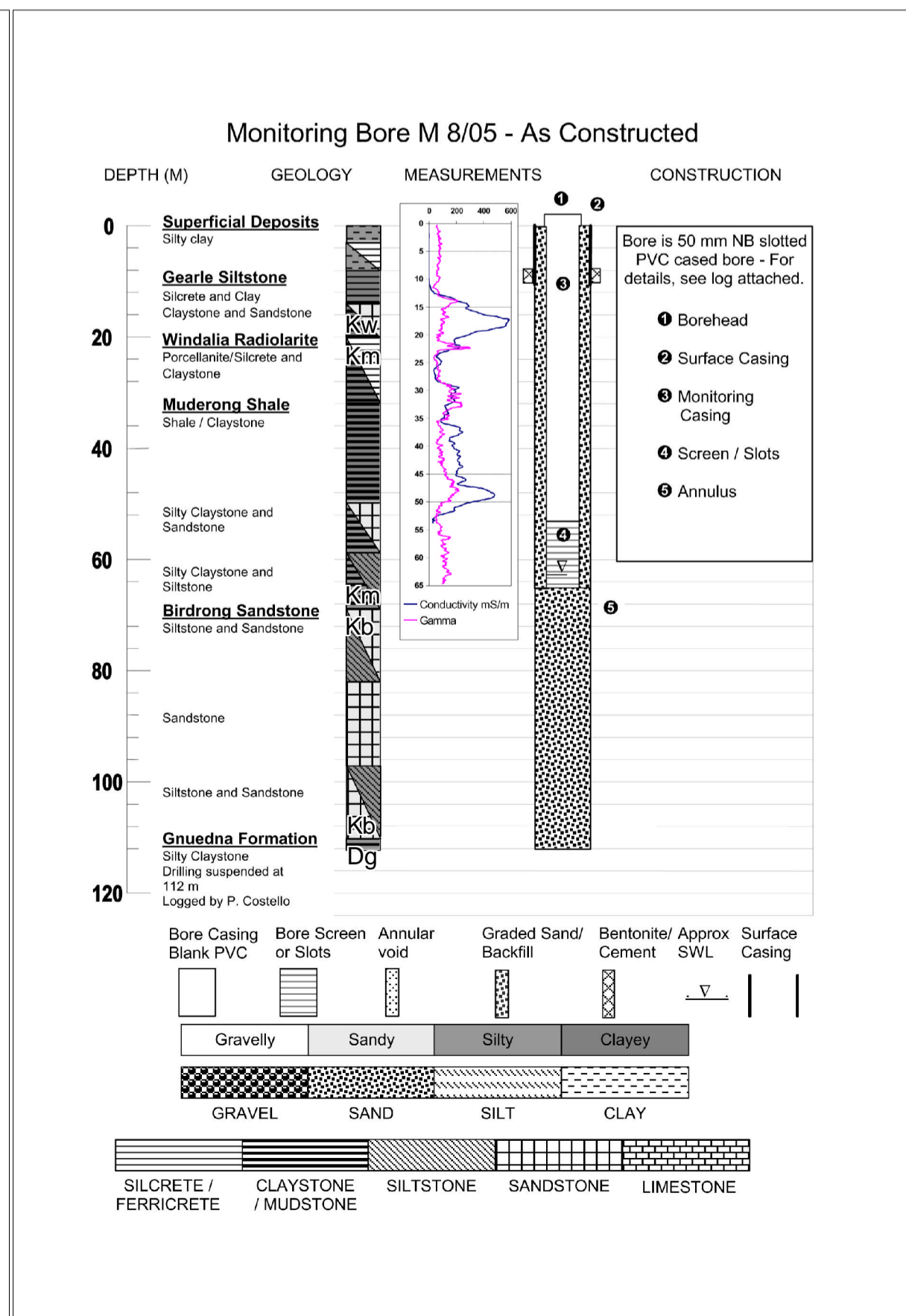
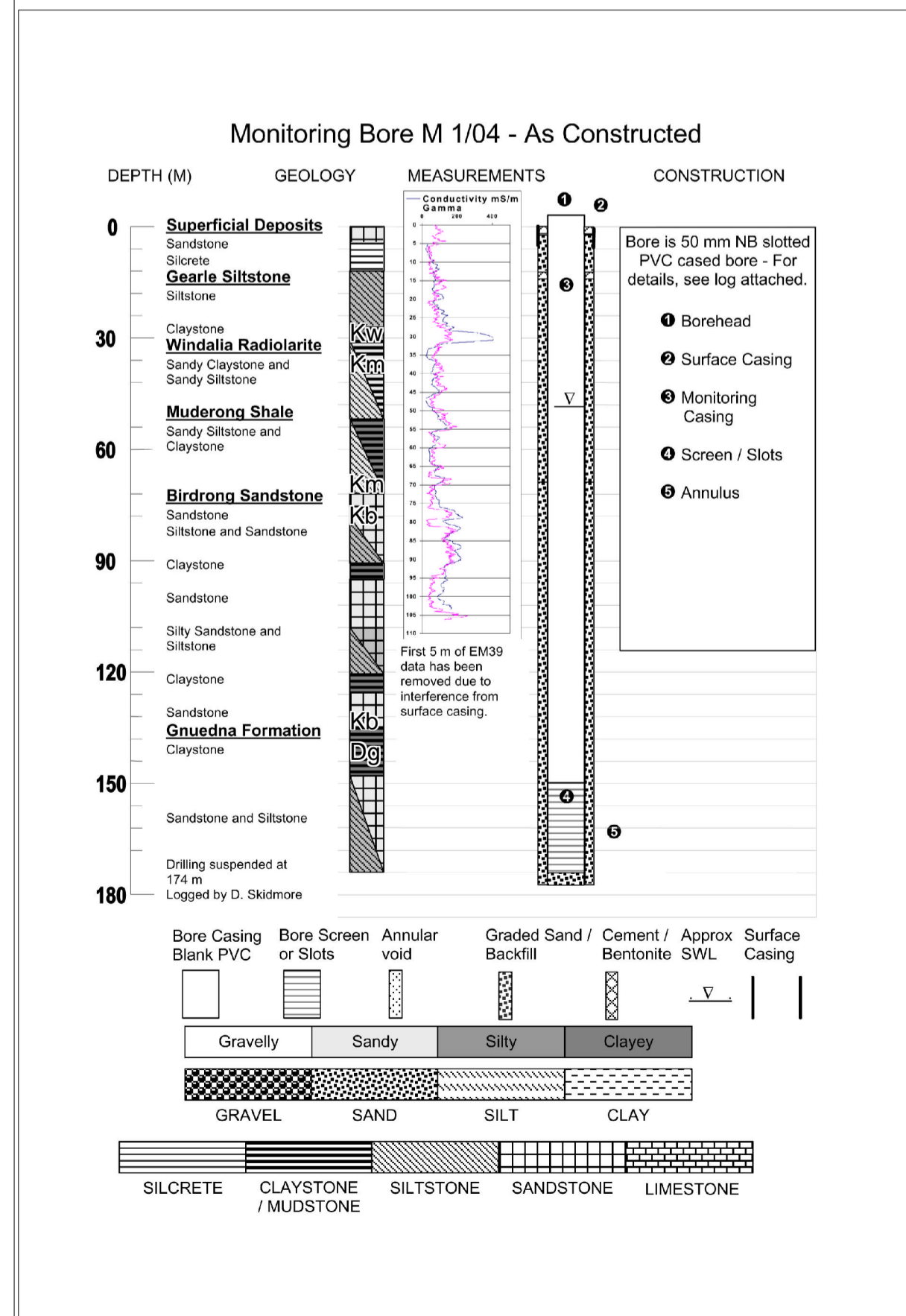
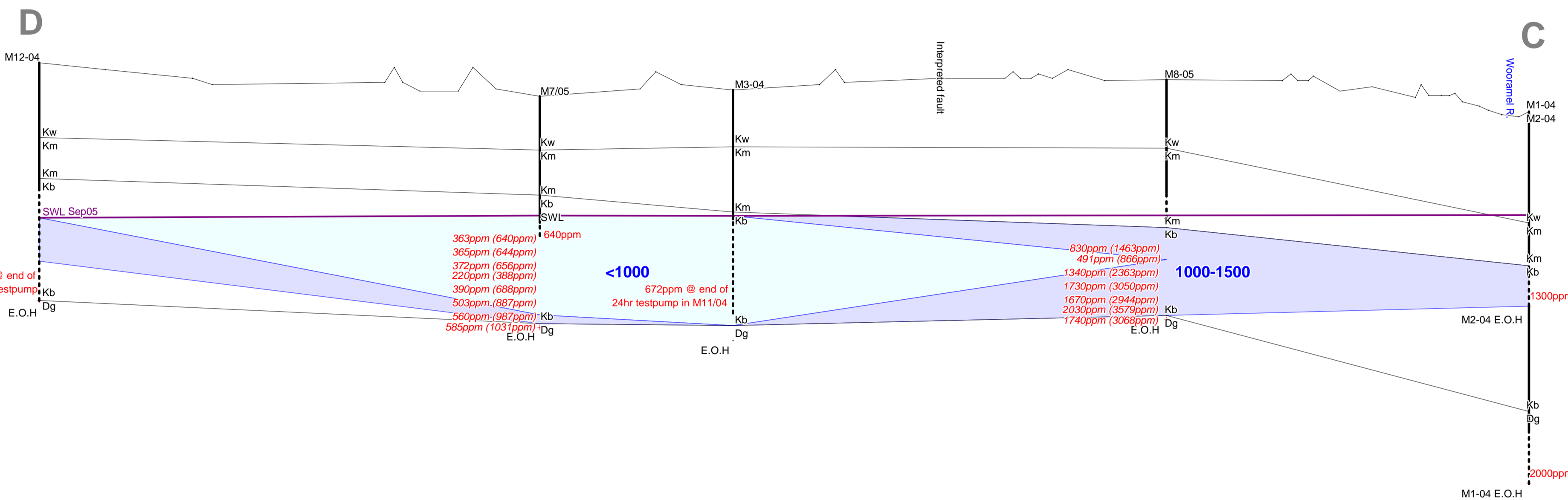


## Meedo North-South Section



### Section Legend

- Interpreted geological fault
- Ground/geological boundary
- Potentiometric contours
- Laboratory measured salinity from purged bore
- Field measured salinity (\*corrected reading)
- Bore
- Bore screen
- #Groundwater TDS <1000ppm
- #Groundwater TDS 1000-1500ppm
- Notes
- \* Field measured salinity during drilling was corrected, by adjusting values adjacent to the screened interval to match the laboratory analysed values from that constructed bore then proportioning this adjustment to the other field values.
- # Groundwater TDS by linear extrapolation between interpreted salinity at bores



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