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

BOREHOLE FINAL REPORT

Borehole

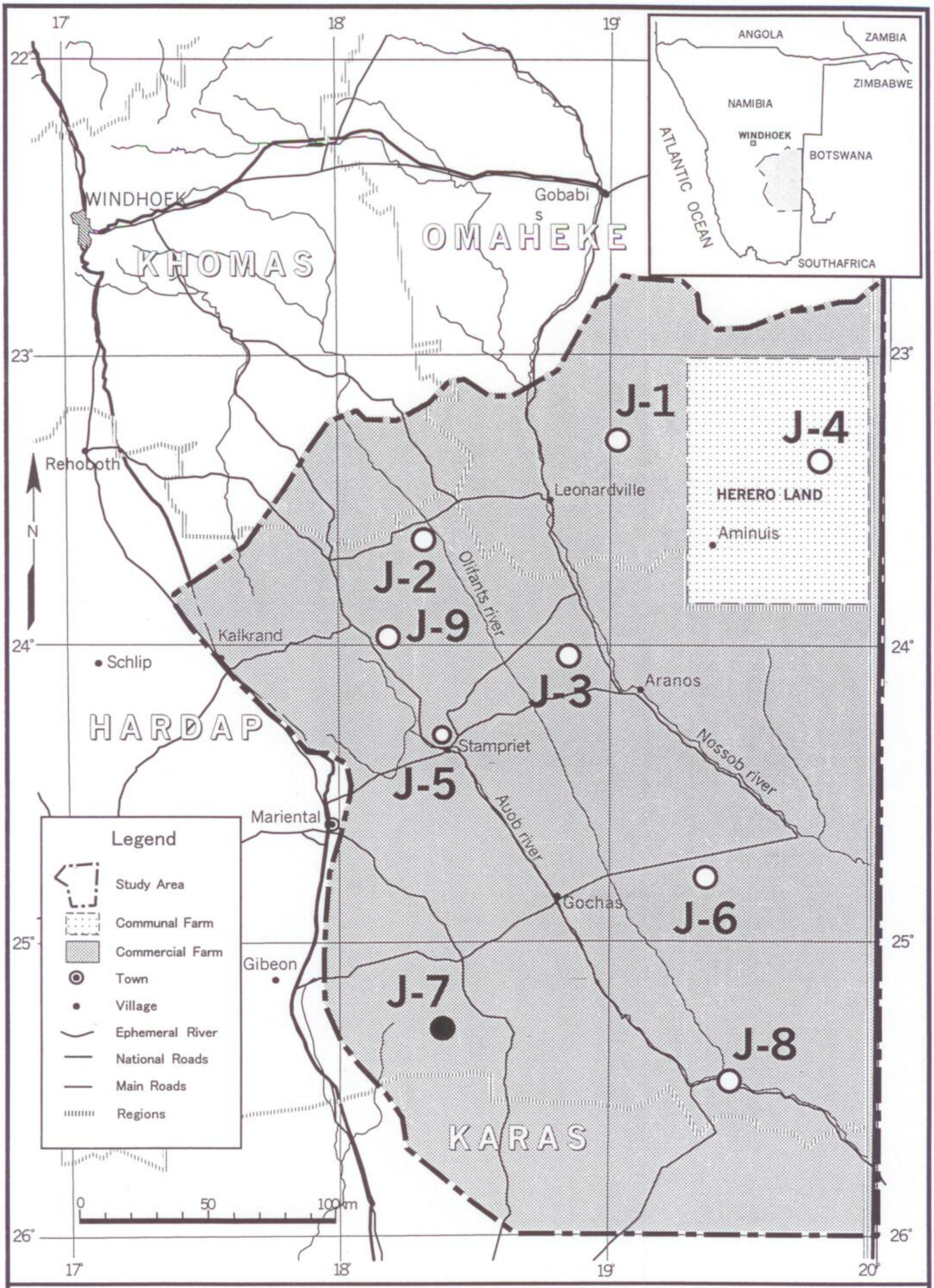
J7-N (WW 39853)

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

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1. Geological Borehole Log

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

GEOLOGICAL BOREHOLE LOG

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

WW 39853
S 25, 29107 °
E 18, 41756 °
Collar elev.: 1144 mamsl

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 – 7	7	Light brownish grey **calcrete**, slightly karsted near surface.	**KALAHARI**
7 – 14	7	Calcretized gravel and conglomerate. **Calcrete** matrix white to light grey.	
14 - 26	12	Pale reddish brown **calcretized sand** with horizons of gravelly calcretized conglomerate.	
26 - 27	1	Pinkish massive **calcrete**.	
27 – 29	2	Pinkish unsorted **sandstone** with scattered quartz granules. Calcareous & porous. **Aquifer**.	
29 – 32	3	Pale grey to pale brownish **conglomerate** cemented with **calcrete**.	
32 -34	2	Poorly sorted, partially consolidated **conglomerate** in a grey sandstone-matrix. Granules and pebbles well rounded. Porous. Aquifer.	
34 - 44	10	Unsorted, non-calcareous sandstone, to moderately calcareous in places, slightly porous with silcretes horizons. Pale reddish brown.	
44 - 49	5	**Conglomerate** in a pinkish calcrete matrix.	
49 - 53	4	Pale yellowish fine to medium grained micaceous **sandstone** (muscovite & biotite) laminated.	**RIETMOND**
53 - 57		Pale yellowish fine to medium grained laminated micaceous **sandstone**, interbedded with pale yellowish orange **shale**. **Aquitard**. Fe oxidation on laminae.	
57 - 62	5	Pale yellowish brown well sorted medium grained non-calcareous **sandstone**. Quartz grains subrounded.	
62 - 65	3	Moderately calcareous, porous medium grained pale yellowish brown **sandstone**. Minor muscovite.	
65 – 68.5	3.5	Moderately calcareous calcareous, porous medium grained pale yellowish brown **sandstone**, interbedded with brownish grey sandstone.	
68.5 - 75	6.5	Fine to medium grained light grey **sandstone**. Grains well rounded. Moderately porous. Scattered dark grey shaly clasts.	**AUOB A 5**
75 - 81	6	Laminated grey fine-grained **sandstone**. Biotite on laminations, increasing with depth.	
81 - 89	8	Grey laminated **siltstone**. Abundant biotite on laminae.	
89 - 93	4	Dark grey micaceous **shale** with minor siltstone horizons. Jointing with calcite veins.	

93 - 99	6	Grey laminated **siltstone/shale** with minor biotite.	**AUOB A 4**
99 - 109	10	Inter-layered **sandstone - siltstone - shale**. Shale grey to dark grey.	
109 - 127	18	**Shale**, light grey turning to grey and dark grey with increasing depth.	
127 - 133	6	White to very pale grey coarse well sorted **sandstone**, porous. Quartz grains sub-rounded. Moderately calcareous at 131 – 133 m. Aquifer.	**AUOB A 3**
133 - 138	5	Grey to pale grey medium grained **sandstone** with scattered shale clasts. Moderately porous. Aquifer.	
138 – 154,5	16,5	Pale grey fine grained laminated micaceous **sandstone** with poor porosity.	
154,5 – 160,5	6	Grey to dark grey micaceous (biotite) fine to very fine **sandstone**. Very thin dark grey shale at 154,5.	**AUOB A 1**
160,5 - 166	5,5	Grey **sandstone**, fine grained with black / dark grey clasts of coal (?). Muscovite associated with coal.	
166 - 175	9	Laminated grey **siltstone / shale**.	**UPPER MUKOROB**
175 - 228	53	Grey to dark grey **shale**. Bituminous at 204 – 209 m. Dropstones at 216 m.	**LOWER MUKOROB**
228 - 234.5	6,5	Fine grained well sorted light grey **sandstone**. Slightly porous. Friable. Sandstone is very fine grained at 234 m. Aquifer.	**NOSSOB**
234.5 - 236	1,5	Laminated very fine light grey sandstone and dark grey **shale**: laminations very thin.	
236 – 238.5	2,5	Light grey very fine **sandstone** or siltstone.	
238.5 - 245	6,5	Sandy shale and **shale**.	
245 - 247	2	**Shale**, dark grey.	**DWYKA**
247 - 249	2	**Shale** and mudstone with sandy shale with prominent **drop-stones**. Grey to dark grey.	
249 – 250 EOH	1	Dark grey **shale**.	

Remarks:

1. This borehole was drilled by air-rotary method and mud-rotary only after grouting.
2. Only the Nossob horizons are screened.

This borehole was logged by F. Bockmuhl.

2. Penetration Record

	Penetration Record Borehole J 7 N WW 39853			
Depth (m)	Pen. Rate (min/m)	Time	Date	Remarks
			28/7/00	Drilling air rotary
1				Water used for drilling 1400 micro S/cm
5				
	1.35			
	1.1			
	1.5			
10	2.3			
	1.5			
	1.45			
	1.45			
	1.45			
	1.66			
	2.2			
	2.25			
	2.3			
	2.85			
20	1.4			
	1.75			
	2.8			
	3.1			
	2.15			
	2.55			
	2.05			
	2.3			Water strike
	1.1			
	1.95			
30	1.35			
	3.85			
	3.9			
	1.85			
	1.35			
	3.8			
	3.1			
	2.25			
	2.95			
	1.8			
40	2.1			
	2.2			
	2.2			
	1.8			
	1.45			
	1.7			
	2.75			
	2.4			
	3.55			
	2.6			
50	4.7			
	4.75			
	1.85			

	3.1			
	2.45			
	2.35			
	2.8			
	1.95			
	2.35			
	2.95			
60	4.45			
	3.3			
	2.55			Water sample: 1165 micro S/cm; 24.3 C
	6.2			
	2.25			
	2.95			
	2.95			
	3.95			
		16:18		1125 micro S/cm
	3.85			
70	3.6			
	3			
	3.55			
	3.45			
	2.75			
	4.05			
	2.3			
	2.5			formation change
	7.3			
80	2.95			
	3.05			
	3.7			
	1.6			
	2.3			
	2			
	2.1			
	2.05			
	2.1			
	2.1			
90	2.2			
	2.15			
	1.85			
	1.25			
	1.95			
	2.35			
	2.05			
	2.2			
	1.95			
	2.8			
100	2.65			
	2.7			End of 311 mm drilling.
	6.45	13:15	30/07/00	Start 254 mm drilling.Mud rotary
	5.6			Water used for drilling 1592 micro S/cm
	7.75			
	6.7	13:44		7.28 mS/cm
	6.6			
	5.1			
	4.7	14:04		7.03 mS/cm

	4.5			
110	4.2			
	3.45			
	5.75	14:24		5.88 mS/cm add Eeze Mix 10 l
	5.9			
	6.35			5.17 mS/cm add 5 l Eeze Mix
	6.8			
	6.8	14:51		5.1 mS/cm
	7.15			
	7	15:11	30/07/00	4.63 mS/cm
	7.15			
120	6.1			4.2 mS/cm
	66.6			
	3.5	08:08	31/07/00	Drilling with drag bit mud rotary
	3.4			
	3.2			
	2.45			
	2.5			1895 microS/cm 22.7 C
	2.7			
	8.2			1559 microS/cm 22.7 C add Ezee Mix
	16.15	08:42		Stop drilling with drag bit mud rotary
130	1.75	11:02	1/08/00	Drilling with tri-cone air rotary
	2.1			
	2.7			
	2.35			
	3.95			
	1.55			
	2.1			
	1.75			
	2.7			
	3.15			
140	3.2			
	3			
	3.3			
	3.55			
	3.15			Water strike ?
	2.9			
	2.55			
	2.35			
	2.1			
	3.25			
150	2.7			
	3.15			
	2.85			
	2.45			
	2.3			
	2.2			
	2.6			
	2.75			
	3			
	2.95			
160	1.9			
	3.45			
	3.35			
	3	13:37	1/8/00	Collect water sample for DWA & C-14
	3.4			

	3.35			
	3.15			
	2.5			
	5.5			
	6.6			
170	8.75			
	6.15			
	5.65			
	4.95			
	5.25			
	5.7			
	4.75			
	5.35			
	5.4			
	4.8			
180	5.25			
	5.5			
	8.5			
	5.6			
	3.25			
	3.3			
	3.75			
	4.1			
	3.4			
	3.25			
190	3.4			
	3.7			
	3.4			
	4.15			
	2.8			
	3.55			
	4.25			
	4.1			
	3.5			
	3.4			
200	3.85			
	3.6			
	3.8			
	3.8	17:30		
	6.2		3/08/00	Drilling 200 mm air rotary
	5.15			
	5.6			
	6.4			
	5.5			
	6.45			
	3.9			
	4.5			
	4.4			
	4.4			
	4			
	4			
	4.6			
	3.7			
	3.6			
	3.55			
	4.1			

	6.5			
	2.8			
	3.2			
	3.1			
	2.9			
	3.1			
	3.15			
	2.75			
	6.9			
	7.65			
	7			
	7.8			
	6.25			
	8.35			
	4.6			
	9.7			
	18.15			
	7.8			
	4.1			
	4.6			
	4.5			
	4			
	4.45			
	4.4			
	2.6			
	4.6			
	5.35			
	7.1			
	7.55			
	6.7	17:35	3/08/00	End of Borehole.

j7npen

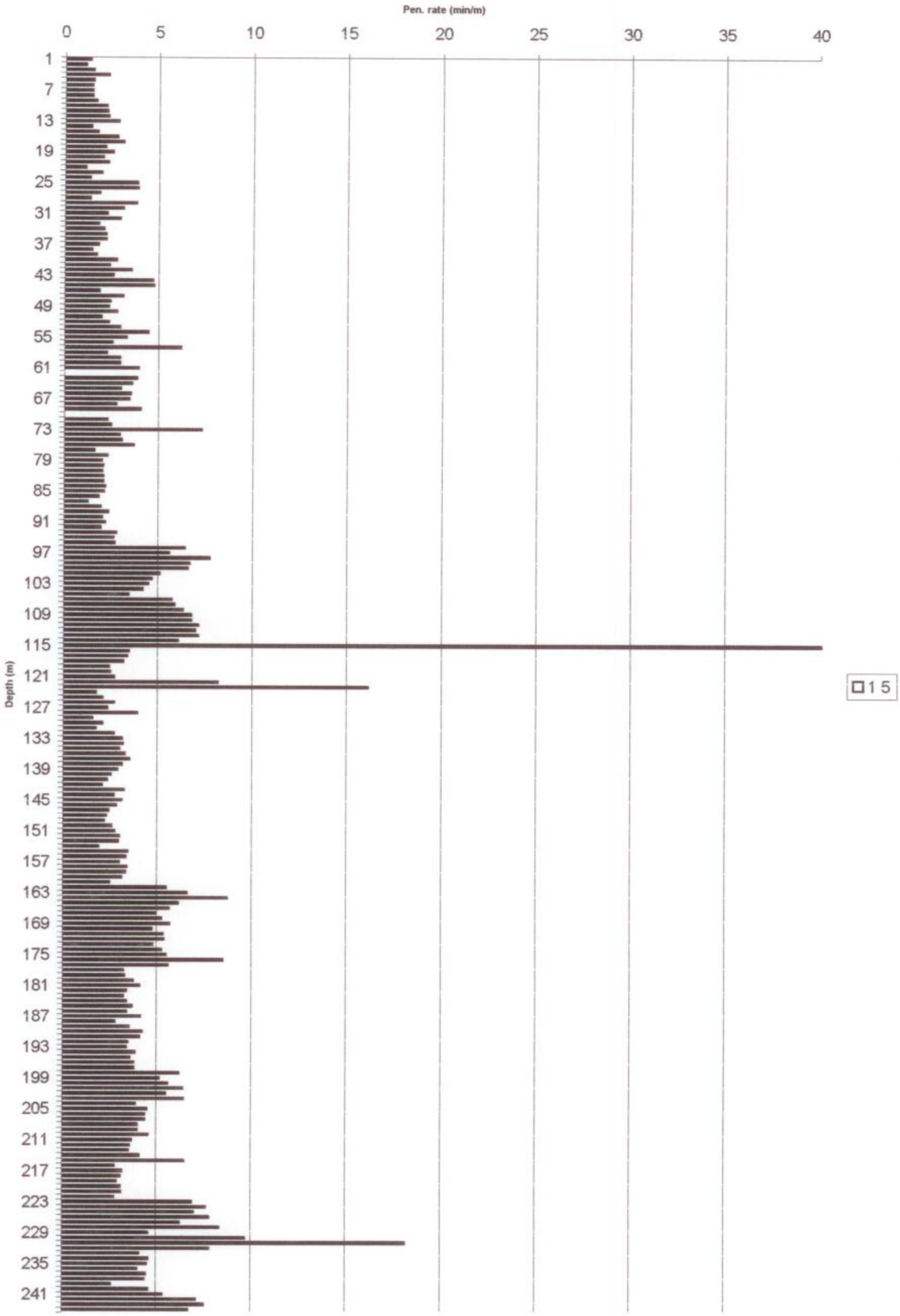


Chart2

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 N LOCALITY: Jakkalsdraai R228 WW 39853 DATE: 28/07/00 (starting)

Remark: This borehole was drilled air-rotary with only for a short distance of mud-rotary employed.

TIME	DEPTH mbgl	MARSH FUNNEL TEST 1000 ml	MARSH FUNNEL TEST 500 ml	E. C. µS/cm	DENSITY	pH	TEMPERATURE ° C	COMMENT
(28/07/00)	62			1165			24.3	Represents water in borehole
16:18	68			1125				Collected sample
	101			*1120*			*25.5*	*End of 311 mm drilling Represents conditions when logging.*
				1400			16.5	Water + foam used for drilling
13:15 (30/07/00)	101			1592	<1.16		17.7	Water used for mixing drill-fluid when drilling mud-rotary.
13:44	105			728			24.3	
14:04	108			703			24.9	
14:35	114	39	27	517			25.7	
15:11	118			420			28.5	
08:27 (31/07/00)	126			1895			22.4	
08:42	129	38	27	1559			22.7	
11:02	130							Start drilling air-rotary

TIME	DEPTH mbgl	MARSH FUNNEL TEST 1000 ml	MARSH FUNNEL TEST 500 ml	E. C. µS/cm	DENSITY	pH	TEMPERATURE ° C	COMMENT
13:37				1363			27	Water with air
17:30 (01/08/00)	*203*			*1388*			*27.7*	*Water in borehole when logging. End of 250 mm drilling.*
20:39 (03/08/00)	*250*			*535 mS/m*		*10.6*	*27.8*	*Water in borehole when logging. End of drilling.*

4. Geophysical Log and Casing Design

Poseidon Geophysics

(Reg. No. 93/650)

CO. Poseidon Geophysics
WELL J7N WW 39853
PROJ.
LCN. Jakkalsdraai
STE. J7
FILING No. J7N

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 J7N WW39853

LOCATION JAKKALSDRAAI

COUNTRY REPUBLIC OF NAMIBIA

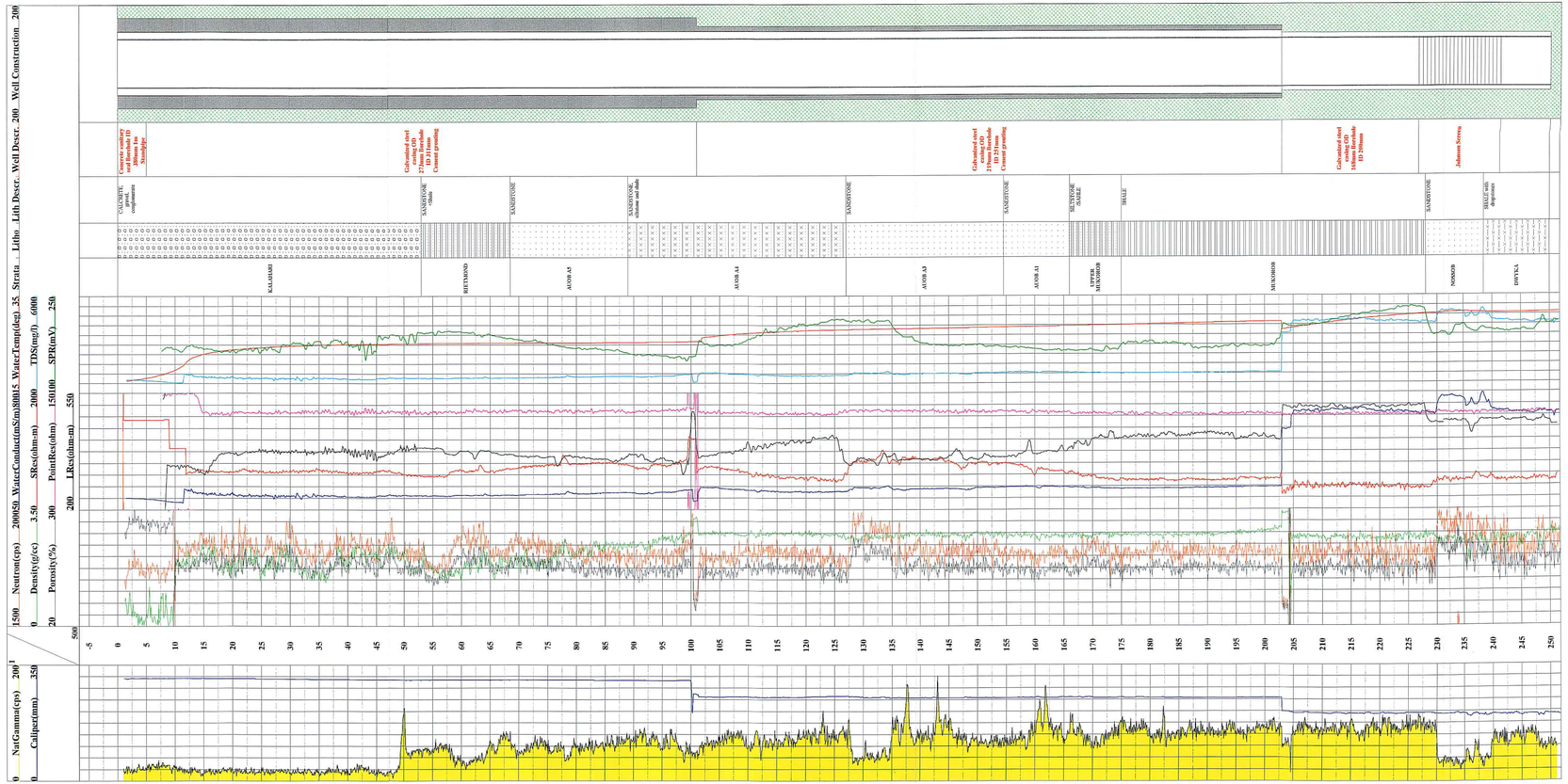
BH COORDINATES

COLLAR ELEVATION
LOG MEAS. FROM Groundlevel

DRILLING MEAS. FROM Groundlevel

DATE	4 August 2000
TYPE LOG	Physical Properties
DEPTH-DRILLER	250m
DEPTH-LOGGER	251.8m
BTM LOGGED INTERVAL	251.8m
TOP LOGGED INTERVAL	0.60m
PERMANENT DATUM	Groundlevel
RECORDED BY	Wimpie Coetzer
WITNESSED BY	Frank Bokmuhl

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 N LOCALITY: Jakkalsdraai R 228 WW 39853 DATE: 6/08/2000 (starting)

TIME (actual)	P.I.D. (mbsu)	½ 90° V-Notch (mm)	Yield (m^3/h)	E.C. (mS/m)	Water Level (mobs)	Remarks
14:00	227	80		436	27.30	Date 7/08/2000
16:00		26		627	34.27	
20:00		25			39.40	Pump through the night
07:00	227	20				Date 8/08/2000. Add 1 pipe
08:00	233	40		807	62.28	
12:00		25			66.72	
16:00		35			68.20	
19:00		25			69.36	Pump through the night.
07:00					70.55	Date 9/8/00. Add 2 pipes. Water level measured just before the start of the next airlift session.
08:00	245	25			70.36	
12:00		20			77.54	
16:00		20			82.55	
19:00		20		428	84.30	Pump through the night.
07:00						Date 10/08/2000: Development stopped.

Remarks:

1. Date 6/8/2000: 25 kg of polyphosphates (introduced into borehole already on 5/8/00) were re-circulated for a total of 11 hours by means of air lift as part of the development.
2. This low yielding borehole was also pumped by electrical submersible pump as part of the development. After 2.35 hours this was abandoned and it was decided to do a short pumping test.

6. Evaluation of Pumping Test

1. PUMPING TEST ANALYSIS

J7-N (WW39853) - Pumping well

1.1. Well Efficiency (Step draw down 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 draw down test are summarised in **Table 1** below. Only four of the two steps were utilised for the evaluation of the borehole efficiency. The third step was interrupted due to pumping problems caused by accumulation of gas in the pump. The well bore effect is dominant throughout the test and only the last 10 minutes of each 120 minutes step was used for the evaluation.

Table 1: J7-N; Borehole efficiency at various pumping rates

Borehole number	Step	Abstraction Rate [m^3/h]	Draw Down* [m]	Borehole Efficiency [%]
J7-N	1	0.3	18.1	86.6
	2	0.6	45.2	69.3

* 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 - 3)

The constant discharge draw down curve of abstraction borehole **J7-N** indicates leakage. For leaky aquifers, the Walton Hantush analysis method with draw down and recovery data was once again used to calculate the hydraulic conductivity of the aquifer and the aquitard **(Annex 2 & 3**).

Aquifer storativity was estimated due to the fact that no suitable observation boreholes was available. The constant discharge test was implemented at a rate of 0.3 m^3/h and was stopped after 9 hours, due to a draw down of 66 m. The water level was close to pump inlet depth. The water level recovered fully after three days. The recovery curve was evaluated using the Theis recovery method.

The results of the constant discharge analysis are summarised in **Table 2** below. The transmissivity of the test pumping is compared to the results of the slug test. Again, the transmissivity of the slug test is slightly higher, due to the bigger influence of the gravel pack and the disrupted formation surrounding the borehole. The evaluated very low values of T = 0.01 and 0.06 m^2/day are, however, in the same order of magnitude.

Table 2: Aquifer Parameters calculated for J7-N; Nossob sandstone

Borehole number	Analysis Method	T	s	k	S	Simulation model
		[m^2/day]	[m]	[cm/sec]	[-]	
J7-N	Theis recovery	0.01	17	6.8×10^{-7}	*8×10^{-4}	Theis
	Slug test (for comparison)	0.06	17	2.1×10^{-6}	N/A	Cooper et al

*Estimated

The Theis model for confined aquifer conditions 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 3** for simulation results).

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

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

$R = 3000 \times 66.61 \times 8.3 \times 10^{-5} = \underline{17\ m}$

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 17 m are considered to be the minimum value.

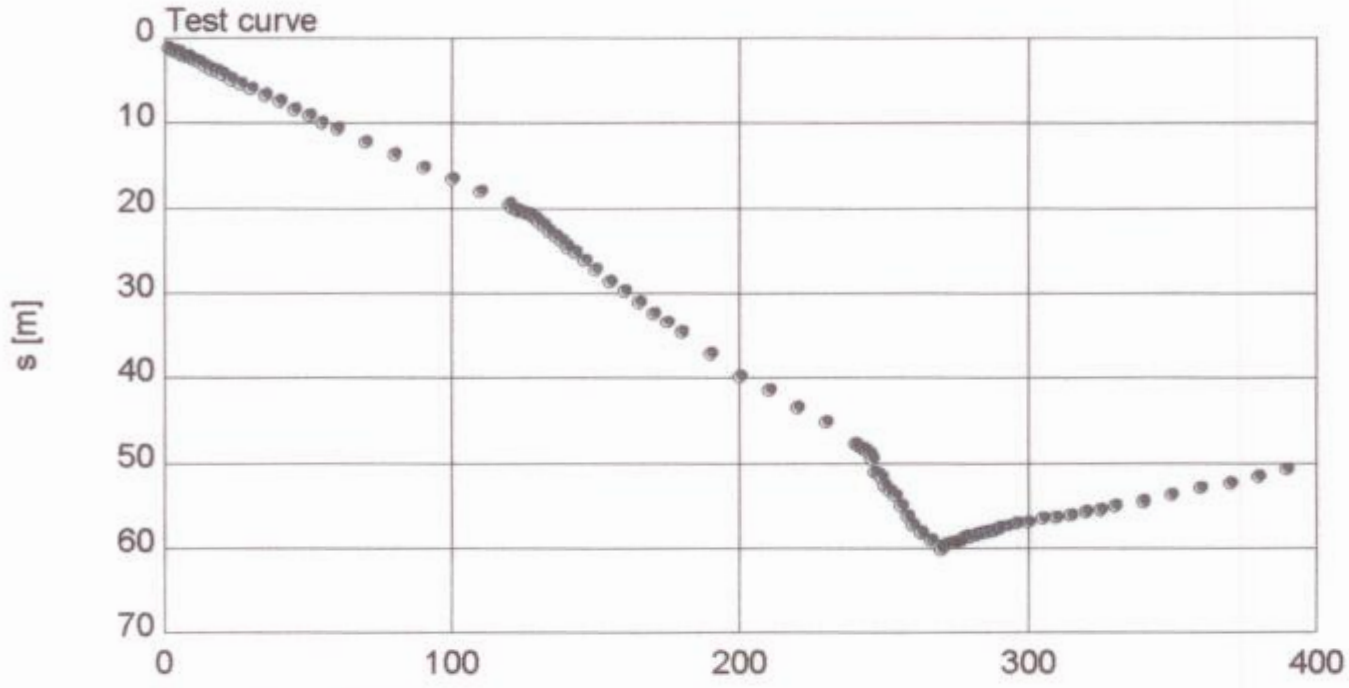
A proper evaluation of R (and storativity S) will only be possible once reliable data from observation wells, penetrating the same aquifer as the pumped well, are available.

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

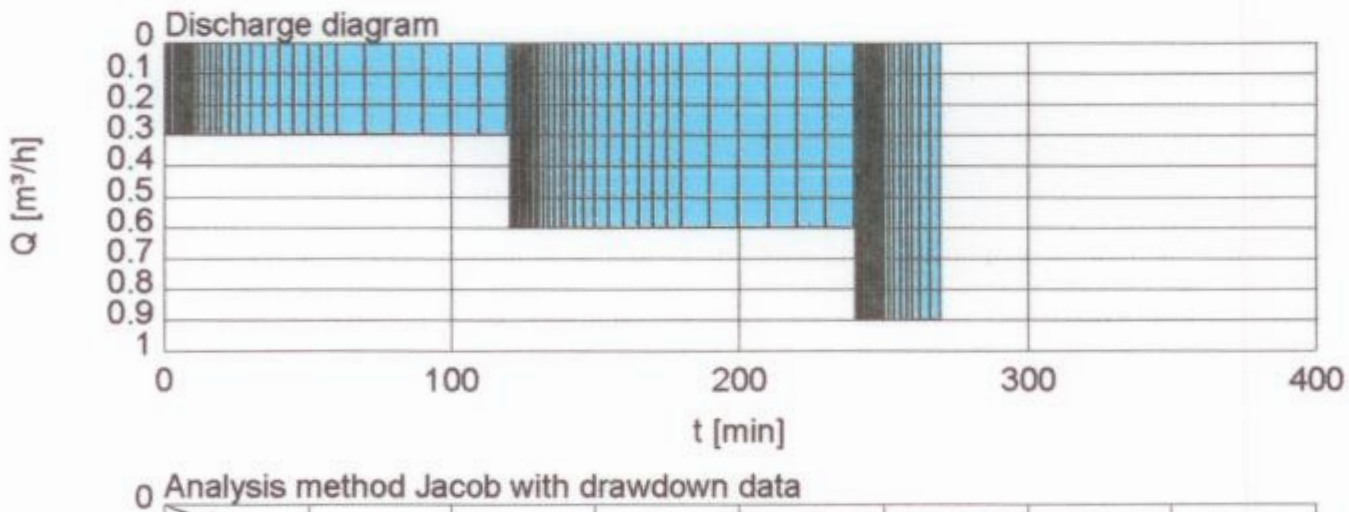
Step test analysis

Pumped well J7_N



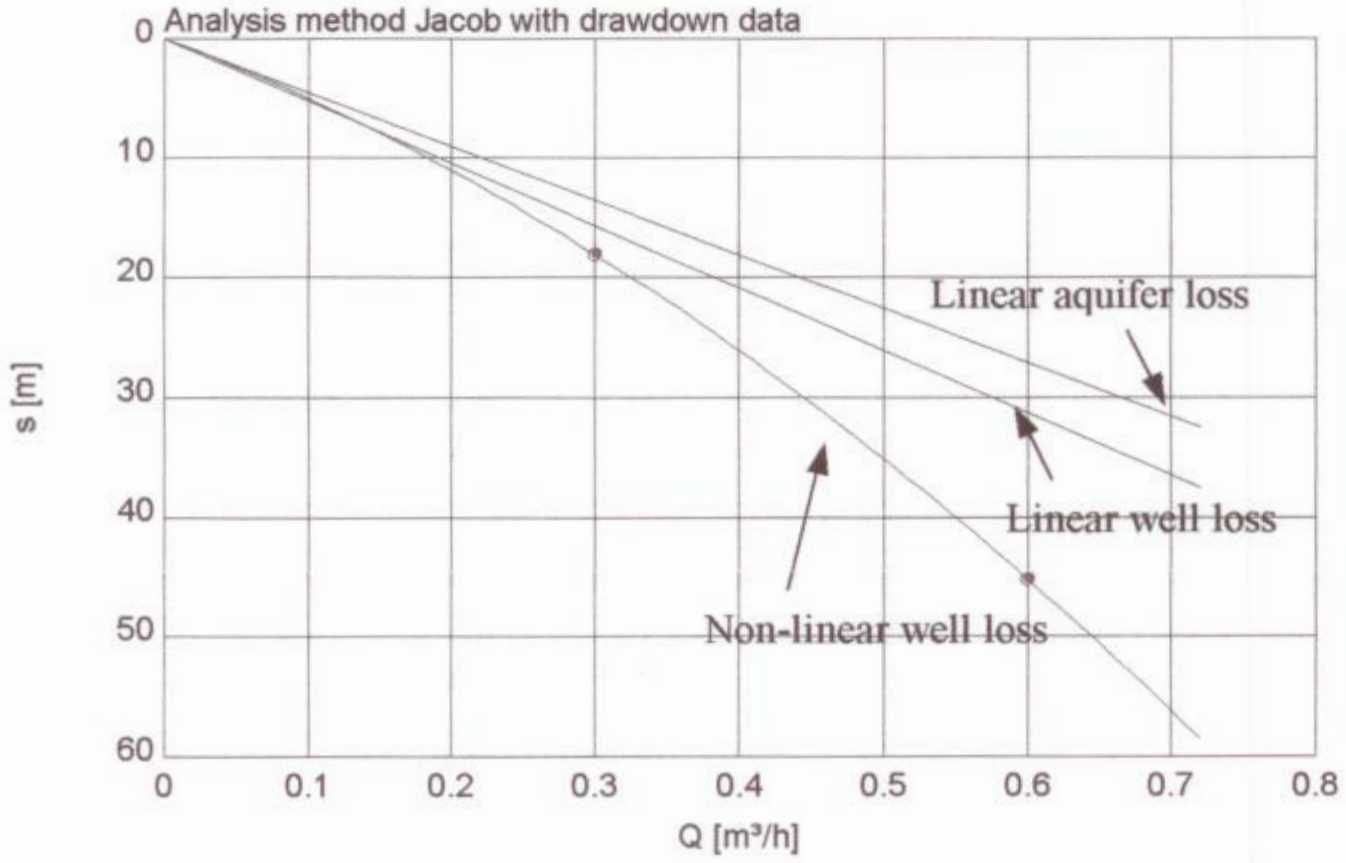
Borehole, well & aquifer

Drilled:	05/08/00
Latitude:	25.29107
Longitude:	18.41756
Elevation:	1100 [m]
Depth:	250 [m]
Stick up:	1.00 [m]
Bh. radius:	0.100 [m]
Casing radius:	0.076 [m]
RWL:	24.91 [m]
max.drawdown:	60.17 [m]
Aq.type:	confined
Aq.thickness:	17.00 [m]
Stratigraphy:	Nossob
Lithology:	Sandstone



Test running

Start:30/08/2000 07:00:00	
Dis.dur.:	270 [min]
Av.dis.:	0.5 [m³/h]
Max.dis.:	0.9 [m³/h]
Min.dis.:	0.3 [m³/h]
Total dis.:	2.25 [m³]
Crew:	Metzger_PM
Supervisor:	PCI



Results

Well performance:

s: (B1+B2)*Q+C*Q²

Linear aquifer loss B1:	37.07
Linear well loss B2:	8.06
Non-linear well loss C:	50.22

	Q [m³/h]	s [m]	Eff [%]
Step 1:	0.30	18.1	86.6
Step 2:	0.60	45.2	69.3

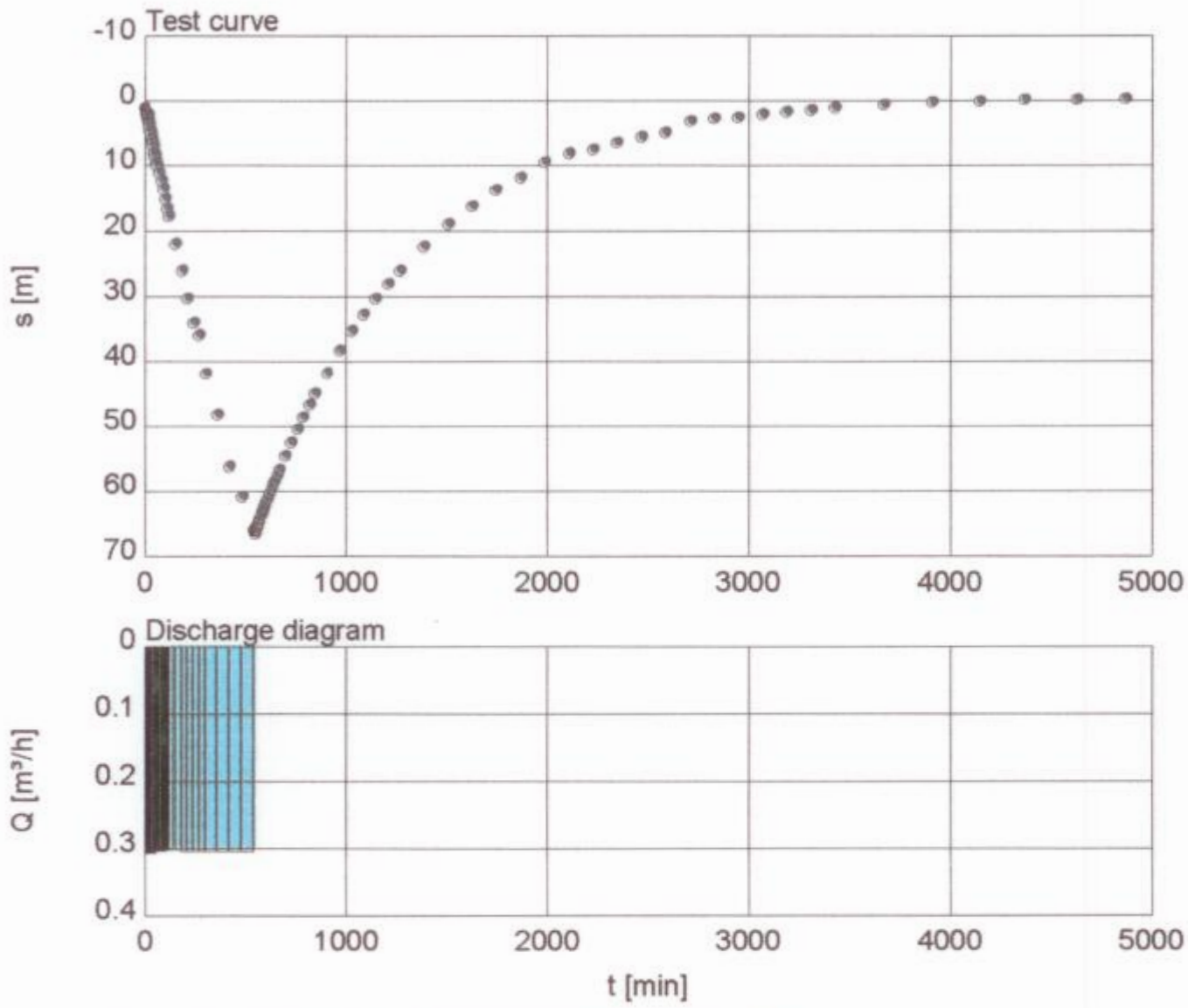
Linear skin factor:	2.1E-2 [-]
Non-linear skin factor:	3.16 [d/m³]
Effective well radius:	9.0E-2 [m]

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J7_N

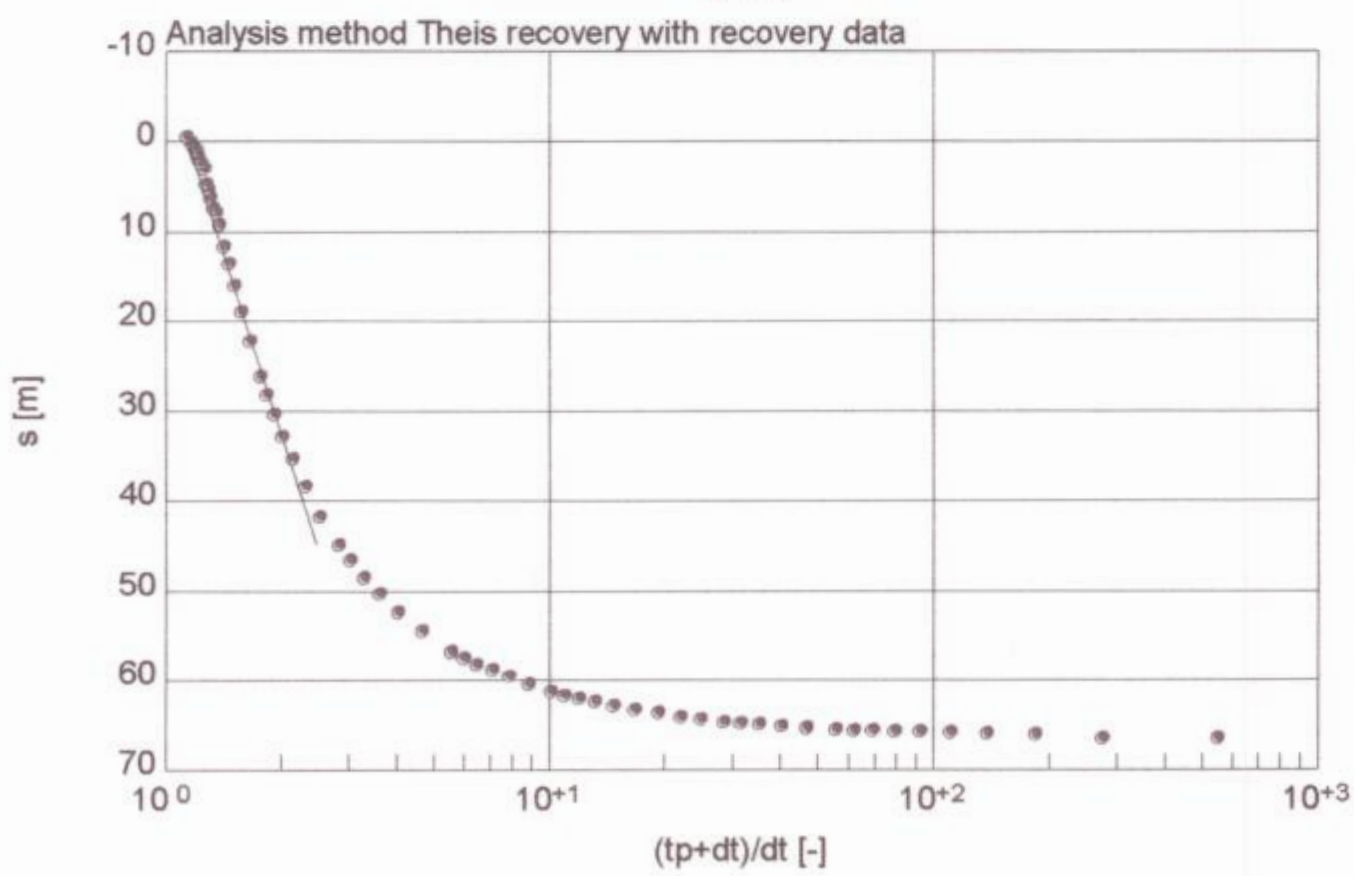


Borehole, well & aquifer

Drilled:	05/08/00
Latitude:	25.29107
Longitude:	18.41756
Elevation:	1100 [m]
Depth:	250 [m]
Stick up:	1.00 [m]
Bh. radius:	0.100 [m]
Casing radius:	0.076 [m]
RWL:	22.99 [m]
max.drawdown:	66.61 [m]
Aq.type:	confined
Aq.thickness:	17.00 [m]
Stratigraphy:	Nossob
Lithology:	Sandstone

Test running

Start:01/09/2000 12:00:00	
Dis.dur.:	547 [min]
Av.dis.:	0.305 [m³/h]
Max.dis.:	0.311 [m³/h]
Min.dis.:	0.303 [m³/h]
Total dis.:	2.78 [m³]
Crew:	Metzger_PM
Supervisor:	PCI



Results

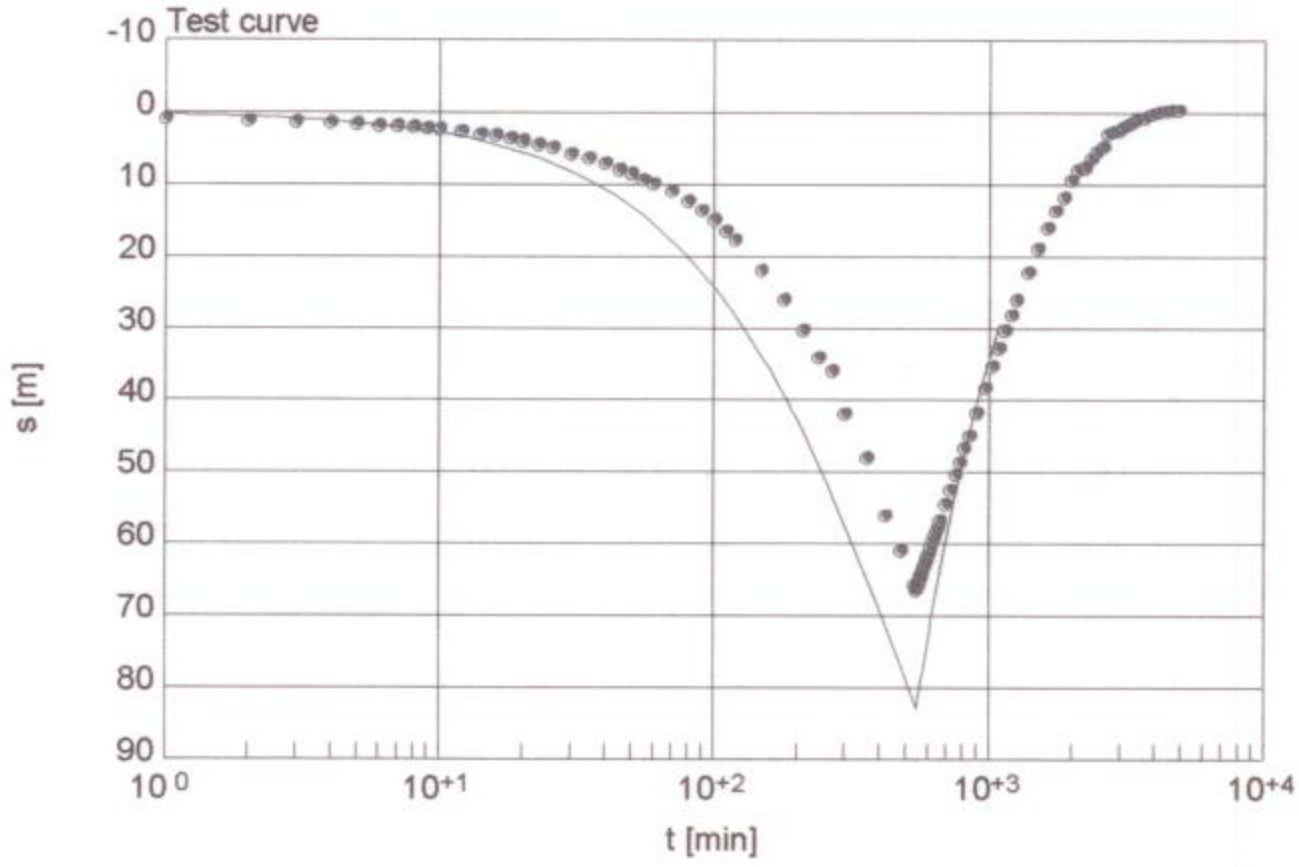
Match parameter:	
Q:	0.305 [m³/h]
b:	133 [m]
tcorr:	547 [min]
to:	1.14 [-]
Aquifer parameter:	
T:	0.0101 [m²/d]
k:	0.000592 [m/d]

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Step test diagnosis

Pumped well J7_N

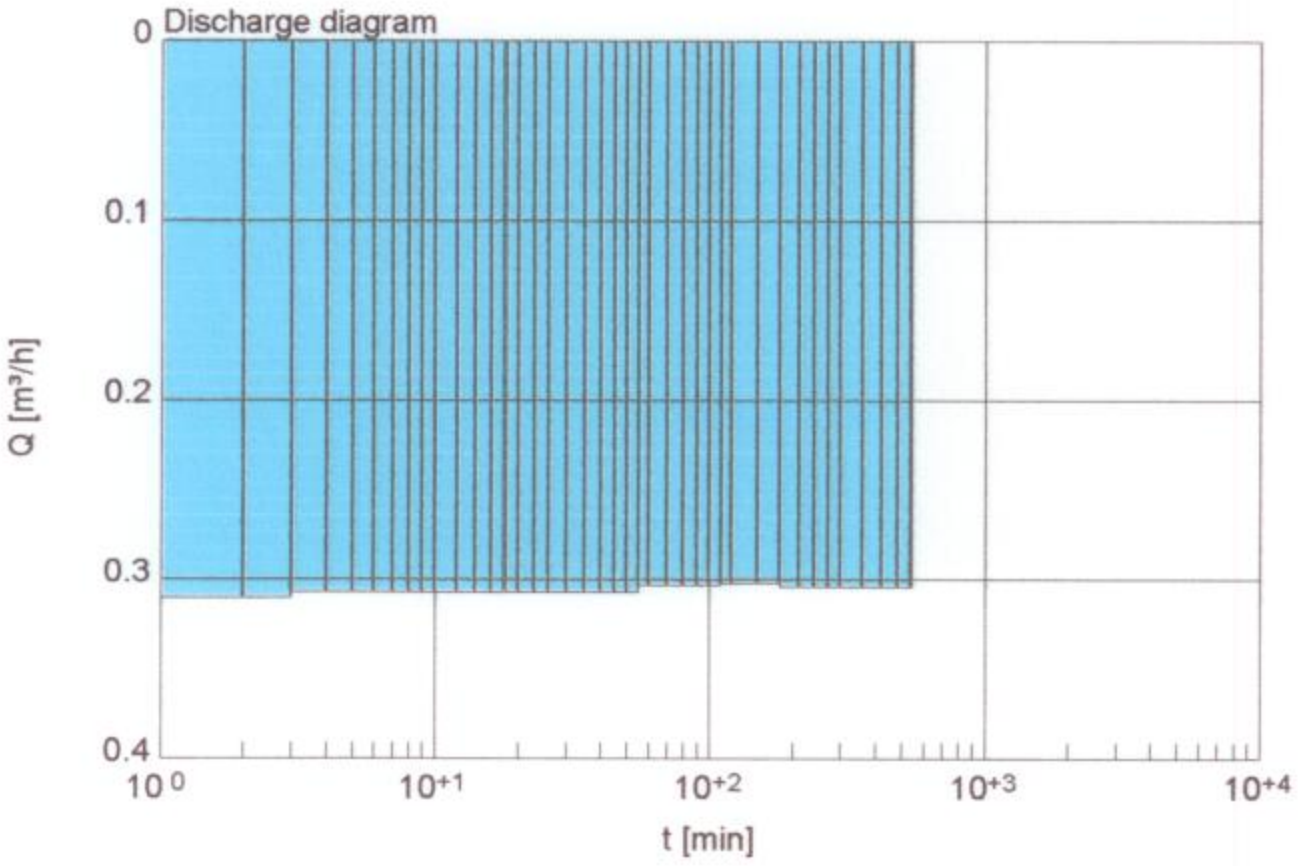


Remarks

Simulation of the draw down/recovery curve applying the Theis model for confined aquifers.

The following parameters were used:

T = 0.04 m2/day
S = 0.0008
Linear skin s = 0.1



Discharge info

Dis.dur.:547 [min]
tcorr: 547 [min]

Av.dis.: 0.30 [m³/h]
max.dis.:0.31 [m³/h]
min.dis.:0.30 [m³/h]
Qn: 0.30 [m³/h]

Dis.sum: 2.78 [m³]

Date 26/10/00	prepared by BIWAC	Annex 3

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

Japan International Co-operation Agency

JICA Study Team

EVALUATION OF TEST PUMPING DATA

Borehole

J6-A (WW39850)

Cobra

BIWAC
Bittner Water Consult
Box 86386
Windhoek
Namibia

METZGER PM DRILLING
Box11733
Windhoek
Namibia

Windhoek

August 2000

7. Water Level Recorder Installation

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

INSTALLATION OF SEBA FLOATERS

JICA REFERENCE: J 7 N LOCALITY: Jakkalsdraai R228

WW 39853

1. **Serial Number of floater**: 4552
2. **Date installed**: 5/10/00
3. **Rest Water Level when installed**: 23.01 mbsu
4. **Distance from stick-up to logger**: 18.00
5. **Distance from logger to water level**: 5.01
6. **Cut off**: 18.0 (0.91 + 17.11)