

Hydrogeology Report No 1995/38

**HYDROGEOLOGY OF THE  
NABAWA SANDPLAIN**

by

**Hazli Aluwi Koomberi**

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**Western Australia**

**Geological Survey**

**Perth, 1995**

## CONTENTS

	Page
ABSTRACT	1
INTRODUCTION	
Location	2
Purpose and scope	2
Climate and landuse	2
Physiography	4
PREVIOUS WORK	4
INVESTIGATION PROGRAM	
Drilling and bore construction	5
Sampling and logging	5
Water Sampling	6
Levelling and monitoring	6
GEOLOGY	
Setting	8
Stratigraphy	
<i>Mesozoic</i>	8
<i>Cainozoic</i>	9
HYDROGEOLOGY	
Aquifer types and yields	14
Groundwater flow and discharge	14
Recharge	14
Storage	15
Throughflow	15
Salinity	16
HYDROCHEMISTRY	21
CONCLUSIONS	25
REFERENCES	26

## Tables

	Page
1. Summary of Bore Details	7
2. Recharge Rates from Chloride Ratios	15
2. Chemical Analyses of Water Samples	22

## Figures

1. Location and Physiography	3
2. Geology	10
3. Thickness of Chapman Group	11
4. Top of Basement Rock Contours	12
5. Schematic Hydrogeological Sections	13
6. Aquifer Saturated Thickness	17
7. Chapman Group Watertable Elevation	18
8. Groundwater Salinity in the Chapman Group	19
9. Piper Trilinear Diagram	24

# HYDROGEOLOGY OF THE

## NABAWA SANDPLAIN

by H.A. Koomburi

### ABSTRACT

The groundwater resource potential of the Nabawa Sandplain, which covers an area of approximately 52km<sup>2</sup> in the southern part of the Northampton Block, has been investigated by drilling ten bores at nine sites. The bores were drilled between May and July 1994 and range in depth from 21 to 84 m, with an aggregate of 566m. Results from the drilling have shown that the Nabawa Sandplain comprises a veneer of Cainozoic sediments, underlain by Mesozoic sediments of the Chapman Group, with a maximum thickness of 58m. The Cainozoic and Mesozoic sediments unconformably overlie basement rocks which are predominantly garnet granulite.

Most of the groundwater in the sandplain is contained in an unconfined aquifer within the sediments of the Chapman Group. The average saturated thickness of the unconfined aquifer is 13m and reaches a maximum of 22m in the northeastern part of the sandplain. The unconfined aquifer is recharged directly from rainfall in areas of outcrop and also by downward leakage from overlying perched aquifers in the Mesozoic and Cainozoic sediments. The groundwater is predominantly brackish to saline (1120-3570mg/L TDS). Groundwater generally flows south and discharges into the Chapman River. The estimated groundwater storage is 100 x 10<sup>6</sup>m<sup>3</sup>.

## **INTRODUCTION**

### **Location**

The Nabawa Sandplain (approximately 52km<sup>2</sup>) is located in the southern part of the Northampton Block. Nabawa townsite located 3 km to the east (Fig. 1) supports the farming community in the Chapman Valley, which had a population of 775 inhabitants in 1993-94. Geraldton is the closest regional centre, approximately 35km southwest of Nabawa, and is reached via the Chapman Valley Road. The sandplain is approximately bounded by the Northampton-Nabawa Road in the north, the Chapman River in the east, the Nabawa-Yetna Road in the south and Skeleton Gully in the west.

### **Purpose and scope**

Limited potable water sources are available for the communities in the Chapman Valley. The occurrence of sandy surface soils and Mesozoic sediments in the Nabawa Sandplain, together with the presence of springs on the periphery of the sandplain, indicated a potential potable groundwater resource. Prior to the investigation, little was known of the thickness and hydrogeological characteristics of the Nabawa Sandplain, as there are only limited data available from farm bores.

The objective of the exploratory drilling project was to investigate the thickness and hydrogeological characteristics of the sandplain and to assess its water resource potential. The project was financed from the 1993-94 Geological Survey of Western Australia (GSWA) groundwater exploration initiative budget and supported by the Water Authority of Western Australia (WAWA).

### **Climate and landuse**

The investigation area has a Mediterranean-type climate with an annual precipitation of 450-500 mm. Most of the rain falls in the winter months of June to August. The summer is hot and dry with maximum temperatures commonly exceeding 38°C.

Most of the sandplain has been cleared of native vegetation for agriculture, mainly for pasture. Clearing began in 1962 with little virgin bush remaining by 1975 (pers.comm. Speed R., 1995). The remaining native vegetation consists mainly of low acacia scrub with some banksia and christmas trees. A recent development in the area is the construction of dams for marron farming.

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## **Physiography**

The sandplain gently slopes to the south with an elevation ranging from 220 to 240mAHD. Physiographically, the sandplain is an isolated remnant of the Victoria Plateau, and is surrounded by the Chapman, Oakabella and Oakajee River Drainage Systems (Playford, et al, 1970). These drainage systems dissect the edges of the sandplain, resulting in a gently undulating terrain. Surface runoff on the sandplain occurs only during prolonged periods of rainfall, mainly during winter. Most of the surface runoff flows into the Chapman River Drainage System.

## **PREVIOUS WORK**

The first geological maps to include the Nabawa Sandplain area were 1:50,000 geological map sheets completed by Jones (1964, 1968) and Noldart (1968). Whincup (1968) completed a brief report on the groundwater prospect for the Nabawa townsite, but investigated only the easternmost periphery of the sandplain. The 1:250,000 geological map and accompanying explanatory notes ( Playford et.al, 1970) clearly identified the Nabawa Sandplain area and described the geology in detail. In 1993 Martin investigates groundwater for the Nabawa townsite for the Water Authority of Western Australia (WAWA), and recommended exploratory drilling on the Nabawa Sandplain.

## **INVESTIGATION PROGRAM**

### **Drilling and bore construction**

The first six sites were drilled by Drillcorp Ltd in May 1994 under contract to GSWA, using an Ingersoll-Rand TH-60 rig, and employing mostly the mud rotary method. At each site drilling ceased at the top of the unweathered basement rocks. A total of seven bores were drilled at six sites with an aggregate depth of 431m. Observation bores were constructed at each site, consisting of 80mm ID mild steel casing with stainless steel wire wound screen. The annulus was gravel packed with graded sand to the surface and a cement block cast at the surface.

Two bores were drilled at site NAB-4. The first bore drilled produced saline groundwater which was initially considered to originate from the weathered bedrock, therefore a second shallower bore was drilled at the site.

After the completion of drilling at the first six sites, three additional sites were selected to obtain a better coverage of the sandplain. These sites were drilled by the WAWA Drilling and Testing Branch in July 1994, using a GEMCO-42 rig employing the twin-tube air core rotary method. A total of three bores were drilled with an aggregate depth of 135m. Observation bores were constructed at each site and consisted of 50mm ID Class 9 PVC casing with slotted PVC casing. The annulus was gravel packed with graded sand to the surface. A protective galvanised standpipe fitted with a locking cap, was cemented at the surface.

### **Sampling and logging**

All the bores were lithologically logged, and the samples are stored at the GSWA core library. Samples from the first six sites were mud rotary sludge samples whereas samples from the last three sites where the twin tube air rotary drilling method was utilised, were dried chips, or sludge when the watertable was reached. A clay sample from NAB-2 was submitted for palynological analysis (Backhouse, 1994).

Gamma ray logs were subsequently run in all the cased bores and induction logs were run in the PVC cased bores.



### **Water sampling**

At the completion of bore construction, the bores were developed by surging and airlifting until the discharged groundwater was clear of sand, and a constant discharge rate could be measured. Groundwater samples from airlifting were analysed by the Chemistry Centre of Western Australia and the Australian Environmental Laboratories. The sample from NAB-8 was found to be contaminated by cement during sampling (Koomberi, 1994).

### **Levelling and monitoring**

Surface elevations were estimated from the 1:100,000 topographic map.

A water level at each bore was measured a day after the completion of drilling and also during June 1995. Field salinity measurements were taken in November 1995 of water samples from springs and several farm bores (Fig. 8).

Bore details are summarised in Table 1, and bore completion reports are presented in Hydrogeology Report 1994/52 (Koomberi, 1994).

Table 1. Summary of Bore Details

Bore Number	—AMG SH50-1—		—Construction—		Total depth (m)	Elevation (approximate mAHD)			Screened interval (mbns)	Salinity TDS (mg/L Calc.)	Airlift yield (m <sup>3</sup> /day)	Status
	Easting	Northing	Commenced	Completed		Surface	Water level (date)	Top of Bedrock				
NAB-1	2 76 179	68 49 700	19/5/94	20/5/94	38.5	242	217 (10/6/95)	211	30-36	1490	10	Monitoring
NAB-2	2 78 225	68 48 014	20/5/94	21/5/94	65.5	250	212 (10/6/95)	197	42-51	1300	52	Monitoring
NAB-3	2 76 479	68 46 842	23/5/94	24/5/94	47.5	220	200 (10/6/95)	184	27-33	1530	86	Monitoring
NAB-4A	2 78 884	68 46 240	24/5/94	25/5/94	84.0	250	202 (10/6/95)	181	54-60	3260	22	Monitoring
NAB-4B	2 78 884	68 46 240	27/5/94	27/5/94	51.5	250	203 (28/5/94)	181	44.63-50.63	3480	4	Monitoring
NAB-5	2 78 056	68 44 007	25/5/94	26/5/94	75	230	187 (11/6/95)	178	42-48	1170	12	Monitoring
NAB-6	2 78 321	68 41 487	26/5/94	27/5/94	69	210	177 (10/6/95)	169	33.12-39.12	730	17	Monitoring
NAB-7	2 75 352	68 44 572	6/7/94	6/7/94	42	230	214 (11/6/95)	203	21-27	1120	dry after 30 min airlifting	Monitoring
NAB-8	2 75 010	68 48 750	7/7/94	7/7/94	21	220	216 (11/6/95)	212	6-8	2910*	1.2	Monitoring
NAB-9	2 79 897	68 48 816	4/7/94	5/7/94	72	250	202.78 (11/6/95)	181	59.80-65.80	3570	30	Monitoring

\* contaminated sample

## GEOLOGY

### Setting

The Mesozoic and Cainozoic sediments, that comprise the Nabawa Sandplain, are outliers of the Perth Basin sediments and are situated within a depression in the Northampton Block. The Northampton Block consists of metamorphic and igneous rocks of Proterozoic age (Fig. 2), and is bordered by the Carnarvon Basin in the north and by the Perth Basin in the south.

The predominant Proterozoic rocks are granulites with bands of quartzites and intrusions of dolerite dykes. The granulites, which are the oldest rocks in the Northampton Block, are sedimentary in origin, with intruded gabbros, and have been subsequently metamorphosed to granulite facies grade by regional metamorphism (Playford et al, 1970). Garnet granulites are the predominant granulite in the sandplain area, and have a gneissic banding largely due to grain size variation and also due to the variation in the concentration of biotite and garnet. Outcrops of quartzite and dolerite dykes are located near the northern edge of the sandplain (Fig. 2). The quartzite is intercalated with the granulite and is fine grained, light-coloured and saccharoidal.

The dolerite dykes intrude the Proterozoic rocks in the area and are either Late Proterozoic or Early Palaeozoic in age. The dykes are thin and are either vertical or steeply inclined (Playford et al, 1970).

### Stratigraphy

#### *Mesozoic*

Marine sediments of the Champion Bay Group have been mapped around the northern half of the sandplain (Playford et al, 1970). However, inspection of drilling samples and nearby outcrops suggest these sediments are terrigenous and it is more likely the sediments are from the Early Jurassic Chapman Group. The Chapman Group is a fluvatile deposit and is made up of the Greenough and Moonyoonooka Sandstone. The Greenough Sandstone is a unit of multicoloured, clayey sandstone with lenses of claystone, siltstone and conglomerate. The Moonyoonooka Sandstone is composed of weakly-lithified, feldspathic sandstone and arkose, with some beds of conglomerate, shale and siltstone (Playford et al, 1970). Samples from the boreholes consisted predominantly of silty sands with minor clays, and are assigned to the

Chapman Group. The sediments are thickest at the northeastern portion of the sandplain (Fig. 3), where they overlie a small depression in the basement rocks (Fig. 4). A maximum thickness of 58m was intersected at site NAB-9.

### *Cainozoic*

Cainozoic sediments, consisting of laterite and unconsolidated yellow to light brown quartz sand, with alluvium and colluvium in the lower part of the sandplain, overlie both the Proterozoic rocks and Mesozoic sediments in the investigation area (Fig. 5).

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## **HYDROGEOLOGY**

### **Aquifer types and yields**

The main aquifer in the Nabawa Sandplain area is within the sediments of the Chapman Group. There are also minor perched aquifers within the Chapman Group and in the Cainozoic sediments.

The main aquifer in the Chapman Group is unconfined, and has an average saturated thickness of 13m, with a maximum saturated thickness of 22m at site NAB-9. The saturated thickness is greatest in the northeast of the sandplain (Fig. 6). The aquifer has a low permeability as it consists predominantly of silty sand with minor clay, and this is reflected in bore yields of less than 2 to 86m<sup>3</sup>/day, obtained during airlifting.

The existence of perched aquifers in the Mesozoic and Cainozoic sediments was apparent from induction and gamma ray logs (Koomberi, 1994). The induction logs also indicated that the perched groundwater was less saline than in the main aquifer in the Chapman Group. Groundwater storage in the perched aquifers is likely to be small.

### **Groundwater flow and discharge**

Approximate watertable contours and groundwater flow directions of the aquifer in the Chapman Group are shown in Figure 7. Generally, groundwater flows south and discharges into the bedrock and as springs which drain into the Chapman River. There is also a southeast and southwest groundwater flow component which discharges into the tributaries of the Chapman River. The basement topography (Fig. 4) in the Nabawa Sandplain area is a significant control on the direction of groundwater flow.

### **Recharge**

The aquifer in the Chapman Group is recharged by direct infiltration of rainfall in outcrop areas (Fig. 2), and by downward leakage from the overlying perched aquifers. Groundwater recharge rates in the sandplain are likely to have increased since clearing of natural vegetation for agriculture began in 1962.

An estimate of natural recharge rates in the Chapman Group can be calculated by the ratio between the input concentration of chloride from rainfall and concentration of chloride in the groundwater, assuming no loss of chloride through surface runoff. An average chloride input of 9mg/L for the Nabawa area was used for the calculation. This figure was derived from

Figure 3 of Hingston and Gailitis (1976). The concentration of chloride in the groundwater from the monitoring bores ranges from 342 to 1910mg/L (Table 2). The estimated recharge rates therefore range from less than 1 to 2.6 %. It is likely that this estimate reflects the pre-clearing recharge regime. Present day recharge rates are likely to be higher.

**Table 2. Recharge Rates From Chloride Ratios**

<i>BORE</i>	<i>Cl (mg/L)</i>	<i>% RECHARGE</i>
NAB1	750	1.2
NAB2	646	1.4
NAB3	771	1.2
NAB4A	1790	<1.0
NAB4B	1910	<1.0
NAB5	588	1.5
NAB6	342	2.6
NAB7	395	2.3
NAB8	365	2.5
NAB9	1840	<1.0

The annual groundwater recharge to the aquifer is estimated to be  $400 \times 10^3 \text{m}^3/\text{yr}$ . This estimate was made using an area of  $52\text{km}^2$ , average annual precipitation of 482mm and an average recharge rate of 1.6%.

### Storage

The total storage of groundwater in the Chapman Group aquifer in the Nabawa Sandplain is estimated to be  $100 \times 10^6 \text{m}^3$ , using an area of  $52\text{km}^2$ , an average saturated thickness of 13m and a storativity of 15 %. Most of this groundwater is brackish to saline. In addition, there is some storage of fresh to brackish groundwater in perched aquifers which is difficult to quantify, but is likely to be small.

### Throughflow

Most of the groundwater in the Nabawa Sandplain drains south towards the Chapman River. An estimate of groundwater throughflow across the 190mAHD watertable contour to the south, towards the Chapman River can be calculated by using Darcy's equation with the following parameters:

k (hydraulic conductivity, from average k value of fine sand and silt (Morris et.al, 1967))	1m/day
b (estimated average saturated thickness)	12m
i (estimated hydraulic gradient)	0.005
l (width of throughflow section along the 190 m AHD (E-F, Fig. 7) watertable elevation contour)	$3 \times 10^3\text{m}$
Q (throughflow)	$kbi l = 1 \times 12 \times 0.005 \times 3 \times 10^3$ $= 180\text{m}^3/\text{day}$ $\text{ie } 66 \times 10^3\text{m}^3/\text{yr}$

From the above calculation the estimated annual groundwater throughflow across the 190 m AHD (E-F, Fig. 7) watertable contour to the south, towards the Chapman River is  $66 \times 10^3 \text{ m}^3/\text{yr}$ . The estimated groundwater recharge to the area which contributes to the above calculated throughflow is  $85 \times 10^3 \text{ m}^3/\text{yr}$ , using an area of  $11\text{km}^2$ , average annual precipitation of 482mm and an average recharge rate of 1.6%. The close agreement between throughflow and recharge estimates indicates that the assumptions in the calculations are reasonably correct, and confirm that the total estimate recharge under natural conditions could be estimated to be  $400 \times 10^3 \text{ m}^3/\text{yr}$ .

With increased recharge due to the clearing of natural vegetation on the sandplain, the watertable will rise. Monitoring of water levels over a period of several years may be required to detect the amount of water level rise.

### Salinity

The distribution of groundwater salinities within the Chapman Group aquifer is shown in Figure 8, and the chemical analyses of groundwater from the observation bores are summarised in Table 3.

Groundwater salinity in the Chapman Group aquifer from the nine drilled sites is predominantly brackish (1120-1530mg/L TDS) to saline (3480-3570mg/L TDS). The groundwater is more saline in the thickest saturated section of the Chapman Group, in the northeast of the sandplain. Only in the southern end of the sandplain at site NAB-6, is the groundwater fresh (730mg/L TDS). This part of the aquifer is narrow and recharge is likely to be localised.

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Induction resistivity logs in bores NAB-7, NAB-8 and NAB-9 (Koomberi, 1995) show a layer of lower salinity groundwater at the top of the Chapman Group aquifer. The logs also show a slight increase in groundwater salinity with depth.

It is likely that the increased groundwater recharge into the aquifer since clearing began has resulted in increased groundwater flow and also some dilution of the saline groundwater. With time, if the sandplain remained cleared, the groundwater would become relatively less saline. The ratio of groundwater storage to groundwater recharge is 250 years, suggesting that a period in excess of 100 years will be required before a new salinity regime is established.

The salinity of the spring south of NAB-8 at 1103mg/L TDS (Fig. 8) is similar to nearby bores, however the salinities of the springs which discharge around the periphery of the sandplain all exceeded 2000mg/L TDS, when sampled in November 1995. The groundwater salinity is less saline in the area at NAB-8 is due to the aquifer in that area is thin and recharge is likely to be localised.

The salinities of farm bores range from 842 to 2314mg/L TDS (Fig. 8) and are consistent with the results from the observation bores. The depths of the farm bores are not known with certainty, and it is possible that they abstract slightly lower salinity groundwater from just below the watertable.

The results of the salinity measurements from the springs and the farm bores indicates that the sandplain aquifer contains mostly brackish groundwater.

## HYDROCHEMISTRY

Chemical analyses of water samples from the observation bores, a creek near Mica Well and a farm bore just north of NAB-8 (Fig. 8), are shown in Table 3, while the concentrations of the major ions, expressed as a percentage of the total milliequivalents per litre, are plotted on a Piper Trilinear diagram (Fig. 9). The diagram shows two distinct chemical composition groups. Most of the observation bores with the exception of NAB-7 and NAB-8 have similar groundwater chemical composition, indicating the same body of water. Another group of water is from NAB-7, the farm bore just north of NAB-8 and a creek near Mica Well. Groundwater from NAB-8, in the diagram is shown not associating with either groups, due to contamination by cement, and the analysis should therefore be considered unrepresentative.

The groundwater pH is generally neutral, with values measured in the laboratory ranging from 6.9 to 8. The nitrate content in the groundwater ranged from less than 0.2mg/L to 29 mg/L.

The groundwater from all the bores and creeks is a sodium chloride type.



**Table 3 . Chemical analyses of water samples**

Bore Number	Sample Date	Elect. Cond. (mS/m at 25°C)	pH	TDS Calc.	TDS Evap.	Tot. Hard.	Tot. Alk.	Ca	Mg	Na	K	Cl	SO <sub>4</sub>	HCO <sub>3</sub>	CO <sub>3</sub>	NO <sub>3</sub>	SiO <sub>2</sub>	F	B	Aquifer
													mg/L							
NAB-1*	20/5/94	277	6.9	1490	-	255	76	28	45	445	8	750	75	93	<2	29	65	0.6	0.18	Mesozoic Sand/ Proterozoic Clay
NAB-2*	21/5/94	222	7.5	1300	-	321	47	20	44	388	8	646	72	57	<2	18	73	0.4	0.17	Mesozoic Sand
NAB-3*	24/5/94	265	7.7	1530	-	310	54	32	56	443	10	771	83	66	<2	16	88	0.5	0.26	Mesozoic Sand
NAB-4A*	25/5/94	562	7.7	3260	-	598	70	52	114	970	18	1790	206	86	<2	12	59	0.7	0.45	Mesozoic Sand/Clay
NAB-4B*	27/5/94	595	7.1	3480	-	697	58	65	130	1040	17	1910	208	71	<2	15	55	1.0	0.49	Mesozoic Sand/Clay
NAB-5*	26/5/94	202	7.4	1170	-	192	46	16	37	342	8	588	69	56	<2	6	78	0.5	0.19	Mesozoic Sand/Clay
NAB-6*	26/5/94	119	7	730	-	124	20	7	26	188	6	342	32	25	<2	6	105	0.2	0.1	Mesozoic Sand
NAB-7 <sup>#</sup>	9/7/94	185	7	1120	1000	145	80	16	25	355	13	495	85	98	<1	<0.2	36	0.5	0.3	Mesozoic Sand/Silt
NAB-8 <sup>#</sup>	7/7/94	485	12.2 <sup>b</sup>	2910	1620 <sup>a</sup>	1070	1150	425	2.2	250	36	365	145	330	105	6.6	4.9	0.2	<0.1	Mesozoic Gravel

Table 3 . (continued)

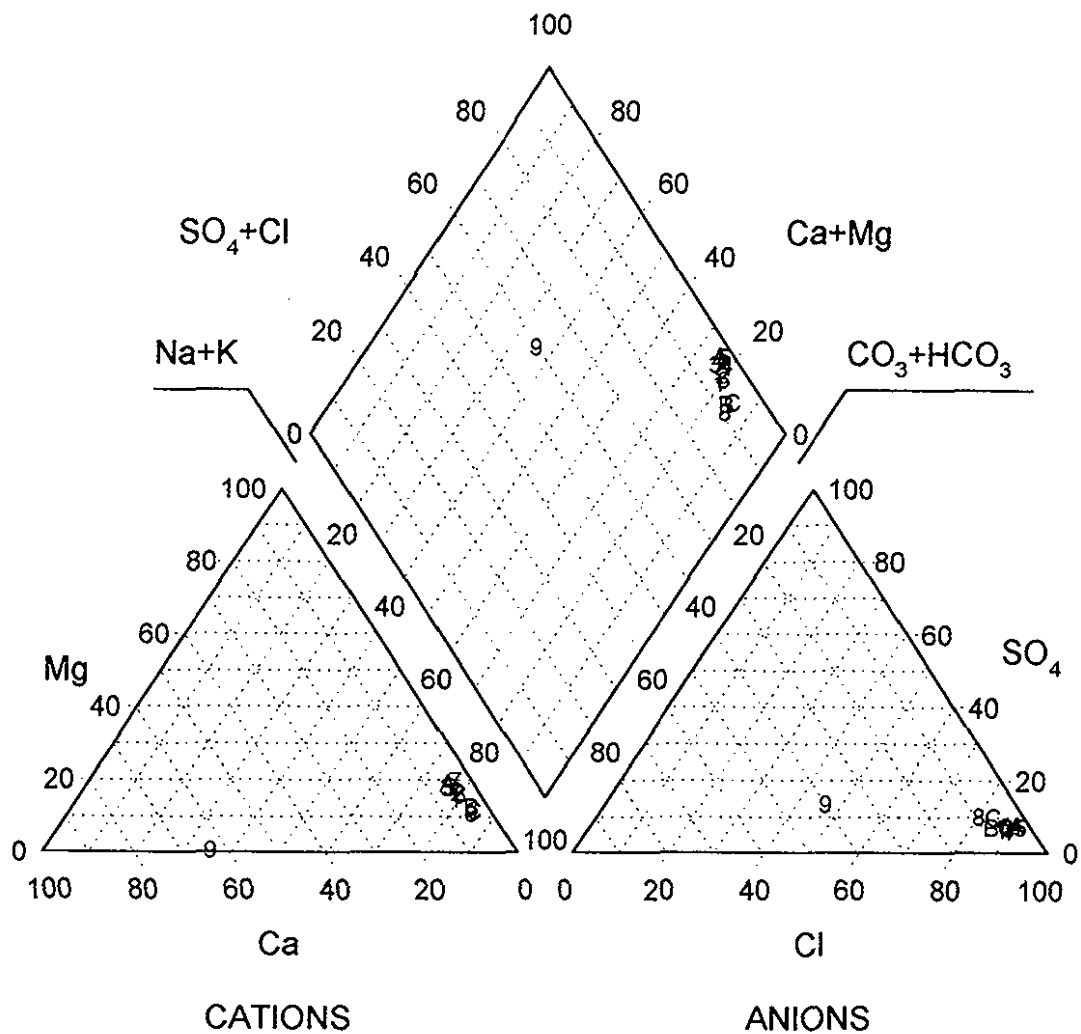
Bore Number	Sample Date	Elect. Cond.  (mS/m at -25°C)	pH	TDS Calc.	TDS Evap.	Tot. Hard.	Tot. Alk.	Ca	Mg	Na	K	Cl	SO <sub>4</sub>	HCO <sub>3</sub>	CO <sub>3</sub>	NO <sub>3</sub>	SiO <sub>2</sub>	F	B	Aquifer	
														mg/L							
NAB-9 <sup>#</sup>	5/7/94	595	7.7	3570	3580	705	74	59	13	990	22	1840	215	90	<1	11	63	0.5	0.3	Mesozoic Gravel/Sand	
Farmers well near NAB-8 <sup>#</sup>	7/7/94	150	8	890	820	110	38	9.1	21	280	3.2	375	60	47	<1	18	73	0.2	0.1	Mesozoic/ Cainozoic Sand?	
Creek near Mica Well <sup>#</sup>	9/7/94	325	7.9	1940	1830	270	125	23	52	640	16	955	110	155	<1	0.4	41	0.4	0.3	Creek	

\* Analysed by Chemistry Centre Of WA

# Analysed By Australian Environmental Laboratories

<sup>a</sup> Low TDS due to loss of carbonates on evaporation

<sup>b</sup> High pH and TDS is likely due to high concentration of Ca and HCO<sub>3</sub> due to contamination from cementing



Key	Bore or Sampling Site
1	NAB1
2	NAB-2
3	NAB-3
4	NAB-4A
5	NAB-4B
6	NAB-5
7	NAB-6
8	NAB-7
9	NAB-8
A	NAB-9
B	Farm bore near NAB-8
C	Creek near Mica Well

FIGURE 9 : Piper Trilinear Diagram

## CONCLUSIONS

Results from nine sites drilled in the Nabawa Sandplain indicate the area is underlain by a veneer of Cainozoic sands overlying predominantly silty sand and minor clay of the Early Jurassic Chapman Group, which in turn overlies garnet granulite basement rocks.

The main aquifer in the sandplain is an unconfined aquifer in the sediments of the Chapman Group. The aquifer has an average saturated thickness of 13m, and a groundwater storage of about  $100 \times 10^6 \text{ m}^3$ . Estimated groundwater recharge for the whole of the sandplain is  $400 \times 10^3 \text{ m}^3/\text{yr}$ . Most of the groundwater in the aquifer is brackish to saline (1120-3570mg/L TDS) and fresh to marginal quality only in the northwest and south of the sandplain area, where the aquifer is comparatively thin.

The potable groundwater resource potential of the Nabawa Sandplain is poor, due to the low permeability of the sediments and the brackish to saline groundwater.

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