Specialist Geohydrology Impact Assessment for the proposed upgrade of Storm Water and Environmental Systems in the Port of Saldanha, Western Cape

July 2018

Prepared for:

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GLOSSARY OF TERMS

Aquifer: A geological formation that has structures or textures that hold water or permit appreciable water movement [from the National Water Act, 1998 (Act No. 36 of 1998)]. Also defined as the saturated zone of a geological formation beneath the water table, capable of supplying economic and usable volumes of groundwater to borehole(s) and / or springs.

Aquifer system: A heterogeneous body of interlayered permeable and less permeable material that act as a water-yielding hydraulic unit covering a region.

Borehole: Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from the National Water Act, 1998 (Act No. 36 of 1998)].

Catchment: The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system, synonymous with the term river basin.

Conceptual model: A simplified, schematic representation of each site, which includes sources, pathways and receptors, as well as the main process characteristics of the geohydrological system. An idealisation of the geohydrological system at the sites on which the numerical model is based. The conceptual model also includes assumptions on the hydrostratigraphy, material properties, dimensionality, and governing processes.

Confined aquifer: An aquifer in which the groundwater is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined groundwater occurs.

Contamination: The introduction of any substance into the groundwater system by the action of humans. The degradation of natural water quality as a result of man's activities, regardless of whether or not contaminant concentrations reach levels that cause significant degradation of water quality and restrict its use.

Ecosystem: An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit.

Electrical conductivity: A measurement of the ease with which water conducts electricity. Distilled water conducts electricity poorly, while sea water, with its very high salt content, is a very good conductor of electricity.

Ephemeral: Refers to watercourses that are generally storm-driven and in which flow occurs less than 20 % of the time; these watercourses have a limited (if any) baseflow component with no groundwater discharge.

Fault: A zone of displacement in rock formations resulting from tensional forces or compression in the earth’s crust.

Formation: A general term used to describe a sequence of rock layers.

Fracture: Cracks, joints or breaks in the rock that can enhance water movement.

Geohydrology: The study of the properties, circulation and distribution of groundwater, in practise used interchangeably with hydrogeology; but in theory hydrogeology is the study of geology from the perspective of its role and influence in hydrology, while geohydrology is the study of hydrology from the perspective of the influence on geology.

Greywacke: A dark coarse-grained sandstone containing more than 15 percent clay.

Groundwater flow: The movement of water through openings and pore spaces in rocks below the water table, i.e. in the saturated zone. Groundwater naturally drains from higher-lying areas to low-lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope (gradient) of the water table and the transmissivity of the geological formations.

Groundwater resource: All groundwater available for beneficial use, including humans, aquatic ecosystems and the greater environment.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

Hornfels: A dark, fine-grained metamorphic rock consisting largely of quartz, mica, and particular feldspars.

Hydraulic conductivity: Measure of the ease with which water will pass through porous material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (in m/d).

Hydraulic gradient: Change in hydraulic head per unit of horizontal distance in a given direction, i.e. the difference in hydraulic head divided by the distance along the groundwater flow path. Groundwater flows from points of high elevation and pressure to points of low elevation and pressure.

Intergranular aquifer: Groundwater contained in intergranular interstices of sedimentary and weathered formations.

Major aquifer system: Highly permeable formations, usually with a known or probable presence of significant fracturing, may be highly productive and able to support large abstractions for public supply and other purposes; water quality is generally very good.

Numerical modelling: The analysis of geohydrological processes using computer models.

Owner Controlled Area: A restricted area surrounding the reactor units to which only authorised personnel have access.

Piper diagram: The Piper diagram not only shows graphically the nature of a given water sample, but also dictates the relationship to other samples. For example, by classifying samples on the Piper diagram, geologic units with chemically similar water can be identified, and the evolution in water chemistry along the flow path defined. Two data points are plotted on the cation and anion triangles and are then combined into a quadrilateral field that shows the overall chemical property of the water sample.

Quaternary catchment: A fourth order catchment in a hierarchal classification system in which a primary catchment is the major unit.

Recent: Time period covering the last 10 000 years of the Earth's geological history

Recharge: The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and / or the lateral migration of groundwater from adjacent aquifers.

Saturated zone: The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.

Semi-confined aquifer: An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur; also referred to as a leaky aquifer.

Sole source aquifer: An aquifer that is needed to supply 50 % or more of the domestic water for a given area, and for which there are no reasonably available alternative water sources should the aquifer be impacted upon or depleted.

Spring: A point where groundwater emerges, usually as a result of topographical, lithological and / or structural control.

Storativity: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is a volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness. This is a measure of the water stored and released in an aquifer and is used to quantify the safe yield of an aquifer system.

Transmissivity: Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer. Transmissivity is used to calculate the yield of a borehole, determine the safe yield of an aquifer system and predict groundwater movement.

Unconfined aquifer: An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.

Water Management Area: An area that is established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources [from the National Water Act, 1998 (Act No. 36 of 1998)].

Water table: The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

Wellfield: An area containing more than one pumping borehole that provides water to a public water supply system or single owner (i.e. Municipality).

Wellpoint: A shallow, small diameter hole used to abstract groundwater from a primary aquifer.

Wetland: Land that is transitionary between terrestrial and aquatic systems, where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil [from the National Water Act, 1998 (Act No. 36 of 1998)].

LIST OF ACRONYMS AND ABBREVATIONS

3D:	Three dimensional
DWA:	Department of Water Affairs (now Department of Water and Sanitation)
DWAF:	Department of Water Affairs and Forestry (now Department of Water and Sanitation)
DWS:	Department of Water and Sanitation
EC:	Electrical conductivity, measured as milli-Siemens per metre (mS/m)
EIA:	Environmental Impact Assessment
GRAII	Groundwater Resource Assessment II Project
GRU:	Groundwater Resource Unit
K:	Hydraulic conductivity, measured as m/d
L/s:	litres per second
m/d:	metres per day
m^3/a:	cubic metres per annum
Ma	million years
mamsl:	metres above mean sea level
MAP:	Mean annual precipitation
mbgl:	metres below ground level
mg/ℓ:	milligrams per litre
Mm^3/a:	million cubic metres per annum
mS/m:	milli-Siemens per metre
SDP	Sustainable Drop Projects (Pty) :td
SSR	Site Safety Report
S_y:	Specific yield
SFPs:	spent fuel pools
T:	Transmissivity, commonly reported in units of m^2/d

EXECUTIVE SUMMARY

Nsovo Environmental Consulting has appointed Sustainable Drop Projects (Pty) Ltd (SDP) to undertake a geohydrological assessment as part of Environmental Impact Assessment (EIA) studies in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and the Environmental Impact Assessment Regulations of December 2014 as amended that Nsovo Environmental Consulting is undertaking on behalf of Transnet SOC Limited for the proposed upgrade of storm water and environmental systems in the Port of Saldanha within the jurisdiction of Saldanha Local Municipality in the Western Cape Province.

The primary objective of the proposed upgrade is to implement relevant recommendations of the Storm Water Master Plan (SWMP) and ensure that it aligns and fully complies with the requirements of South African Legislation as well as world best practices. The proposed scope of work entails the following key activities:

- The development of two new storm water retention/evaporation ponds;
- Introduction of infiltration channels where necessary;
- The resizing and reshaping of thirteen (13) existing storm water retention ponds;
- The development of a waste water treatment facility;
- Caisson collection reservoir and pumping system
- The upgrade of storm water management infrastructure; and
- The cleaning of existing storm water management systems

The methodology employed for this specialist geohydrological baseline and impact assessments were as follows:

- Available studies undertaken at the Port of Saldanha as well as the wider region were reviewed to determine baseline information available and to determine gaps in information;
- A site visit was conducted on 2 May 2018 to help to provide a better understanding of the dominant geohydrological processes at the site as well as help provide input for geohydrology assessments.
- The existing groundwater resources potentially affected by the proposed Project were described and mapped, including groundwater levels, groundwater quality, hydrological linkages with other surface and groundwater resources and existing users of groundwater resources in the area;
- The potential hydrogeological impacts were assessed and an impact report (this report) drafted to inform the Environmental Impact Assessment Report.

The likely impact during the upgrade of the infrastructure on the resources underlying the site was identified as follows:

- Hydrocarbon contamination: Downward migration of leaked and / or spilled fuel, oil and grease into the underlying aquifer system;
- Hazardous waste/chemicals contamination: Downward migration of contaminants from onsite waste storage areas and /or chemical storage areas into the underlying aquifer system;
- Organic and bacterial (microbiological) contamination: Downward migration of contaminant from leaking and / or spilling temporary on-site sewage facilities into the underlying aquifer system.

It was recommended that the following mitigation measures would be sufficient:

- Place drip trays under stationary machinery, only re-fuel machines at the temporary fuelling station, install temporary structures to trap fuel spills at the temporary fuelling station.

- Immediately clean oil and fuel spills and dispose of contaminated material (soil, etc.) at licensed disposal sites only.
- Equip the site with sufficient ablution facilities. Secure chemical toilets to ensure that they do not blow over in windy conditions.
- Do not make uncontrolled releases of any pollutants, including sediment, sewage, cement, fuel, oil, chemicals, hazardous substances, waste water, etc., into the environment.
- Compile a procedure for the storage, handling and transport of different hazardous materials and ensure that it is strictly adhered to.

The potential impacts during the operational phase were identified as follows:

- Fuel and oil leaks from the vehicle transporting the iron ore
- Storm water with iron ore dust in the retention ponds which could percolate into the groundwater resources and the shore/sea in the vicinity of the site.

It is considered that under normal design operational conditions, such releases are highly unlikely.

It is expected that without mitigation, the quantity of potential non-radioactive contaminants used and/or stored, and spilled and/or leaked at the sites, will be low and therefore insufficient to extensively contaminate the primary aquifers. With mitigation, the intensity is reduced to **low**.

The essential mitigation measures recommended are as follows:

- Proper maintenance plan for the retention pond system to ensure effective operation
- Use existing ablution and waste water treatment facilities at the Site.
- Do not make uncontrolled releases of any pollutants, including, radioactive substances, sewage, fuel, oil, chemicals, hazardous substances, waste water, etc., into the environment.
- Ensure vehicles and equipment are in good working order and drivers and operators are trained.
- Ensure that good housekeeping rules are applied.

1. INTRODUCTION

Nsovo Environmental Consulting has appointed Sustainable Drop Projects (Pty) Ltd (SDP) to undertake a geohydrological assessment as part of Environmental Impact Assessment (EIA) studies in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and the Environmental Impact Assessment Regulations of December 2014 as amended that Nsovo Environmental Consulting is undertaking on behalf of Transnet SOC Limited for the proposed upgrade of storm water and environmental systems in the Port of Saldanha within the jurisdiction of Saldanha Local Municipality in the Western Cape Province. See **Figure 1-1** for locality.

The proposed development entails the upgrade of the existing storm water infrastructure at the Port in order to improve the storm water infrastructure systems. Various storm water management infrastructures have been constructed within the Port. The Storm Water Master Plan (SWMP), 2013, for the Port of Saldanha indicates that the existing storm water management infrastructure of certain areas in the Port is inadequate for 1:50 year flood line conditions, therefore, if the infrastructure is not upgraded and/or replaced, uncontrolled discharge into the bay and municipal system will be imminent. Consequently, Transnet proposes to undertake the upgrading of the storm water and environmental systems within the Port.

1.1 Project Description

The primary objective of the proposed upgrade is to implement relevant recommendations of the Storm Water Master Plan (SWMP) and ensure that it aligns and fully complies with the requirements of South African Legislation as well as world best practices. Subsequently, Transnet proposes to upgrade the storm water and environmental systems in the Port with the view to prevent future uncontrolled discharges into the marine environment and the municipal sewage system. This requires that all surface water runoff from contaminated areas within the Port is contained and iron ore dust and other pollutants are removed either by settlement of sediments and/or treatment to bring the effluent pollutants concentrations to within allowable concentrations before the runoff enters the natural environment. Storm water management infrastructure including surfaces, channels, ponds, berms and infiltration trenches need to be installed and/or altered for this purpose. The proposed scope of work entails the following key activities:

- The development of two new storm water retention/evaporation ponds;
- Introduction of infiltration channels where necessary;
- Incorporation of proprietary filter systems at the Multi-purpose Terminal with the capacity to filter heavy metals out of the stormwater
- The resizing and reshaping of thirteen (13) existing storm water retention ponds;
- The development of a waste water treatment facility;
- Caisson collection reservoir and pumping system
- The upgrade of storm water management infrastructure; and
- The cleaning of existing storm water management systems.

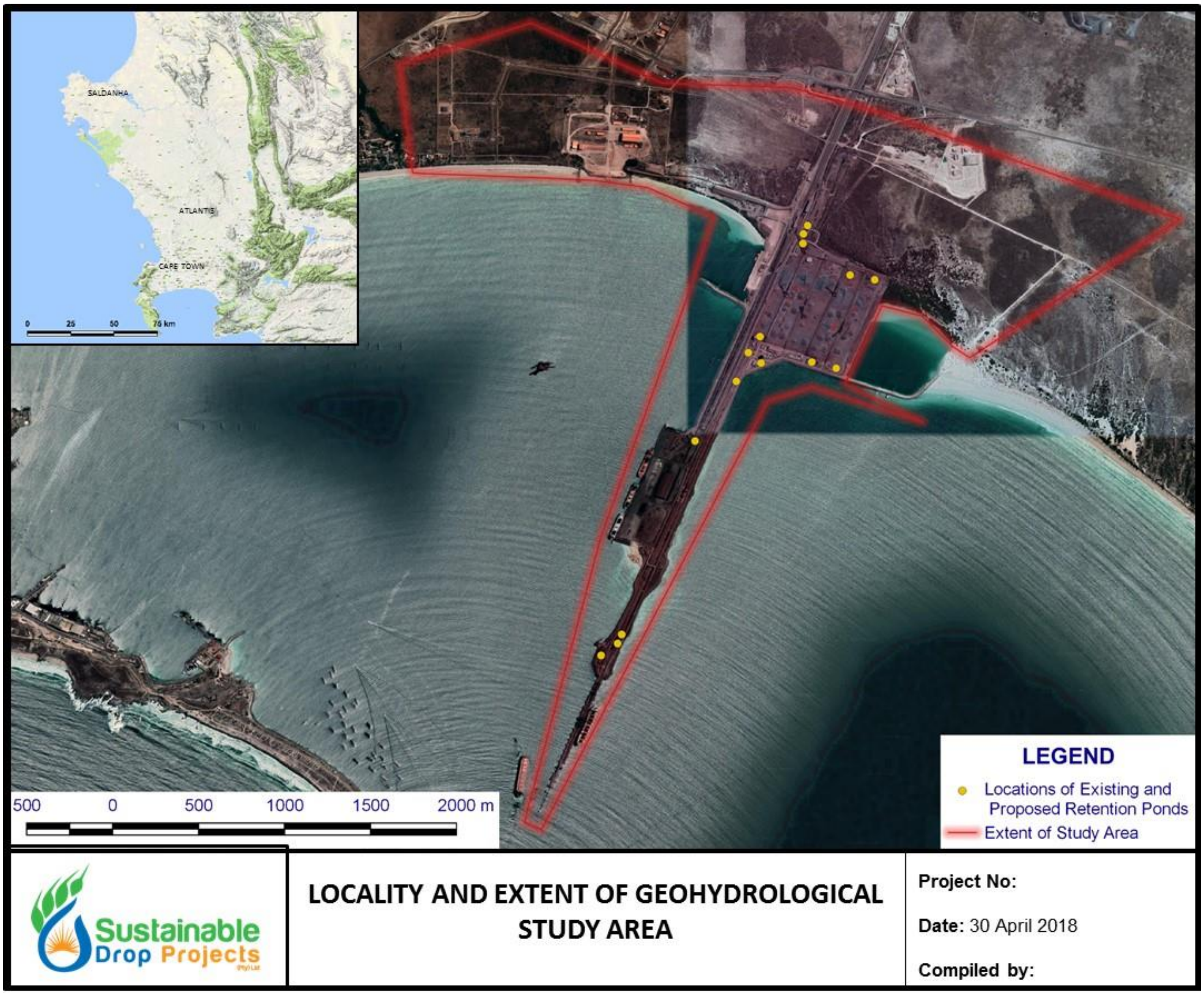

Figure 1-1: Locality and Extent of Geohydrological Study Area

1.2 Terms of Reference

The following scope of work was provided:

- Describe the existing baseline characteristics of the project site and place this in a regional context (study area);
- Identify and assess potential impacts of the project, including impacts associated with the proposed developments including the resizing and reshaping of the existing ponds, the development of the two new ponds and operation phases, using SDP's prescribed impact rating methodology;
- Identify and describe potential cumulative impacts of the proposed Project in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to avoid and/or minimise impacts and/or optimise benefits associated with the proposed project; and
- Recommend and draft a monitoring campaign, if applicable.

1.3 Deliverables

The main deliverable will be an impact assessment report. The report will consist of the following components:

- **Baseline description**: a description of the environment of the study area in its current state, relevant to the geohydrology of the Project site; and
- **Impact assessment**: an assessment of how the proposed Project will alter the status quo as described in the baseline description, and recommended measures to mitigate and monitor impacts.

1.4 Methodology

The methodology employed for this specialist geohydrological baseline and impact assessments were as follows:

- Available studies undertaken at the Port of Saldanha as well as the wider region were reviewed to determine baseline information available and to determine gaps in information;
- A detailed hydrocensus was conducted on and around the site to a distance of about two kilometres
- so as to obtain a representative population of the boreholes in the area.
- A site visit was conducted on 2 May 2018 to help to provide a better understanding of the dominant geohydrological processes at the site as well as help provide input for geohydrology assessments.
- The existing groundwater resources potentially affected by the proposed Project were described and mapped, including groundwater levels, groundwater quality, hydrological linkages with other surface and groundwater resources and existing users of groundwater resources in the area;
- The potential hydrogeological impacts were assessed and an impact report (this report) drafted to inform the Environmental Impact Assessment Report.

1.5 Project Team

The geohydrological project team for the hydrogeology assessment comprised:

Paulo Kagoda. Hydrogeologist. Paulo has 13 years of experience in hydrogeology, impact assessments, water and wastewater treatment, project management, quality control and reporting. He has carried out numerous specialist groundwater studies and water supply projects in southern Africa. Paulo was the project manager and compiled this report.

Pramod K. Sinha. (Pr. Eng) Senior Hydrogeologist, Pramod has 36 years of experience in water resources planning and management in India, Botswana and South Africa. He specialises in groundwater modelling, and has generated numerous flow and transport models for industry and government. Pramod was responsible for overseeing the assessment process as part of his quality control role and reviewed this report.

1.6 Information Sources

The information collected and used in this study can be summarised as follows:

- Draft Basic Assessment Report for the Proposed Upgrade of Storm Water and Environmental Systems in the Port of Saldanha within Saldanha Bay Local Municipality in the Western Cape Province provided by the client (Nsovo Environmental Consulting)
- The Saldanha Port Stormwater Master Plan of 2013 provided by the Client (Nsovo Environmental Consulting)
- Port of Saldanha locality mapping provided by the Client (Nsovo Environmental Consulting)
- KML file with locations of the 15 ponds provided by the Client (Nsovo Environmental Consulting)
- Existing and New Capacities of the 15 ponds provided by the Client (Nsovo Environmental Consulting)
- Aerial photography (Google Earth)
- Rainfall and Evaporation data obtained from the Water Research Commission (WR2012 Study)

2. GEOHYDROLOGY BASELINE

2.1 Physiography and Climate

The Project site is located on the northern shore of Saldanha Bay. Saldanha Bay is located approximately 100 km north of Cape Town on the West Coast. (**Figure 1-1**) and is located within the jurisdiction of Saldanha Bay Local Municipality which is under the West Coast District Municipality. Access to the Project site is via the Saldanha Bay Road. The residential properties located around the study area are community households which are dominated by medium to low density residential developments which include Saldanha and Vredenburg which are located approximately 9km and 12km from the Port respectively, while the industrial and commercial related activities in the local municipality cut across a wide array of sectors including agriculture, community services, construction, general government services, finance, manufacturing, transport and trade.

The Project site falls within quaternary catchment G10M and in the Berg-Olifants Water Management Area (**Figure 2-1**). The site has a Mediterranean climate characterised by dry summers and wet winters. The nearest South African Weather Service (SAWS) rainfall station to the Port of Saldanha is the Saldanha Bay (Customs) station – Station No. SAWS 0060780. The average annual rainfall recorded at this station from 1900 to 2007 is 268.9 mm/a (See Appendix 1 for the historical monthly data). This station falls within Rain Zone G1D (WRC, 2015). Evaporation data was obtained from Evaporation Zone 23B, Evaporation Station G1E005 (WRC, 2015).

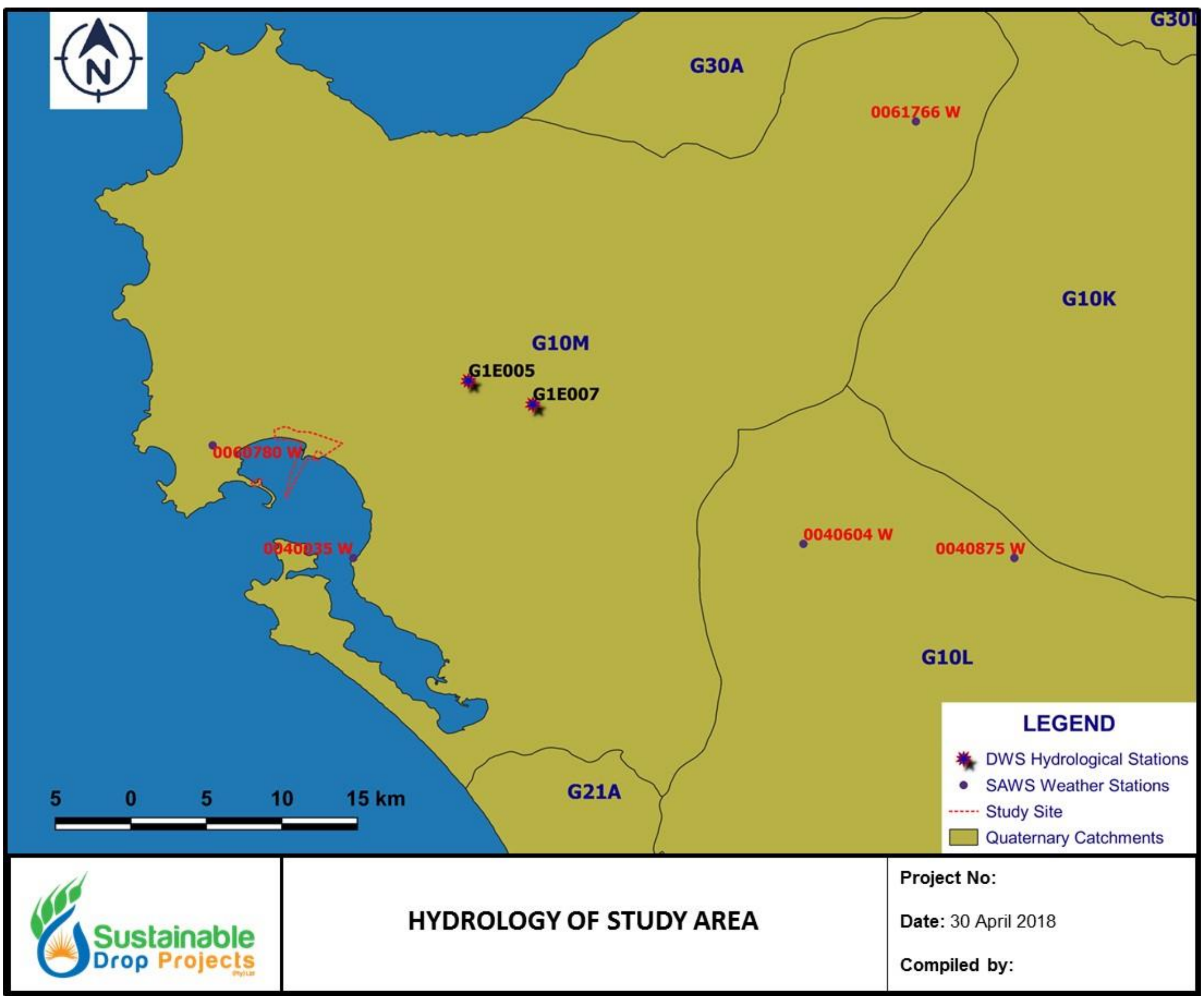

Figure 2-1: Hydrology of the Study Area

Table 2-1: Monthly Rainfall and Evaporation Distribution for Saldanha Bay (for the period 1900-2007)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Monthly rainfall data (mm)												
Min	0.0	0.0	0.0	0.0	0.0	3.8	6.4	0.0	0.0	0.0	0.0	0.0	174.0
Avg	7.04	7.03	9.42	22.39	47.58	61.96	57.23	49.36	26.87	13.6	7.4	2.6	268.9
Max	76.80	61.00	80.00	90.10	299.70	302.30	401.80	164.00	75.80	66.0	27.0	11.5	455.4
	Monthly evaporation data (mm)												
Average	270.9	223.5	206.6	126.7	71.8	47.0	45.8	64.1	100.0	155.6	216.8	265.7	1795

2.2 Geology

2.2.1. Regional Geology

In the Western Cape Province, where the study site is located, the oldest rocks are gneisses and granites of the Mokolian Namaqua-Natal Metamorphic Province (approximately 1100 million years old) exposed north of Vredendal. These rocks are overlain by the Gariep Supergroup rocks, which are approximately 650 million years old, and similar-aged rocks of the Malmesbury Group. The Kaaimans and Cango Groups occur in the southwestern and southern parts of the province, respectively. The Malmesbury and Kaaimans Groups are intruded by the 550–510 million-year-old Cape Granite Suite. The slightly younger Vanrhynsdorp Group occurs in the northwestern part and the Klipheuwel Group in the southwestern part of the province (Ngcofe and Cole, 2014).

2.2.2. Site Geology

The unconsolidated to semi-consolidated sediments underlying the Project site belong to the Sandveld Group, which is subdivided into the Elandsfontyn, Varswater, Velddrif, Langebaan, Springfontyn and Witzand formations. The lithostratigraphy of the Sandveld Group is summarised in **Table 2-2** (Johnson et al., 2006) and the surface geology is shown in **Figure 2-2**. The sediment thickness varies considerably and reaches a maximum thickness of between 30 and 80 m (Theron, 1992).

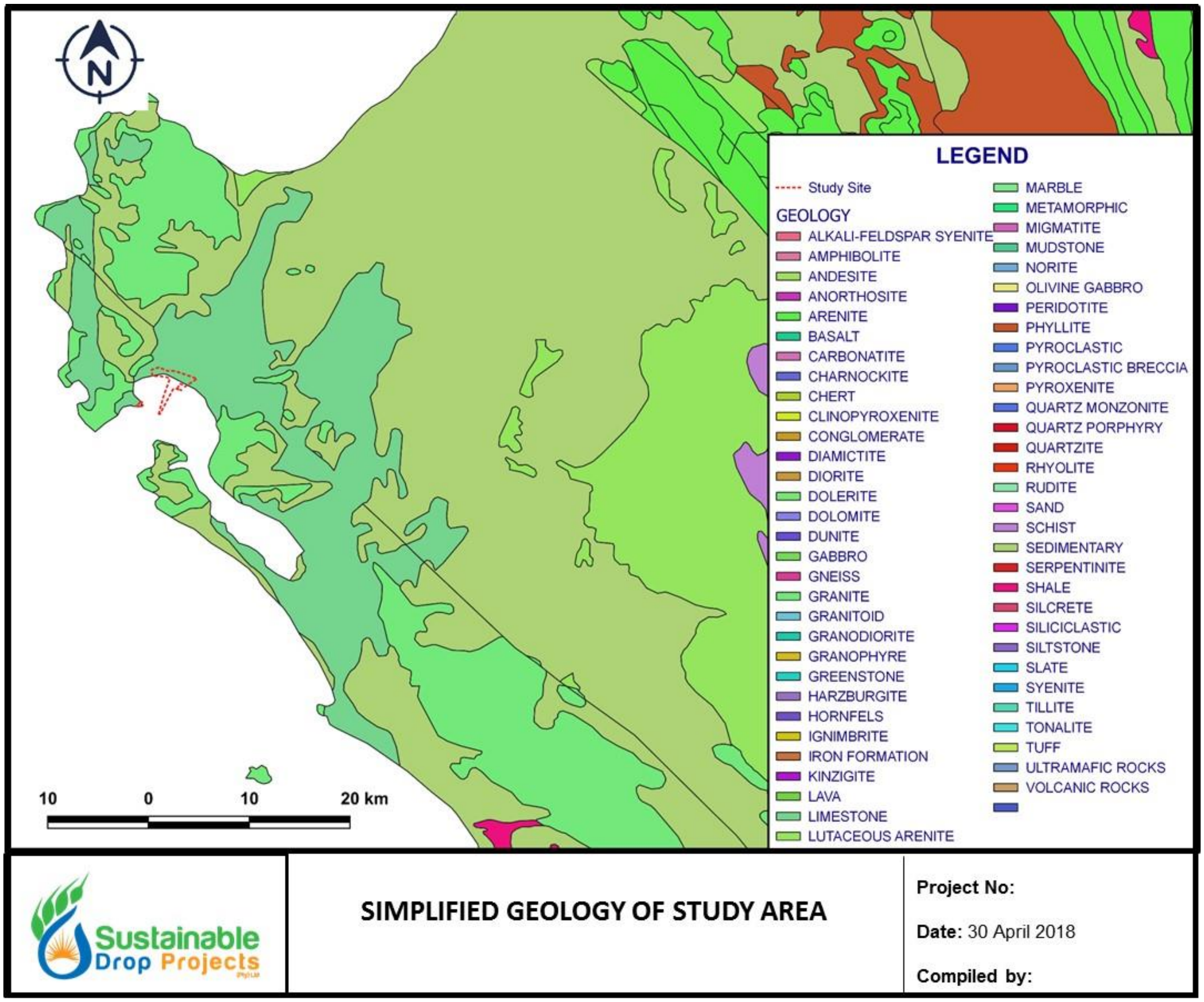

Figure 2-2: Simplified Geology of the Geohydrological Study Site

Table 2-2: Summary of the Sandveld Group Lithostratigraphy (after Johnson et al., 2006)

Formation	Member	Origin	Type	Description	Epoch	Age (Ma)
Witzand		Aeolian	SAND	Fine- to medium-grained, whitish grey to slightly reddish, calcareous, cross-stratified, dune snails, echinoid spicules, forams and comminuted sea shells	Holocene	0.01 to 0
Springfontyn		Aeolian	SAND	Fine- to medium-grained, quartzitic sand, muddy and peaty in places	Pleistocene to Holocene	1.8 to 0.01
Langebaan		Aeolian	CALCAREOUS SANDSTONE	Cross-bedded, fine- to medium-grained, with calcrete layers	Late Pliocene to Late Pleistocene	2 to 0.2
Velddrif		Shallow marine	GRAVEL and SAND	Shelly and pebbly, cross-bedding	Plio-Pleistocene to Late Pleistocene	1.8 to 0.2
Varswater	Muishond Fontein	Estuarine / shallow-marine	SAND	Phosphatic, quartz-sand	Miocene to Pliocene	23 to 5
	Langeberg	Estuarine / shallow-marine	SAND	Non-phosphatic, carbonaceous clay and lignite lenses	Miocene to Pliocene	23 to 5
	Konings Vlei	Shallow-marine	GRAVEL	Pebbles and cobbles	Miocene to Pliocene	23 to 5
	Langeenheid	Estuarine	SAND	Argillaceous (clayey sand / silt)	Middle Miocene	14
Elandsfontyn		Fluvial	SAND and GRAVEL	Angular clasts, carbonaceous clay and lignite lenses	Early to Middle Miocene	23 to 14

The sediments of the Sandveld Group are underlain by meta-sediments belonging to the Tygerberg Formation of the Malmesbury Group. The Tygerberg Formation consists mainly of alternating greyish, medium to fine grained greywacke and phyllitic shale. Where intruded by the Cape Granite Suite (not present on-site) and narrow dolerite dykes (present on-site), the sediments are baked to massive bluish-grey hornfels along their contacts. These dykes, as well as faults in the vicinity of the site, have been delineated by the Council for Geoscience. The bedrock at the site consists of a steeply dipping, interlaminated and bedded succession of greywacke, siltstone and mudstone, with occasional shale interbeds of the Malmesbury Group. Gradational sequences and contacts are characteristic and the beds grade mainly from coarse to fine grained in upward-fining successions. The degree and depth of weathering varies considerably across the site. Unweathered greywacke is present within 6 m of the bedrock surface, while weathering of mudstone and siltstone extends to 26 metres below ground level in some places. The bedrock is brecciated along fault zones, and is intensely jointed and often sheared along such fault planes. Quartz veins, pyrite and clay gouge are ubiquitous in the joints and faults, especially where the wall-rocks of the faults are brecciated.

2.3 Geohydrology

2.3.1. Aquifer Types

Groundwater in and around the Project area occurs in the unconfined Langebaan Road Aquifer that is located between the lower Berg River and Saldanha Bay. The geomorphological origins of Saldanha Bay are related to deep fluviatile incision of bedrock by a "proto-Berg" river during Miocene or pre-Miocene times, as revealed by marine geological and geophysical investigations in Saldanha Bay (De la Cruz, 1978).

2.3.2. Aquifer Parameters

Hydraulic conductivity values vary over more than 10 orders of magnitude in nature (Calver, 2001). Typical hydraulic conductivity values are:

- For an unconsolidated silty sand to gravel – 0.01 to 10,000 m/d (Freeze and Cherry, 1979)
- For fluvial deposits (alluvium) – 0.1 to 1000 m/d (Hiscock, 2005)
- For lacustrine silt and clay – 1^{E-8} to 1^{E-4} m/d (Hiscock, 2005).

A numerical model DWAF (2008) setup to model the Langebaan Road Aquifer found satisfactory model performance with hydraulic conductivity set at 10 m/d. It must be noted, however, that the study assumed homogeneity throughout the aquifer. Previously Timmerman (1985a) had provided estimates for transmissivity (T) (hydraulic conductivity x thickness) of the sand deposits on the area from hydraulic testing but these are considered unreliable owing to numerous issues that Timmerman (1985a) reported affected the process. These included:

- Gravel packs seldom being placed in the correct positions, hence the possibility that unknown units are targetted in the pumping
- Incorrect well and screen design causing sand infiltration into the holes and sand blocking screens artificially reducing the hydraulic conductivity of the formation surrounding the hole.

2.3.3. Hydrocensus Survey

A detailed hydrocensus was conducted on and around the site to a distance of about five kilometres so as to obtain a representative population of the boreholes in the area. During the hydrocensus, all available details of boreholes were collected. Of the 32 within the five kilometer radius (**Appendix 2**), five are within the study site and are discussed to some detail in 2.3.4. Available information was collected on the use of the boreholes in the area, the water levels and yields of boreholes, etc. The information can be used to assess the risk which potential groundwater pollution poses to groundwater users.

2.3.4. Depth to Groundwater

According to the WR2012 study, the average water level for the Southwestern Cape Coastal Sandveld where the site is located is about 9.72m below surface. However, within the site, there are geosites whose details were extracted from the National Groundwater Archive and are presented here in **Figure 2-3** and **Table 2-3**.

The difference in depth to groundwater levels suggest that the boreholes on site are accessing a perched water aquifer, perhaps above the calcrete geology typically found in the area.

Table 2-3: Static Water Levels readings for boreholes within the Study site

Borehole Id. No.	Location	Longitude	Static Water Level (mbgl)	Date
BG00171[1]	-33.00008	18.001	7.92	1 April 2012
			7.55	14 January 2015
BG00172[1]	-33.00018	18.00099	4.47	30 March 2012
			4.21	14 January 2015
BG00173[1]	-33.00014	18.00107	3.96	26 March 2012
BG00174[1]	-33.00008	18.001	4.31	28 March 2012
3318AA00235[2] (DWA No. G1N0389)	-33.00206	18.00394	2.98	2 November 2004
			3.08	7 December 2004
			3.20	11 January 2005

[1] Reference in the National Groundwater Archive provided as "Specialist Hydrogeological study, Crude Oil tank farm, Saldanha" dated 5/2/2012
[2] Reference in the National Groundwater Archive provided as "Internal Documentation"

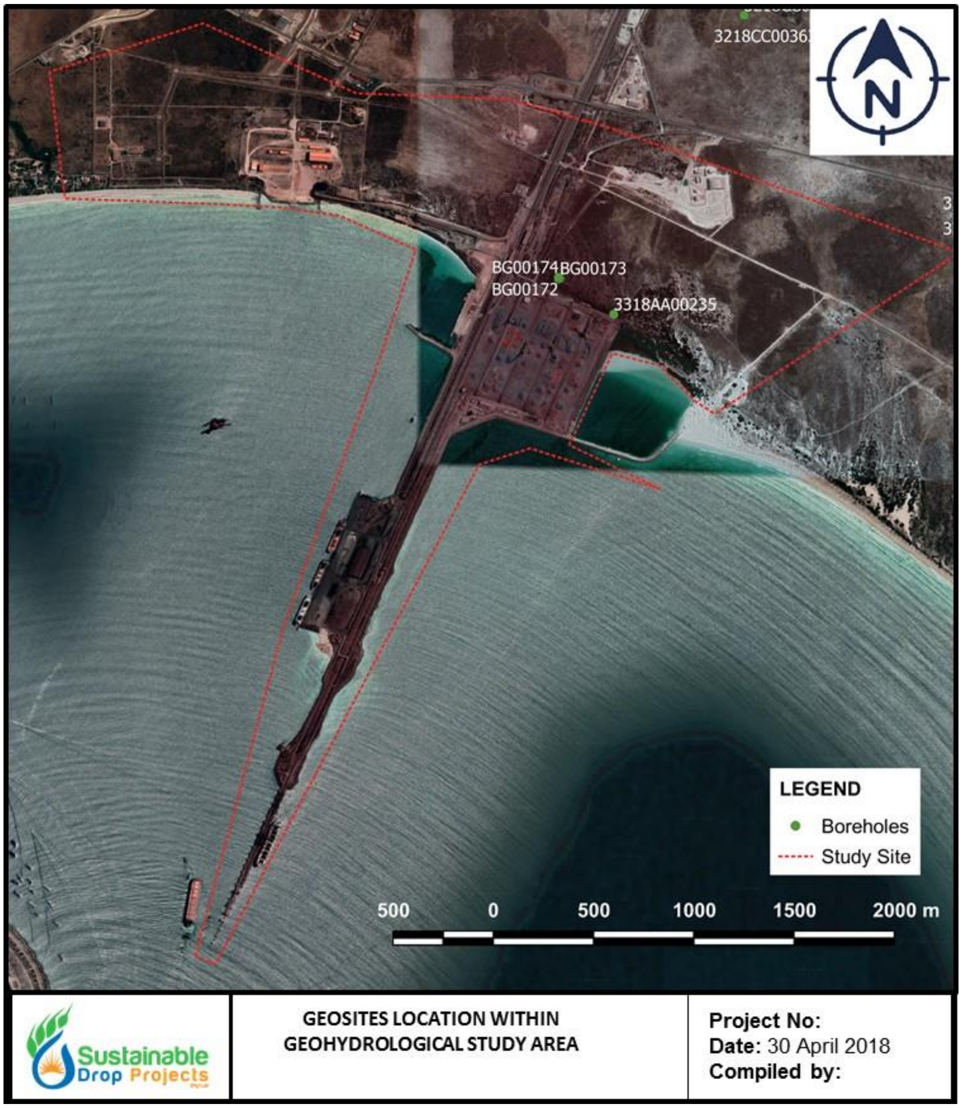

Figure 2-3: Geosites Location within the Study Area

In addition to the static water levels data presented in **Table 2-3** above, monitoring data for borehole with a NGA ID reference of 3318AA00235 (also identified by DWS as hydrological Station No. G1N0389) for the period 7 September 2004 to 27 February 2018 was obtained and this presented in **Figure 2-4** and in Appendix 2. There is no indication of significantly declining water levels prior to November 2016. Seasonal trends are evident, as is the short duration influence of pumping. The likely explanation for continued fall in water levels after November 2016 could be the impact of the drought conditions faced by the Western Cape province that have led to a reduction in aquifer recharge.

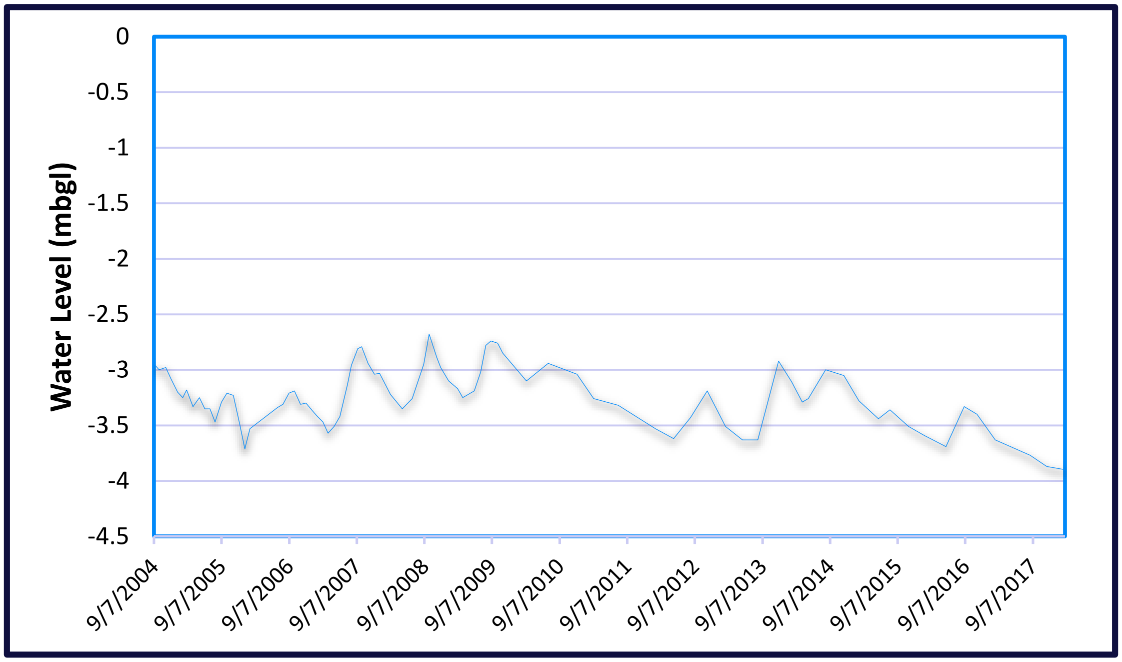

Figure 2-4: Groundwater level fluctuation in Monitoring Borehole DWA G1N0389 on the study site

Also observed is that the water table depths vary seasonally with higher levels seeming following the wet season as reflected in **Figure 2-5**.

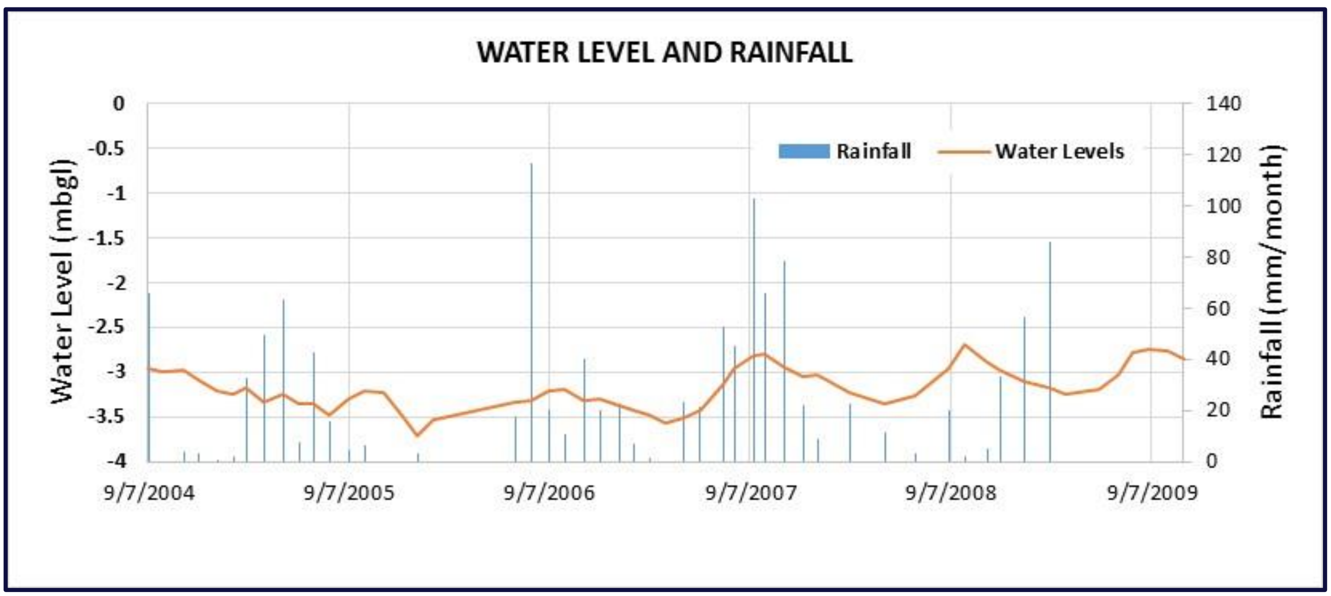

Figure 2-5: Groundwater Fluctuations vs Rainfall Seasonal Pattern

2.3.5. Aquifer Recharge

Estimates of recharge (as a percentage of rainfall) in the vicinity of the site have previously been made by Timmerman (1985b) who, based on a 15% recharge rate estimate from rainfall, set the short-term yield of Langerbaan Road Aquifer System at 19.5 x 10^6 m^3/a and the long-term yield at 30 x 10^6 m^3/a.

In a re-evaluation conducted by CSIR, the recharge rate was estimated at 8% recharge from rainfall (Weaver *et. al.,* 1997).

Woodford and Fortuin (2003) used a GRID-based GIS modelling technique to estimate effective annual recharge, which relates to an average effective recharge of 3.9% of annual rainfall. The GRAII and Water Balance Model

(DWAF, 2007) methods all generate recharge estimates that are approximately 5% of the rainfall, and at a maximum at 8% (DWAF, 2007).

A number of references including DWAF (2008) indicate that groundwater flows in a south-westerly direction across the site towards the coast and Saldanha Bay.

2.3.6. Borehole Yields and Groundwater Use

While the primary water resource is the Berg River; groundwater still plays a significant role as a water supply source. Data regarding water use is available from GRAII. Water use, summed for each type of use, for quaternary catchment G10M is given in **Table 2-4** below.

Table 2-4: Groundwater Use in Quaternary Catchment G10M

Catchment	Groundwater Use (Million m^3/a)						
	Total	Rural	Municipal	Agric. Irrigation	Agric. Livestock	Mining	Industry
G10M	1.999	0.007	0.0837	0.0000	0.4073	0.0000	1.5010

The closest municipal abstraction of groundwater occurs approximately 30 kilometres to the north east of the sites close to Langebaanweg.

2.3.7. Aquifer Classification and Vulnerability

Using the Aquifer Classification according to the Aquifer Classification Map of South Africa (Parsons and Conrad, 1999), the aquifer at the site is classified as a poor aquifer system with low vulnerability and low susceptibility to contamination. For more on the classification, the maps are included as **Appendix 3.**

2.3.8. Groundwater Quality

The electrical conductivity (EC) of water is a physical property which is widely used as an alternative to the chemical measuring of total dissolved solids (TDS), to determine water quality. Pure water has a low conductivity and an increase in conductivity generally reflects a decrease in water quality. The EC of groundwater in the area is generally between 150 and 300 mS/cm (Hohls et. al., 2002). According to WRC (1998) this represents saline conditions and is unacceptable for long-term drinking purposes.

2.4 Conceptual Geohydrological Model

A conceptual geohydrological model is a descriptive representation of a groundwater system that incorporates an interpretation of the geological and hydrological conditions. It consolidates the current understanding of the key processes of the groundwater system, including the influence of stresses, and assists in the understanding of possible future changes. The main concepts were introduced in the Subsections 2.3.1 to 2.3.7 above, and are summarised below:

- There is no downstream use of groundwater.
- Groundwater at the site is near/at the end of its flow path.
- Depth to the groundwater table within the study site has been recorded as high as 3.08 metres below ground level all the way to just above 8 metres below ground level. This may impose a depth limitation as far as the resizing the existing ponds is concerned.
- The receiving environment/downstream receptor of any contamination will be the shore zone/sea.

- Groundwater flow is from inland, across the Project site, in a south-westerly direction towards the coast, where it discharges into the ocean
- Natural groundwater quality is marginally saline.
- Hydraulic conductivity values of 10 m/d have been used to model the Langerbaan Road Aquifer System (assuming homogeneity across the aquifer) with satisfactory performance.

3. IMPACT IDENTIFICATION, ASSESSMENT AND MITIGATION

The assessment of potential impacts on the groundwater resources discussed below is relevant to the proposed upgrade.

3.1. Construction Phase

During the upgrade of the stormwater system which is understood to include development of two new storm water retention ponds, resizing and reshaping of thirteen (13) existing storm water retention ponds, the groundwater, development of a waste water treatment facility, etc. as detailed in project description above, resources underlying the site may potentially be impacted as follows:

- Hydrocarbon contamination: Downward migration of leaked and/or spilled fuel, oil and grease into the underlying aquifer system;
- Hazardous waste/chemicals contamination: Downward migration of contaminants from onsite waste storage areas and/or chemical storage areas into the underlying aquifer system;
- Organic and bacterial (microbiological) contamination: Downward migration of contaminant from leaking and / or spilling temporary on-site sewage facilities into the underlying aquifer system.

With respect to hydrocarbon, hazardous waste, chemicals and organic and bacterial (microbiological) contamination of the aquifer, the intensity is assessed to be low on account of the existing housekeeping practice as observed during the site visit and the low storm water volumes that result in some of the retention ponds being empty especially during the summer months as supported by the Climatic Water Balance Assessment (Appendix 4) and classification for the site. Consequently, the natural quality of groundwater at the sites should not be notably degraded. It is presently not known what types of hazardous substances may be, stored, transported or disposed of, or otherwise managed, at the site during construction. However, typical examples, associated with construction, of such potential contaminants are paints and solvents, vehicle wastes (e.g. used motor oil, etc.), mercury-containing wastes (e.g. thermometers, switches, fluorescent lighting, etc.), caustics and cleaning agents and batteries.

It is expected that without mitigation, the quantity of potential contaminants used and / or stored, and spilled and/or leaked at the sites, will be low and therefore insufficient to extensively contaminate the primary aquifer. With mitigation, the intensity reduces to **low (Table 3-1).**

Table 3-1: Potential groundwater contamination caused by construction activities

Aspect	Corrective measures	Impact rating criteria					Significance
		Nature	Extent	Duration	Magnitude	Probability	
Geo-hydrology	No	Negative	2	2	6	2	20 (<30 = Low)
	Yes	Negative	1	2	2	1	5 (<30 = Low)

Corrective Actions	• Place drip trays under stationary machinery, only re-fuel machines at the temporary fuelling station, install temporary structures to trap fuel spills at the temporary fuelling station. • Immediately clean oil and fuel spills and dispose of contaminated material (soil, etc.) at licensed sites only. • Equip the site with sufficient ablution facilities. Secure chemical toilets to ensure that they do not blow over in windy conditions. • Do not make uncontrolled releases of any pollutants, including sediment, sewage, cement, fuel, oil, chemicals, hazardous substances, waste water, etc., into the environment. • Compile a procedure for the storage, handling and transport of different hazardous materials and ensure that it is strictly adhered to. • Ensure vehicles and equipment are in good working order and drivers and operators are trained with respect to actions to be taken in the case of a fuel spill or leak. • Ensure that good housekeeping rules are applied.

3.2. Operations Phase

The potential impacts during the operational phase are as follows:

- Fuel and oil leaks from the vehicle transporting the iron ore
- Storm water with iron ore dust in the retention ponds which could percolate into the groundwater resources and the shore/sea in the vicinity of the site.

However, under normal design operational conditions, such releases are highly unlikely.

It is expected that without mitigation, the quantity of potential non-radioactive contaminants used and/or stored, and spilled and / or leaked at the sites, will be insufficient to extensively contaminate the primary aquifers. With mitigation, the intensity is reduced to **Low** (**Table 3-2**).

Table 3-2: Potential groundwater contamination caused by operational activities

Aspect	Corrective measures	Impact rating criteria					Significance
		Nature	Extent	Duration	Magnitude	Probability	
Geo-hydrology	No	Negative	2	2	6	2	20 (<30 = Low)
	Yes	Negative	1	2	2	1	5 (<30 = Low)
Corrective Actions	• Proper maintenance plan for the retention pond system to ensure effective operation • Use existing ablution and waste water treatment facilities at the Site. • Do not make uncontrolled releases of any pollutants, including sediment, sewage, cement, fuel, oil, chemicals, hazardous substances, waste water, etc., into the environment. • Ensure vehicles and equipment are in good working order and drivers and operators are trained. • Ensure that good housekeeping rules are applied.						

3.3. Fatal Flaws (Statement of Acceptability)

The geohydrological specialist study indicates that there are no groundwater related fatal flaws with respect to upgrading the stormwater and environmental systems.

3.4. No Go Option

In case the proposed upgrade is not implemented, the existing storm water system status quo will continue with no change in groundwater contamination risk.

3.5. Groundwater Monitoring

Groundwater monitoring with the existing boreholes at the study site is recommended on account of the observed static water levels in boreholes on site being higher than 5 metres below ground level especially if the resizing that is proposed for some of the existing ponds will make them deeper thus increasing the opportunity for percolation of storm water into the shore/sea.

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APPENDICES

APPENDIX 1: RAINFALL DATA

SAWS Station No. 0060780

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1900										29	9.5	6
1901	76.8	18.9	6.3	13.7	74.8	20.6	53.9	21.2	11.8	5.4	37.4	4.4
1902	6.3	8.2	11.6	29.8	65.8	52.8	52.8	67.7	72.3	21.3	5.9	2.6
1903	22.9	1.9	8.9	38.4	66.3	110	19.7	53.4	37.2	35.4	2	2.6
1904	15.9	2.3	3.5	58.2	31.8	88.1	38.8	99.9	29.6	28.3	14.3	8.2
1905	3.6	2.5	9.8	2.3	58.4	75.8	29.9	44.6	31.3	19.8	6.7	2.5
1906	5.7	0	14.8	9.3	33.9	46.7	13.9	53	13	9	4.6	14
1907	6.1	2.5	13.8	24.4	72.1	20.9	6.4	11.4	28.3	23.6	9.6	9.2
1908	8.9	4.2	5.5	44.6	5	34.5	30.3	48	15.9	11.7	9.4	4
1909	2.3	0	22.6	7.4	23	21.1	23.2	86.1	11.1	29.3	1.6	20
1910	0	8.7	8.6	17.2	52.2	68.5	86.8	48	21.6	14.5	12.1	14
1911	5.4	5.7	6.9	5.8	32.2	24.5	61.9	37.3	41.2	16.6	7.9	15
1912	0	5.7	9	18.2	71.1	54	26.2	38.9	46.6	6.2	19.8	2.4
1913	2.3	4.8	2.1	25.6	52.1	58.7	69.9	70	26.4	21.3	18.3	11
1914	14.9	4.1	4.5	23.2	12.8	80.7	84.3	95.4	49.5	2.7	14.9	2.5
1915	1.6	4	10.3	46.4	37.1	46.9	97.7	28.9	28.1	9.8	14.7	3.1
1916	9	2.4	8.7	9.4	57	75.4	63.4	83.5	27	8.7	2.9	6.1
1917	2.9	1.4	4	19.1	55.8	98.4	121	21.1	11.6	11.8	12.8	4.9
1918	0	6.3	9.4	6.2	66.2	62.7	55.4	####	26	35.6	11.9	4.8
1919	7.3	2.9	2.2	11.3	10.9	41.7	51.7	34.9	35.7	7.2	6.1	0
1920	0	3.2	1.2	9.8	71.1	111	78.9	72.3	60.3	20.4	7.4	9.6
1921	11.7	15.5	4.2	18.3	3.3	226	62.4	90.2	20.1	17.3	2.9	12
1922	34	2.5	5.7	17.8	35.3	156	41.1	88.1	4.3	11.3	2.5	1.7
1923	5.4	0	7.1	24.6	128	119	66.1	65	27.9	14.3	40.4	3.5
1924	4.1	1.7	5.2	11.2	10.5	82.2	40.3	86.5	23.9	25.4	32.3	2.5
1925	3.8	1.7	0	3.7	37.3	188	83.7	12.7	21.5	24.7	22.9	5.3
1926	3.9	14.9	3.1	8.8	53.9	11	73.9	36.1	15.1	32.1	9.6	0
1927	4	9.7	4.6	13.8	47.4	42.1	33.6	69.2	10.8	4.9	14.6	11
1928	9.3	0	7.8	3.7	0	84.1	26.2	50.4	22.7	4.7	7.2	18
1929	1.3	2.7	6.3	25.8	67.5	35.9	52.1	39.8	20.6	8.8	7.5	14
1930	6.8	7.4	5.4	13.4	2.8	14	37	43	69.2	9.1	22.8	4.1
1931	0	12.4	1.5	41	54.9	23.6	22.5	80.4	33.7	17.7	1.3	5.4
1932	6.3	32.4	3.6	3.9	122	82.9	42.8	40	36.7	10.6	3.7	6
1933	7.7	13.2	6.9	6	40.7	105	94.9	63	10.5	17.2	6.6	2.6
1934	4.9	2.8	11	7.8	62.1	28.8	39.8	62.9	31.5	21.5	19	0
1935	0	2.2	10.4	35.9	63.1	47.3	73.3	40.6	26.4	8.8	17.2	4.6
1936	18.4	6.4	9.1	2.5	42.3	17.6	48.3	54.1	40.2	4.5	5.9	11
1937	2.6	0	25.5	21.9	31.8	78.9	94.8	21.8	8.5	11.5	3.7	0
1938	8	2.8	5	30.2	47.5	31.6	36.9	32.9	36.8	10.1	0	16
1939	0	12.9	1.9	14.3	59.1	23.6	43.2	65.3	10.2	8.4	8.4	0.9
1940	0	22.9	12.4	51.2	34.3	59.8	22.6	10.9	29.4	14.1	24.4	6.6
1941	0.3	3.3	0.3	48.5	89.5	75.6	53.2	46.2	41.5	27.3	6	14
1942	1.7	0	0	7.1	49.1	135	20	46.5	29.2	11.6	0	15
1943	23.8	12.7	16.8	3.8	28.9	34	52.7	60.2	26.1	23.1	10.2	0

1944	13	0	3.8	15	68.3	128	60	56.7	7.6	10.7	12	15
1945	0	0	0	12.7	108	87.4	41.1	38.8	0	9.8	2.8	7.7
1946	2.5	1.8	16	27.7	69.9	18.6	31.6	24.6	75.8	13.7	7.8	5.6
1947	1.3	0.5	20	11.8	15.5	19	83.6	31.7	26.9	24.3	3.3	0
1948	2.5	4.8	23.4	23.7	34.5	33.6	69.6	8.4	49.9	9.1	0.5	2.8
1949	9.2	0	2	20.3	26.9	50.3	32.1	50	45.2	7.9	9.2	5.1
1950	5.6	0.3	8.6	61.8	12.5	25.5	107	10.9	36.8	18.2	18.3	34
1951	7.6	1	3.8	39.1	17.8	90.1	26.6	15.3	23.6	23.9	15.2	1.3
1952	3.9	6.8	6.2	16	56.7	67.4	51.6	43.6	26.5	4.1	55.1	2.3
1953	0	3	19.8	85.4	57.8	24.3	61.2	64.1	11.2	2.3	65.3	11
1954	12.4	4.7	5.3	27.3	189	41.7	402	151	7.4	28.4	2.8	5.6
1955	0	35.5	8.4	17.9	24	30.6	181	104	25.4	29.7	24.4	19
1956	8.1	4.1	20.3	21.1	54.2	302	169	36	13	27.5	0	14
1957	4.6	44.7	6.5	14	300	119	76	62.5	16.5	59.7	5.7	4.1
1958	3.9	61	7.6	44.5	52.1	26	16	36	26.7	19.1	11.4	0
1959	1	12.7	11.4	86.4	116	17.1	33	21.5	8.9	10.2	0	1.3
1960	0	4.2	4.8	29.5	40.6	40	17.8	45.7	17.8	9.5	0	96
1961	4.1	0.8	5.1	11	44.2	43.5	67.8	56.9	42.3	21.6	0	5.1
1962	6.4	9.3	7.6	26.4	36.8	172	42.7	87.5	19	121	21.6	0
1963	2.5	0	17.8	6.4	5.1	40	77.5	159	19.5	27.9	52.3	2.5
1964	0	13	0	10.8	22.6	72.1	56.9	37	16	15	31.8	0
1965	2	52.1	40.6	20.1	18.5	36.1	32	25.5	15.8	13.3	0	34
1966	7.6	0	33.4	8.2	40.6	77.5	54	20.7	68.3	5.8	4.2	6.4
1967	25.4	0	0	13.2	41.4	82.7	52.1	38.1	15.8	20.2	45.7	0
1968	8	2.1	0	17.5	55	38.3	84.7	21.5	2.3	27	5.7	2.8
1969	14	5.3	6.5	20.9	0	39.8	17.8	37.4	23.6	36	3	0
1970	0	11.6	1	0	50.3	54.5	60.2	53.8	28.9	11	0.5	5.7
1971	1.5	0	6.5	1.1	25.3	48.6	37.3	61.5	15.2	9.2	0.5	0.4
1972	8.5	4.5	4	25.9	26	54.5	13	36.6	16	3.5	0	28
1973	0	4.5	15.3	2.5	25.7	10.7	51.5	20.5	12.3	5.5	3	26
1974	0	0	9	2.6	47.5	73.5	14.8	164	10.9	23	9.6	1.2
1975	3.5	4	4	18	63.5	22	31.5	32	5.5	23	4	0
1976	0	0	22	18.4	26.5	118	62.6	30.5	22.3	0	30.5	13
1977	14.5	2.5	6.5	48.2	88.2	79.4	117	55.5	21	4	32.5	6
1978	7.9	10.2	8.3	8.2	15.2	3.8	6.5	58	35.7	25.5	8	22
1979	11.2	9.1	2.4	3.2	31.1	49.7	12.9	44.9	17.5	33.2	4.6	0.2
1980	22.8	6.5	0	27.2	76	76.4	19.6	19.3	9	21.7	103	26
1981	34.1	0	33	18.3	9.6	53.2	93.1	62.5	34.5	7	7.4	0.8
1982	22	0	20.5	32.5	37.7	60	43.2	35.5	4.5	9.5	7	23
1983	7	33	18.5	5.5	81	54	40.8	10	26.7	20	2	6
1984	3.5	0.5	8	14.1	92.4	31.5	29.5	15	40.1	42.5	0	9.9
1985	14	8.5	80	40	28.5	59	63	43	39	1.4	1.1	0
1986	20	0	9.5	14.5	18.1	66.2	64.4	48.1	36	11	4	1
1987	2.9	5.5	4.5	25.5	60.3	35.2	87.1	72.5	34.7	2.5	5.2	10
1988	0	0	10.4	86.3	8.2	43.1	35.1	77	35.8	2.4	4	2.5

1989	0.6	11.1	32.7	27	47.8	25.5	61.2	39.2	44.8	25.5	26.3	4
1990	10	2	0	71.2	57.7	65.3	87.8	19.6	6.8	0	8	7.7
1991	1	6	7.5	14	28.7	64.2	125	15.1	67.8	34.2	11.2	6.8
1992	2	14.5	4.5	23.2	40.1	75.2	38.6	18.2	25.2	32.7	9.7	2.5
1993	0	2	4	90.1	60.7	38.5	77.3	61.1	3.6	5	0	12
1994	0	0	0	19.2	17.6	157	41.1	9.6	68.5	14	0	0
1995	8.5	1.2	14.5	0	11.5	52.9	76		10.3	26.5	3	7
1996	5.5	29.9	7	19	12.5	64.5	23	81.5	47.5	12	12.5	12
1997	1.6	0.9	11.5	22	23.5	72.3	11.5	29	5.2	3.8	41	4
1998	7.4	0	1.5	2.5	37.4	36.5	37.7	18	2.5	6	30.2	13
1999	0	0	0	13	27	29.5	45.5	0	60	0	7.7	5
2000	2.5	0	0	0	15	18	51.5	19.5	69	4.1	19.2	5.2
2001	7.1	1.5	0	36	67.5	29	145	58.8	38.2	10	8.1	0
2002	0.7	5.5	12.5	28	46.5	35.6	63	75.8	14.5	14	7.7	8.1
2003	9.7	0	22.5	4.5	20.5	4.8	16	110	25	8.8	3	7.5
2004	27.5	0	13.8	24	0	68	55	34	19	66	0	4.2
2005	3.5	0.2	2.3	32.5	49.5	63.5	7.5	43	16	4.4	6.5	0
2006	0	3	0	18	117	20	11	40.5	20	22.5	7	1.5
2007	0	23.5	21.5	53	45	103	66	78.5	22	8.7	22.5	12
2008	3.6	20	2	4.9	33.6	56.6	85.7					

APPENDIX 2: HYDROCENSUS SURVEY RESULTS AND GROUNDWATER LEVELS DATA

2-1 Hydrocensus Survey Results

2-2 DWA Hydrological Station No. G1N0389

Table A-1: DWS Monitoring Boreholes within a 5km radius of Study Site

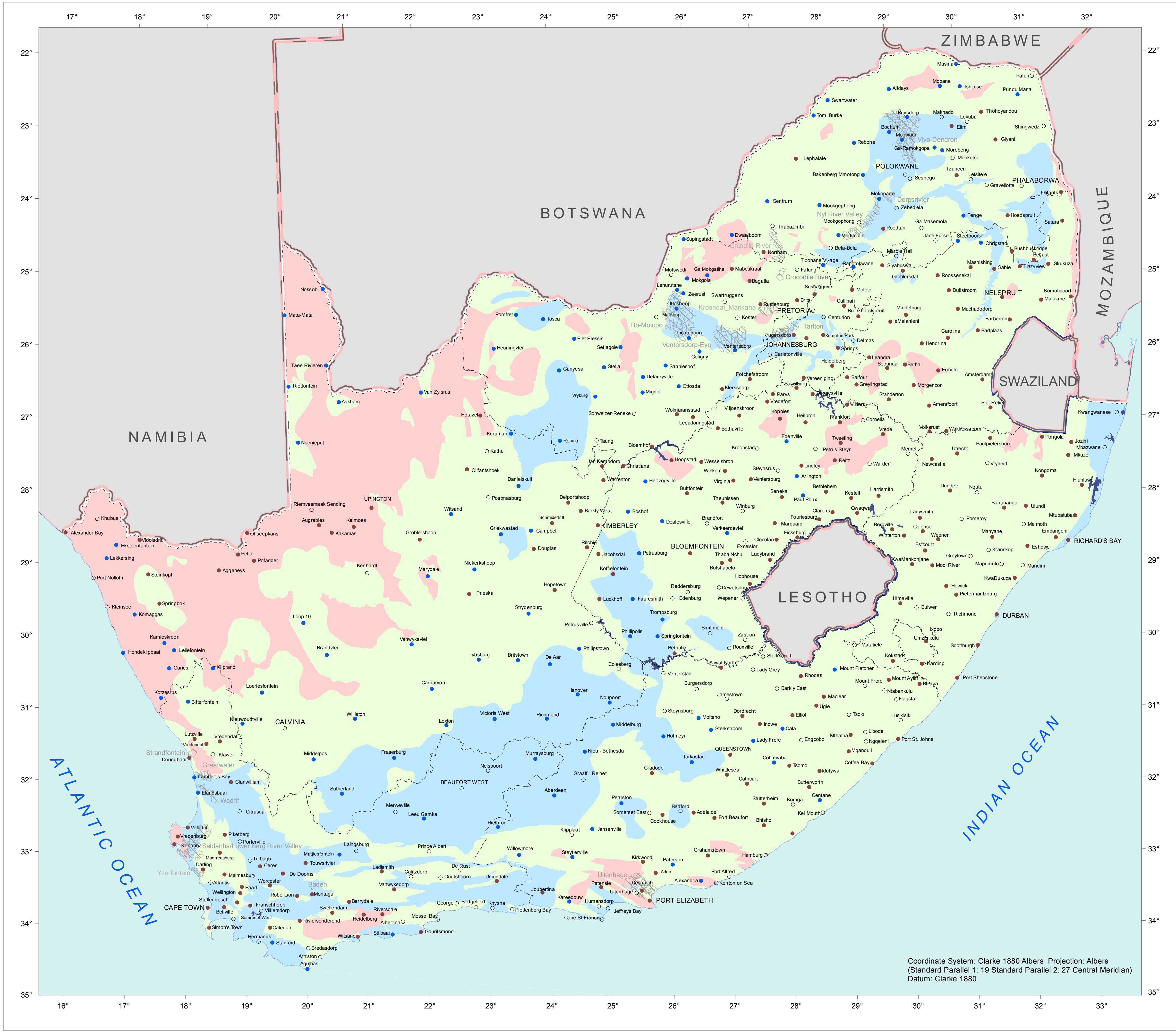
Geosite Identifier	Latitude	Longitude	Farm Name	Province
3218CC00371	-32.98827	18.02823	YZERVARKENSRUG	Western Cape
3218CC00360	-32.98055	18.01395	YZERVARKENSRUG	Western Cape
3218CC00361	-32.9861	18.0109	YZERVARKENSRUG	Western Cape
3218CC00362	-32.98749	18.01645	YZERVARKENSRUG	Western Cape
3218CC00363	-32.98721	18.01479	YZERVARKENSRUG	Western Cape
3218CC00352	-32.98083	18.01645	YZERVARKENSRUG	Western Cape
3218CC00353	-32.98249	18.01673	YZERVARKENSRUG	Western Cape
3218CC00354	-32.98249	18.01729	YZERVARKENSRUG	Western Cape
3218CC00359	-32.99666	18.02701	YZERVARKENSRUG	Western Cape
3218CC00348	-32.98749	18.02923	YZERVARKENSRUG	Western Cape
3218CC00349	-32.98749	18.0284	YZERVARKENSRUG	Western Cape
3218CC00350	-32.98777	18.02756	YZERVARKENSRUG	Western Cape
3218CC00351	-32.98305	18.02784	YZERVARKENSRUG	Western Cape
46113	-32.98103	17.96632	FARM	Western Cape
3218CC00345	-32.98999	18.03284	YZERVARKENSRUG	Western Cape
3218CC00346	-32.9911	18.03173	YZERVARKENSRUG	Western Cape
3218CC00347	-32.9911	18.03284	YZERVARKENSRUG	Western Cape
BG00171	-33.00008	18.001	OS FONTEIN	Western Cape
BG00172	-33.00018	18.00099	OS FONTEIN	Western Cape
BG00173	-33.00014	18.00107	OS FONTEIN	
BG00174	-33.00008	18.001	OS FONTEIN	Western Cape
3318AA00159	-33.01425	18.03285	OS FONTEIN PTN TIEKOSKLIP	Western Cape
3318AA00235	-33.00206	18.00394	ELANDSFONTEIN	Western Cape
3318AA00269	-33.01168	18.04163	OS FONTEIN PTN TIEKOSKLIP	Western Cape
BG00001	-32.9823	17.96882	FARM	Western Cape
3218CC00372	-32.99127	18.02823	YZERVARKENSRUG	Western Cape
3218CC00373	-32.99127	18.02923	YZERVARKENSRUG	Western Cape
3218CC00374	-32.98427	18.02723	YZERVARKENSRUG	Western Cape
3218CC00375	-32.98727	18.01623	YZERVARKENSRUG	Western Cape
3218CC00364	-32.99694	18.02729	YZERVARKENSRUG	Western Cape
3218CC00365	-32.99666	18.02701	YZERVARKENSRUG	Western Cape
3218CC00366	-32.99694	18.02701	YZERVARKENSRUG PTN SALDANHA STEEL PLANT	Western Cape

Table A-2: Water Levels data for DWA Hydrological Station No. G1N0389

Measurement Date	Water Level (Reference Level is Ground Surface)
9/7/2004	-2.95
10/4/2004	-3
11/9/2004	-2.98
12/7/2004	-3.08
1/11/2005	-3.2
2/8/2005	-3.25
3/2/2005	-3.18
4/5/2005	-3.33
5/10/2005	-3.25
6/7/2005	-3.35
7/5/2005	-3.35
8/2/2005	-3.47
9/6/2005	-3.29
10/5/2005	-3.21
11/8/2005	-3.23
12/13/2005	-3.49
1/10/2006	-3.71
2/7/2006	-3.53
7/6/2006	-3.34
8/3/2006	-3.31
9/6/2006	-3.21
10/5/2006	-3.19
11/7/2006	-3.31
12/6/2006	-3.3
1/11/2007	-3.37
2/6/2007	-3.42
3/7/2007	-3.47
4/4/2007	-3.57
5/8/2007	-3.51
6/7/2007	-3.42
7/19/2007	-3.13
8/8/2007	-2.96
9/12/2007	-2.81
10/3/2007	-2.79
11/6/2007	-2.94
12/12/2007	-3.04
1/8/2008	-3.03
3/6/2008	-3.22
5/9/2008	-3.35
7/2/2008	-3.26
9/2/2008	-2.95

10/1/2008	-2.68
11/12/2008	-2.89
12/3/2008	-2.98
1/16/2009	-3.1
3/4/2009	-3.17
4/1/2009	-3.25
6/3/2009	-3.19
7/7/2009	-3.02
8/4/2009	-2.78
9/1/2009	-2.74
10/7/2009	-2.76
11/3/2009	-2.85
3/12/2010	-3.1
7/7/2010	-2.94
12/9/2010	-3.04
3/10/2011	-3.26
7/20/2011	-3.32
2/7/2012	-3.53
5/15/2012	-3.62
8/14/2012	-3.43
11/13/2012	-3.19
2/19/2013	-3.51
5/21/2013	-3.63
8/13/2013	-3.63
12/3/2013	-2.92
2/11/2014	-3.11
4/10/2014	-3.29
5/13/2014	-3.26
8/14/2014	-3
11/20/2014	-3.05
2/10/2015	-3.28
5/26/2015	-3.44
7/28/2015	-3.36
11/4/2015	-3.51
1/28/2016	-3.59
5/25/2016	-3.69
9/1/2016	-3.33
11/8/2016	-3.4
2/15/2017	-3.63
8/22/2017	-3.77
11/21/2017	-3.87
2/27/2018	-3.9

APPENDIX 3: AQUIFER CLASSIFICATION MAPS OF SOUTH AFRICA



water affairs
Department:
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Aquifer Classification of South Africa

Background:
Implementation of the Reconstruction and Development Programme (RDP) in South Africa has highlighted the importance of groundwater resources in the country as the role they will play in satisfying the targets of the RDP. As a result, exploration, development and protection of aquifers is receiving unprecedented attention. Provision of the appropriate information to national water resource managers and planners is a critical part of the process which aims to provide a further twelve million people with adequate access to potable water.

Data Sources:
This map is based on the Borehole Prospects map provided by JR Vegter, Hydrogeological Consultant and AJ Seymour, DWA.

Description:
This map indicates the aquifer classification system of South Africa. Blue represents the major aquifer region which is a high-yielding system of good water quality. Green represents the minor aquifer region which is a moderately-yielding aquifer system of variable water quality. Pink represents the poor aquifer region which is a low to negligible yielding aquifer system of moderate to poor water quality.

LEGEND

Water Source
- Groundwater
- Combination (Ground and surface water)
- Surface water

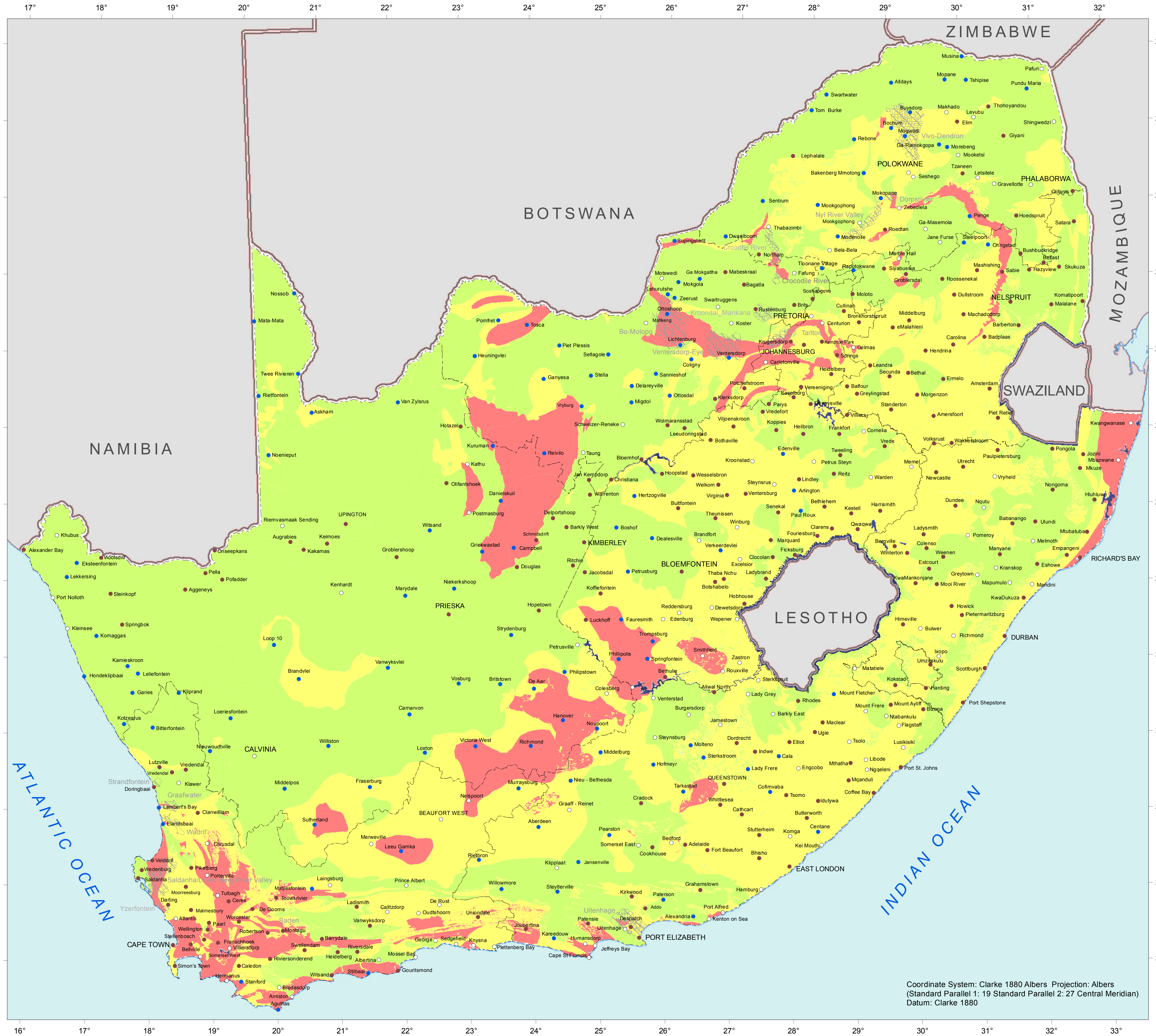
DURBAN Major towns/Cities

Aquifer Classification
- Poor
- Minor
- Major

- Province
- International boundaries
- Dams
- Special aquifer regions

Original Map Compilation: Andiswa Matoti, Julian Conrad and Susan Jones, CSIR, 22 March 1999.

Recompiled: August 2012
Directorate: Hydrological Services
Sub-Directorate: Groundwater Information



water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Aquifer Vulnerability of South Africa

Background:
Implementation of the Reconstruction and Development Programme (RDP) in South Africa has highlighted the importance of groundwater resources in the country as the role they will play in satisfying the targets of the RDP. As a result, exploration, development and protection of aquifers is receiving unprecedented attention. Provision of the appropriate information to national water resource managers and planners is a critical part of the process which aims to provide a further twelve million people with adequate access to potable water.

Data Sources:
This map is based on the Borehole Prospects map provided by JR Vegter, Hydrogeological Consultant and AJ Seymour, DWA.

Description:
This map indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Green represents the least vulnerable region that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached. Yellow represents the moderately vulnerable region which is vulnerable to some pollutants, but only when continuously discharged or leached. Red represents the most vulnerable aquifer region, which is vulnerable to many pollutants except those strongly absorbed or readily transformed in many pollution scenarios.

LEGEND

Water Source

- Groundwater
- Combination (Ground and surface water)
- Surface water

DURBAN Major Towns/Cities

Vulnerability Ratings

- Least
- Moderate
- Most

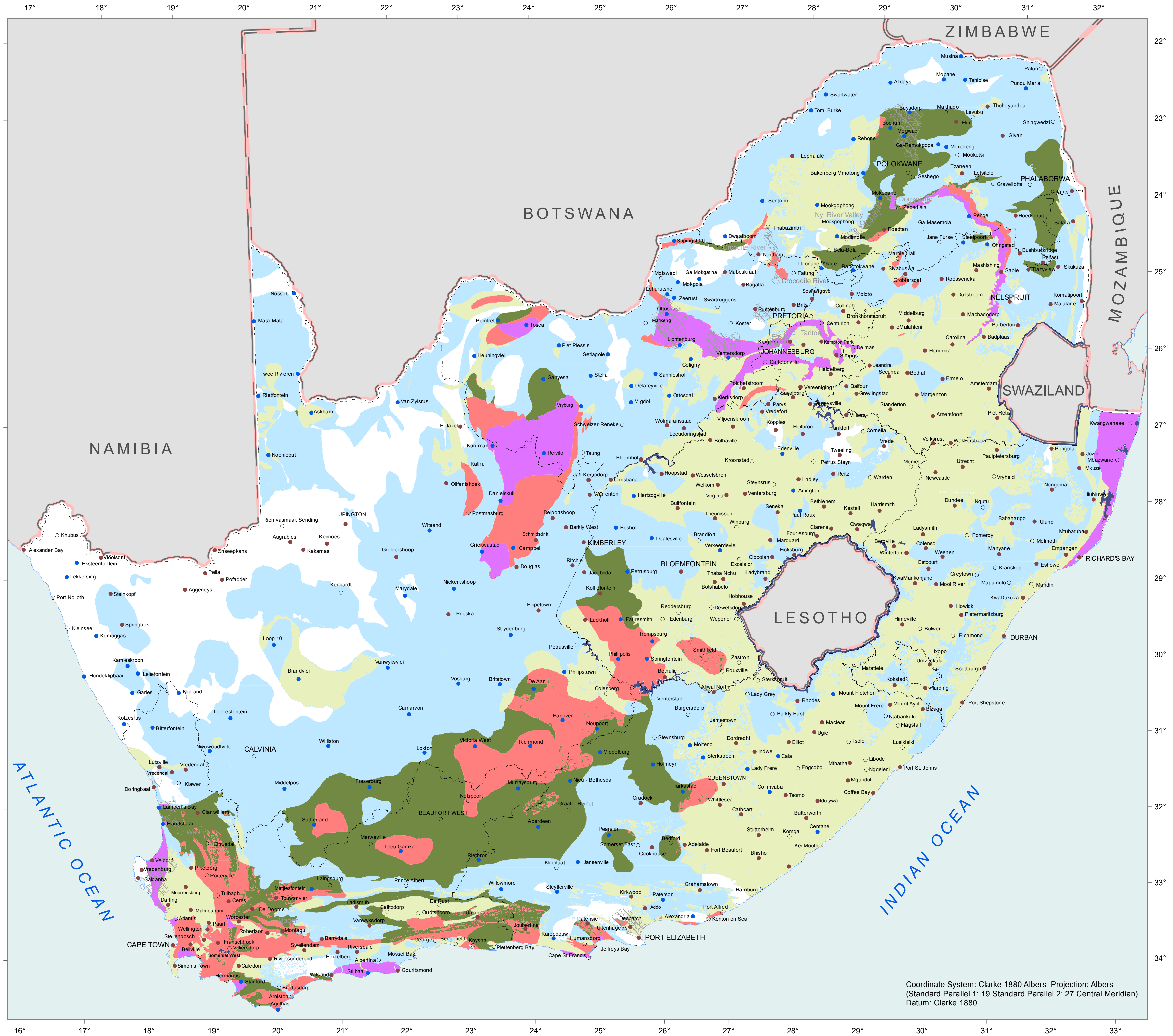
- Province
- International boundary
- Dams
- Special aquifer regions

Original Map Compilation: Andiswa Matoti, Julian Conrad and Susan Jones, CSIR, 22 March 1999.

Recompiled: July 2013
Directorate: Hydrological Services
Sub-Directorate: Groundwater Information

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Aquifer Susceptibility of South Africa



Coordinate System: Clarke 1880 Albers Projection: Albers
(Standard Parallel 1: 19 Standard Parallel 2: 27 Central Meridian)
Datum: Clarke 1880

Background:
Implementation of the Reconstruction and Development Programme (RDP) in South Africa has highlighted the importance of groundwater resources in the country as the role they will play in satisfying the targets of the RDP. As a result, exploration, development and protection of aquifers is receiving unprecedented attention. Provision of the appropriate information to national water resource managers and planners is a critical part of the process which aims to provide a further twelve million people with adequate access to potable water.

Data Sources:
This map is based on the Borehole Prospects map provided by JR Vegter, Hydrogeological Consultant and AJ Seymour, DWA.

Description:
This map indicates the qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

Susceptibility Matrix

VULNERABILITY	AQUIFER CLASSIFICATION: Poor	Minor	Major
Least	Low 1	Low 2	Medium 3
Moderate	Low 2	Medium 4	High 6
	Medium 3	High 6	High 9

LEGEND

Water Source
- Groundwater
- Combination (Ground and surface water)
- Surface water

Province
International boundary
Dams
Special aquifer regions
DURBAN Major Towns/Cities

Original Map Compilation: Andiswa Matoti, Julian Conrad and Susan Jones, CSIR, 22 March 1999.

Recompiled: June 2013
Directorate: Hydrological Services
Sub-Directorate: Geohydrological Information

APPENDIX 4: CLIMATIC WATER BALANCE ASSESSMENT REPORT

Climatic Water Balance Assessment for the proposed Upgrade of Storm Water and Environmental Systems in the Port of Saldanha, Western Cape

March 2018

CLIENT

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Report Name	**Climatic Water Balance Assessment for the proposed Upgrade of Storm Water and Environmental Systems in the Port of Saldanha, Western Cape**
Submitted to	**Nsovo Environmental Consulting**
Report Writer	**Paulo Kagoda**

Climatic Water Balance

It is a simple calculation that assists in deciding whether leachate management is required or not. It therefore provides a conservative means of determining whether or not significant leachate generation will occur. The Climatic Water Balance (B) is calculated using only the two climatic components of the full water balance, namely Rainfall (R) and Evaporation (E).

The Climatic Water Balance is defined by: B = R – E

Where:

B is the Climatic Water Balance in mm of water

R is the rainfall in mm of water

E is the evaporation from a soil surface in mm of water.

This is calculated for the wet season of the wettest year on record wettest. This is a six month period from May to October. The data used are the precipitation and S-pan evaporation obtained from the latest edition of the Department of Water and Sanitation's evaporation and precipitation records.

The most representative/closest weather station was G1E007 "Langebaan @ Langebaan Road" whose location details are presented in Table 1 below.

Station	Latitude	Longitude
G1E007 Langebaan @ Langebaan Road	-32.97096	18.15770

The factor of 0.88 used to convert S-pan evaporation to soil evaporation

1. For wettest year (2001) B= 322.1– (0.88 x482.6) = - 102.59
2. (1984) B= 299.8 – (0.88 x474.9) = -118.12
3. (1987) B= 294.5 – (0.88 x495.6) = - 141.63
4. (1986) B= 278.6 – (0.88 x516.2) = - 175.66
5. (1999) B= 269.9– (0.88 x555.6) = - 219.03
6. (1989) B= 259.7 – (0.88 x469.3) = - 153.24

As the results are well into the negative on at least 6 occasions, B is unlikely to be positive in more than 1 year in 5, on average. Any site situated in the climate represented by the above statistics would be classified B–.

The site is classified as B- (climatic water balance).