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 J4-A (WW 39846)

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Windhoek Namibia

Windhoek October 2000



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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

Aminuis North East	WW 39846
Jica Reference : J - 4 - A	S 23, 40049°
Date completed : 8 May 2000	E 19, 62577°
	Collar elev.: 1253 m

GEOI	OGI	CAL	BOREH	OLE	LOG
ULUL	NOUI	Uni	DUNLI	ULL	LOU

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 - 3	3	Light brown, very fine to fine sand (dune sand).	
3 - 4	1	Light brown to white very fine to fine sand, rounded quartz, well sorted. Intercalated horizons of light red to orange sandstone. (Non-calcareous)	
4 - 6	2	Light reddish orange fine-grained sandstone, moderately sorted, slightly calcareous in places, porous.	KALAHARI
6 - 7	1	Light red sandstone, with white, slightly calcareous nodules. Sandstone well sorted and porous.	
7-9	2	Light red sandstone with horizons of ferricrete. Sandstone grains well sorted, fine grained and porous.	
9 - 13	4	Light red sandstone, very fine to fine grained, porous. Colour darker red at 13 m.	
13 - 15,5	2,5	Massive light grey calcretized sandstone / calcrete.	
15,5 - 37,5	22	Dolerite, light brown to greenish, highly weathered and fractured, calcareous in minor horizons. Possible aquifer.	
37,5 - 39,5	2	Baked shale, red to light brown and yellowish. Very brittle. Possible aquifer.	KAROO DOLERITE
39,5 - 41	1,5	Light greenish weathered dolerite. Minor calcareous coating on fracture planes.	
41 - 53,5	12,5	Dolerite: weathered, soft, light brown to slightly greenish. Possible aquifer.	
53,5 - 58	4,5	Light brown sandstone, fine grained. Rounded quartz, silica cemented, hard. (Baking effect of dolerite)	
58 - 59	1	Light brown sandstone, fine to coarse grained, unsorted. Grains mostly sub-rounded.	
59 - 60	1	SAMPLE LOST	
60 - 64	4	Light brown fine-grained sandstone. Porous.	AUOB
64 - 67	3	Light grey sandstone , with intercalated impure red- brown sandstone. Muscovite and feldspar in sample.	A 5
67 - 77	10	Light grey to white medium grained sandstone.	
77 - 81	4	Light brown to white fine / medium grained sandstone.	
81 - 84	3	As above, but calcareous.	
84 - 87,5	3,5	Light brown to white/light grey sandstone: slightly calcareous and fine to medium grained.	
87,5 - 90	2,5	Soft white to light red shale, gradually changing to light brown.	AUOB A 4

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90 - 92	2	Light brown to brown soft shale.	
92 - 95,5	3,5	Reddish shale.	
95,5 - 99	3,5	Impure brown sandstone , red and brown biotite on bedding planes. Sandstone medium to fine grained, non -calcareous.	
99 - 102	3	Light brown calcareous sandstone, biotite rich in places, medium grained, rounded.	
102 - 105	3	Light brown to white sandstone , fine grained, non- calcareous with minor reddish quarzitic layers and a thin prominent light whitish to green shale parting at 104 m.	
105 - 108	3	Light reddish sandstone / shale inter-layered. Slightly calcareous in places	AUOB A 3
108 - 113,5	5,5	Light brown sandstone with subordinate shale and inter-layered feldspathic, manganese (?) coated horizons. Calcareous in places.	
113,5 - 130	16,5	Light pink fine to medium grained sandstone. Grains rounded to sub-rounded. Micaceous in places. Calcareous at 115 m, 117 - 119 m, 123 m. Minor shale partings at 120 m, 127 m, and 129 - 130 m. Colour changing to darker pink / red with depth.	
130 - 133	3	Light brown mudstone / siltstone inter-layered with shale; dark yellow limonite stains on bedding planes of shale.	
133 - 136	3	Brown to yellow very fine sandstone inter-layered with shale (Mn-encrustations at 133 m?)	
136 - 143	7	Brown shale, changing to dark greyish brown shale at 143 m. Slightly sandy at143 m.	AUOB A 2
143 - 145	2	Brownish grey fine to very fine sandstone with prominent very carbonaceous shale partings at 145 m.	
145 - 148	3	Light reddish brown siltstone with inter-layered very fine sandstone.	
148 - 155	7	Black carbonaceous shale, weathered/oxidized at 155 m to a light grey /reddish colour with large coal clasts.	
155 - 177,5	22,5	Red medium grained sandstone, feldspathic, fining downwards. Interbedded layers of shale and minor clasts of coal at 156 and 162 m. Calcareous at 173, 174 m.	AUOB A 1
177,5 - 187	9,5	Sandstone/shale inter-layered. Pale grey. Very fine siltstone /sandstone with piritiferous horizons. NB: Calcareous from 183 m to 187 m.	UPPER MUKOROB
187 - 196	9	Black carbonaceous shale.	
196 - 204 EOH	8	Dark grey shale with horizons of white, yellow and red shale inter-layered.	LOWER MUKOROB

REMARKS:

- 1. Drilling method employed was mud-rotary, resulting in severely ground drill-cuttings.
- 2. The upper Kalahari and Karoo horizons have been cased and pressure grouted.

This borehole was logged by F. Bockmuhl.



2. Penetration Record



Donth (m)	Pop Date (min/m)
Depth (m)	Pen. Rate (min/m)
1	
5	
	1.4
	2
	2.75
10	2.8
	2.2
	2.35
	2.00
	3.4
15	3.4
15	2.0
	2.95
	1.7
	1.6
	1.45
20	2
	1.95
	2.7
	2.95
	2.5
25	2
	2.7
	2.55
	2.95
	3
30	3 15
	2 4 5
	2.40
	2.5
	2.25
	2.05
	Z.1
	1.7
	1.8
	1.3
10	1.35
40	1.5
	1.65
	1.75
	1.95
	2.5
	3.1
	1.6
	2.35
	1.5
	2.6
50	2.1
	2.25
	1.85
	1.8

	3.25
	12.3
	18.1
	19.55
	7.6
60	3
	4 4 5
	2 75
	2.13
	2.1
	2.5
	3.2
	2
	2
	1.9
70	1.75
	1.8
	1.3
	2.3
	2.5
	2
	0.75
	0.85
	1 25
	2 35
80	4.35
00	4.20
	0.45
	6.9
	6.5
	4.35
	3.8
	5
	2.65
	12.1
	13.7
90	10.55
	5.7
	8.35
	13
	26
	3 35
	0.00
	1 95
	1.05
	1./5
400	1.6
100	2.6
	2.2
	1.7
	1.6
	1.7
	1.95
	1.85
	1.8
	1.9
	1.8
110	1 75
	1.75

	1.7
	1.75
	1.65
	6.85
	5.6
	5.85
	6.5
	7.7
	2.1
120	4.8
	3 75
	4.85
	1.8
	1.0
	2.2
	2.8
	3.35
	3.1
	2.7
	2.8
130	3.1
	5.35
	5.85
	5.35
	4.35
	4 35
	4.4
	6.55
	0.55
	4.00
110	5.35
140	5.2
	6.35
	3.3
	2.2
	1.66
	5.33
	5.15
	5.5
	5.66
	4.14
150	5
	4 65
	5 33
	4 75
	5.75
	5.75
	0.10
	0.25
	4.16
	2.33
	2.15
160	2.66
	2.4
	3.35
	2.4
	3.36
	3.1
	3.35

	3.4
	3.35
	3.2
0	2.1
	2.5
	2
	2.85
	2.8
	2.3
	3.25
	3.4
	3.3
	4.9
0	4.25
	3.85
	4.85
	3
	3.25
	3.1
	5.4
	7.9
	3.9
	3.35
0	3.1
	5.16
	3.25
	3.85
	4.85
	5.33
	5.8
	21.9
	2.66
	4.45

200	18.45
	18.1
	6.2
	12.4
204	46
204.3	39

Penetration Record J 4 A



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 4 A LOCALITY: Aminius WW 39846 DATE: 20 to 25 April 2000

TIME	DEPTH mbgl	MARSH FUNNEL TEST 1000 ml (sec)	MARSH FUNNEL TEST 500 ml (sec)	E. C. mS/cm	DENSITY	рН	TEMPERATURE ° C
14:25 (20/04)	7	31		2.4			22.3
11:00	59.5	31 27		2.42 2.71			25.7 23.1
18:20 (23/04)	79			3.53			
19:30 (25/04)	204.3	31 27		2.78 2.7			27.2 24.2

GENERAL REMARKS:

- 1. This borehole was logged in two steps: firstly to a depth of 59.5 m in a borehole diameter 9 7/8" and secondly to the end of hole (\$\$ 7 7/8").
- 2. Parameters for both the drillfluid and the water used for mixing the drillfluid were obtained from samples filtered through a very fine sieve.
- 3. To obtain values for electrical resistivity in Ω -m., the E.C., expressed in S/m., should be inversed (1/x).
- 4. A water sample was collected by air-rotary method. The E.C of this sample was also recorded.

COMMENT		
2		
Shortly before logging		
Water used for mixing		
Water sample collected by air-		
rotary method. Yield $2 - 3$		
cub.m/h		
After trip – before log		
Water used for mixing		

4. Geophysical Log and Casing Design



P05	eiden Geophysics (Pop. Ho. SX550)				
	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				
iysics	WELL ID J4A WW39846				
 Poseidon Geophy VELL.J4A WW 39846 ROJ. CN. Aminuis TE. J4 ILLNG No. J4A 	LOCATION AMINUIS COUNTRY REPUBLIC OF NAMIBIA				
BH COORDINATES	S 23.40049 E 19.62577				
COLLAR ELEVATION LOG MEAS. FROM G	1253m roundlevel				
DRILLING MEAS. FROM	M Groundlevel				
DATE	26 April 2000				
TYPE LOG Physical Properties					
DEPTH-DRILLER	204m				
DEPTH-LOGGER	201.60m				
TODI OCCED DITERV	3TM LOGGED INTERVAL 201.60m				
UPLOGGED INTERVAL 0.60m					
ERMANENT DATUM OTOLINIALINA OTOLINA OTOLIN					
KECORDED BY	ECORDED BY Clemence Kambewu				
WITNESSED BY	Frank Bokmuhl				
	JAPAN INTERNATIONAL COOPERATION AGENCY				



Galvanized steel canoni grouting & cement grouting Borchote diameter 251mm	Johnson Screen	Galvanized steel easing 152mm OD with filter gravel Borehole diameter 200mm	Johnson Screen Johnson Screen		Johnson Screen
SANDSTONE		SHALE SHALE SANDSTONE with minor shale		SHALE & SHALE &	SANDSTONE SANDSTONE shale shale
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	80 32 70 65 60 80 42	10 32 50 82			
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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 4 A LOCALITY: Okonyama, Aminuis NE

	Water Level (mbsu)	E.C. (µS/cm)	Yield (m ³ /h)	¹ / ₂ 90° V- Notch (mm)	P.I.D. (mbsu)	TIME (actual)
Start	RWL 28,8 m				63,48	15:00
	36.50					15:13
	42.79					15:20
	47.38		0.4	35		15:32
All			0.144	20		15:50
	52.65					16:00
	62.35		1	47	85.8	17:51
Fluctuate	65.23		0.8	42		18:07
	66.10		0.72	40		18:19
	66.15			40		18:19
	66.65		0.72	40		18:25
	66.38			40		18:50
	66.40		0.72	40		18:56
	66.30		1	45		19:07
	66.75			45		19:16
	66.65		1	45		19:22
	64.50					19:48
	64.05					19:55
	66.62			42		20:07
	66.65		1	45	85.8	20:12

WW 39846 DATE: 09/05/2000 (starting)

Remarks
very low airflow.
ow to recover
5 W to 1000 vol.
airflow continuously

	Water Level (mbsu)	E.C. (µS/cm)	Yield (m ³ /h)	½ 90° V- Notch (mm)	P.I.D. (mbsu)	TIME (actual)
	66.68		1.25	48	85.8	20:32
	66.68		1	45		20:55
	66.70			45		21:10
	67.10		1.25	48		21:52
	66.90			48		22:30
Date 10/05/2000.	67.00		1.5	52		04:10
With all the drill	67.10		2	58		06:00
	66.85		2.25	61		07:55
Stop ar	66.95		2.35	62	85.8	08:05
Start again to surg	RWL 60.43				115.8	09:30
			4.68	80		09:39
	69.35		5.35	85		09:50
			5	83		10:10
V	63.65					10:20
	71.30		5.35	85		10:46
	62.35					11:05
			5.75	87		11:25
	72.05		6.12	90		12:10
	61.53					12:30
	67.8		5.85	88		12:45
	72.15		6.5	92		13:30
						13:40
	70.20		5.35	85	115.8	14:30
			5.35	85		14:55
						15:00

Remarks	
	_
	-
	_
irflow constant through night.	_
uid removed, yield increases.	
ater cloudy.	
install more pipes.	
borehole: airflow is fluctuated	
ontinuously.	
	-
ter dirty again	-
ter untij uguni	-
	-
	_
	-
	-
	_
	_
	*

TIME (actual)	P.I.D. (mbsu)	½ 90° V- Notch (mm)	Yield (m ³ /h)	E.C. (µS/cm)	Water Level (mbsu)	Remarks
15:40	115.8	85	5.35	62.6		TDS 41 mg/l, T 25.3°C, pH 7.97
16:40		85			70.35	Stop to install more pipes
08:20	176	88	5.85	71	71.1	Date 11/05/00. TDS 47 mg/l, Water still milky.
10:40		85	5.35		72.10	Water clear
11:00	176					Stop developing.

Remarks:

- 1. Developing by airlift was done on 9/5/00 for effective 8,5 hours.
- 2. On 10/05/00 airlifting was done for effective 21 hours.
- 3. On 11/05/00 airlifting was done for effective 11 hours.
- 4. In addition this borehole was cleaned and bailed by cable tool on 8/05/00, of which 1,5 hours are considered as part of developing.

6. Evaluation of Pumping Test



1. PUMPING TEST ANALYSIS

J4-A (WW39846) - Pumping well

J4-K (WW39845) - Observation well

J4-N (WW39847) - Observation well

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

Well Efficiency was analysed by making use of the Rorabaugh 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.

Borehole number	Step	Abstraction Rate [m ³ /h]	Draw Down* [m]	Borehole Efficiency [%]
	1	5.0	7.9	53.8
	2	10.0	12.0	52.9
J4-A	3	15.0	16.9	52.1
	4	20.0	21.3	51.4
	5	25.0	29.1	50.9

Table 1: J4-A: borehole efficienc	v at various	pumping rates
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* at cut-off time t, 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)

An average abstraction rate of 19.5 m³/h was applied for the constant discharge test. The constant discharge draw down curve of abstraction borehole **J4-A** indicates confined conditions. For confined aquifers, the Theis analysis method with draw down and recovery data was used to calculate the hydraulic conductivity of the aquifer (Annex 2 & 3).

The aquifer storativity was estimated due to the fact that the observation boreholes J4-K and J4-N are located in other aquifers and not in the pumped Auob sandstone aquifer. During the duration of the constant discharge test, the water levels of both observation boreholes J4-N and J6-K were stable throughout the test (Annex 5).

1

The results of the constant discharge analysis are summarised in Table 2 below.

Borehole A number M	Analysis	Т	S	k _f [cm/sec]	s [-]	Simulation model	Comments
	Method	[m²/day]	[m]				
J4-A	Theis- draw down	87.6	50	2.0 x 10 ⁻³	*1 x 10 ⁻⁵		*Storativity estimated -
	Theis - recovery	85.4	50	1.9 x 10 ⁻³	*1 x 10 ⁻⁵	Theis	Observation boreholes not located in the tested aquifer

Table 2: Aquifer Parameters calculated for J4-A; Auob sandstone

The Theis model for confined aquifer conditions was used to simulate and verify the actual data and analysis approach of the constant discharge test. No leaky conditions could be evaluated for J4-A. Simulation parameters summarised in Table 2 were used in simulation of the actual pumping test data (See Annex 4 for simulation results).

Annex 5 compares the draw down results of the pumping borehole J6-A and observation boreholes J4-K and J4-N. It is obvious that pumping from the Auob sandstone aquifer did not have any influence on the Kalahari and Nossob aquifers although both borehole were drilled well within the radius of influence (See below).

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

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

 $R = 3000 \times 21.0 \times 4.45 \times 10^{-3} = 280 \text{ m}$

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 280 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.



Evaluation of Test Pumping Data

Step test analysis

Pumped well J4_A

0 Test curve Borehole, well & aquifer Drilled: 04/00 Latitude: 23.40049 Longitude: 19.62577 Elevation: 1253 [m] 273 [m] Depth: 10 Stick up: 1.00 [m] Bh. radius: 0.1255 [m] Casing radius: 0.084 [m] 999999 RWL: 59.83 [m] 20 max.drawdown: 27.91 [m] 0.0.0.0.0.0 1 Aq.type: confined Aq.thickness: 50.00 [m] ۲ 1 Auob Sandstone Stratigraphy: 900000 Lithology: Sandstone 30 0 100 200 300 700 400 500 600 O Discharge diagram Test running Start:07/09/2000 07:00:00 Dis.dur.: 600 [min] 10 Av.dis.: 15 [m3/h] Max.dis.: 25 [m3/h] Min.dis.: 5 [m³/h] 20 Total dis.: 150 [m³] Crew: Metzger_PM Supervisor: PCI 30 0 200 300 400 700 100 500 600 t [min] O Analysis method Rorabaugh with drawdown data Results Well performance: s: (B1+B2)*Q+C*QP Linear aquifer loss B1: 0.84 Linear well loss B2: 0.23 10 Non-linear well loss C: 1.4E-2 Exponent P: 1.62 Linear aquifer loss

[m] s

Q [m³/h]



Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J4_A



Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J4_A



Evaluation of Test Pumping Data

Test pumping diagnosis



Evaluation of Test Pumping Data

Test pumping diagnosis



Pumped well J4_A



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 4 A LOCALITY: Okonyama, Aminuis

WW 39846

1.	Serial Number of floater:	4561
2.	Date installed:	18/09/00
3.	Rest Water Level when installed:	60.23 mbsu
4.	Distance from stick-up to logger:	55.0 m
5.	Distance from logger to water level:	5.25 m
6.	Cut off:	55.0 m (0.91 + 54.11)

