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The Comprehensive Reserve Determination Study for the Integrated Vaal River System: Lower Vaal Water Management Area

Prepared for:

DWAF

November 2007

Compiled by

K Raath

Inception report: **AI-R-2007-11-15**

The Comprehensive Reserve Determination Study for the Integrated Vaal River System: Lower Vaal Water Management Area.

15 November 2007

Conducted on behalf of:
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Compiled by:

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REPORT DISTRIBUTION LIST

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LIST OF ABBREVIATIONS

Abbreviation	Description
BPEO	Best Practicable Environmental Option
DWAF	Department of Water Affairs and Forestry
Ec	Electrical Conductivity
EIA	Environmental Impact Assessment
EMPR	Environmental Management Programme Report
MAMSL	Meter Above Mean Sea Level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBGL	Meter Below Ground Level
MBGL	Meter Below Ground Level (i.e. depth)
NEMA	National Environmental Management Act
NWA	National Water Act
TDS	Total Dissolved Solids
WMA	Water Management Area

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1 INTRODUCTION

AGES was appointed by the Department Water Affairs and Forestry to conduct a study of the Lower Vaal WMA; with emphasis on the development of a framework from where the water resources can be managed by DWAF.

The Vaal River system is the most important water resource system in South Africa as it provides water to more than 40 % of the country's inhabitants. There are numerous industries and mines in the supply area, which supports the production of more than 50 % of the country's gross domestic product.

Due to extensive development in the Vaal River System the local surface water resources in all three the Vaal WMAs have been fully exploited. It was therefore necessary to augment the supply by developing various water schemes importing water from the Thukela and Usutu to Mhlathuze WMAs, as well as from the Kingdom of Lesotho through the Lesotho Highlands Water Project. Groundwater is of major importance in the Lower Vaal WMA and constitutes the only source of water over much of the WMA. Development of surface water naturally occurring in the WMA has reached its potential and all the water is being fully utilised.

2 TERMS OF REFERENCE

2.1 Objectives

The purpose of the study is to provide the client with the following:

1. Resource Unit delineation; an updated resource unit classification taking cognisance of surface water quaternary catchment boundaries and the aquifers present in these catchments

2. Water balance and conceptual aquifer model, using the GRDM tool

3. Rapid reserve determinations to verify and validate the reserve determination by the GRDM method

4. Intermediate level reserve determinations

5. Management and strategy development

3 STUDY AREA

The Vaal River forms the main tributary to the Orange River and originates on the plateau west of the Drakensberg escarpment and drains much of the central highveld of South Africa. The Lower Vaal WMA lies between the middle Vaal and Lower Orange WMA's, with the upper Orange WMA to the south of the Lower Vaal WMA and Botswana to the north. Figure 1 depicts the location of the Lower Vaal WMA.

The Lower Vaal WMA is located downstream of Bloemhof Dam and upstream of Douglas Weir. It extends to the headwaters of the Harts, Molopo and Kuruman River in the north and the Vaal River Downstream of Bloemhof in the south. It covers a catchment area of 51,543 km^2. It lies in the North West and Northern Cape Provinces, with the south-eastern corner in the Free State, and borders on Botswana in the north, as well as on the Crocodile (West) and Marico, Middle Vaal, Upper Orange and Lower Orange water management areas.

Major rivers in the Lower Vaal Water Management Area include the Molopo, Harts, Dry

Harts, Kuruman and Vaal rivers. The tertiary drainage areas in the Lower Vaal WMA comprises C31, C32, C33, C91, C92, D41, D42, and D73 (Figure 1).

3.1 Overview and Background to the Lower Vaal

The climatic conditions vary considerably from west to east across the WMA, with the Mean

Annual Precipitation (MAP) reducing from 500 mm in the east to 200 mm in the west with an average of 350 mm. This tendency is reversed when considering potential annual evaporation, which increases from 2650 mm in the east to 2700 mm in the dry western parts of the WMA.

The land use in the Lower Vaal WMA is characterised by agriculture with the main crops being maize, cotton, groundnuts, vegetables and sunflowers. Agricultural activities are however dominated by livestock farming. There is also extensive diamond mining activities located in the Lower Vaal water management area. These activities are generating substantial return flow volumes in the form of treated effluent from the urban areas and mine dewatering that are discharged into the river system. These discharges are having significant impacts on the water quality in the main stream of the Vaal River in the Lower Vaal WMA.

The Lower Vaal WMA has an average economy, contributing approximately 2% of the GDP of South Africa. It is expected that economic activity will remain relatively static in the medium to long term. Mining and agriculture are important contributors to the economy of the region, and is expected to continue to play an important role in the economy of this WMA.

The water balance for the Lower Vaal indicates that for the year 2000 an overall surplus in supply of 30 million m^3/annum was available. With the commissioning of Phase 1b of the Lesotho Highlands Water Project during the latter part of 2003 an additional 344 million m3/annum is available to the Vaal river system. This surplus is expected to be gradually depleted over time to supply the growing water requirements in mainly the Upper Vaal WMA. The Lower Vaal system is expected to be in balance for the year 2025 using the base requirement scenarios.

This estimated excess in supply will only be available if all the transfers are fully operational. In practice the volume of water conveyed through the Thukela-Vaal Transfer scheme will be determined annually, effectively operating the system such that the water demands are in balance with the supply. The quantity transferred will thus increase over time in line with the growth in the water requirements.

Due to the very low growth rate of the projected water requirements the impact of Water Conservation and Demand Management could result in a substantial decrease in water requirements in the Lower Vaal WMA.

Different geological formations occur over the south-eastern part of the water management area, giving rise to a variety of soil types. The northern and western part, which corresponds remarkably well with the catchment of the Molopo River, is mainly underlain by sedimentary formations and covered by Kalahari sands. A large portion of the central and north-east corner of Lower Vaal WMA is underlain by the Transvaal Supergroup consisting of dolomite, chert and subordinate limestone. This area is characterised by a high potential for groundwater with a 50 to 75% probability and accessibility throughout the dolomitic area. The groundwater level is between 8 to 20 metres deep on average. Rich diamond bearing intrusions occur near Kimberly with alluvial diamonds found in the vicinity of Bloemhof, Schweizer-Reneke, Wolmaranstad, Barkley West and several other places. Iron ore and a variety of other minerals are found in the central to south-western parts of the water management area. (DWAF, Internal Strategic Perspective, Lower Vaal Water Management Area, October 2004, P WMA 10/000/00/0304)

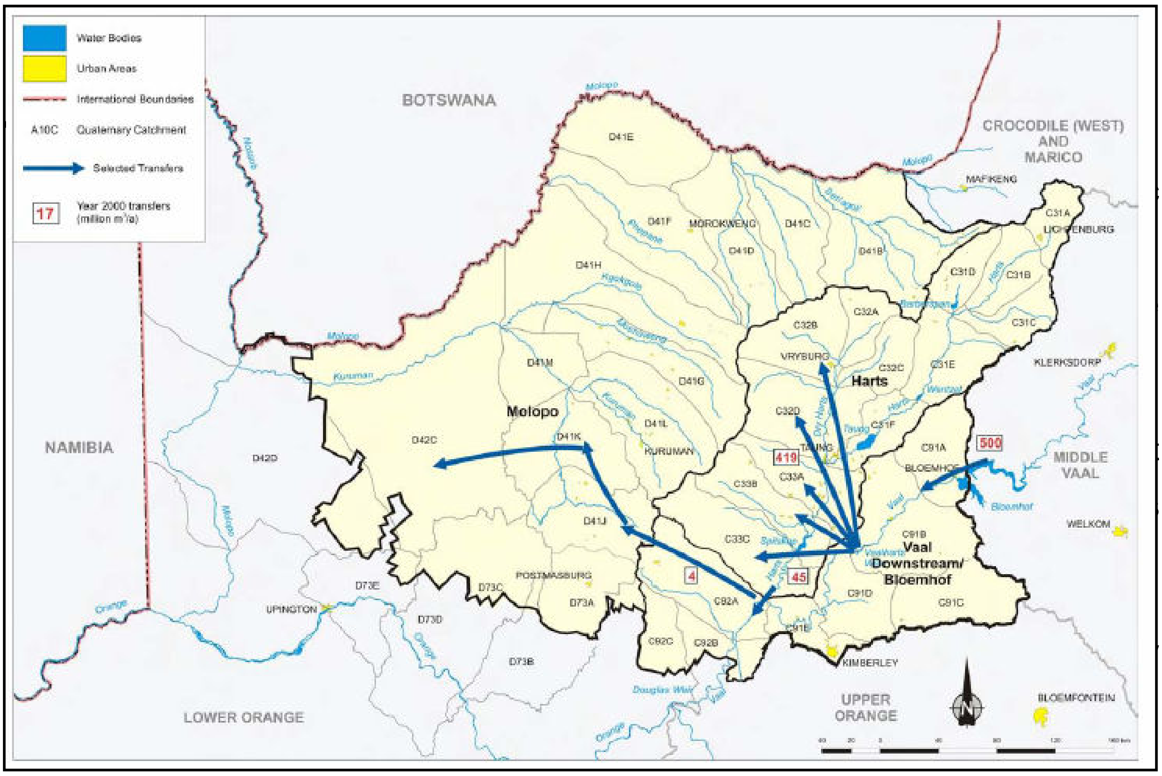

Figure 1 Location of the Lower Vaal WMA (ISP : DWAF, 2005)

5 RESERVE COMPONENTS

1. Basic Human need: Relative to the size of the Lower Vaal WMA there is very little surface water and the majority of communities in this WMA are dependant on groundwater. The purpose of this study is to determine the effect of mining activities, irrigation and base flow on the groundwater and the subsequent effect on groundwater available for basic human need.
2. Base Flow: This study will determine the base flow necessary for surface water systems, river flow, wetlands, pans etc. and will qualify and quantify base flow loses due to several factors such as evaporation and evapo-transpiration.

3 Wetlands: The location and amount of wetlands need to be determined, as well as the possible affect that a reduction in groundwater might have on the wetland.

4 Springs: There are several very important springs in the Lower Vaal Water Management area for example the Molopo's Oog near Lichtenburg, the spring in Kuruman and several others of which many have their origin in dolomite. It is of utmost importance to identify these springs and determine the roles they have played historically and are currently playing in providing potable water to communities and the effect a reduction in groundwater will have on these sources.

5 Pans: There are numerous pans in the Lower Vaal Water Management area which will play an important role in base flow determination since a large part of base flow end up in pans in stead of rivers where evaporation and recharge play an important role.

6 DELIVERABLES

The study has been defined in the contents of the documentation Terms of Reference compiled by DWAF and supplied for the purpose of explanation of the current study entitled:

"Groundwater Reserve Determination Study: Lower Vaal Water Management Area"

AGES has the following understanding of the Scope of Work:

1) Resource Unit delineation

Collating and interpreting existing and background information from the area to assess the validity of the proposed resource unit classification. Subsequent to this, provide an updated resource unit classification taking cognisance of surface water quaternary catchment boundaries and then the aquifers present in these catchments. Once the critical or stressed resource units have been identified, make an assessment as to which units require field validation of hydrogeological data and basic, in-field hydrochemistry determinations.

2) Water balance and conceptual aquifer model

Using the suggested methodology of groundwater resource directed measures and the GRDM tool, a water balance of the selected resource units will be determined and thereby calculate the desktop or rapid groundwater reserve component.

Complete conceptual aquifer model drawings for the stressed/selected resource units

3) Rapid reserve determinations

An assessment of the regional Lower Vaal Management area water balance of quaternary catchments including the selected Resource Units will be completed. This serves to verify and validate the Desktop or Rapid level reserve determination by the GRDM method.

4) Intermediate level reserve determinations

The resource units selected for intermediate level reserve determination will have this done as far as practically possible using the data available from the study. Aquifer characterisation through drilling and testing as well as numerical model development of the aquifer resource units falls out of scope of this study.

5) Management strategy development

Interpretation of resource quality objectives, classification of the resource units (i.e. PSC) and the development of a monitoring programme to ensure sustainable allocation and use of the aquifer/s in the long term. This management strategy follows the guidelines set out in the GRDM approach documentation. This does not include the setting of Desired Status Categories / Management Classes.

7 STATUS QUO

7.1 Previous reserve determination studies

AGES has compiled a numerical water balance for two other WMA's in South Africa, Crocodile (West) River and Olifantsriver catchments. The numerical water balance is a programme written to simplify the computation of a water balance for many quaternary catchments. It performs Monte Carlo simulations on rainfall data for the rainfall zones across the catchment. An assessment of the aquifer's water balance on a regional scale is thereby possible. The interpretation of the monthly base flows from the groundwater is also possible with this water balance model. It has been termed the GRYM or Groundwater Resources Yield Model. It is proposed that this model be used in the current study for the Lower Vaal Catchment.

7.2 Summary of current monitoring points

All historical data from DWAF and other institutions will be used and verified if possible within the budget constraints.

7.3 Relevant studies/ Reports related to the study area

AGES have numerical models and detailed hydrogeological data in the following catchments, which falls in the Lower Vaal Management Area, catchments D41K, C32D, C33A, C31F, D41J and D73A. which is part of the tertiary catchments mentioned in section 4 above. The experience of the AGES team is related to the mining activity in the Kuruman and Lime Acres areas.

7.4 Proposed EWR (ecological water requirement) Sites

Due to the intermittent nature of surface runoff in the WMA, provision for the ecological component of the Reserve has no impact on the yield from local resources. If the area adjacent to a watercourse has standing water or saturated soil for as long as a season, it is normally termed a wetland. There are several pans and wetlands that are Environmental sensitive areas such as Baberspan near Sannieshof and a pan close to Kimberley which is known for their rich birdlife.

8 TECHNICAL APPROACH

8.1 Methods and approach

As mentioned above a numerical water balance model was developed at AGES which will be used in this study. This programme was written to simplify the computation of a water balance for many quaternary catchments. It performs Monte Carlo simulations on rainfall data for the rainfall zones across the catchment. An assessment of the aquifer's water balance on a regional scale is thereby possible. The interpretation of the monthly base flows from the groundwater is also possible with this water balance model. It has been termed the GYM or Groundwater Yield Model. The GYM will make provision for evaporation and evapo-transpiration in its calculations.

Data and information that will be used are the following:

- GIS data generated by AGES as well as GIS data received from DWAF
- NGDB database
- WARMS database
- DWAF Geohydrology Northern Cape
- GH Reports
- 1:5 000 000 Geohydrological maps and brochures
- 1: 50 000 Topographical maps
- 1: 250 000 Geological maps
- Consultants reports and other academic reports

The GRA II data will also be used but is currently being validated by DWAF. The GYM software will be used to verify the GRDM tool and vice versa.

The specific base flow volumes needed for the rivers and surface water bodies as well as data regarding the surface water bodies must be provided by DWAF to be able to calculate the reserves with GYM. (Groundwater yield model and Numerical model integration into a resource management plan, Augustus 2007, Koos Vivier, Annette Wiethoff, Joubert Bulasigobo and F Faul, Africa Geo-Environmental Services (AGES)

8.2 Riparian Vegetation

A riparian zone is the interface between land and a flowing surface water body. Plant communities along the river margins are called riparian vegetation. Riparian zones occur in many forms including grassland, woodland, wetland or even non-vegetative. To be able to bring the riparian vegetation into calculation with the Groundwater Yield Model the specific areas and locations of indigenous, alien and cleaned riparian zones must be provided by DWAF.

8.3 Basic Human needs Reserve

As mentioned previously groundwater constitutes the only source of water over a large area of the Water Management area and the Basic Human need reserve is the most important component of the study.

8.4 Mining

There are quite a number of mining operations in the Lower Vaal WMA, ranging from base metal mining, diamond mining, limited gold mining in the Kalahari greenstone belt and smaller mining operations such as limestone quarries and diamond diggings in alluvial deposits along the Vaal River and its tributaries.

These mining activities will be an important factor in the groundwater reserve calculations.(Figure 2)

Groundwater use at most of these sites is limited and should any seepage occurs in opencast pits or underground workings, the water is usually pumped and utilized in processes to minimize use of other water sources. The diamond diggings have little impact on water quality. Large amounts of water are abstracted locally during the processing of the diggings with the result that the surface environment and drainage patterns are altered. Currently the Kalahari Goldridge mines supply their own water by circulating water from the pit and sludge lagoons as well as from boreholes (Total 120 Ml/year). It is estimated that the mining activities will affect the boreholes and that an additional amount of 30- 50 Ml/month will be needed in the next 5 years.

Kimberley is also an important diamond mining area that will have an impact on the groundwater.

The Sishen Mine, currently the major supplier of iron ore in the country, is located in the Lower Vaal WMA. An increase in mining and transportation activities can be expected with the construction of the Sishen-Coega railway line that will link Sishen with the Coega initiative near Port Elizabeth. Sishen Mine makes use of groundwater abstracted directly from the mining area although it can obtain water from the Vaal River via the 700mm diameter Vaal-Gamagara pipeline. Approximately 1.5 million m^3 of water is abstracted monthly from the mine and it is anticipated that the groundwater will gradually be depleted and that Sishen Mine will eventually have to import water.

Other important mining areas include Kudumane (iron, manganese and asbestos etc), Ganyesa (diamonds, mica group clay and salt) and Taung (diamonds, limestone, dolomite and salt).

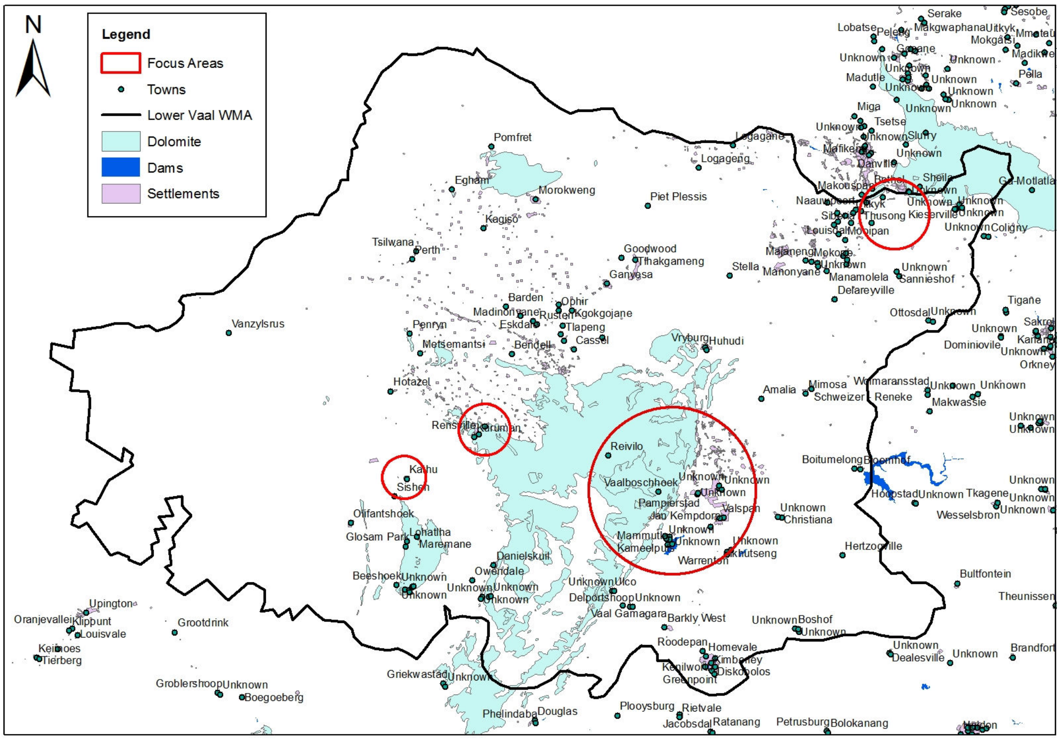

Figure 2 Lower Vaal focus areas

8.5 Dolomite

Solution cavities in dolomitic rocks of the Ghaap Group and Chuniespoort group often develop in association with diabase dykes and faults and contain large quantities of exploitable groundwater. These dolomitic areas around Mafeking and Kuruman are especially vulnerable to pollution and over utilisation of groundwater. (Figure 3)

8.6 Agriculture

Almost every farm unit in the WMA is dependent on groundwater for domestic use and stock watering. There are however no abstraction volumes available but in terms of quantities of water, stock farming has a relatively small influence on the regional groundwater resource.

Large-scale irrigation is developed where aquifer types are suitable. The lithologies from which abstraction for irrigation takes place vary between dolomitic/karstic aquifers, weathered granite and quartzite and at contact or faulting zones. Problems encountered at these irrigation areas are over utilisation of the resources with the associated lowering of water tables. Special attention will be given to these areas during the study.

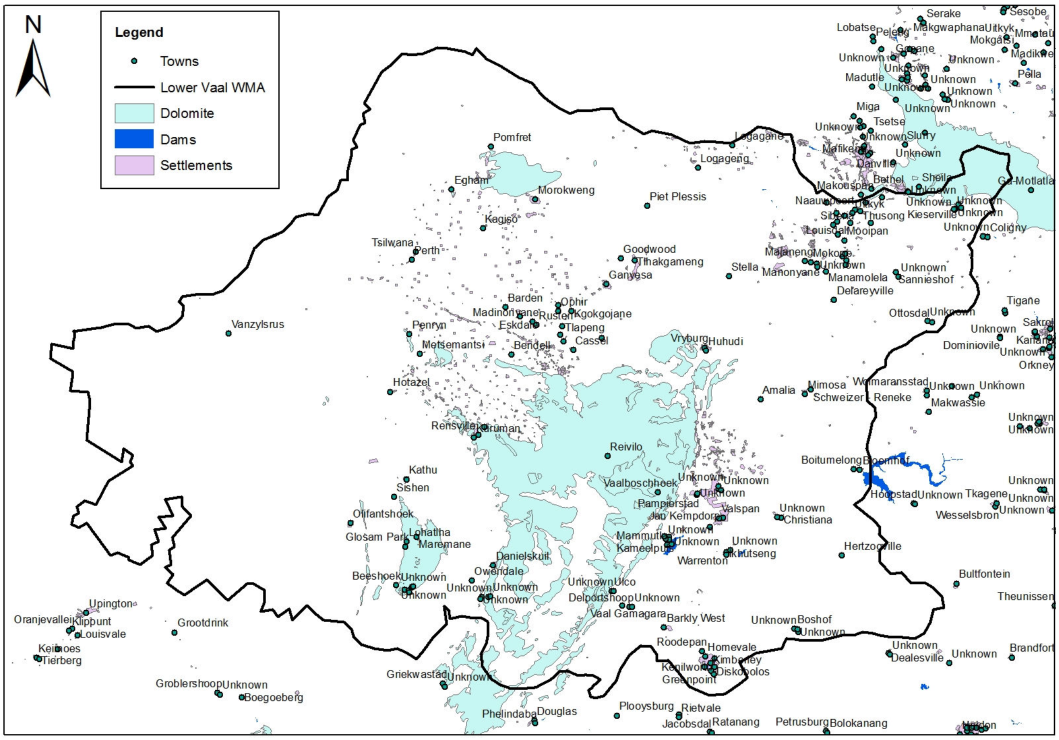

Figure 3 Lower Vaal dolomitic areas

8.7 Stakeholder awareness

There will be continuous correspondence and ongoing liaison between AGES and stakeholders. Any public processes are outside the scope of this study. Regional DWAF offices will be included in the study development and progress.

9 DETAILED PROJECT PLAN

9.1 Phase 1: Inception

Literature review (incl. sourcing data, consultants reports, evaluating contents, existing information assessment)

1. Assessment of report content, initiation of GIS, sorting of information for relevance,

Inception Report compilation

2. Provide technical guidance and leadership by experienced hydrogeologist
3. Incorporation of spatial data onto a GIS
4. Interpretation of hydrogeological data
5. Report compilation and technical specialist input

- **Delineation of resource units (incl. GIS-interpretation, geohydrological assessment)**
  1. Technical guidance for delineation of management units / resource units, GRDM software operation, interpretation into project planning
  2. Provide technical guidance and leadership by experienced hydrogeologist
  3. GIS delineation of resource units, printing of relevant maps, assist with interpretation of GIS-based spatial information
  4. Interpretation of NGDB data and compilation of supporting graphs and figures
  5. Specialist input into geological information section and practical delination of resource units based on (1) Quaternary (2) Hydrogeology

- **Detailed task breakdown and project planning**
  1. Compilation of project plan and resource scheduling
  2. Compilation of Inception report and technical input
  3. Technical guidance and leadership by experienced hydrogeologist

9.2 Phase 2: Implementation

- **Identification of resource units requiring ground validation**
  1. Input into the determination of the resource units, data management
  2. Logic and practicality of implementation of field work to the resource units,

determine detail required and coverage of survey

3. Specialist input by experienced hydrogeologist

- **Field verification (Hydrocensus)**
  1. Planning and management of hydrocensus, field work and land owner liason
  2. Field work
  3. Maps supporting field work and planning

- **Field water quality determination**
  1. Planning and management of hydrocensus, in field water quality determination & field work and land owner liason
  2. Field work, data interpretation
  3. Maps supporting field work and planning

- **Aquifer models (conceptual)**
  1. Technical specialist guidance on geology
  2. Development of conceptual aquifer model of resource units identified
  3. Provide technical guidance and leadership by experienced hydrogeologist

- **GRDM-specific tasks (i.e. physiography & climate, geohydrology, background information compilation into document)**
  1. Data collation, management and incorporation of relevant data into report form
  2. Guidance on the GRDM methodology, compilation of technical documentation
  3. Provide technical guidance and leadership by experienced hydrogeologist

- **Integration with Surface Water reserve studies (incl. meetings, data collection and comparison, assessment of data)**
  1. Communication with SW reserve specialists, project management
  2. Provide technical guidance and leadership by experienced hydrogeologist
  3. Data management and control

- **Water balance (Quaternary catchment based / resource unit based)**
  1. Development of WMA-specific integrated water balance for Quaternary Catchments
  2. Collation and input of data into the water balance
  3. Interpretation of water balance results

- **Reserve Determination**
  1. Compile all data required for this stage into usable form
  2. Reserve determination using GRDM tool as well as results from water balance
  3. Technical specialist input

- **Water resource classification**
  1. Data management and control
  2. Classification of resource using the GRDM methodologies and the Toolbox provided by DWA&F
  3. Provide technical guidance and leadership by experienced hydrogeologist

- **Setting RQO**
  1. Technical specialist guidance on geology
  2. Development of conceptual aquifer model of resource units identified
  3. Provide technical guidance and leadership by experienced hydrogeologist

- **Development of a monitoring programme**
  1. Technical specialist guidance on developing a monitoring programme
  2. Development of monitoring programme for the WMA and RU's
  3. Provide technical guidance and leadership by experienced hydrogeologist

9.3 Phase 3: Study Termination

- **Reporting and close out, data transfer**
  1. Data management and transfer
  2. Technical documentation & knowledge transfer
  3. Provide technical guidance and leadership by experienced hydrogeologist

9.4 Phase 4: Project Management

Arcus Gibb will be responsible for the overall management of the Vaal WMA; as well as the project management of the integration of the surface and the groundwater component of the Vaal WMA. The Lower Vaal Reserve determination study will be managed by AGES.

Table 1 Study and Budget Scheduling

Cash flow & scheduling																					
Task Nr	Task	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	
		Sept. '07	Oct. '07	Nov. '07	Dec. '07	Jan. '08	Feb. '08	March '08	Apr. '08	May '08	June '08	July '08	Aug. '08	Sept. '08	Oct. '08	Nov. '08	Dec. '08	Jan. '09	Feb. '09	March. '09	
1	Literature review (incl. sourcing data, consultants reports, evaluating contents, existing information assessment)		18 246	64 200	29 000																**R 111 446**
2	Delineation of resource units (incl. GIS-interpretation, geohydrological assessment)		5 250	28 009	36 250																**R 69 509**
3	Integration with Surface Water reserve studies (incl. meetings, data collection and comparison, assessment of data)			2 847			3 672			3 192			3 292			3 292			3 292		**R 19 587**
4	Detailed task breakdown and project planning			17 007	14 030																**R 31 037**
5	Identification of resource units requiring ground validation			2 189		25 007	10 361														**R 37 557**
6	Field verification (Hydrocensus)					95 068	95 069	95 068													**R 285 205**
7	Field water quality determination					29 154	29 153	29 153													**R 87 460**
8	Aquifer models (conceptual)								17 350	17 351	17 350										**R 52 051**
9	GRDM-specific tasks (i.e. physiography & climate, geohydrology, background information compilation into document)						12 022	12 023	12 022	12 023											**R 48 090**
10	Water balance (Quaternary catchment based / resource unit based)										27 232	27 233	27 232								**R 81 697**
11	Reserve Determination													18 945	18 945	18 945					**R 56 835**
12	Water resource classification															16 720	16 720	16 720			**R 50 160**
13	Setting RQO																15 757	15 755			**R 31 512**
14	Development of a monitoring programme																22 491	22 490			**R 44 981**
15	Meeting attendance	2 200	2 535		4 735		4 736		4 735		4 735		4 735	2 202		4 735	4 735		4 735	4 735	**R 47 353**
16	Reporting and close out, data transfer																		22 709	22 709	**R 45 418**
																					R 0
		R 2 200	R 26 031	R 114 252	R 84 015	R 149 229	R 155 013	R 136 244	R 34 107	R 32 566	R 49 317	R 27 233	R 35 259	R 21 147	R 18 945	R 43 692	R 59 702	R 54 965	R 30 736	R 27 444	**R 1 099 896**

Table 2 Schedule of Manpower

Time and cost schedule

Task No	Team member	Position in company	Study position/ activity	Time schedule	Hourly rate (Excl VAT)	Total cost (Excl VAT)
				Man hours	Rand / hour	Rand
1	**Task 1 : Literature review (incl. sourcing data, consultants reports, evaluating contents, existing**					
1.1	K Raath	Senior Geohydrologist	Assessment of report content, intiation of GIS, sorting of information for relevance, Inception Report compilation	30	R 320	R 9 600
1.2	JJP Vivier	Project Leader	Provide technical guidance and leadership	20	R 440	R 8 800
1.3	J Bulasigobo	GIS	Incorporation of spatial data onto a GIS	50	R 250	R 12 500
1.4	C Kriek	Geohydrologist	Interpretation of hydrogeological data	60	R 250	R 15 000
1.5	E van Zyl	Project Manager	Assist in data sourcing and reporting	45	R 320	R 14 400
1.6	JC Vivier	Senior Environmental Scientist	Report compilation and technical specialist input	20	R 440	R 8 800
	Sub total for professional fees					**R 69 100**
	Disbursements					R 2 500
	Travel					R 800
	Accomodation					R 250
	Subsistence					R 800
	Printing					R 550
	Miscellaneous					R 1 200
	Sub total for disbursements					**R 6 100**
	Total cost : Task 1					**R 75 200**
2	**Task 2 : Delineation of resource units (incl. GIS-interpretation, geohydrological assessment)**					
2.2	JJP Vivier	Project Leader	Provide technical guidance and leadership	30	R 440	**R 13 200**
2.3	J Bulasigobo	GIS	GIS delineation of resource units, printing of relevant maps, assist with interpretation of GIS-based spatial information	55	R 250	**R 13 750**
2.4	C Kriek	Geohydrologist	Interpretation of NGDB data and compilation of supporting graphs and figures	45	R 250	**R 11 250**
2.5	K Raath	Senior Geologist	Specialist input into geological information section and practical delination of resource units based on (1) Quaternary (2) Hydrogeology	30	R 320	**R 9 600**
	Sub total for professional fees					**R 47 800**
	Disbursements					R 2 900
	Travel					R 1 200
	Accomodation					R 580
	Subsistence					R 1 200
	Printing					R 550
	Miscellaneous					R 1 200
	Sub total for disbursements					**R 7 630**
	Total cost : Task 2					**R 55 430**

3	**Task 3 : Integration with Surface Water reserve studies (incl. meetings, data collection and comparison,**					
3.1	K Raath	Senior Geohydrologist	Communication with SW reserve specialists, project management	20	R 320	R 6 400
3.2	JJP Vivier	Project Leader	Provide technical guidance and leadership	5	R 440	R 2 200
3.4	C Kriek	Geohydrologist	Data management and control	18	R 250	R 4 500
	Sub total for professional fees					**R 13 100**
	Disbursements					R 600
	Travel					R 120
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 800
	Miscellaneous					R 1 000
	Sub total for disbursements					**R 2 520**
	Total cost : Task 3					**R 15 620**
4	**Task 4 : Detailed task breakdown and project planning**					
4.1	E van Zyl	Project manager	Compilation of project plan and resource scheduling	45	R 320	R 14 400
4.2	K Raath	Senior Geohydrologist	Compilation of Inception report and technical input	10	R 320	R 3 200
4.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	10	R 440	R 4 400
	Sub total for professional fees					**R 22 000**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 100
	Miscellaneous					R 450
	Sub total for disbursements					**R 2 750**
	Total cost : Task 4					**R 24 750**
5	**Task 5 : Indentification of resource units requiring ground validation**					
5.1	C Kriek	Geohydrologist	Input into the determination of the resource units, data management	40	R 250	R 10 000
5.2	K Raath	Senior Geohydrologist	Logic and practicality of implementation of field work to the resource units, determine detail required and coverage of survey	40	R 320	R 12 800
5.3	JJP Vivier	Project Leader	Specialist input	10	R 440	R 4 400
	Sub total for professional fees					**R 27 200**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 100
	Miscellaneous					R 450
	Sub total for disbursements					**R 2 750**
	Total cost : Task 5					**R 29 950**

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6	**Task 6 : Field verification (Hydrocensus)**					
6.1	C Kriek	Geohydrologist	Planning and management of hydrocensus, field work and land owner liason	230	R 250	R 57 500
6.2	J van der Merwe	Student	Field work	250	R 130	R 32 500
6.3	J Bulasigobo	GIS	Maps supporting field work and planning	60	R 250	R 15 000
	Sub total for professional fees					**R 105 000**
	Disbursements					R 6 000
	Travel - km & R/km	R 3.60				R 36 000
	Accomodation					R 10 000
	Subsistence					R 16 000
	Printing					R 4 500
	Miscellaneous					R 1 200
	Sub total for disbursements					**R 73 700**
	Total cost : Task 6					**R 178 700**
7	**Task 7 : Field water quality determination**					
7.1	C Kriek	Geohydrologist	Planning and management of hydrocensus, in field water quality determination & field work and land owner liason	80	R 250	R 20 000
7.2	E van Zyl	Senior Geologist	Data interpretation	40	R 250	R 10 000
7.3	J Bulasigobo	GIS	Maps supporting field work and planning	20	R 250	R 5 000
	Sub total for professional fees					**R 35 000**
	Disbursements					R 4 000
	Travel					R 3 000
	Accomodation					R 8 000
	Subsistence					R 2 500
	Printing					R 1 100
	Miscellaneous					R 1 200
	Sub total for disbursements					**R 19 800**
	Total cost : Task 7					**R 54 800**
8	**Task 8 : Aquifer models (conceptual)**					
8.1	K Raath	Senior Geologist	Technical specialist guidance on geology	30	R 250	R 7 500
8.2	J Bulasigobo	Senior Geohydrologist	Development of conceptual aquifer model of resource units identified	60	R 250	R 15 000
8.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	25	R 440	R 11 000
	Sub total for professional fees					**R 33 500**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 2 900
	Miscellaneous					R 450
	Sub total for disbursements					**R 4 550**
	Total cost : Task 8					**38050**

9	**Task 9 : GRDM-specific tasks (i.e. physiography & climate, geohydrology, background information**					
9.1	C Kriek	Geohydrologist	Data collation, management and incorporation of relevant data into report form	40	R 250	R 10 000
9.2	K Raath	Senior Geohydrologist	Guidance on the GRDM methodology, compilation of technical documentation	50	R 320	R 16 000
9.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	20	R 440	R 8 800
	Sub total for professional fees					**R 34 800**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 900
	Miscellaneous					R 450
	Sub total for disbursements					**R 3 550**
	Total cost : Task 9					**R 38 350**
10	**Task 10 : Water balance (Quaternary catchment based / resource unit based)**					
10.1	F Faul	IT Engineer	Development of WMA-specific integrated water balance for Quaternary Catchments	80	R 440	R 35 200
10.2	Corne Kriek	Geohydrologist	Collation and input of data into the water balance	35	R 250	R 8 750
10.2	James vd Merwe	Student	Collation and input of data into the water balance	35	R 130	R 4 550
10.3	JJP Vivier	Project Leader	Interpretation of water balance results	30	R 440	R 13 200
	Sub total for professional fees					**R 61 700**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 800
	Miscellaneous					R 450
	Sub total for disbursements					**R 3 450**
	Total cost : Task 10					**R 65 150**
11	**Task 11 : Reserve Determination**					
10.1	C Kriek	Geohydrologist	Compile all data required for this stage into usable form	40	R 250	R 10 000
10.2	K Raath	Senior Geohydrologist	Reserve determination using GRDM tool as well as results from water balance	50	R 320	R 16 000
10.3	JJP Vivier	Project Leader	Technical specialist input	20	R 440	R 8 800
	Sub total for professional fees					**R 34 800**
	Disbursements					R 1 600
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 200
	Miscellaneous					R 750
	Sub total for disbursements					**R 3 550**
	Total cost : Task 11					**R 38 350**

12	**Task 12 : Water resource classification**					
12.1	C Kriek	Geohydrologist	Data management and control	35	R 250	R 8 750
12.2	K Raath	Senior Geohydrologist	Classification of resource using the GRDM methodologies and the Toolbox provided by DWA&F	25	R 320	R 8 000
12.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	35	R 440	R 15 400
	Sub total for professional fees					**R 32 150**
	Disbursements					R 4 500
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 2 900
	Miscellaneous					R 450
	Sub total for disbursements					**R 7 850**
	Total cost : Task 12					**R 40 000**
13	**Task 13 : Setting RQO**					
13.1	K Raath	Senior Geologist	Technical specialist guidance on geology	20	R 320	R 6 400
13.2	J Bulasigobo	Senior Geohydrologist	Development of conceptual aquifer model of resource units identified	40	R 250	R 10 000
13.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	12	R 440	R 5 280
	Sub total for professional fees					**R 21 680**
	Disbursements					R 1 200
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 1 800
	Miscellaneous					R 450
	Sub total for disbursements					**R 3 450**
	Total cost : Task 13					**R 25 130**
14	**Task 14 : Development of a monitoring programme**					
14.1	E van Zyl	Project Manager	Technical specialist guidance on developing a monitoring programme	40	R 320	R 12 800
14.2	K Raath	Senior Geohydrologist	Development of monitoring programme for the WMA and RU's	20	R 320	R 6 400
14.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	28	R 440	R 12 320
	Sub total for professional fees					**R 31 520**
	Disbursements					R 1 900
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 2 000
	Miscellaneous					R 450
	Sub total for disbursements					**R 4 350**
	Total cost : Task 14					**R 35 870**

15	**Task 15 : Meeting attendance**					
15.1	K Raath	Senior Geohydrologist	AGES technical contributions	30	R 320	R 9 600
15.2	JJP Vivier	Project Leader	Provide technical guidance and leadership	30	R 440	R 13 200
15.3	E van Zyl	Project Manager		10.5	R 320	R 3 360
	Sub total for professional fees					**R 26 160**
	Disbursements					R 3 600
	Travel					R 4 000
	Accomodation					R 0
	Subsistence					R 1 200
	Printing					R 2 900
	Miscellaneous					R 1 700
	Sub total for disbursements					**R 13 400**
	Total cost : Task 15					**39560**
16	**Task 16 : Reporting and close out**					
16.1	C Kriek	Geohydrologist	Data management and transfer	20	R 250	R 5 000
16.2	K Raath	Senior Geohydrologist	Technical documentation & knowledge transfer	45	R 320	R 14 400
16.3	JJP Vivier	Project Leader	Provide technical guidance and leadership	15	R 440	R 6 600
	Sub total for professional fees					**R 26 000**
	Disbursements					R 3 000
	Travel					R 0
	Accomodation					R 0
	Subsistence					R 0
	Printing					R 3 000
	Miscellaneous					R 1 200
	Sub total for disbursements					**R 7 200**
	Total cost : Task 16					**R 33 200**

10 REFERENCES

1. DWAF, (2004) Internal Strategic Perspective, Lower Vaal Water Management Area. Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3, DWAF report no. P WMA 10/000/00/0304

2. http://en.wikepedia.org/wiki/Riparian

3. DWAF, (1999) Vaal River System Analysis Update: Hydrology of the Lower Vaal Catchment, MJ Tukker, DWAF report no. PC00/00/16596

4. Groundwater yield model and Numerical model integration into a resource management plan, Koos Vivier, Annette Wiethoff, Joubert Bulasigobo and F Faul, Africa Geo-Environmental Services (AGES)

5. Tender Submission (2007) Project Number: WP8829/8, Groundwater Reserve Determination Study: Lower Vaal Water Management Area Prepared for DWAF, A Wiethoff, AGES