STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT
PLAN FOR THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN
IN THE REPUBLIC OF NAMIBIA
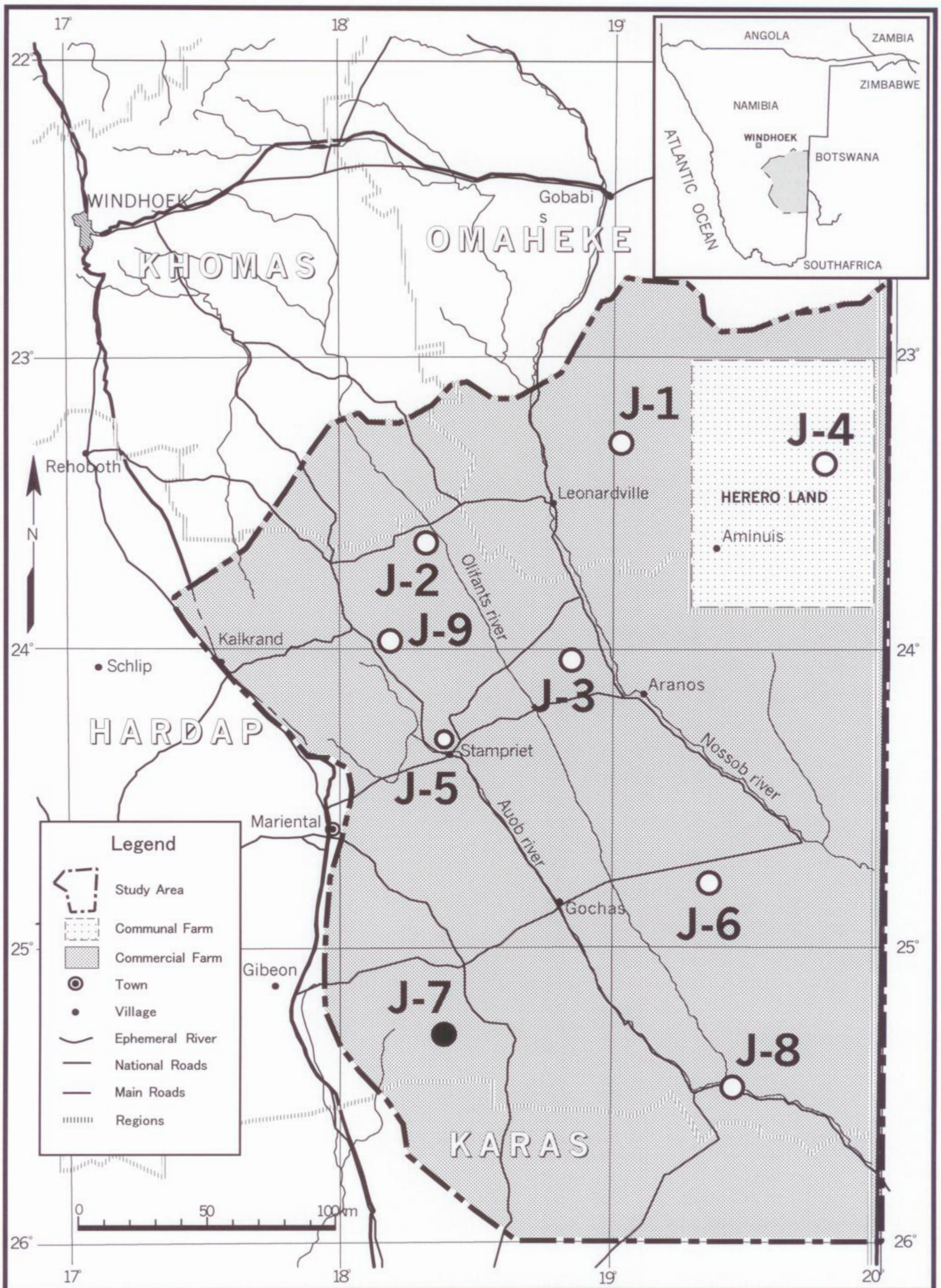
Japan International Cooperation Agency
Pacific Consultants International

<u>BOREHOLE FINAL REPORT</u>

Borehole
J7-K (WW 39852)
Jakkalsdraai R 228

METZGER PM DRILLING
P.O.Box 11733
Windhoek
Namibia

Windhoek
October 2000

Location Map of Test Boreholes

THE STUDY ON THE GROUNDWATER IN THE STAMPRIET ARTESIAN BASIN | JICA

Legend

- Study Area
- Communal Farm
- Commercial Farm
- Town
- Village
- Ephemeral River
- National Roads
- Main Roads
- Regions

Contents per Chapter

1. Geological Borehole Log

GEOLOGICAL BOREHOLE LOG

Farm Jakkalsdraai
Jica Reference: J 7 K
Date completed: 5 August 2000

WW 39852
S 25. 29149 °
E 18. 41784 °
Collar elev.: 1144 mamsl

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 - 7	7	**Calcrete**: light brownish grey, slightly karsted near surface.	KALAHARI
7 -15	8	Calcretized gravel and **conglomerate**. Calcrete matrix white to light grey.	
15 - 25	10	Light brownish grey **calcretized sand** with horizons of gravelly calcretized conglomerate.	
25 - 26	1	Pinkish massive **calcrete**.	
26 - 29	3	Pinkish unsorted **sandstone**. Scattered quartz granules. Calcareous & porous. Aquifer.	
29 - 32	3	Pale grey to pale brownish conglomerate, **calcrete** cemented.	
32 - 36	4	Grey poorly sorted partially consolidated **sandstone/conglomerate**. Calcareous. Granules and pebbles well rounded. Porous. Aquifer.	
36 - 44	8	Unsorted **sandstone**, non-calcareous to moderately calcareous in places and slightly porous. Silcrete horizons. Colour pale reddish brown.	
44 - 48	4	Pinkish calcrete **conglomerate**.	
48 – 55 EOH	7	Pale yellowish well laminated **sandstone**, micaceous, with interlayered yellowish **shale** horizons. Shale increases towards 55 m.	**RIETMOND**

Remarks:

1. This borehole was drilled by the air-rotary method. Drill-additives consisted only of rotafoam.

Borehole logged by F.Bockmuhl.

1

2. Penetration Record

	Penetration Record Borehole J 7 K		WW 39852		
Depth (m)	Pen. Rate (min/m)	Time	Date	Remarks	
0		08:00	3/8/00	Drilling for conductor pipe	
				Drilling 311 mm	
	3.6				
5					
	2.5	09:20			
	1.4				
10	1.35	09:37			
	1.35				
	2				
	1.4				
	1.7				
	2.1				
	2.4				
	1.5				
	0.95				
	1.15				
20	2.25				
	1.45				
	2.1				
	2.15				
	1.6				
	2.1				
	2.75				
	2.75				
	1.45				
	3.25				
30	3.5				
	3.8				
	2.1				
	2.05				
	2.2				
	1.45				
	1.5				
	3.1				
	2.45				
	2.75				
40	2.2				
	2.75				
	3.05				
	2.35				
	2.2				
	2.9				
	3.35				
	1.85				
	2.7				
	2.95				
50	1.45				
	1.3				
	1.5				

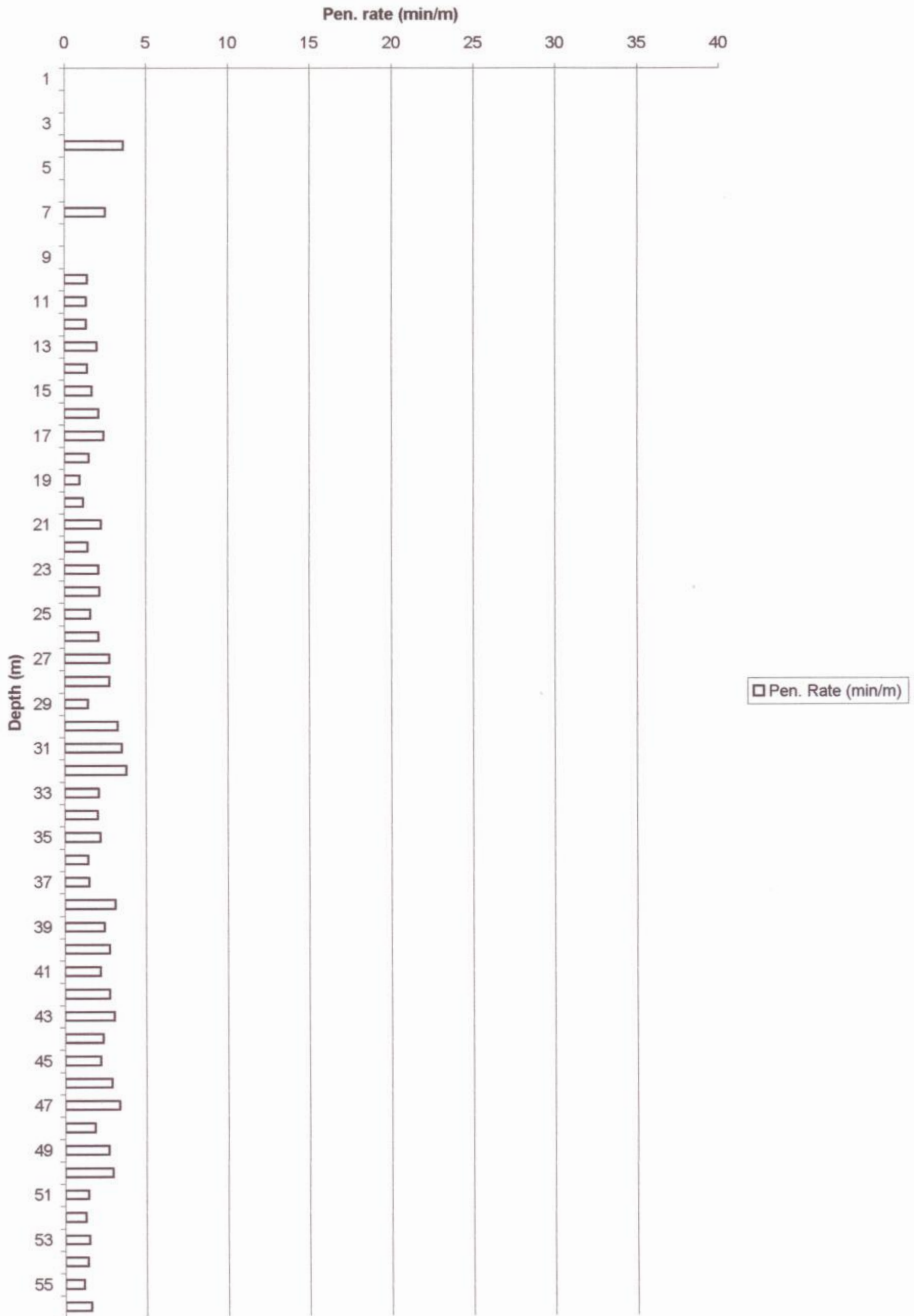|		1.4				
		1.15				
55		1.6	12:10	3/8/00	End of Borehole	

Penetration Record J 7 K

Chart1

3. Mud Rotary Drilling Log

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

MUD ROTARY DRILLING LOG

JICA REFERENCE: J 7 K   **LOCALITY: Jakkalsdraai R 228**   **WW 39852**   **DATE: 3/08/2000**

Important remark: This borehole was drilled by the air-rotary method, without any re-circulating drilling fluid. The measurements recorded below are at the end of drilling, before logging, and represent the water inside the borehole while logging was taking place.

TIME	DEPTH mbgl	MARSH FUNNEL TEST 1000 ml	MARSH FUNNEL TEST 500 ml	E. C. μS/cm	DENSITY	pH	TEMPERATURE ° C	COMMENT
10:15	55	34	18	1165	<1.16		24.3	See above.

4. Geophysical Log and Casing Design

Poseidon Geophysics

(Reg. No. 93/550)

CONSULTANT	PACIFIC CONSULTANTS INTERNATIONAL
COMPANY	METZGER PM DRILLING
PROJECT	The Study on the Groundwater Potential Evaluation and Management Plan in the Southeast Kalahari (Stampriet) Artesian Basin
WELL ID	J7K WW39852
LOCATION	JAKKALSDRAAI
COUNTRY	REPUBLIC OF NAMIBIA

CO. Poseidon Geophysics
WELL...J7K WW 39852
PROJ.
LCN. Jakkalsdraai
STE. J7
FILING No. J7K

BH COORDINATES

COLLAR ELEVATION
LOG MEAS. FROM   Groundlevel

DRILLING MEAS. FROM   Groundlevel

DATE	5 August 2000
TYPE LOG	Physical Properties
DEPTH-DRILLER	55m
DEPTH-LOGGER	56m
BTM LOGGED INTERVAL	56m
TOP LOGGED INTERVAL	0.60m
PERMANENT DATUM	Groundlevel
RECORDED BY	Wimpie Coetzer
WITNESSED BY	Frank Bokmuhl

JICA
JAPAN
INTERNATIONAL
COOPERATION
AGENCY
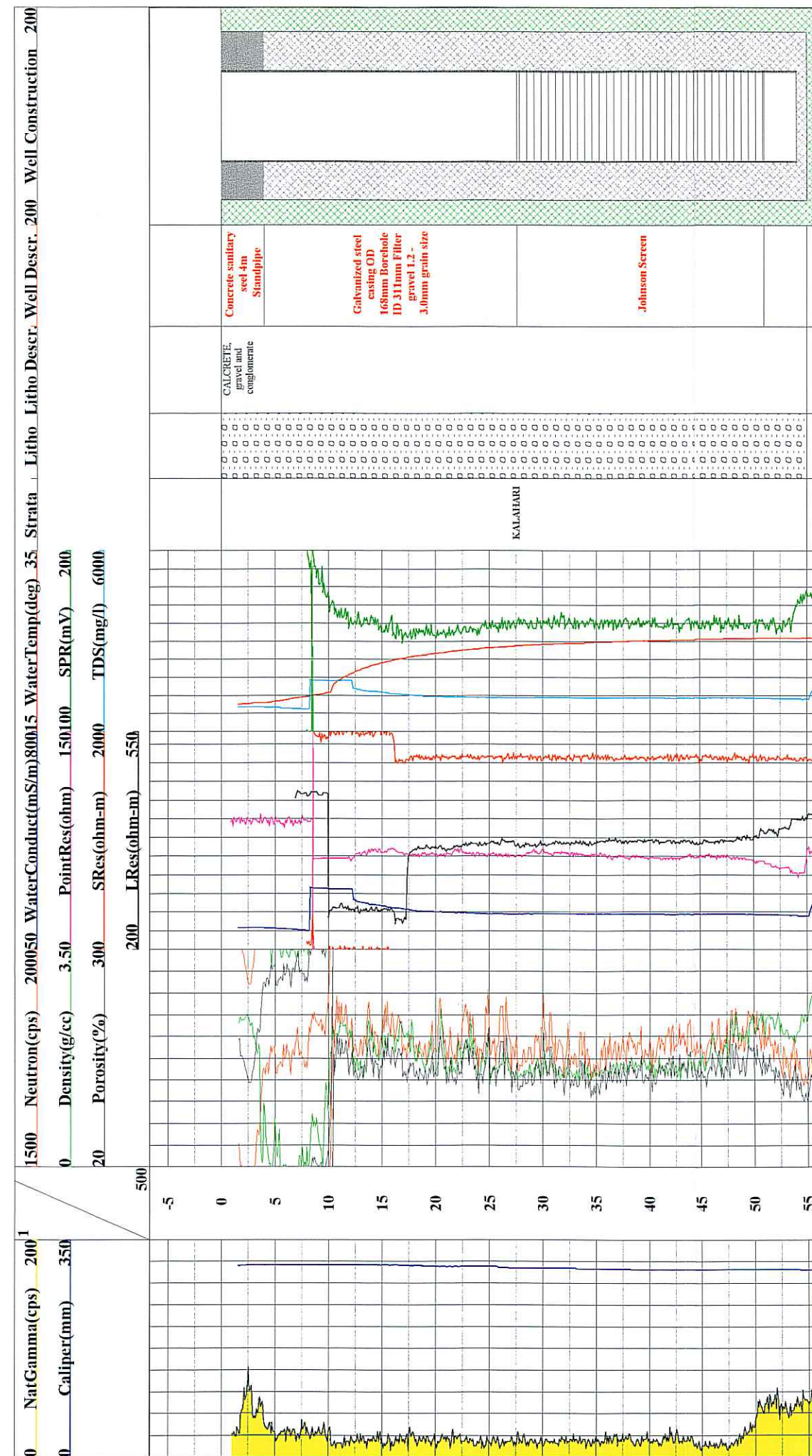
5. Borehole Development Data

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

BOREHOLE DEVELOPMENT DATA

JICA REFERENCE: J 7 K   **LOCALITY: Jakkalsdraai R 228**   **WW 39852**   **DATE: 6/08/2000   (starting)**

TIME (actual)	P.I.D. (mbsu)	½ 90° V-Notch (mm)	Yield (m³/h)	E.C. (mS/m)	Water Level (mbsu)	Remarks
12:00					10.20	**Date 6/8/00: Cable Tool Data**.
17:00						5 hours plunging. Introduce chlorine into borehole while plunging.
08:00						Date 7/8/00. Plunging for 9 hours in order to settle gravel properly in borehole.
17:00				129	10.20	
08:00						Date 8/8/00.
15:00				122	10.20	Plunging for 8 hours.
17:00			1.4			Bailing. 80 bailers @ 35 l removed for a total of 2800 l.
08:00						Date 9/8/00. Bailing.
15:00					10.0	End of development by cable tool rig.
09:00	29	75	4.0	109	25.40	Date 10/08/00: **Development by airlift.**
12:00		70	3.24		25.40	
16:00	41	60	2.16	104	26.45	
19:00	41	60	2.16		26.66	Pump through the night.
07:00						Date 11/08/00. Add two pipes
09:00	53	110	10.08	123	25.40	
12:00		120	12.6		25.50	
16:00		120	12.6		25.70	

TIME (actual)	P.I.D. (mbsu)	½ 90° V- Notch (mm)	Yield (m³/h)	E.C. (mS/m)	Water Level (mbsu)	Remarks
19:00	53	120	12.6		25.50	Pump through the night.
08:00	53	106	9.2	104	25.33	Date 12/08/00.
12:00		107	9.5		25.70	
16:00	53	105	9		25.30	

Remarks:

1. This borehole was bailed and plunged for 30 hours.
2. Development by airlift took place for effective 52 hours.
3. Finally this borehole was developed by means of pumping with an electrical submersible pump. Data for these 3 hours is tabulated below. Date for this activity was 20/08/2000.

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m³/h)	E.C. (mS/m)	Remarks
12.41	0	10.53			Before the start of developing.
12.42	1	20.42			Start
	2	16.59			
	3	14.88			
	4	16.53			
	5	16.58			
	6	16.60			
	7	16.60	5.35		
	8	16.16			
	9	16.66			
	10	16.68			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m³/h)	E.C. (mS/m)	Remarks
	12	16.74			
	14	16.77		234	
	16	16.80			
	18	16.87			
	20	16.89			
	23	16.92			
	26	16.96			
	30	16.94			
	35	16.99			
	40	17.03			
	45	17.04			
	50	17.04			
	55	17.06	5.35	164	
13:41	60	17.08			
	61	21.39			
	62	21.10			
	63	22.08			
	64	22.48			
	65	22.77			
	66	23.02			
	67	23.22			
	68	23.41			
	69	23.52			
	70	23.63	10		
	72	23.82			
	74	23.95			
	76	24.04			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	78	24.15	10.14		
	80	24.22			
	83	24.28			
	86	24.35			
	90	24.41			
	95	24.46			
	100	24.53			
	105	24.58			
	110	24.56			
	115	24.70		109	
14:41	120	24.73			
	121	29.04			
	122	29.15			
	123	29.18			
	124	29.60			
	125	29.95			
	126	30.49	15.15		
	127	31.64			
	128	32.23			
	129	32.60			
	130	32.79			
	132	33.08			
	134	33.19			
	136	33.42			
	138	33.53	15.2		
	140	33.65			
	143	33.77			

4

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	146	33.92			
	150	34.09			
	155	34.12			
	160	34.19			
	165	34.25			
	170	34.22			
	175	34.25		106	
15:41	180	34.47			
	181	40.48			
	182	42.10	19.51		Stop because of venturi effect: Pump inlet depth at 46 m.
15:44		24.88			Start Recovery measurements
16:43		11.15			

6. Evaluation of Pumping Test

1. PUMPING TEST ANALYSIS

J7-K (WW39852) - Pumping well

J7-N (WW39853) - Observation well

J7-Huis - Observation well

J7-Wind – Observation well

1.1. Well Efficiency (Step Drawdown Test) (Annex 1)

Well Efficiency was analysed by making use of the Jacob method for draw down data. Aquifer parameters used for the calculation of well efficiency were obtained from the evaluation results of the constant discharge test, which is discussed in **Section 1.2** below.

The well efficiencies at the range of pumping rates used during the step drawdown test are summarised in **Table 1** below.

Table 1: J6-K: Borehole efficiency at various pumping rates

Borehole number	Step	Abstraction Rate [m³/h]	Draw Down* [m]	Borehole Efficiency [%]
J7-K	1	1.0	6.24	59.1
	2	2.1	12.40	56.7
	3	3.0	19.30	54.9
	4	4.0	26.50	53.0
	5	5.1	35.80	51.1

* at cut-off time Δt, after which well bore storage has no affect on the well performance

Data on the linear and non-linear well losses and skin factors as well as the efficient well radius are presented in **Annex 1**.

1.2. Constant Discharge Test Analysis (Annex 2 - 5)

The abstraction rate of the constant discharge test was 7 m³/h. The constant discharge draw down curve of abstraction borehole **J7-K** indicates leaky conditions. For leaky aquifers, the Walton / Hantush I analysis method with draw down and recovery data was used to calculate the hydraulic conductivity of the aquifer and the aquitard as well as the leakage factor B **(Annex 2 & 3)**. Using the normal Theis or Cooper-Jacob analysis will result in the over estimation of the hydraulic conductivity of the leaky aquifer and an under estimation of the hydraulic conductivity of the aquitard. (Kruseman, De Ridder, 1992).

The occurrence of leakage could be due to water derived from storage within the aquitard. The sandstone within the Rietmond Formation is confined and under higher hydraulic pressure and will also contribute to leakage occurring into the upper Kalahari aquifer. The results of the constant discharge analysis are summarised in **Table 2** below.

During the duration of the constant discharge test, a slight rise in the water level of observation borehole **J7-N** was observed, while the water level of **J7-Wind** fluctuated due to the borehole being pumped for water supply to the farm house (See **Annex 5.1**).

The water level of **J7-Huis** was clearly affected by the abstraction from J7-K. The observation borehole is located at a distance of 230 m and a maximum draw down of 0.6 m was observed after 72 hours pumping (See **Annex 5.2**). The draw down curve was analysed for transmissivity and storativity values. The transmissivity was calculated as T = 68 m²/day, while the storativity was calculated as S = 0.00023, which is a typical value for confined and leaky aquifers. The transmissivity is double the transmissivity calculated for the pumping borehole J7-K. However, the draw down curve is also affected by pumping of J7-K, which is about 150 m away. The draw down curve is therefore rather 'bumpy' (See **Annex 3.1**). This must be born in mind when utilising the calculated aquifer parameter obtained from observation borehole **J7-Huis**.

Table 2: Aquifer Parameters calculated for J7-K; Kalahari

Borehole number	Analysis method	T	s	k	S	Comments
		[m²/day]	[m]	[cm/sec]	[-]	
J7-K	Walton / Hantush I - draw down	30	30	1.2×10^{-3}	$*5 \times 10^{-3}$	*Storativity estimated
	Walton / Hantush I - recovery	32	30	1.2×10^{-3}	$*5 \times 10^{-3}$	
	Walton / Hantush I - draw down from observation borehole J7-Huis	68	30	2.6×10^{-3}	2×10^{-4}	Storativity calculated

The Walton / Hantush I model for leaky condition from aquitard storage was used to simulate and verify the actual data and analysis approach of the constant discharge test. Simulation parameters summarised in **Table 2** were used in simulation of the actual pumping test data (See **Annex 4** for simulation results).

The radius of influence (R) was estimated after SICHARDT (1928) using the equation:

$R = 3000 \times s \times K_f^{1/2}$

$R = 3000 \times 10.14 \times 5 \times 10^{-3} = \underline{155\ m}$

where

R = Radius of influence

s = Draw down in abstraction borehole at end of pumping

K_f = Permeability of the aquifer

The equation is approximately correct for unconfined aquifers. In case of a confined aquifer the radius of influence most probably larger and the 155 m are considered to be the minimum value. A draw down of 0.6 m was measured in observation borehole J7-Huis at a distance of 230 m. A more realistic value for R, namely $\underline{310\ m}$, is double the calculated value of 155 m.

Evaluation of Test Pumping Data

Step test analysis

Pumped well J7_K
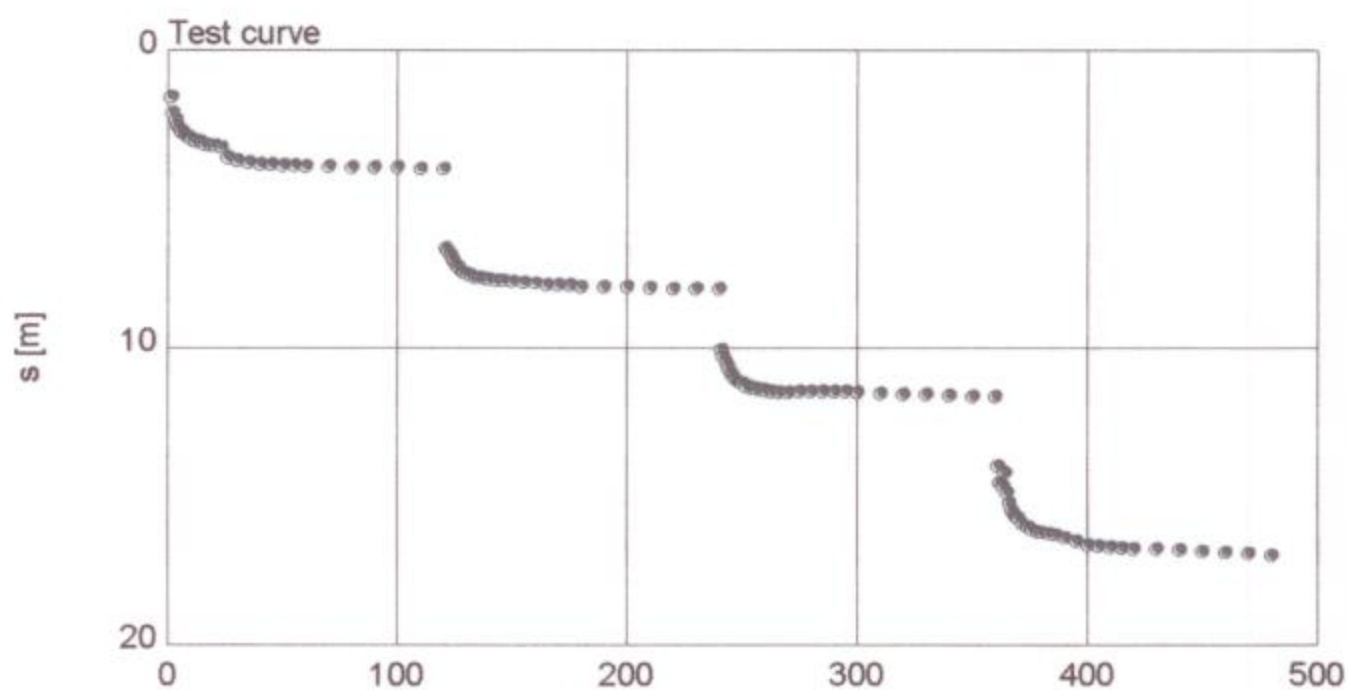
Test curve

Borehole, well & aquifer

Drilled:	21.07.2000
Latitude:	25.29149
Longitude:	18.41784
Elevation:	1150 [m]
Depth:	55 [m]
Stick up:	0.70 [m]
Bh. radius:	0.1555 [m]
Casing radius:	0.084 [m]
RWL:	10.59 [m]
max.drawdown:	16.96 [m]
Aq.type:	confined
Aq.thickness:	30.00 [m]
Stratigraphy:	Kalahari
Lithology:	sandstone

Discharge diagram
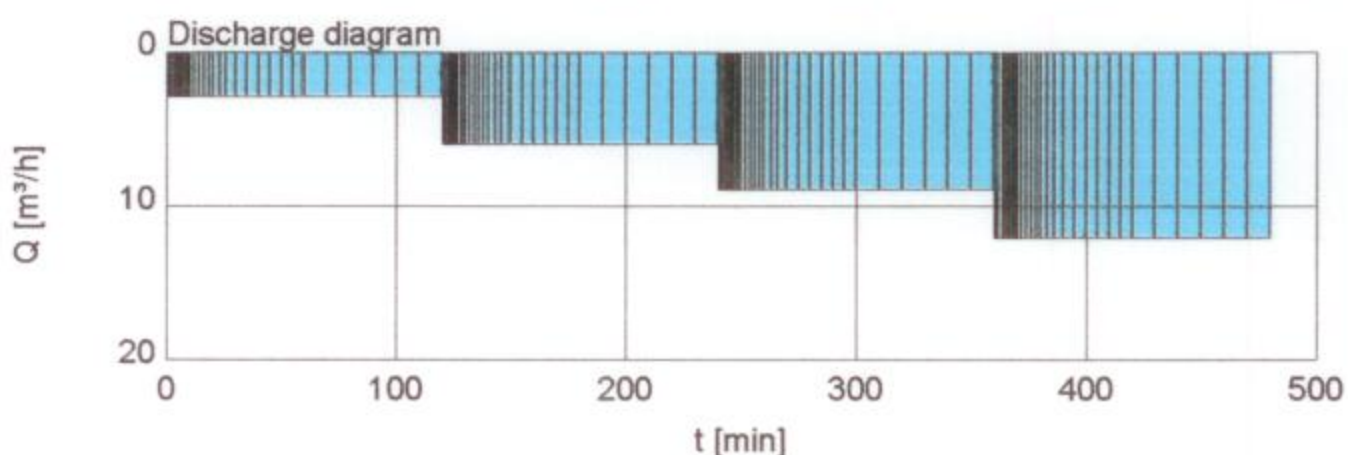
Test running

Start:21/08/2000 07:01:00	
Dis.dur.:	480 [min]
Av.dis.:	7.56 [m³/h]
Max.dis.:	12.1 [m³/h]
Min.dis.:	3 [m³/h]
Total dis.:	60.5 [m³]
Crew:	Metzger_PM
Supervisor:	PCI

Analysis method Rorabaugh with drawdown data

Linear aquifer loss

Linear well loss

Non-linear well loss
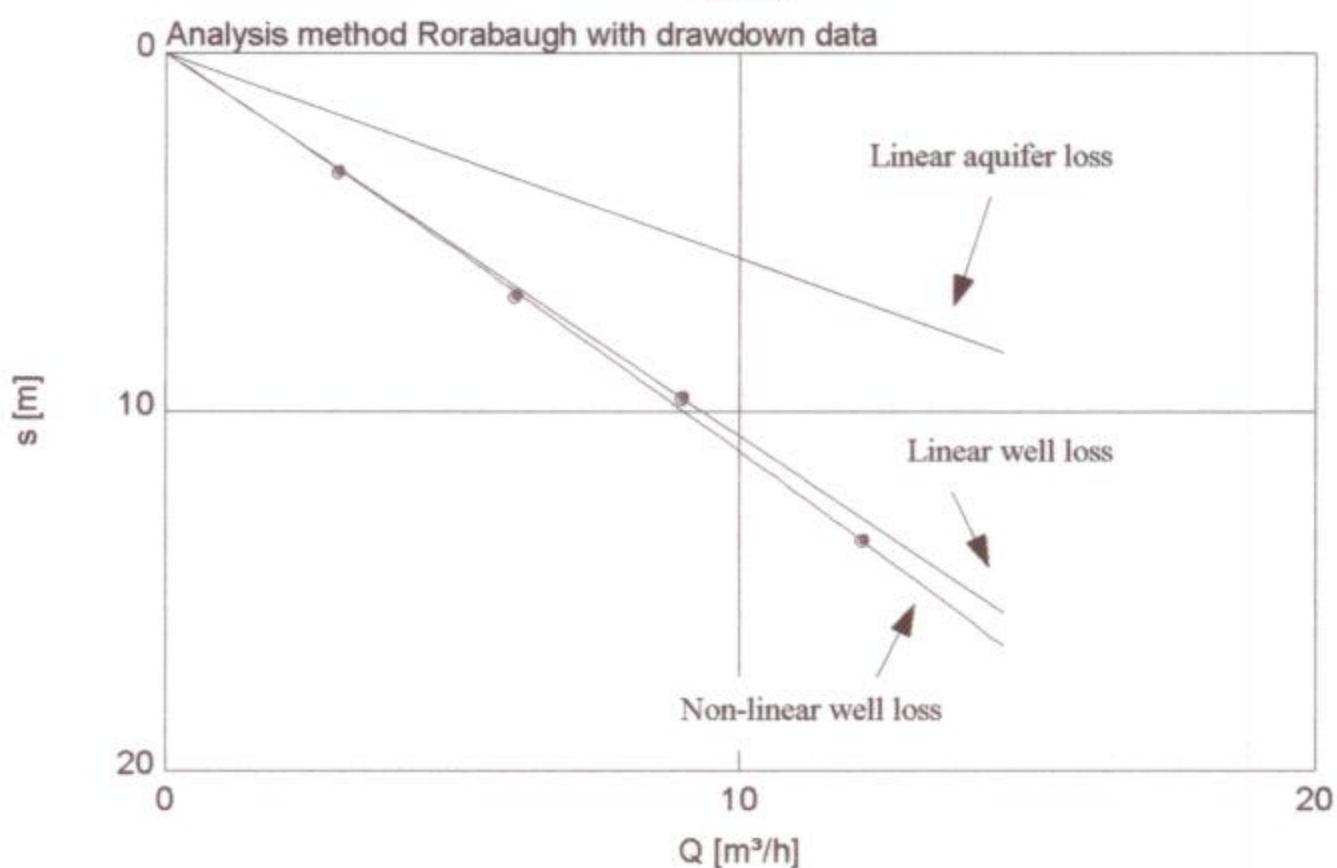
Results

Well performance:

$s: (B1+B2)*Q+C*Q^P$

Linear aquifer loss B1:	0.57	
Linear well loss B2:	0.50	
Non-linear well loss C:	3.8E-3	
Exponent P:	2.05	

	Q [m³/h]	s [m]	Eff [%]
Step 1:	3.00	3.36	53.2
Step 2:	6.10	6.82	52.6
Step 3:	9.00	9.63	52.0
Step 4:	12.1	13.6	51.3

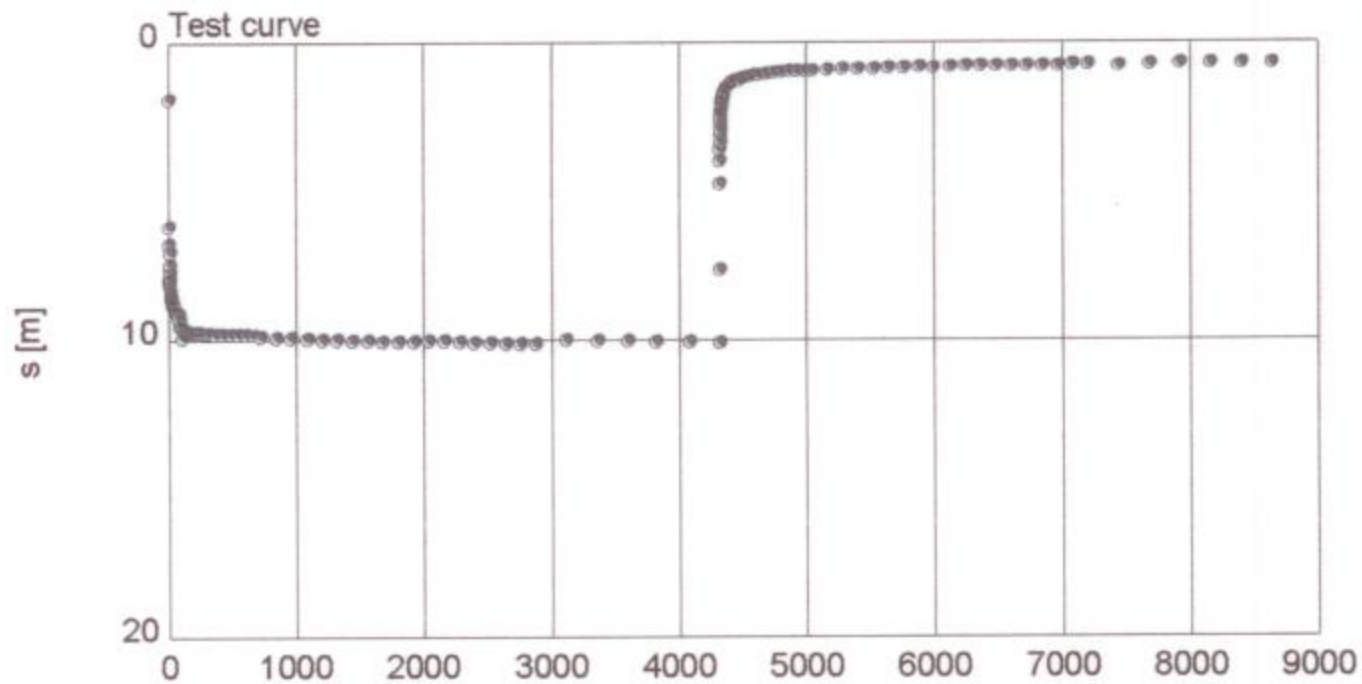|	
Linear skin factor:	4.58 [-]
Non-linear skin factor:	0.83 [d/m³]
Effective well radius:	1.0E-3 [m]

Groundwater Study in the Stampriet Artesian Basin
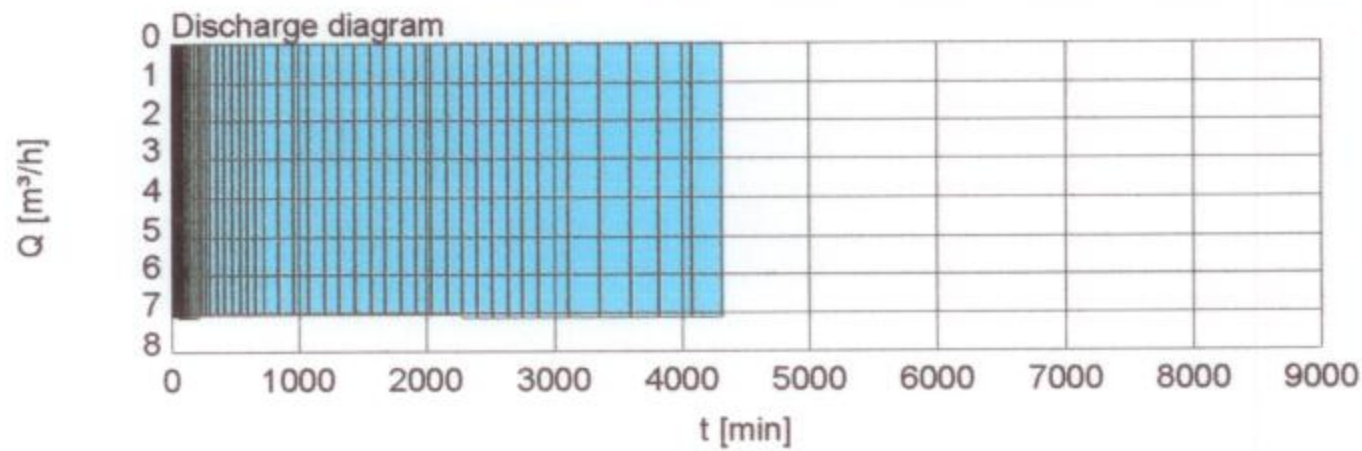
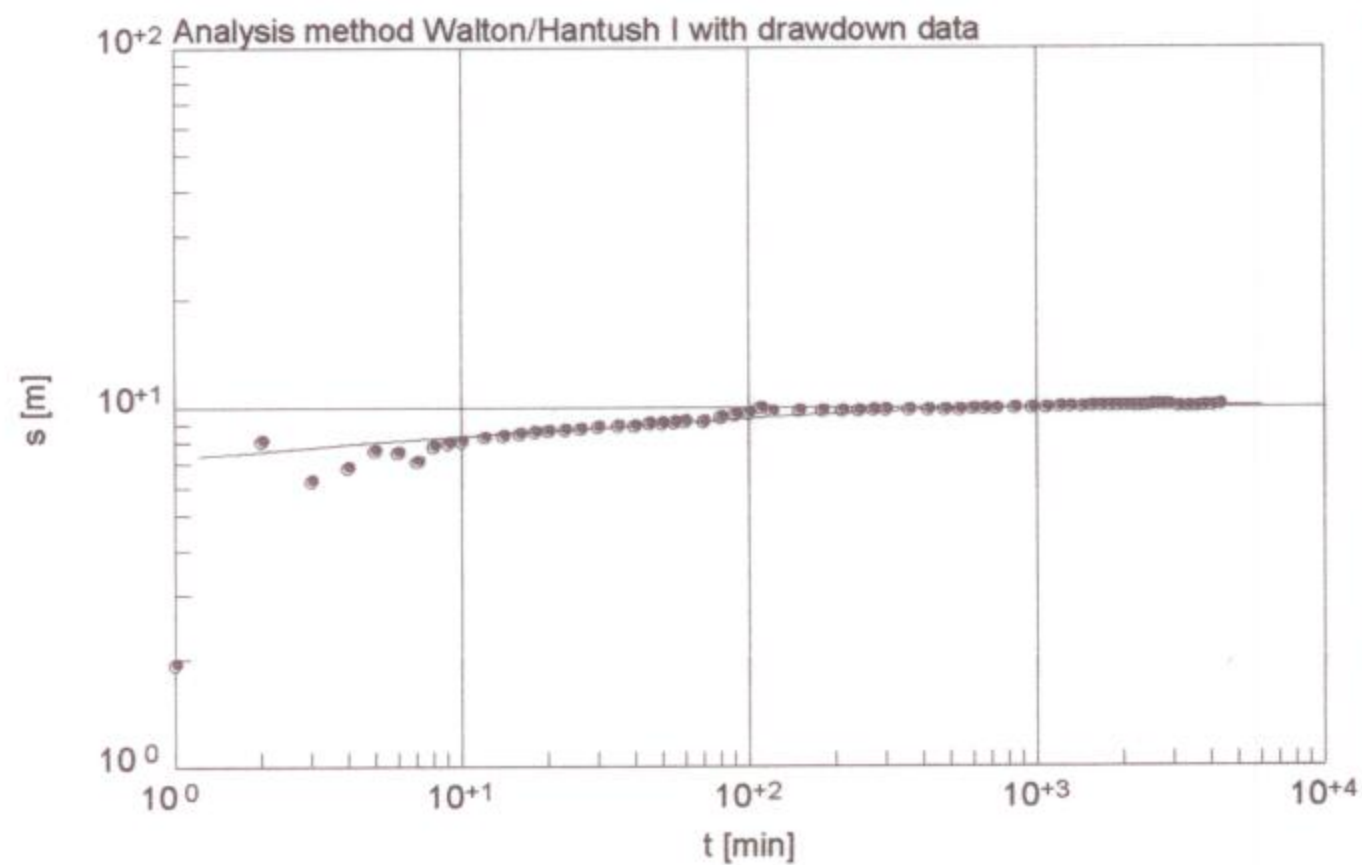## Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J7_K

Test curve

s [m] — t axis 0 to 9000

Borehole, well & aquifer

Drilled:	21.07.2000
Latitude:	25.29149
Longitude:	18.41784
Elevation:	1150 [m]
Depth:	55 [m]
Stick up:	0.70 [m]
Bh. radius:	0.1555 [m]
Casing radius:	0.084 [m]
RWL:	10.04 [m]
max.drawdown:	10.14 [m]
Aq.type:	confined
Aq.thickness:	30.00 [m]
Stratigraphy:	Kalahari
Lithology:	sandstone

Discharge diagram

Q [m³/h] — t [min]

Test running

Start:22/08/2000 07:01:00	
Dis.dur.:	4320 [min]
Av.dis.:	7.11 [m³/h]
Max.dis.:	7.15 [m³/h]
Min.dis.:	7.07 [m³/h]
Total dis.:	512 [m³]
Crew:	Metzger_PM
Supervisor:	PCI

Analysis method Walton/Hantush I with drawdown data

s [m] — t [min]

Results

Match parameter:

Q:	7.11 [m³/h]
t:	302 [min]
s:	9.87 [m]
1/u:	5.03E9 [-]
W(u,r/B):	21.7 [-]

Aquifer parameter:

T:	29.9 [m²/d]
k:	0.997 [m/d]

Boundary parameter:

B:	1E4 [m]
m´:	20 [m]
k´:	5.98E-6 [m/d]

Date 04/09/00   prepared by BIWAC   Annex 2

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J7_K

Test curve

s [m] — vertical axis (0, 10, 20)
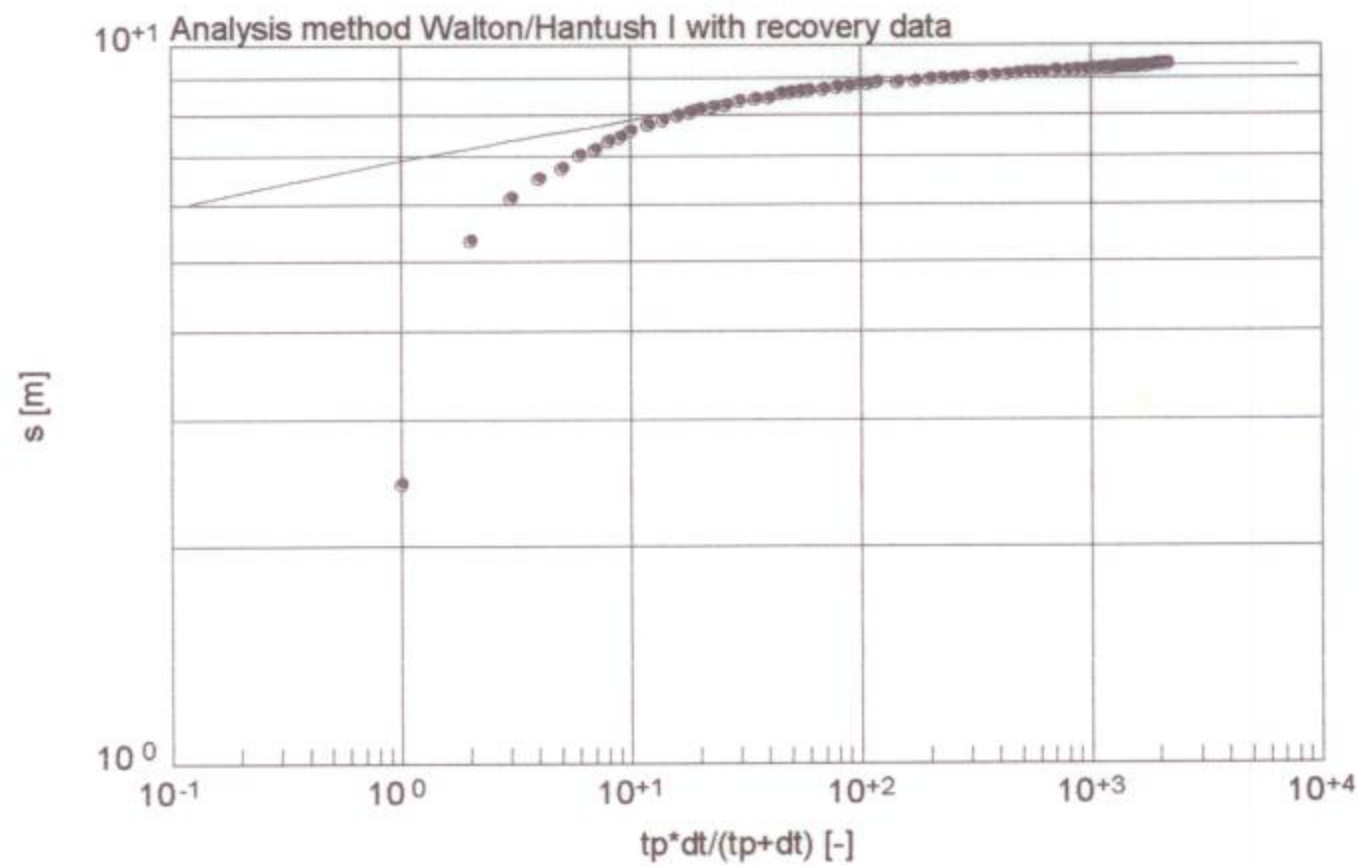t-axis (0, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000)

Borehole, well & aquifer	
Drilled:	21.07.2000
Latitude:	25.29149
Longitude:	18.41784
Elevation:	1150 [m]
Depth:	55 [m]
Stick up:	0.70 [m]
Bh. radius:	0.1555 [m]
Casing radius:	0.084 [m]
RWL:	10.04 [m]
max.drawdown:	10.14 [m]
Aq.type:	confined
Aq.thickness:	30.00 [m]
Stratigraphy:	Kalahari
Lithology:	sandstone

Discharge diagram

Q [m³/h] — vertical axis (0–8)
t [min] axis (0, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000)

Test running	
Start:22/08/2000 07:01:00	
Dis.dur.:	4320 [min]
Av.dis.:	7.11 [m³/h]
Max.dis.:	7.15 [m³/h]
Min.dis.:	7.07 [m³/h]
Total dis.:	512 [m³]
Crew:	Metzger_PM
Supervisor:	PCI

Analysis method Walton/Hantush I with recovery data

s [m] — vertical axis (10^{+1} to 10^0)
$tp*dt/(tp+dt)$ [-] axis (10^{-1}, 10^0, 10^{+1}, 10^{+2}, 10^{+3}, 10^{+4})

Results	
Match parameter:	
Q:	7.11 [m³/h]
t:	262 [min]
s:	8.88 [m]
1/u:	6.58E9 [-]
W(u,r/B):	21.2 [-]
Aquifer parameter:	
T:	32.4 [m²/d]
k:	1.08 [m/d]
Boundary parameter: [1]	
B:	1E4 [m]
m´:	20 [m]
k´:	6.47E-6 [m/d]

Date 04/09/00   prepared by BIWAC   Annex 3

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping analysis

Observation well J7Huis

Test curve
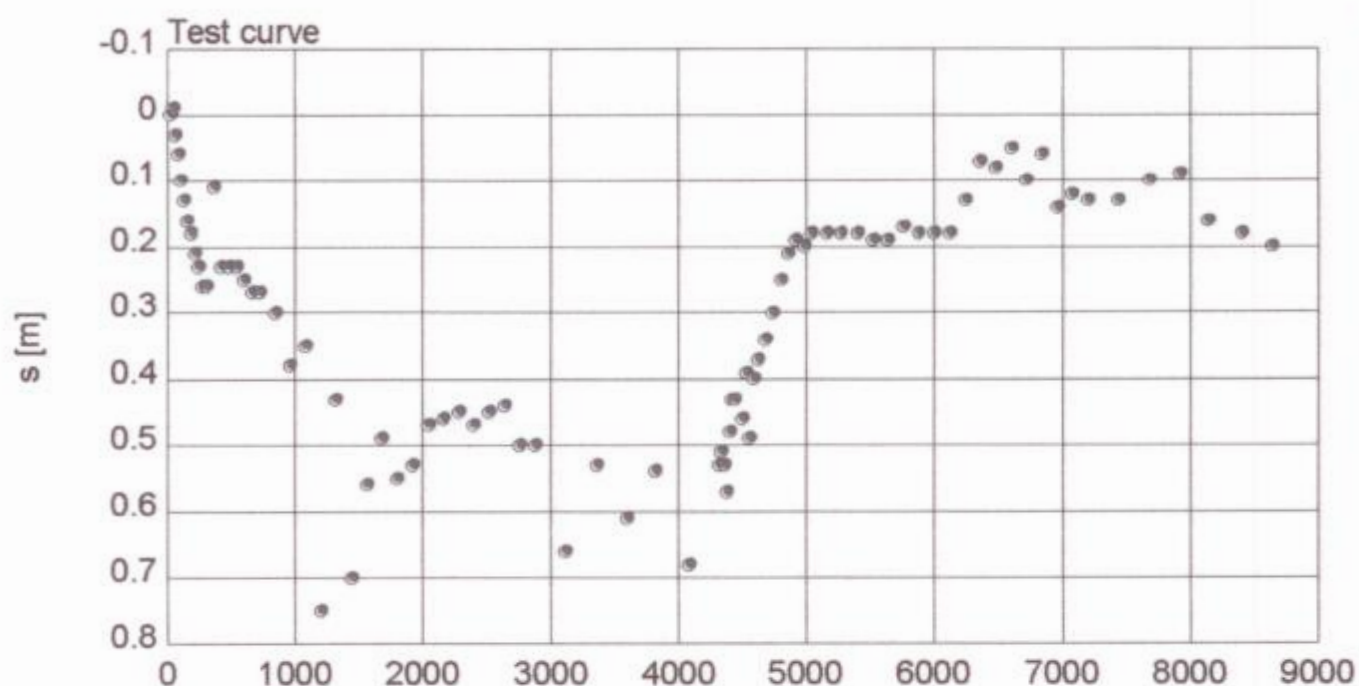
Borehole, well & aquifer

Drilled:	22.07.2000
Latitude:	25.46148
Longitude:	19.43324
Elevation:	1150 [m]
Depth:	346 [m]
Stick up:	0.48 [m]
Well distance:	230.00 [m]
RWL:	10.77 [m]
max.drawdown:	10.14 [m]
Aq.type:	confined
Aq.thickness:	-75.00 [m]
Stratigraphy:	Kalahari
Lithology:	sandstone
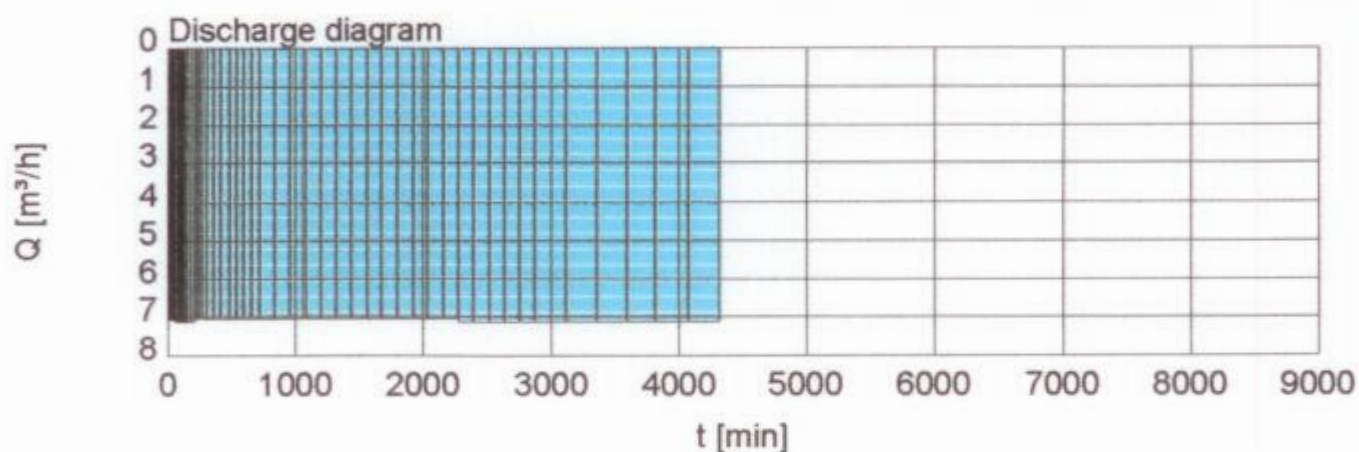
Discharge diagram

Test running

Start:22/08/2000 07:01:00	
Dis.dur.:	4320 [min]
Av.dis.:	7.11 [m³/h]
Max.dis.:	7.15 [m³/h]
Min.dis.:	7.07 [m³/h]
Total dis.:	512 [m³]
Crew:	Metzger_PM
Supervisor:	PCI

Analysis method Walton/Hantush I with drawdown data
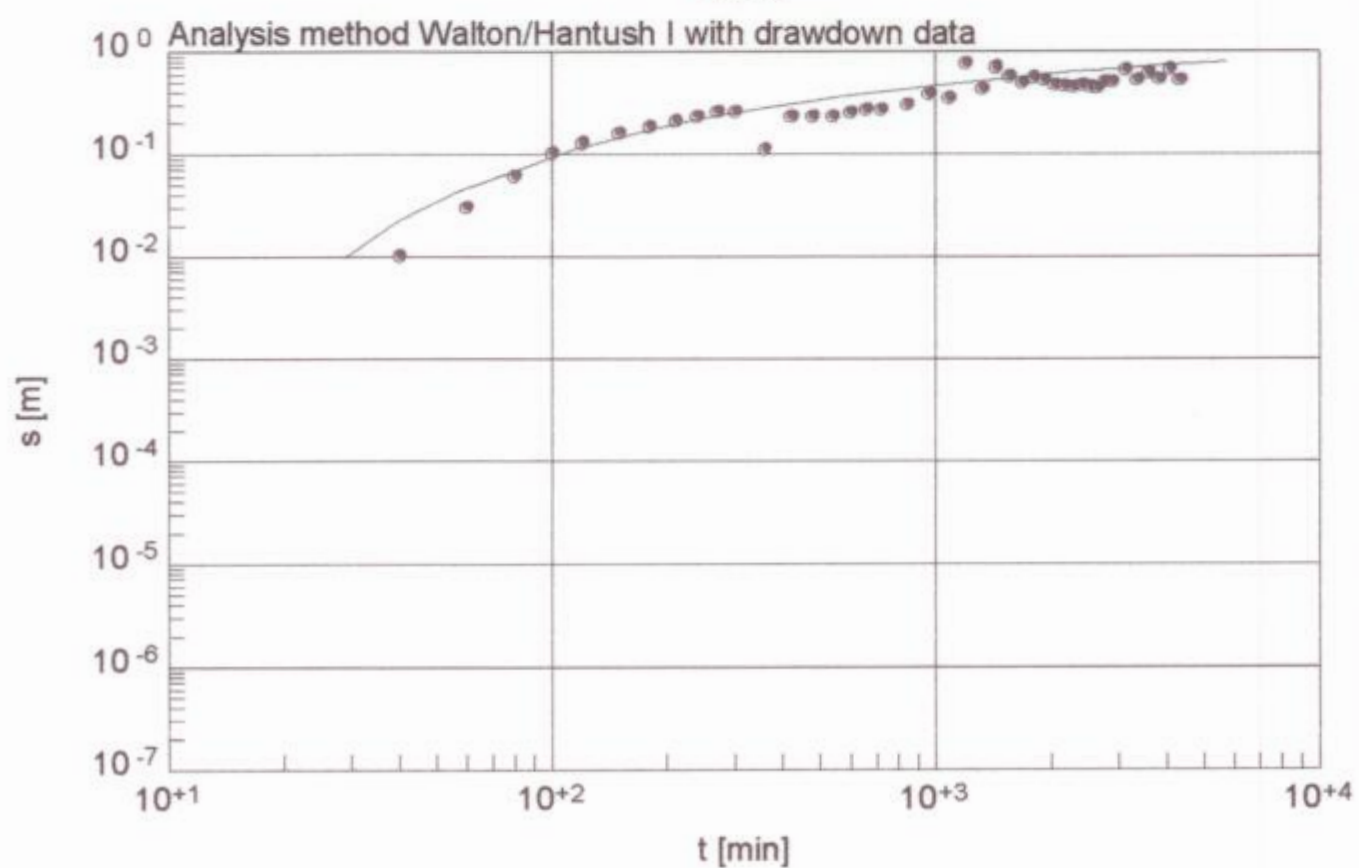
Results

Match parameter:

Q:	7.11 [m³/h]
t:	196 [min]
s:	0.166 [m]
1/u:	3.42 [-]
W(u,r/B):	0.832 [-]

Aquifer parameter:

T:	68 [m²/d]
S:	0.0002 [-]

Boundary parameter:

B:	1E4 [m]
m´:	20 [m]
k´:	1.36E-5 [m/d]

Groundwater Study in the Stampriet Artesian Basin

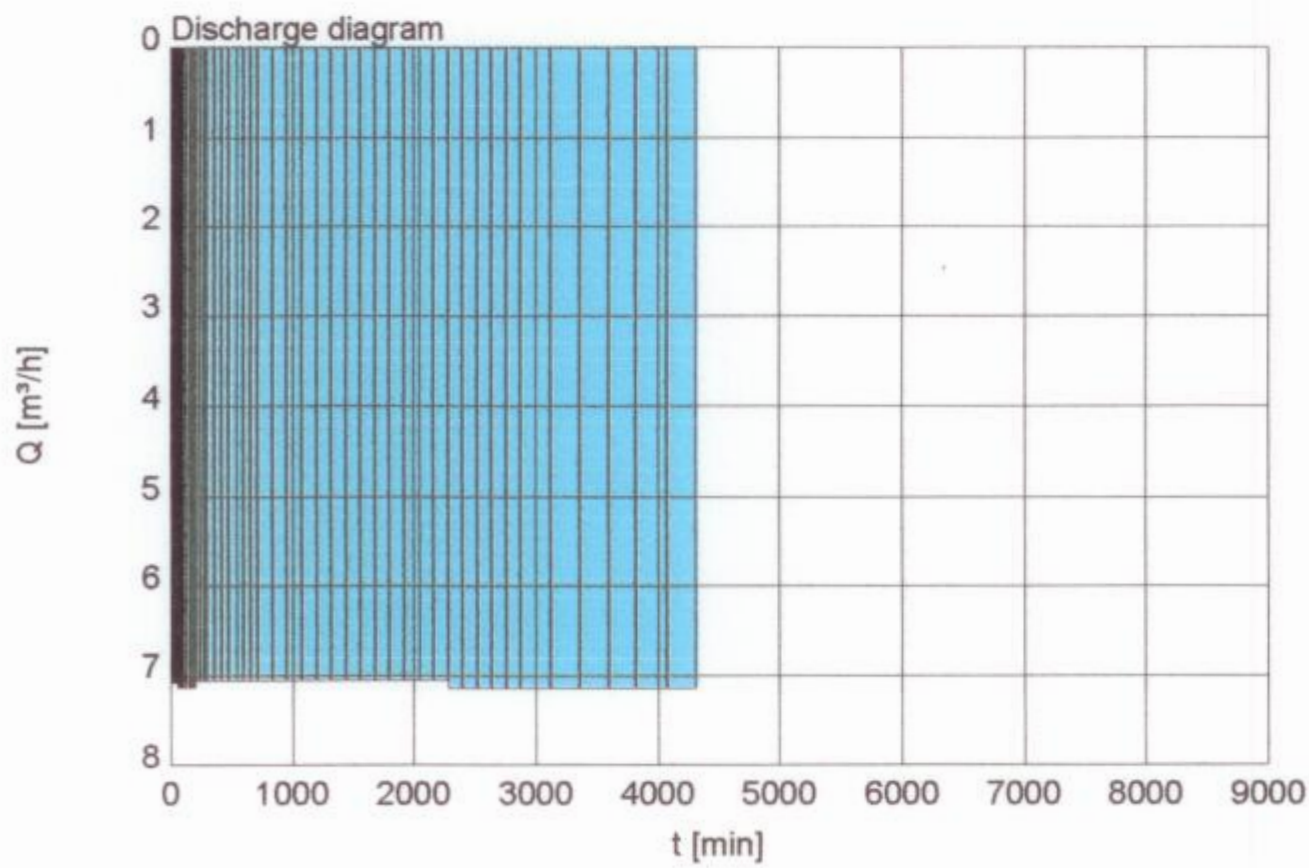## Evaluation of Test Pumping Data

Test pumping diagnosis

Pumped well J7_K

Test curve
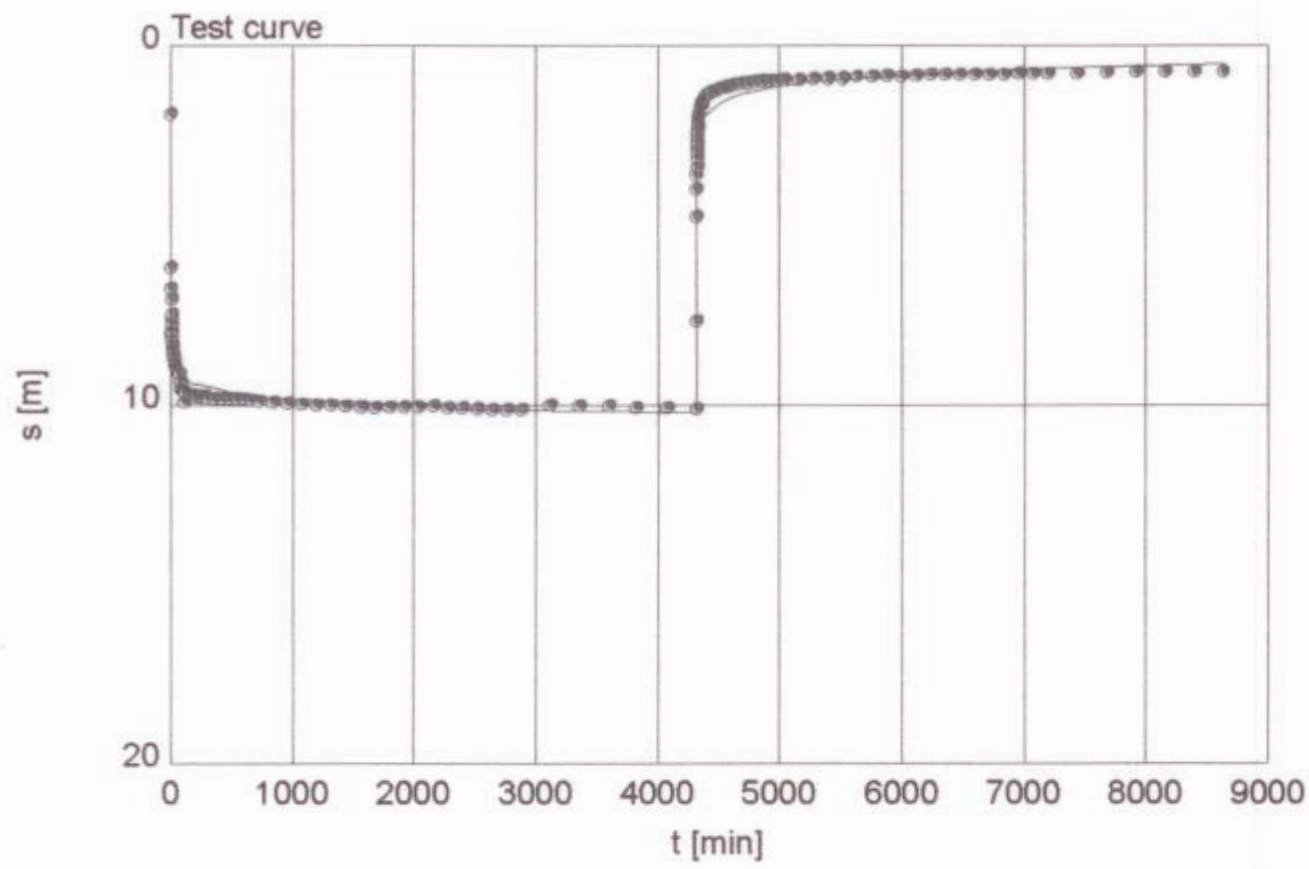
Remarks

Simulation of the actual draw down during the constant discharge test using the Walton/Hantush I model for leaky aquifers

Discharge diagram

Discharge info

Dis.dur.: 4320 [min]
tcorr: 4283 [min]

Av.dis.: 7.11 [m³/h]
max.dis.: 7.15 [m³/h]
min.dis.: 7.07 [m³/h]
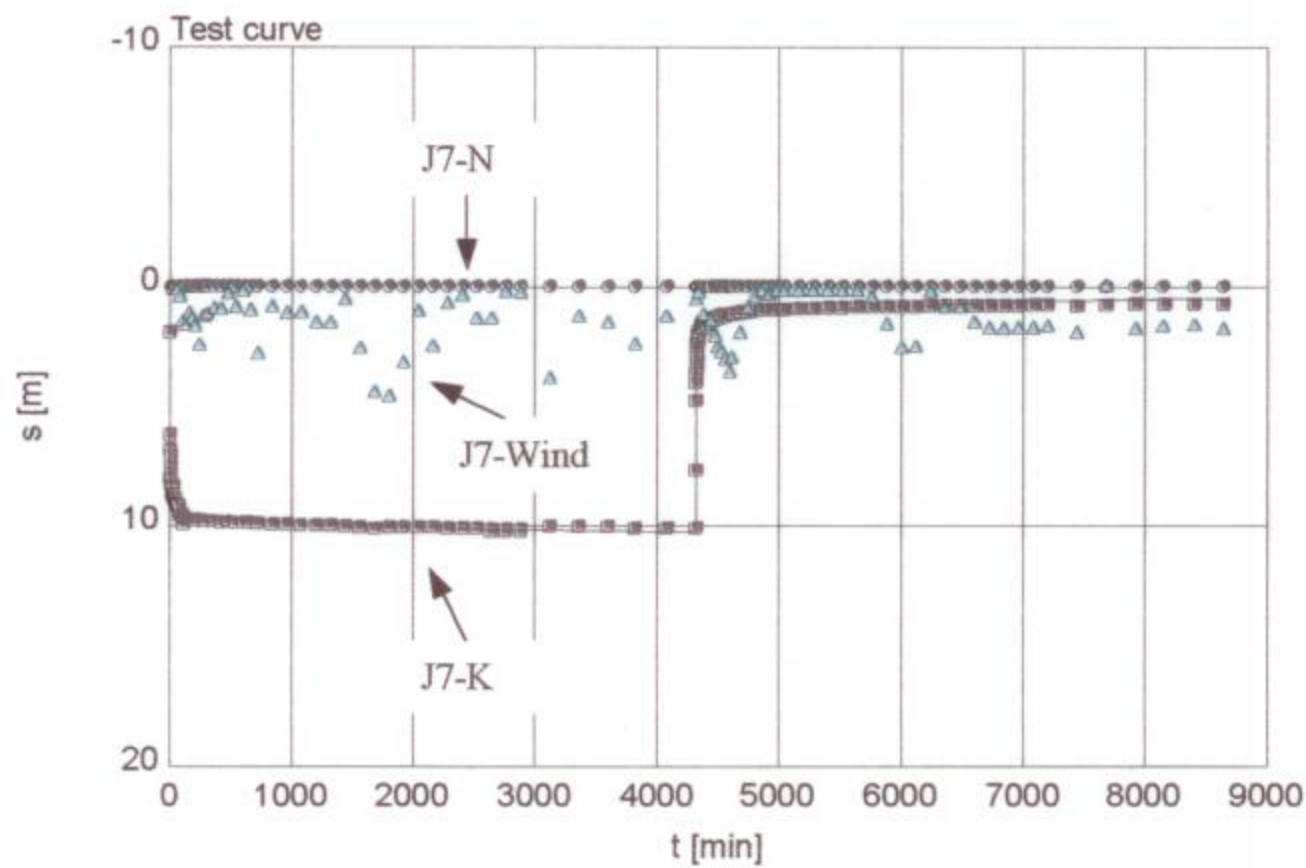Qn: 7.15 [m³/h]

Dis.sum: 512 [m³]

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping diagnosis

Pumped well J7_K

Test curve

Axis labels: s [m] (vertical, from -10 to 20), t [min] (horizontal, 0 to 9000)

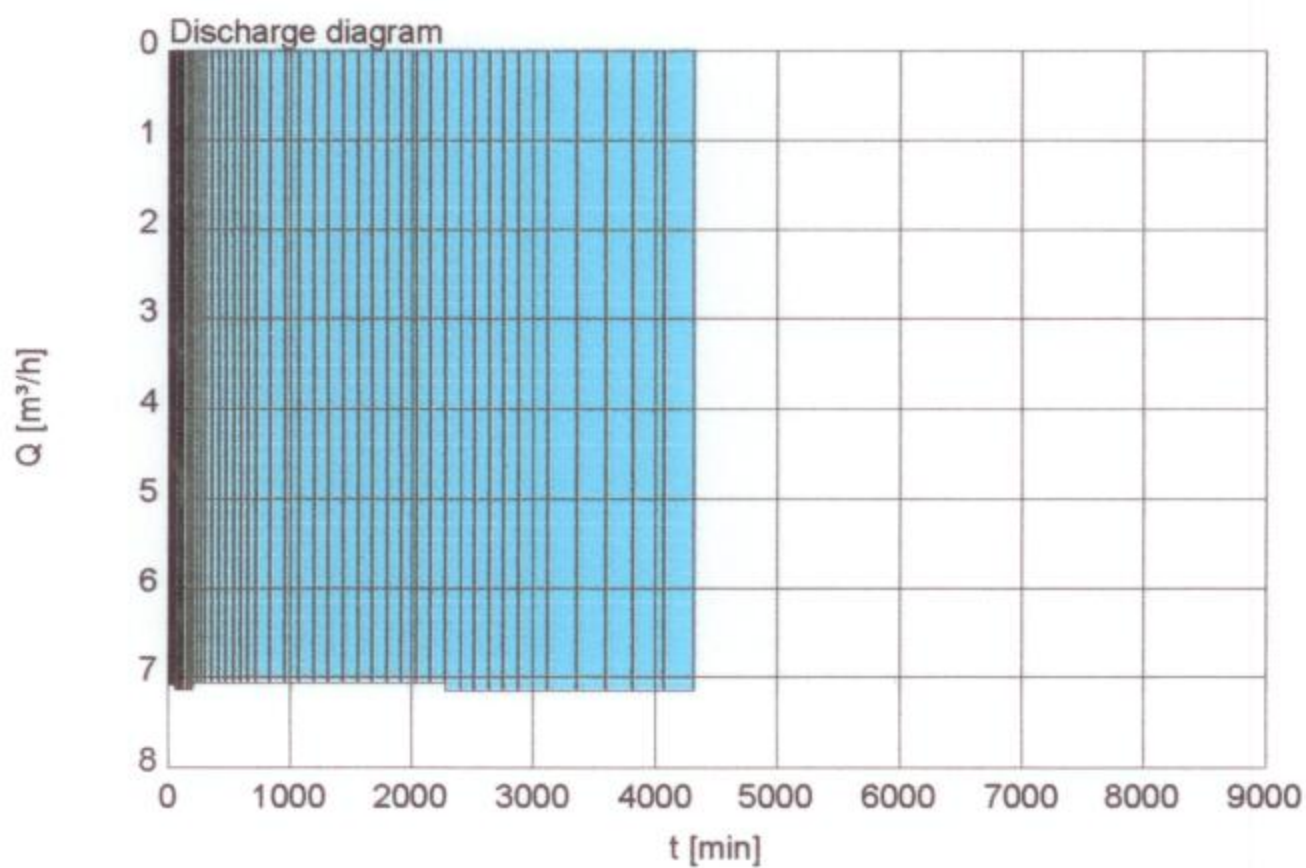Curves labeled: J7-N, J7-Wind, J7-K

Remarks

Merged data of J7_K and observation boreholes J7_N (56.2 m distance) and J7_Wind (320 m distance).

J7_Wind is installed with a wind pump and was pumped during the test.

J7_N was not influenced by the pumping from J7_K.

Discharge diagram

Axis labels: Q [m³/h] (vertical, 0 to 8), t [min] (horizontal, 0 to 9000)

Discharge info

Dis.dur.:4320 [min]
tcorr: 4283 [min]

Av.dis.: 7.11 [m³/h]
max.dis.:7.15 [m³/h]
min.dis.:7.07 [m³/h]
Qn: 7.15 [m³/h]

Dis.sum: 512 [m³]

Distance of observation boreholes: JK-N = 56.2 m;   Jk-Wind = 320 m

Date 04/09/00   prepared by BIWAC

Annex 5.1

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping diagnosis
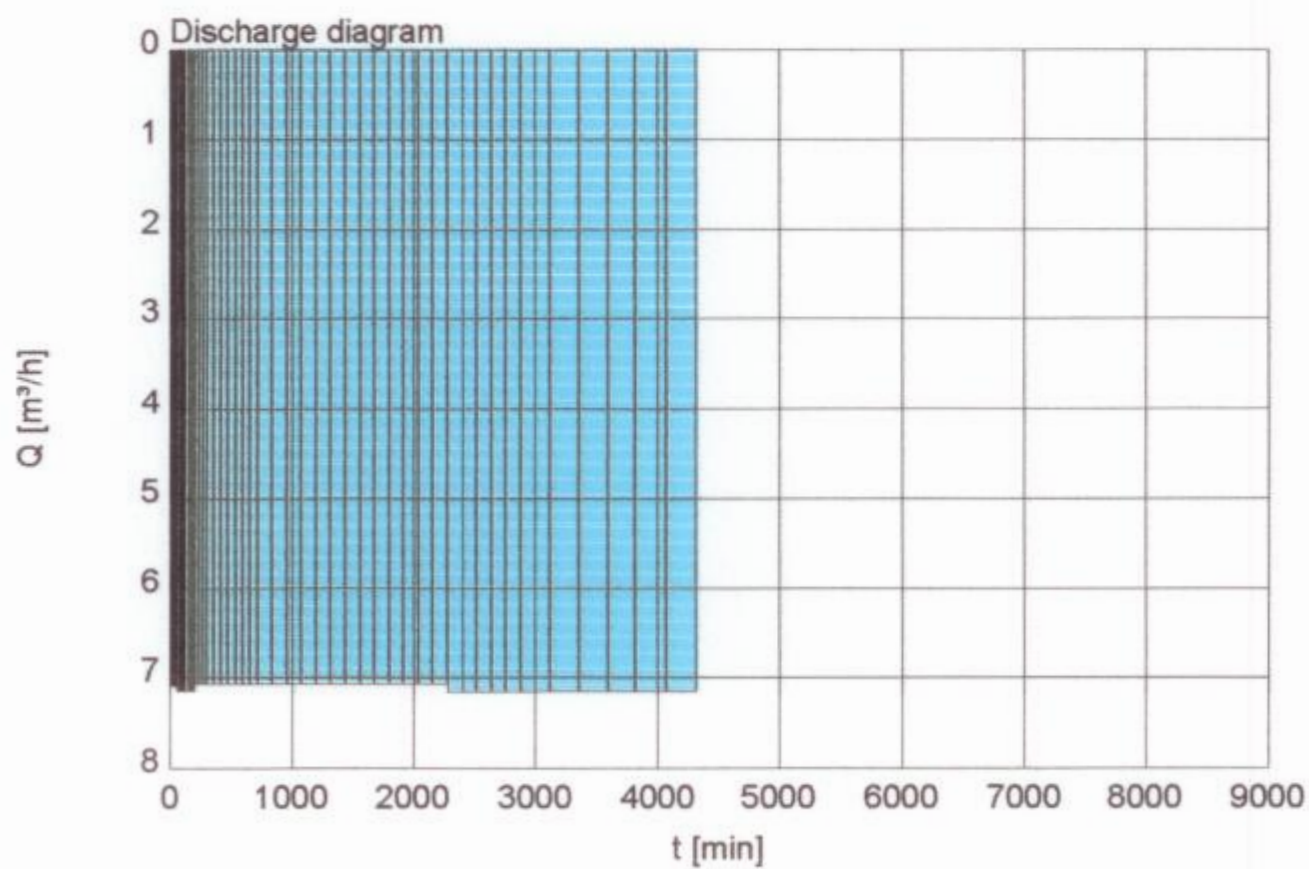
Pumped well J7_K

Test curve
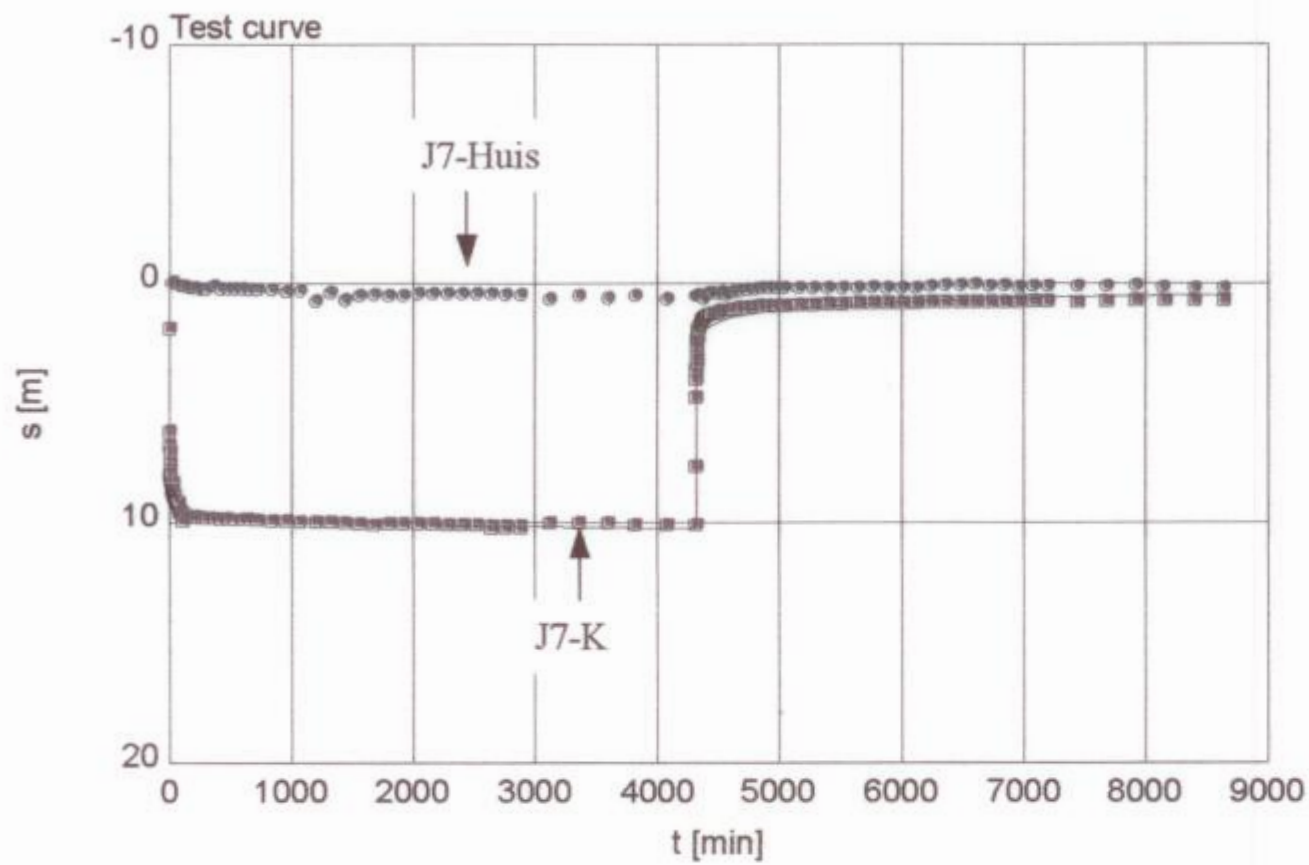
Remarks

Merged data of J7_K and observation borehole J7_Huis (230 m distance).

J7_Huis penetrates the same aquifer as J7_K and the water level was influenced by the abstraction.

Transmissivity and storativity values were calculated from the J7_Huis data (See Annex 3.1).

Discharge diagram

Discharge info

Dis.dur.:4320 [min]
tcorr: 4283 [min]

Av.dis.: 7.11 [m³/h]
max.dis.:7.15 [m³/h]
min.dis.:7.07 [m³/h]
Qn: 7.15 [m³/h]

Dis.sum: 512 [m³]

Distance of observation borehole: JK-Huis = 230 m

Date 04/09/00   prepared by BIWAC   Annex 5.2

7. Water Level Recorder Installation

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

<u>INSTALLATION OF SEBA FLOATERS</u>

JICA REFERENCE: J 7 K   LOCALITY: Jakkalsdraai R 228

WW 39852

1. **Serial Number of floater**:   4542
2. **Date installed**:   5/10/00
3. **Rest Water Level when installed**:   11.10 mbsu
4. **Distance from stick-up to logger**:   6.0 m
5. **Distance from logger to water level**:   5.10 m
6. **Cut off**:   6.0 m (0.91 + 5.110