WATER
ENVIRONMENTAL
ENGINEERING
EARTH SCIENCES

63 Wessel Road Woodmead 2191 PO Box 2597 Rivonia 2128 South Africa
**Telephone:** +27 (0)11 803 5726 **Facsimile:** +27 (0)11 803 5745 **Web:** www.gcs-sa.biz

Our Ref: LIRA.07.142
Your Ref:

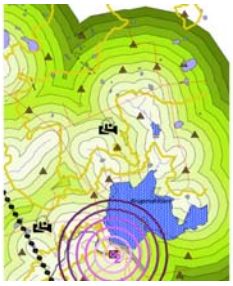
# Hydrogeology of Leisure Isle, Knysna

# Final Report

## July 2009

## LIRA
## Project Number: LIRA.07.142




**GCS (Pty) ltd.**
Johannesburg Durban Kimberley Windhoek
**Directors:** AC Johnstone (Managing) SE Scawthon (Financial) AH Barbour (Non-exec)* V Cresswell (Non-exec)*
**Reg No:** 2004/000765/07 Est. 1987

# Hydrogeology of Leisure Isle, Knysna

**Final Report**
**Version - 2**

**July 2009**

**LIRA**
**LIRA.07.142**

## DOCUMENT ISSUE STATUS

| | | | |
|---|---|---|---|
| **Report Issue** | Final | | |
| **Reference Number** | LIRA.07.142 | | |
| **Title** | Hydrogeology of Leisure Isle, Knysna | | |
| | **Name** | **Signature** | **Date** |
| **Author** | Andrew Johnstone |  | 14 July 2009 |

## 1. INTRODUCTION

Leisure Isle is situated in the Knysna estuary and is completely surrounded by a tidal lagoon (see Figure 1). The geology of the Island comprises unconsolidated fine grained sand and as a result is a primary aquifer. The domestic water supply to the 450 houses on the Island is piped from the Knysna municipality. The Island has no formal waste water disposal system and all waste water disposal is by means of septic tanks or conservancies.

The domestic water supply, rainfall related groundwater recharge, geology and hydrogeology and the waste water disposal, makes the Leisure Isle unique in terms of the aquifer and hydrogeological regime.

This paper describes the hydrogeology of Leisure Isle and is aimed at providing the residents with information regarding the aquifer in order to facilitate a better understanding and as a result, make more enlightened decisions regarding the environmental management of Leisure Isle.


**Figure 1: Google Earth Satellite Image of Leisure Isle**

## 2. GEOLOGY AND HYDROGEOLOGY

The geology of the Island comprises unconsolidated fine grained sand. The sand, where saturated, forms an aquifer which has primary permeability as the water is held in the pore spaces between the individual sand grains. Typical permeability values for the fine grained sand are 1- 3 m/day while the storage capacity is in the order of 20% (i.e. 200ℓ of water is stored per cubic meter of saturated sand).

The aquifer is recharged by two mechanism namely rainfall and by leakage from the septic tanks on the Island (See Section 4).

Natural recharge to Leisure Isle aquifer is from rainfall. Studies in the area, in similar hydrogeological environments (Wilderness & Sedgefield), calculated that between 20 & 30% of annual rainfall recharges the aquifer. There is no defined stream flow off the Island due to the porous nature of the sands and the topography of the Island. The remainder of the rainfall is utilized by evapo-transpiration.

The area of the Island is 91ha (910 000$m^2$) and the mean annual rainfall over the last years is 600 mm per year.

As approximately 25% of the rainfall recharges the aquifer the net annual rainfall recharge to the Leisure Isle aquifer is calculated as 110 000 $m^3$/year.

## 3. WATER SUPPLY TO THE ISLAND

The domestic water supply to the Island is from the Knysna municipality. There are 450 houses on the Island of which LIRA (Leisure Isle Residents Association) estimated that approximately two thirds of these houses are permanently occupied which equates to 300 homes. The homes (except for the B&B) generally have two occupants for at least 9 months of the year. The remainder of the houses are holiday homes and these are usually occupied by families or extended families for the holiday period of the year which at a push, is approximately 3 months.

The average total municipal water consumption on Leisure Isle is 90 407 $m^3$/year (Knysna Municipality).

All water that is used on Leisure Isle stays on the Island as there is no sewerage reticulation system (See Section 4).

## 4. WASTE WATER DISPOSAL

There is no pipe sewerage disposal system on the Island, all waste water is disposed of by means of septic tanks. The solids are allowed to biodegrade in the tank while the “grey” water seeps into the aquifer. Approximately 95% of the water consumed finds is way into the aquifer either by means of the septic tanks or from garden irrigation with municipal water. As a result the waste water recharges the aquifer.

*Waste Water Recharge = domestic water consumption X 95% = 92 600 $m^3$/year*

## 5. THE ISLAND SPIKES

Messers, Vosey and Bridgman estimate that 85% of the houses on the Island have a "spike". A spike is essentially a Well Point that is installed to below regional groundwater level into the alluvial aquifer. The "spike" is connected to an end-suction pump and the water is used to irrigate the gardens on the Island. The typical yield of a spike is 500-1500ℓ/hr and is largely a function of the pump that is connected to the "spike".

The estimate is that an average irrigated garden on Leisure Isle property is 100$m^2$. Given the mean annual rainfall and evaporation, the average garden is irrigated for 30 weeks per year with 25mm/week of groundwater. This equates to a total abstraction of groundwater by means of "spikes" on the Island of:

380 houses x 100$m^2$ of garden x 0.025m of groundwater / week x 30 weeks = 28 500 $m^3$ / year

## 6. ISLAND WATER BALANCE

The Island water balance is critical to the understanding of the Leisure Isle hydrogeology. The groundwater input and outputs of the Island are shown on Figure 2 and quantified in Sections 3, 4 & 5. If there is a positive water balance on the Island there is very little chance of saline intrusion into the Island aquifer. A positive water balance will result in an increase in the height of the groundwater level a steeper gradient to the lagoon and the discharge of freshwater into the lagoon plus the maintenance of the fresh/seawater interface

| | | $m^3$/year |
|---|---|---|
| Inputs into the Leisure Isle Aquifer | | |
| Annual Rainfall recharge | = | + 94 500 |
| Disposal of Waste Water | = | + 92 600 |
| Total | = | 187 100 |
| Outputs from the leisure Isla Aquifer | | |
| "Spike" garden irrigation | = | 28 500 |
| Excess water | = | 158 600 |

This excess water goes into storage in the aquifer resulting in a rise in the region groundwater level, and a greater volume of discharge into the lagoon.

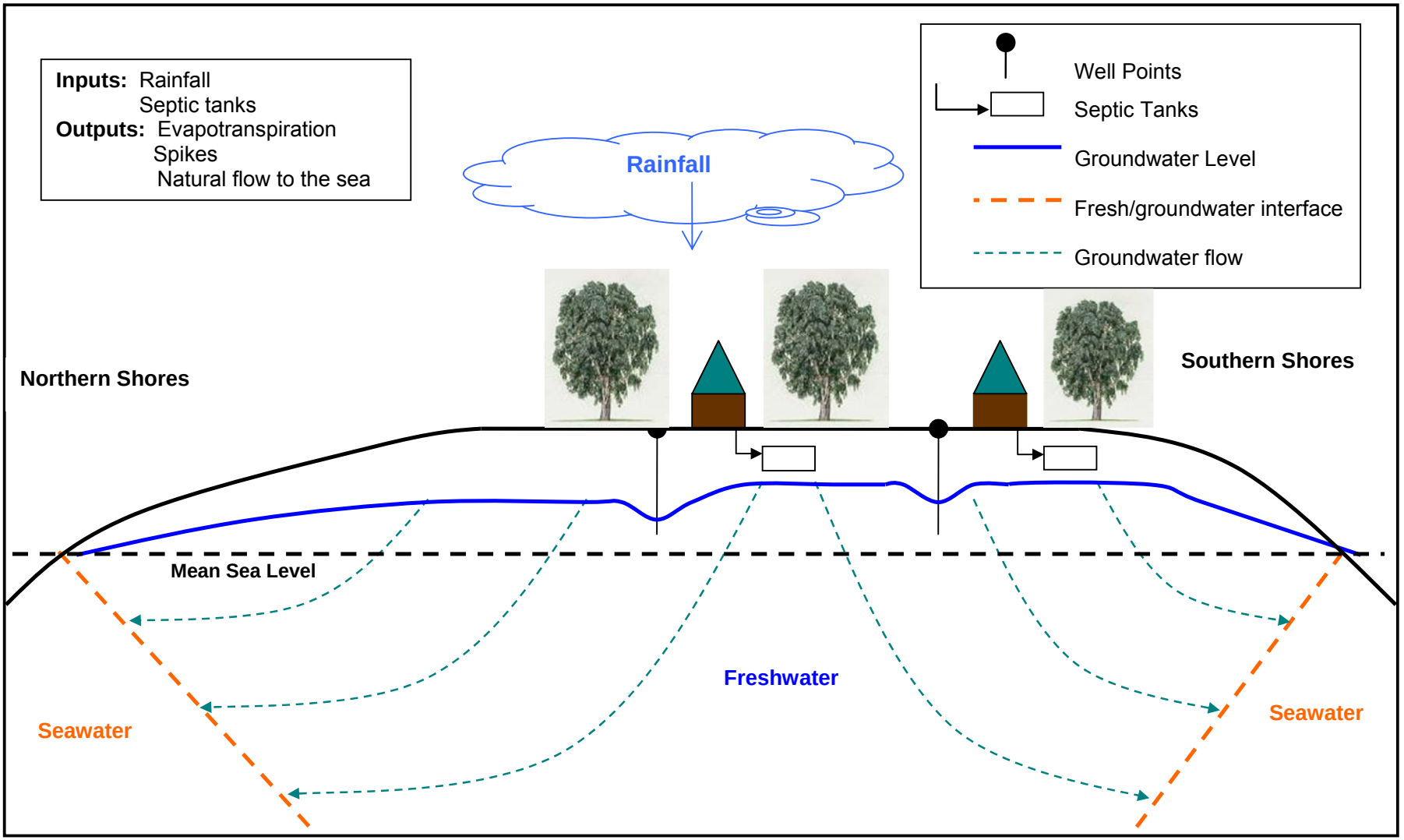



**Figure 2: Schematic Hydrogeological Diagram of the North South Section through Leisure Isle.**

## 7. THE FRESH WATER / SEAWATER RELATIONSHIP

The relationship between fresh water and seawater in the Island environment or along a coastal aquifer has been studied and measured in many environments throughout the world. The relationship was first studied by Ghyben and Herzberg (1905), who established the relationship between fresh and seawater in a coastal primary aquifer.

Ghyben and Herzberg and subsequent research found that the freshwater/seawater interface is governed by the density difference between fresh and seawater, plus the hydraulic gradient of the fresh water to the sea. Essentially the Ghyben Herzberg relationship can be explained by the following equation and is graphically shown in the figure below:

$$Hs = \frac{Pf}{Ps - Pf} Hf = \frac{1.00}{1.025 - 100} Hf = 40Hf$$

Where: Hs = depth of saline water below mean sea level
Hf = depth of groundwater above mean sea level
Pf = fresh water density = 1 000kg/m$^3$
Ps = saltwater density = 1 025kg/m$^3$

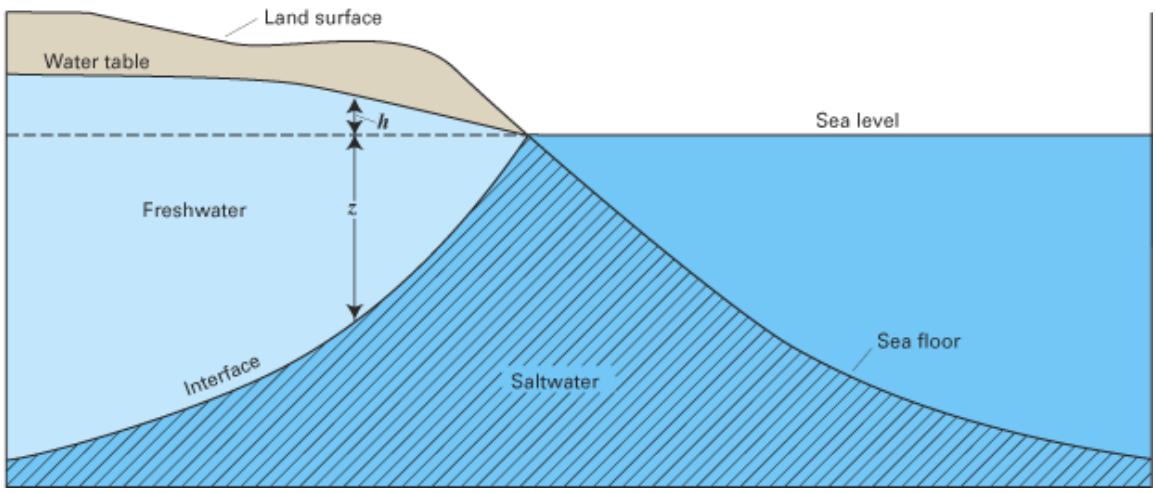



**Figure 3: Freshwater-saltwater interface in coastal aquifer draining into ocean**

$$Hs = 40Hf$$

This essentially means that for every one metre of fresh water above mean sea level there is 40 m of fresh water below it. The topography of the Island is gentle with the highest point being 5 m above mean sea level. The groundwater level will mimic topography and if the groundwater level is 3 m above mean sea level in the centre of the Island there would be 120 m of fresh water above the seawater/fresh water interface.
The Island's hydrogeological environment is dynamic with seasonal rainfall and an excess water balance on the Island between recharge and abstraction.
This results in a hydraulic gradient towards the sea where "excess" fresh water discharges into the lagoon. This gradient is also dynamic and the volume of fresh water discharging into the lagoon is dependent on the tidal fluctuation (i.e. more fresh water into the lagoon during low tide).

## 8. CONCLUSIONS

This paper is aimed at explaining the hydrogeology of the Island in order that the aquifer can be managed and informed decisions can be made regarding potential developments on the Island that may impact on the Leisure Isle aquifer.

The aquifer at present has an excess water balance and as a result the potential of saline intrusion into the aquifer is very remote. Critical to this balance is the natural rainfall recharge and the "artificial" recharge from the septic tank waste water disposal system.

## 9. USED REFERENCES

Bouwer, J.S., 1978: Groundwater Hydrology, McGraw Hill.

International Association of Hydrogeologists, 1991: Volume 11, Hydrogeology of Salt Water Intrusion , Heise

Davis S.N & De Wiest R.J.M, 1966: Hydrogeology, Wiley.

Personal Communication with Roger Vosey, Chairman of the Leisure Isle Residents Association (LIRA).