Appendix B

Groundwater Overview for Lower Orange Water Management Area

DEVELOPMENT OF INTERNAL STRATEGIC PERSPECTIVES

GROUNDWATER OVERVIEW FOR LOWER ORANGE CATCHMENT MANAGEMENT AREA

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TABLE OF CONTENTS

1 Overarching Issues

The following is a brief description of the major groundwater issues in the Lower Orange Water Management Area (WMA). For more detailed information please refer to the references and the sources of data referred to in Section 1.

1.1 Availability of groundwater information in the catchment area

The following data sources with regard to groundwater are available:

- NGDB database
- WARMS data base
- DWAF Geohydrology Northern Cape
- GH Reports
- 1: 5000 000 Geohydrological maps and brochures
- Consultants reports and other academic reports

The NGDB is heavily populated with groundwater data for the WMA. There are over 400 points currently being monitored throughout the Northern Cape (including the Lower Vaal WMA). Most of the data are related to water supply schemes and ambient water quality monitoring.

The WARMS database also contains valuable information with regard to large-scale abstraction for water supply schemes and irrigation. Verification of the data still has to be performed.

The Geohydrology offices in the Northern Cape also has good data on groundwater utilization and the natural quality of groundwater due to the close relationship with ongoing water supply projects and other groundwater investigations. Another vast source of information is from GH reports (> 500) and the 1: 500 000 geohydrological maps completed for the region by the Geohydrology Directorate.

Several consultant reports and academic reports are also available. PD Toens and Associates have been involved in ongoing monitoring of groundwater resources in the Northern Cape for a number of years.

1.2 Overview of groundwater resources and use throughout the catchment area

1.2.1 Industrial and mining

Mining plays an important role in the WMA's economic development. Several diamond mines are located in the WMA including the Kleinzee, Alexcor and Hondeklipbaai mines. Diamonds are recovered at these mines from alluvial deposits. A number of small-scale diamond diggings are also found in the area. Some impacts do exist with regard to localized dewatering of aquifers. These impacts are however localized and very little data exist in this regard. Black Mountain base metal mine utilizes surface water from the Orange River for processes and no data is available on the water resource utilized by the Okiep Copper Mines.

1.2.2 Agriculture

Most farming settlements are dependent on groundwater for domestic and stock watering use. The groundwater resource is of such a nature that it cannot be utilized for large-scale irrigation throughout the WMA, except in the areas underlain by dolomitic aquifers. Volumes of total abstraction are available for this use.

1.2.3 Domestic

As discussed above, groundwater is utilized for individual domestic use in most rural and farming areas. Groundwater is the most important resource for bulk water supply in areas located far from the surface water bulk supply network. The naturally poor quality (See Section 1.3.1) and poor yields of some aquifers are a constraining factor in the utilization of this resource. This is overcome in some areas by good water management practices and treatment of the groundwater.

Data received from DWAF (see Table 1) estimate the total abstraction for groundwater at 10 mil m^3 per year for domestic supply for approximately 100 000 inhabitants dependant on the source (DWAF, 2003). The majority of the water (43%) is abstracted from the granite and gneiss aquifers (See Section 2), 25% is from the Dwyka and Ecca Karoo sediments, 17 % from the Beaufort Karoo sediments and the remainder is abstracted from the dolomites (6%) and other primary aquifers (2%).

1.3 Groundwater quality in the catchment area

1.3.1 Natural

Groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO3 as N) and flourides (F) are thought to represent the majority of serious water quality problems. The water quality was evaluated in terms of TDS and potability. The information was obtained from DWAF Geohydrology. The potability evaluation done was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume 1 (DWAF, 1998).

The portion of the groundwater resources considered to be potable has been calculated as the portion classified as ideal, good and marginal (Class 0 -blue, 1- green and 2 - yellow) according to the classification system given in Section 6.4.1. Water classified as poor and unacceptable (Class 3 - red and 4 - purple) is considered not to be potable (See **Point and** diffusive pollution

Agricultural activities are a source of diffuse water contamination. The contribution of each farm on a local scale is often fairly small but the contribution on a catchment scale needs to be included in assessing any pollution situation. Most findings regarding this issue can only be assessed in a generic way due to the lack of data in the WMA. Nitrates are the contaminant of most concern, since they are very soluble and do not bind to soils, nitrates have a high potential to migrate to groundwater. Because they do not evaporate, nitrates/nitrites are likely to remain in water until consumed by plants or other organisms. Generally on a local scale the areas of intense cultivation are the major contributors in terms of inorganic nitrates. The primary inorganic nitrates, which may contaminate drinking water, are potassium nitrate and ammonium nitrate both of which are widely used as fertilizers. Where feedlots are operated the contribution of organic nitrates to groundwater contamination can be far more problematic. For most farming activities organic nitrate is not a severe problem in South Africa. High-density cultivation at surface water irrigation schemes along the Orange River contributes to the nitrate load of localized aquifers in the WMA. Other contaminants of concern are pesticides and herbicides. The contribution of these to groundwater contamination is very difficult to quantify on catchment scale. Site-specific data relating to likely loading/application volumes and history, soil profile and local geohydrology are required.

Table 2).

The mineralogical groundwater quality in the Lower Orange Water Management Area is not particularly good in terms of its TDS rating. In general the groundwater quality is rated as class 2 to class 4, marginal to completely unacceptable. The southern portion of the inland region, De Aar, Victoria West and Sutherland has a class 2 rating, together with the areas surrounding Prieska, Griekwastad, Upington and Springbok. The rest of the WMA, particularly north of Brandvlei and Carnarvon and the coastal strip are rated as class 3 and 4. The Sutherland, De Aar, Upington belt has a varying range of potable groundwater from a moderate 50% to approximately 90%. The balance of the WMA, has a predominant potable usage of less than

30%, with the occasional improvement to 50% (V3, 2002). See Figure 1 for average TDS values for the area under investigation as mapped by Simonic (1999).

Natural occurring radioactivity is found in some of the groundwater resources associated with geological formations such as granites and gneisses. Fortunately the values are mostly low except at Kotzerus, Kharkams, Bulletrap, Fonteintjie, Kenhardt and Riemvasmaak, which fall into Class 2 according to the potable water classification (Van Dyk, 2003).

Table 1 Groundwater consumption, population and quality of dependant communities in the Northern Cape

Community	Population	Consumption m^3/day		Average consumption	
		Winter	Summer	l/p/dag W	l/p/dag S
Brandvlei	2200		245		111
Britstown	6500	993	1124	153	173
Calvinia	8000	1131	1820	141	228
Carnarvon	6000	714	900	89	150
De Aar	29600	7000	8900		301
Fraserburg	3500	280	527		151
Groot Mier	250		35.25		141
Hanover	5200		733		141
Klein Mier	370		52.17		141
Loeriesfontein	2400	110	181	46	75
Loubos	500	40	50		100
Loxton	800		180		225
Niewoudville	1400	80	286	57	204
Noupoort	6100	928	1433	46	235
Rietfontein	1700	138	215		126
Strydenburg	2300	176	220	77	96
Sutherland	2600		366.6		141
Van Wyksvlei	1800	302	424	167	236
Victoria Wes	10000		1457		146
Vosburg	650		91.65		141
Welkom	241		33.981		141
Williston	2800	444	655	158	234
Bankara Bodulong	5520	414.2	621.2	75	113
Buffelsrivier	1200	66	96		80
Bulletrap	315	34	57		181
Campbell	2800		60		21
Colesberg	14000		1588		113
Danielskuil	2700		380.7		141
Deben	5748		125		22
Dibeng	300		42.3		141
Eksteenfontein	600	32	42		70
Garies	2000	140	260		130
Griekwastad	5200		616		118
Groenwater	300		42.3		141
Holpan	1200		72		60
Hondeklipbaai	1300		183.3		141
Jennhaven	200		28.2		141
Kammasies	369		52.029		141
Kammieskroon	1800	94	253.8		141
Karkams	1692	240	251		148
Kenhardt	4000	300	800	75	200
Kheis	670	18	25		37
Khubus	2254	136	177		79
Kleinzee+GM	3640		513.24		141
Klipfontein	663		7		11
Koingnaas	1500		211.5		141
Kommagas	3976	393	467		117
Kono	200		28.2		141
Lekkersing	600	48	56		93
Leliefontein	842	45	61		72
Majeng	300		42.3		141
Marydale	2550	118	238		93
Niekerkshoop	2000		282		141
Nourivier	470	19	30		64
Onseepkans	600		84.6		141
Paulshoek	836	15	16		19
Philandersbron	530	35	110		208
Pofadder	5450	Pyplyn	768.45		141
Richmond	6000	475	713	79	119

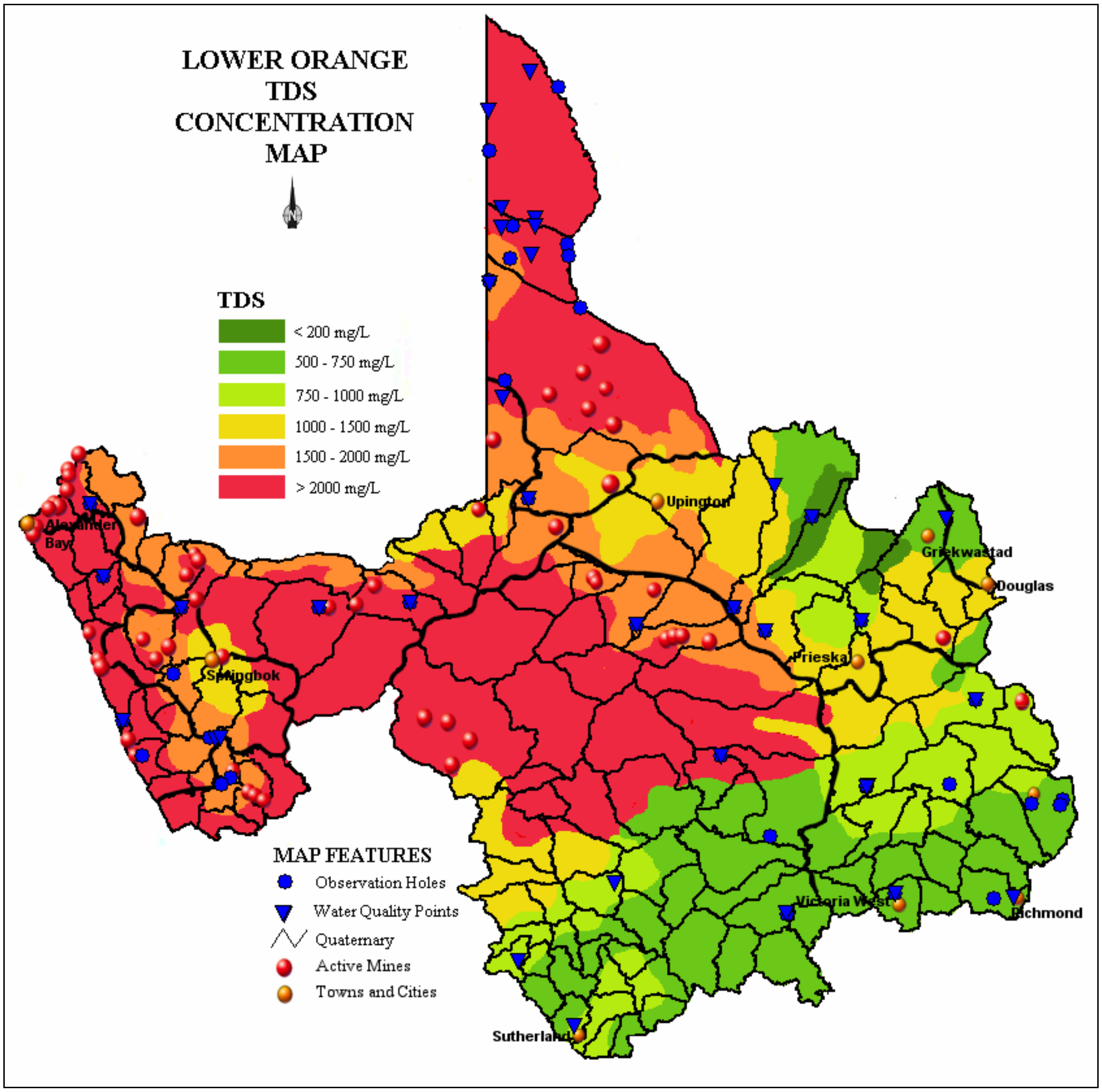

Figure 1 Mapped TDS values within the WMA

1.3.2 Point and diffusive pollution

Agricultural activities are a source of diffuse water contamination. The contribution of each farm on a local scale is often fairly small but the contribution on a catchment scale needs to be included in assessing any pollution situation. Most findings regarding this issue can only be assessed in a generic way due to the lack of data in the WMA. Nitrates are the contaminant of most concern, since they are very soluble and do not bind to soils, nitrates have a high potential to migrate to groundwater. Because they do not evaporate, nitrates/nitrites are likely to remain in water until consumed by plants or other organisms. Generally on a local scale the areas of intense cultivation are the major contributors in terms of inorganic nitrates. The primary inorganic nitrates, which may contaminate drinking water, are potassium nitrate and ammonium nitrate both of which are widely used as fertilizers. Where feedlots are operated the contribution of organic nitrates to groundwater contamination can be far more problematic. For most farming activities organic nitrate is not a severe problem in South Africa. High-density cultivation at surface water irrigation schemes along the Orange River contributes to the nitrate load of localized aquifers in the WMA. Other contaminants of concern are pesticides and herbicides. The contribution of these to groundwater contamination is very difficult to quantify on catchment scale. Site-specific data relating to likely loading/application volumes and history, soil profile and local geohydrology are required.

Table 2 Water qualities of groundwater resources utilized by some communities in the WMA (from DWAF –Geohydrology)

Settlement	pH	N	F	$CaCO_3$	Na	Mg	Si	PO4-P	SO_4	Cl	K	Ca	Ec	TDS
Kotzesrus	8.0	0.94	1.8	158	2792	262	15.5	0.014	734	5541	25.1	745	1590	10297
Garies	8.2	2.18	0.6	132	430	77	10.9	0.089	149	827	8.6	99	313	1762
Paulshoek	7.7	<0.04	0.5	105	136	25	8.6	<0.005	53	236	3.5	42	101	625
Leliefontein	7.6	<0.04	2.1	71	24	6	18.4	<0.011	17	45	1.1	30	35	212
Nourivier	7.9	1.73	2.5	77	49	11	14.1	0.013	28	82	0.9	27	50	302
Kharkams	8.0	0.33	3.6	150	222	56	15.8	0.009	132	468	5.8	95	194	1167
Kammieskroon	7.8	0.89	1.2	169	270	90	12.6	<0.005	116	763	5.1	167	278	1621
Komaggas	8.5	2.93	0.6	116	191	53	13.4	0.009	78	382	8.7	38	159	906
Lekkersing	8.2	5.07	0.5	156	459	84	8.5	0.010	180	849	14.5	100	325	1901
Eksteenfontein	8.0	3.15	0.4	167	254	71	10.8	<0.005	132	576	8.6	101	237	1361
Khubus	8.0	0.33	0.5	140	262	43	20.8	<0.005	94	739	16.3	21	265	1539
Kosies	6.9	2.82	0.3	45	93	14	25.1	0.010	34	133	5.1	13	69	360
Eyams	7.2	3.58	0.4	28	69	12	16.7	<0.005	22	128	4.8	14	52	300
Gladkop	8.2	2.28	1.3	139	206	93	12.2	0.006	118	659	4.4	136	249	1398
Bulletrap	8.0	4.82	3.5	178	566	121	16.6	0.017	410	1257	5.4	290	487	2891
Fonteintjie	7.3	4.61	1.1	76	92	20	16.9	0.011	113	153	1.8	49	90	544
Kenhartd	8.2	1.26	2.4	237	131	25	16.2	0.005	118	180	2.5	89	112	843
Riemvasmaak	8.1	6.26	3.6	445	122	31	18.7	0.006	60	59	6.9	99	115	952
	8.1	11.07	6.4	365	466	26	17.9	0.006	336	360	5.1	71	246	1764
Marydale	8.1	15.43	1.2	287	159	45	31.5	0.013	119	167	16.8	55	140	982
Loubos	8.4	1.74	1.1	235	60	9	9.9	<0.005	32	11	1.0	51	54	459
Welkom	9.0	19.39	2.2	495	510	5	12.8	0.015	163	283	6.0	6	233	1663
Klein Mier	8.5	10.32	1.7	505	292	6	22.6	0.009	49	76	4.7	12	133	1103
Groot Mier	8.6	40.87	5.5	941	1093	12	20.4	0.113	358	547	8.9	11	472	3365
Philandersbron	8.2	7.62	0.9	362	144	24	11.1	0.014	169	82	1.1	110	125	1006
Rietfontein	8.1	7.16	0.9	393	117	33	14.3	0.007	75	118	1.2	106	122	962
Noenieput	8.2	39.68	1.6	436	387	47	11.4	0.006	251	439	3.0	172	290	2008

Activities related to urban areas can also result in localized or even diffuse pollution of groundwater. Poor management of sewage treatment works can contribute to the groundwater pollution as can landfill sites, on-site sanitation (especially in informal settlements) and spills resulting from accidents or leaking underground tanks.

Uncontrolled dumping and accidents related to the transport industry also contribute to localized pollution in the WMA. Often goods that contain hazardous substances or perishables are confiscated by authorities and these are then dump at illegal sites. A need for incinerators has been identified.

Mining activities that impact on the groundwater quality include the Okiep Copper mine and the Black Mountain lead, zinc, copper and silver mine.

Mineralisation in the O'okiep area tends to occur in basic rocks intruded in the form of 'steep structures' into granitic terrain of the Namaqualand Metamorphic Complex, and may extend to depths of over 1000 m (www.metorexgroup.com/Ookiep.htm). The major copper minerals are bornite ($Cu_5 FeS_4$) with 62% copper, and chalcopyrite ($CuFeS_2$) with 32.5% copper. Open stoping is employed at the mine, together with backfilling at times at O'okiep. Ore is concentrated by flotation and transported to the nearest available smelter. O'okiep smelts its own concentrates. The Black Mountain Mine is situated in the Northern cape near Aggeneys. The facility produces zinc concentrate together with lead and copper concentrates, from which silver is also recovered. Development of the nearby Gamsberg zinc deposit, is currently under consideration (http://www.dwaf.gov.za/orange).

There are many impacts on the environment dealing with the water quality and waste disposal from copper mining. These adverse water quality impacts are caused primarily by land disposal practices that fail to contain wastes, by run-on and run-off controls that are inadequate to prevent surface water from flowing through impoundments, or by groundwater infiltrating surface impoundments. These open-pit mining methods also can cause disturbances that can lower the water table in an area, causing water shortages, land subsidence, and fracturing. However due to the low rainfall in area the impacts on the groundwater quality are less than expected and very localized. Acid Mine Drainage, elevated TDS, SO_4, and low pH with associated higher trace metal concentrations have been found at tailings dumps.

A radioactive waste disposal site for low- and intermediate level waste generated at the Koeberg Nuclear Power Plant, is located north of Springbok on the flat plains of the Bushmanland plateau. Waste is buried in metal drums and solidified in concrete in the trenches. Up to date no significant contamination of the groundwater has occurred (Van Blerk, 2000).

Sprinkbok Hard Chrome is an industry located in Springbok, an incident has occurred where Cr^{+6} was released into the environment but no data is available on the impact the incident had on the groundwater resource.

As discussed in Section 1.2.1 impacts on groundwater quality from the diamond mining industry in the WMA is negligible.

1.4 Groundwater management and monitoring requirements in the catchment area

1.4.1 Current groundwater monitoring and management

There are a total of approximately 400 monitoring points throughout the Lower orange and Lower Vaal WMAs. The monitoring points serve all two of the levels of groundwater monitoring namely level 1 or national monitoring network and level 2 or regional. Some points are shown of Figure 1. The monitoring includes water levels and ambient water quality. There are automatic data loggers at some stations. The aim is to expand the network to approximately 500 but the required equipment and personnel is currently not available. The required expansion as well as reporting and individual user reporting could be solved with the establishment of WUAs. However up to date no WUAs has been established in the Lower Orange WMA.

Individual permits and licenses is another management tool, which are used at large scale abstraction points. This is mainly restricted to municipal and mine users. Compliance monitoring is required by these licenses.

DWAF Regional office has received several license applications by individual users, but these are mainly for irrigation purpose in the Lower Vaal WMA. One groundwater reserve (D56B) has been completed in the Lower Orange WMA.

1.4.2 Current (quality and quantity) requirements

No formal quality and quantity requirements have been set to date but DWAF is in the process of addressing the issue.

1.5 Poverty eradication and the role groundwater can play in the catchment

Often groundwater is an inexpensive resource to develop for domestic water supply for communities that are located far from existing surface water bulk supply systems. However cognizance has to be taken of the groundwater quality and exploitability when the level of sanitation is considered. DWAF Geohydrology is actively involved in water supply schemes for domestic use from groundwater resources in the WMA. In total it comprises 30% of all exploration and development work done by the regional Geohydrology section. The ambient water quality of the resources is however a problem when developing water supply schemes for communities and the health implications of this water supply needs to be considered.

Emerging farmers can also benefit by the exploitation of groundwater but the potential for irrigation development from groundwater resources in the WMA is limited. Livestock farming could be in option in this regard, but DWAF considers this type of development to be the Department of Agriculture’s responsibility.
Working for water are currently clearing invasive prosopis and thus contributing to poverty eradication, invader eradication and improvement of water resources in the WMA.

2 Groundwater according to geolithological units and catchments associated or enclosed with the units (1: 1000 000 geology).

The Lower Orange WMA, is underlain by very diverse lithologies. Several broad lithostratigraphic units fall within the boundaries. A simplified geological map of the WMA is presented in Figure 2. From oldest to youngest these units comprise the following (V3, 2002):

- **Namaqualand-Natal Basement Complex**. Rock of this complex, ranges from homogenous granites through to migmatites and gneisses. The area underlain by the Namaqualand-Natal Complex is situated in the vicinity of the Orange River between Upington and Springbok. The area is an assembly of compact sedimentary, extrusive and intrusive rocks.
- **Ventersdorp Supergroup**, represented by andesitic lavas and occasional sedimentary rocks related to post extensive erosion, are encountered in very small 2-5 isolated inliers between Prieska and Douglas.
- Dolomitic and related carbonate rocks of the **Postmasberg Group, Campbell and Griquatown Sequence, all forming part of the Griqualand West Sequence**, occupy the north-eastern lobe of the WMA. Dolomites, limestones and related sedimentary rocks (often iron or manganiferous ore bearing) make up this broad lithostratigraphic unit.
- **Abbabis and Kheis Groups** are represented by relatively small inliers of diverse sedimentary successions consisting of shales, sandstones, banded iron formations and conglomerates. These rocks are encountered in the vicinity of Upington and are not widespread.
- **Damara Sequence** encountered in the immediate vicinity of Alexander Bay and Port Nolloth, is represented by the Fish River, Schwarzrand, Kuibis, Malmesbury, Gariep, Swakop, Otavi, Nosib, Rehoboth and Sinclair Groups. Lithologies in these various groups are very diverse, ranging from shales, sandstones, diamictites, banded iron formation through to limestones and calcareous sedimentary formations.

- **Karoo Sequence** represented by the Ecca Group and Dwyka Formation, and to a lesser extent the Beaufort Group, occupy the southern lobe of the WMA, and comprises thick successions of sedimentary rocks. Sedimentary rocks range from mudrocks through coarser varieties (sandstones, conglomerates) to diamictites and rhythmites (pleistocene deposits). Karoo or Jurassic dolerite is fairly common throughout the sequence and also frequently intrudes older rocks.
- Quaternary and Tertiary dune deposits, consisting of "**Kalahari red sands**", occupy the extreme northern part of the WMA bordering on Namibia. These dune deposits are of considerable thickness and comprise fine aeolian sands with occasional coarser gravel deposits.

The geohydrology is just as complex as the geology in the area but can be simplified to four main aquifers namely the Karoo sediments, the weathered granites and gneisses from the Basement complex, dolomites and associated formations and the primary aquifers such as the Kalahari sands and the alluvial deposits along streams and rivers and the coastal plains north of the Buffelsrivier. The first three of these aquifer types are typical dual porosity or secondary aquifers water associated with weathering and fracturing of the matrix. Typical yields and other characteristics for all aquifers are listed in Table 3. Primary aquifers are found in Kalahari sands and alluvial deposits associated with rivers and coastal plains.

Table 3 Yields and characteristics for major aquifer types in the WMA (Van Dyk, 2003)

Legend	Aquifer type	AverageYield (L/s)	Quality	Characteristics
G	Granites and gneisses	0.1 - 2	Poor quality (high SO_4 and F)	Lower rainfall areas. Stagnant systems, rich in dissolved salts from mineral dissolution
D	Dolomitic aquifers	0.5 - 5	Good quality	Higher rainfall regions, active systems, high pollution potential, shallow water levels
KB	Karoo Sediments - Beaufort	0.0 - 5	Good quality	Low to high yields, high pollution potential, shallow water levels
KDE	Karoo Sediments – Ecca and Dwyka	0.0 - 5	Poor quality (NaCl- rich)	Low to moderate yields rich in dissolved salts from mineral dissolution
P	Primary aquifers	0.0 - 5	Variable quality (mostly poor quality)	Complicated borehole construction

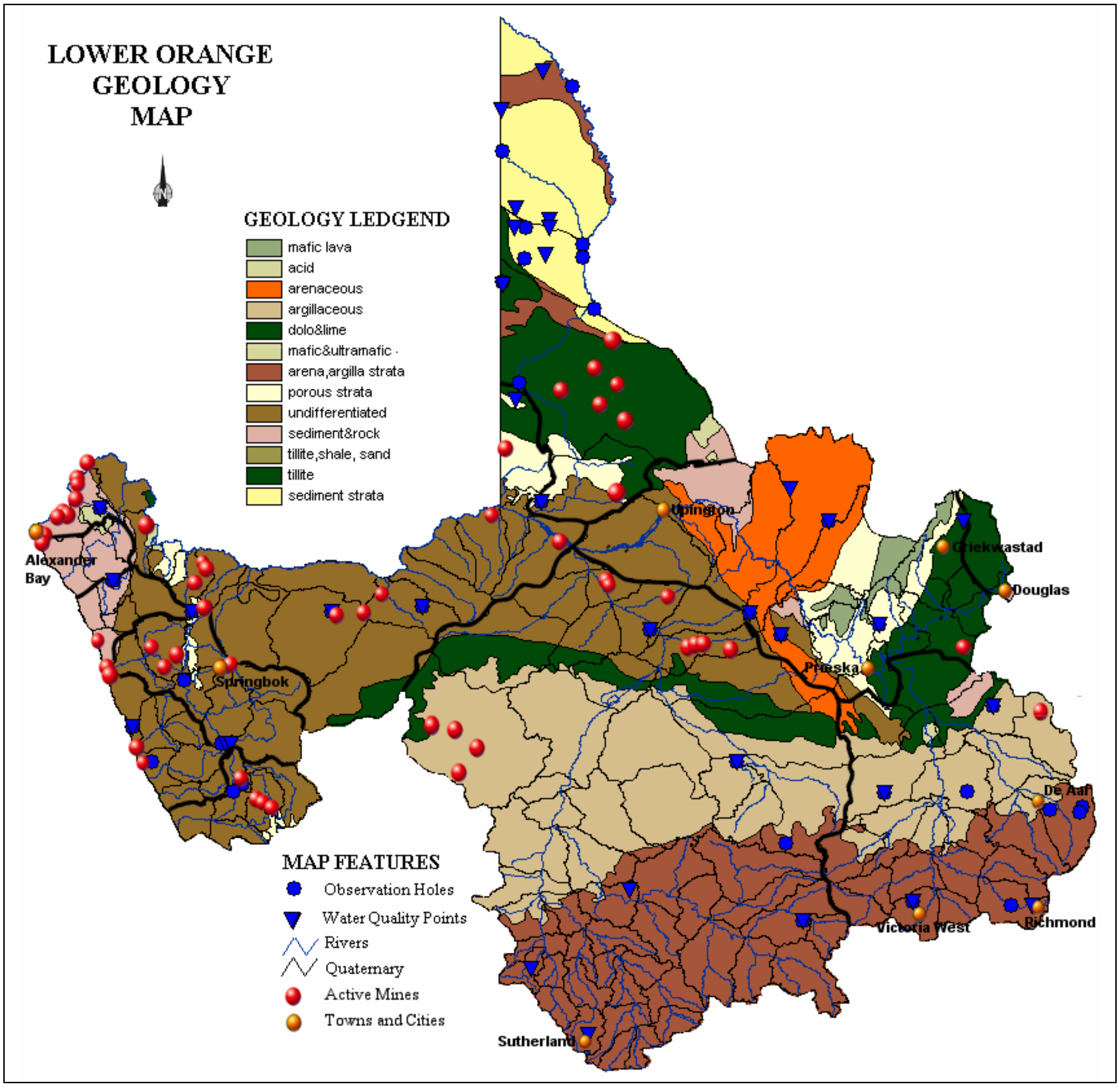

Figure 2 Simplified geology of the WMA

3 Riverbed Sand Aquifers

At small scale a number of these aquifers are utilized mostly along dry riverbeds, Buffelsriver, Saaipoort along Carnarvon leegte, along Gamagara river, Driekop Kanhardt. In the drier west almost all abstractions from boreholes associated with a proximate riverbed. Along the Orange River some abstraction along riverbeds is also taking place (Van Dyk, 2003). General characteristics of riverbed aquifers can be summarized as:

- Coarse gravels and sands are more typical of alluvial deposits. However, flood plains consist mainly of fine silt. Towards the end of a river's course, the river slows down dumping some of the heavier materials on these flood plains. Boreholes drilled into these types of formations normally have higher yields. It is important to note that borehole design is plays an important role in the yield of boreholes drilled into riverbed aquifers.
- Alluvial deposits grain size varies considerably, fine and coarse materials are intermixed. The hydraulic conductivities vary between 10^{-3} to 10^{3} m/d and their porosities vary

between 25 – 70%. However, flood plain porosities usually range 35 – 50% and the hydraulic conductivities vary between $10^{-8} – 10^{-1}$ m/d.

- In general riverbed aquifers are high recharge areas and often recharge deeper underlying aquifers and are unconfined in nature.

The surface-water groundwater interaction is often intermittent (depending on the elevation of the water level, groundwater may recharge the surface water body or the surface water may recharge groundwater). This is normally dependent on the rainfall cycle. Therefore boreholes drilled into these aquifers are almost always successful.

4 Groundwater-Surface Water Linkage

Groundwater-surface water interaction has not been studied sufficiently in the Northern Cape due to the limited surface water. According to records documented by Van Tonder and Dennis (2003), under natural conditions there is seldom a connection between surface water and groundwater. However observed surface water recharge in normally dry riverbeds. Current quality problems experienced in the Vaal and Orange rivers, waterlogging experienced with irrigation along these riverbanks indicate interaction. Therefore a study is currently motivated by DWAF Geohydrology to investigate Groundwater-surface water interaction in the Vaal and Orange rivers (Van Dyk, 2003).

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