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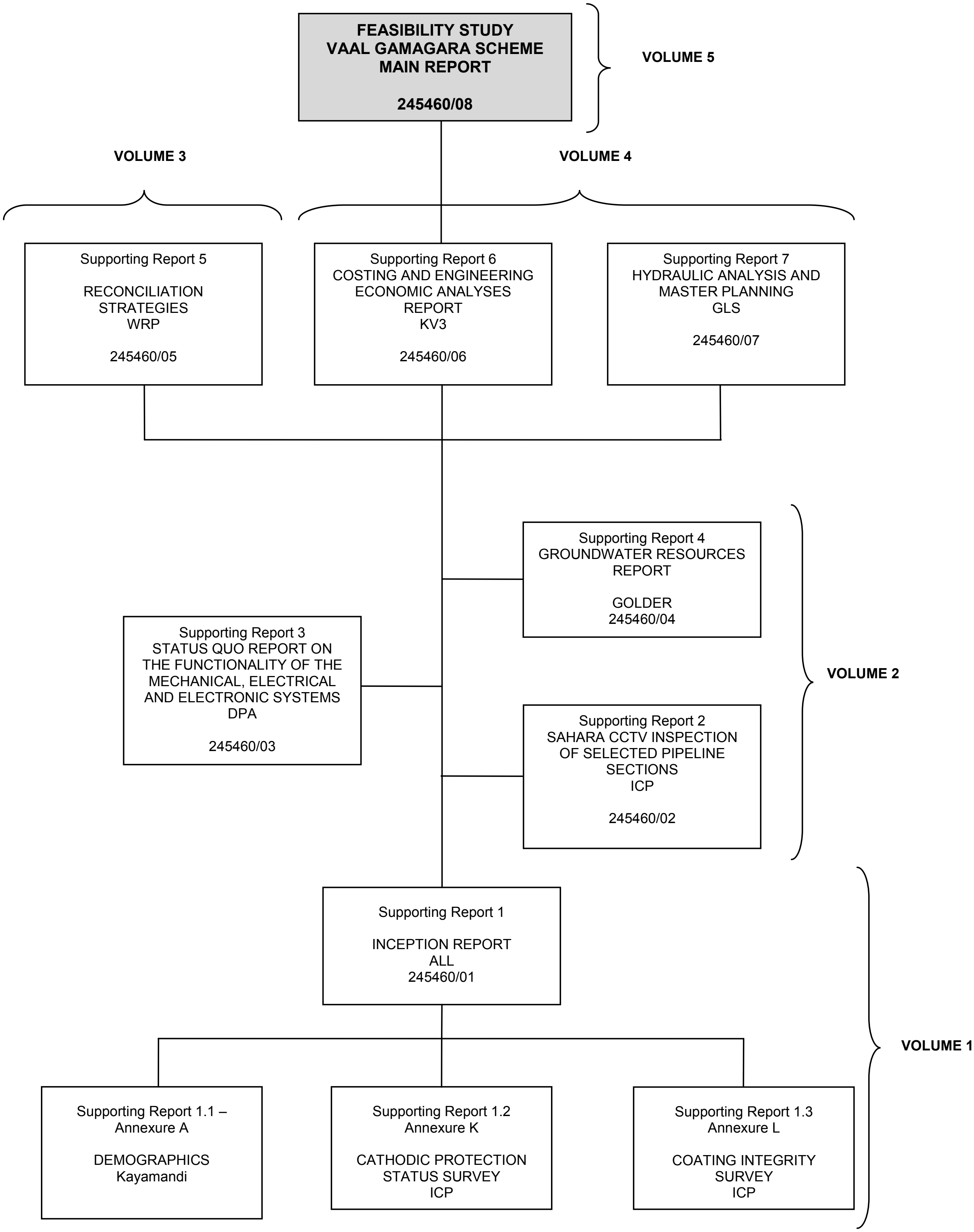
FEASIBILITY STUDY
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	245460/06	Supporting Report 4	COSTING AND ENGINEERING ECONOMIC ANALYSES REPORT
VOLUME 3	245460/05	Supporting Report 4	RECONCILIATION STRATEGIES
VOLUME 2	245460/04	Supporting Report 3	GROUNDWATER RESOURCES
	245460/03	Supporting Report 3	STATUS QUO REPORT ON THE FUNCTIONALITY OF THE MECHANICAL, ELECTRICAL AND ELECTRONIC SYSTEMS
	245460/02	Supporting Report 2	SAHARA CCTV INSPECTION OF SELECTED PIPELINE SECTIONS
VOLUME 1	245460/01	Supporting Report 1	INCEPTION REPORT
	245460/01	Annexure L to Inception Report	COATING INTEGRITY SURVEY
	245460/01	Annexure K to Inception Report	CATHODIC PROTECTION STATUS SURVEY
	245460/01	Annexure A to Inception Report	DEMOGRAPHIC PROJECTION

REFERENCE

This report is to be referred to in bibliographies as:

Sedibeng Water Vaal Gamagara Scheme, South Africa, 2011. Main Report: Feasibility, Prepared by KV3 Engineers in association with Kayamandi Development Services, WRP Consulting Engineers, Golder Associates, GLS Consulting, Isinyithi Cathodic Protection (ICP), Delport Du Preez Consulting Engineers (DPA)

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EXECUTIVE SUMMARY

Background and purpose of the study

In the process of compiling the Internal Strategic Perspectives (ISPs) for all the Water Management Areas (WMAs) in the country, the Department of Water Affairs (DWA) identified the need to develop strategies that will ensure adequate future reconciliation of water requirements and water availability in the main metropolitan areas, as well as in smaller municipal areas and towns. Some basic reconciliation options were addressed as part of the ISPs, but at the time it became clear that more detailed strategies needed to be developed. This would ensure effective and efficient management of the water resources supplying the economic hubs and smaller urban areas in the country, while at the same time managing their water requirements to ensure water use efficiency. To this end, DWA developed strategies for all the towns in the country, of which the Development of Reconciliation Strategies for All Towns in the Central Region [1] is a product.

The purpose of the All Town Reconciliation strategies [1] were to gather information about the bulk water balance situation of all towns in the country, to select the towns that are most in need of strategies for reconciliation of water availability with future water requirements, and to identify the most appropriate series of interventions that will form part of such strategies.

During the first phase of the study for the Central planning region (Vaal River and Orange River catchments) existing information regarding the water requirements, water supply infrastructure and water availability of all the towns in the study area have been gathered. The towns or grouping of towns to be studied further were then selected and prioritised. The next phase was to develop the actual reconciliation strategies for the selected towns. It became evident during this phase of the study that the towns that are being supplied from the Vaal Gamagara Scheme (refer to **Figure 4.1**) cannot be studied in isolation from the other users from this pipeline, because of the interaction between these users and the complications around the way water is being supplied from the pipeline and groundwater, mostly from the dewatering of mines. This area was therefore selected for more detailed reconciliation strategy development.

Sedibeng Water and DWA decided that the best way to achieve the above would be to develop reconciliation strategies for the area at large and through the development of a Water Master Plan and management information system for Sedibeng Water's infrastructure system at Vaal Gamagara, which is in line with current best practice. KV3 Engineers as Lead Consultant was appointed in association with a multi disciplinary consulting team for the *Development of Reconciliation Strategies for the Area Served/Interacting by/with Sedibeng Water's Vaal Gamagara Scheme as well as a Water Master Plan*.

The multi disciplinary team consisting out of KV3 Engineers, Kayamandi Development Services, WRP Consulting Engineers, Golder Associates, GLS Consulting, Isinyithi Cathodic Protection (ICP), Delport Du Preez Consulting Engineers (DPA) commenced with the study in November 2009 and was completed August 2011.

Study Area

The Study Area falls within the Northern Cape Province and is mostly located within Water Management Area (WMA) 10 with some extension to WMA 14. It covers the area served/interacting by/with Sedibeng Water's Vaal Gamagara Scheme, as well as possible extension to the Mier area, two rural settlements at Skeifontein and Groenwater (Metsimatale). Local authorities included in the study but not served by the VGG scheme were Heuningvlei, Dibeng, Campbell, Danielskuil and Kuruman. Additional domestic water users, not initially included in the Terms of Reference (ToR) were also identified and were included in the study (Campbell, Griekwastad and Schmitsdrift). Other water users served by the scheme included mines (existing, possible new mines and prospecting mines), industries, Governmental and agricultural users. The possibility to supply Botswana either via the extension of the Kalahari East water scheme and/or with an off-take from Blackrock was also analysed.

The Vaal Gamagara (VGG) Government Water Supply Scheme (**Figure 4.1**) was completed in 1968 with the purpose to deliver Vaal River water to the area. It consists of a purification works that can purify 13.27 million m³/a water, pumps, 11 reservoirs and 370 km of pipes to deliver this water to users in the study area. The pipeline has the capacity to convey/import approximate 15 million m³/a into the D41J and D41K catchments (refer to **Annexure D – Map 1**).

De-watering of mines in proximity to Postmasburg (D73A catchment) and Kathu (D41J), and distribution of this water via the Vaal Gamagara pipeline can increase the volume of water imported to the northern part of the scheme (D41J, D41K and D41L catchments).

The Kalahari East Pipeline currently exports water at approximately 1.8 million m³/a from the D41J catchment (with the off-take from the Vaal Gamagara pipeline north of Sishen mine) for stock-farming and related domestic purposes to areas where no potable groundwater prevails, the so-called salt block areas in the D42C catchment.

The objectives of the study can be summarised as follows:

- Establish water demand and use.
- Investigate the quality and quantity of the two available water sources namely groundwater and the Vaal Gamagara scheme.

- Investigate the capacity of existing infrastructure and the need for upgrading, as well as the economic viability thereof. The calibration of the existing hydraulic model form part of this objective.
- Investigate possible augmentation options.
- Determine the economic viability of possible conveyance options.
- Develop reconciliation strategies for all municipalities and the bulk water users.
- Develop a Master Plan for the Vaal Gamagara water supply scheme.

Consulting Team and main tasks

The team for the study consists of the consulting firm KV3 Engineers with sub-consultants; WRP Consulting Engineers, GLS Consulting, Golder Associates Africa, Isinyithi Corrosion Engineering, DelportduPreez Consulting, MDA and Kayamandi Development Services.

The contributions from the associated firms, in broad terms, include the following:

- KV3 Engineer: Lead Consultant and management of multi-disciplinary team, overall co-ordination, data collection, liaison with stakeholders, costing and engineering economic evaluation.
- WRP Consulting Engineers: Surface water resources (yield/system analyses), water conservation, water demand management and water requirements.
- GLS Consulting: Compiling and calibration of hydraulic model and analyses of current and future scenarios.
- Golder Associates Africa: Groundwater resources, water quality aspects, purification and re-use.
- Isinyithi Corrosion Engineering: Condition assessment of existing pipeline.
- DelportduPreez: Pump stations and associated works (telemetry, control systems, etc.).
- Kayamandi Development Services: Demography, social and economic aspects.
- MDA: Environmental aspects.

Conceptualisation of the Assignment

The approach that was followed for the assignment is best illustrated through the list of the tasks in **Table 1**.

Table 1: Proposed Task Layout

No.	Task Description	Sub-Tasks
1	Inception Phase	Inception Report
2	Summary of Previous and Current Studies	Gather information, stakeholder consultation
		Analyse existing information and make preliminary recommendations
		Water Requirements and water related constrains
3	Preliminary Screening Workshop	Preliminary Screening Workshop
4	Calibration of existing hydraulic model	Calibrate existing hydraulic model
5	Current and Future Water Requirements of Water Users	Demographic and Economic Growth Scenarios
		Estimate future water requirements and WC/WDM
6	Current Water Sources and Possible Augmentation Options	Surface and Groundwater Options
		Comparison of Availability and Water Requirements
7	Development of Reconciliation Strategy	Water resource/options
		Reconciliation Strategies
8	Development of a Water Master Plan	Water demand analysis
		Establish monitoring system for UAW
		Establish internal condition of existing pipe line
		Compilation of strategy and master plan
		Data and information of existing infrastructure
		Criteria for the evaluation and planning of the system
		Computer modeling of the water distribution system
		Strategy and master plan for extensions and upgrade of the system
9	Stakeholder Participation	Inception meeting
		Workshops, meetings and one on one consultations

Table 1 is illustrated graphically in **Figure 1.1** with reference to the Supporting Reports to where the tasks' details and findings are documented.

Summary and findings of study

Throughout the study duration seven (7) supporting reports were compiled documenting the findings, recommendation and proposed a way forward. The outcome and recommendation of one study/report fed into the next phase of the study. These seven reports form an integral part of the study as a whole and can not be interpreted separately. These 8 official reports (7 supporting reports and the Main Report) were delivered and combined into 5 Volumes as illustrated in the Document Information (in front of each Volume).

The objectives of the Main Report are to summarise the supporting reports while making clear reference to these reports should more detail be required and clearly document the recommendations and way forward. To follow are a brief summary of the finding and recommendations of the study.

Demographics

The study was approached by firstly conducting a demographic study of the total area. The study entailed refining, updating and extending information relating to the economic growth and population size of towns (referring to **Section 3** of Main Report). These figures played an integral roll in determining the water demand of the area and eventually the scheme's required capacity for a 20 year planning horizon (2010 to 2030).

It is anticipated that the total population of the towns served by the VGG scheme will increase with 67% (high scenario) over the 20 year planning period as indicated in **Table 2**. Kathu/Dingleton and Hotazel indicated the highest average growth rate of around 4.5% and 8% respectively. This could mainly be attributed to development and expansion in the mining sector.

Table 2: Future projected household, 2010 to 2030 – Towns served by VGG scheme

GROUPING	BASE	PROJECTED LOW POPULATION				PROJECTED HIGH POPULATION			
	2010	2015	2020	2025	2030	2015	2020	2025	2030
Koopmansfontein	176	181	185	189	193	181	186	190	195
Vaal Gamagara	250	256	262	267	273	256	263	269	276
Delportshoop Longlands	16 101	16 835	17 940	18 894	19 733	16 950	18 990	20 607	21 901
Postmasburg & Beeshoek	30 169	33 770	35 755	37 595	39 330	34 271	37 449	40 285	42 876
Kathu/Dingleton	19 459	36 863	38 457	39 916	41 271	38 169	40 876	43 287	45 478
Olifantshoek	9 603	8 903	9 345	9 690	9 959	8 970	9 978	10 710	11 230
Hotazel	1 558	5 452	5 804	6 121	6 413	5 630	6 248	6 777	7 240
TOTAL	**77 316**	**102 260**	**107 748**	**112 672**	**117 172**	**104 427**	**113 990**	**122 125**	**129 196**

Water Requirements

The demographic information together with information gathered from the other water user sectors was used to derive the water requirement projections.

The study area was divided into segments of the existing Vaal Gamagara Scheme pipeline route (refer to **Figure 4.1**). The current and future water requirements were estimated for each of the users in three categories, namely local authority, mines and other water users.

The local authority water users include the following Local Municipalities (LM): Dikgatlong, Kgatelopele, Siyancuma, Tsantsabane, Gamagara, Ga-Segonyana, Joe Morolong (previously known as Moshaweng) and Kgalagadi..

Mining includes mine houses: Assmang, De Beers, BHP Billiton, Kumba Iron Ore, Kgalagadi Manganese, National Manganese, PMG Mining, Kudumani Manganese Resources, Tarnisani, Dynamic Mining Company, Diro Minerals, United Manganese of Kalahari, Sedibeng Iron Ore, Tshi pi e Ntle Manganese and Amari Resources.

The other users included agriculture, (mainly stock watering along the scheme and farmer domestic use), the Kalahari East Water Scheme (also stock watering and farmer domestic use), Governmental water supply (Lohatla Military Base and Koopmansfontein Experimental Farm among others), potential solar power projects and international cross border users, namely Botswana.

The total water currently used from the Vaal Gamagara Scheme is 13.7 million m^3/a, which is projected to increase substantially to 40.1 million m^3/a by 2030. The water use currently supplied from ground water is 36.7 million m^3/a and is currently projected to increase to 46.0 million m^3/a by 2030.

From **Figure 2** it can be seen that additional ground water resources will be developed up to a point where all the available ground water resources are utilised (2015), after which the further growth in water use will need to be supplied from the Vaal Gamagara Scheme.

The total current and projected water use from the Vaal Gamagara Scheme, according to the different water use sectors, is presented in **Table 3**. From the table it can be deduced that the mining sector currently utilises the most water (63.5%) of the Vaal Gamagara Scheme, whereas the local authorities and other water users currently utilise 14.7% and 21.8% of the total scheme's water use respectively.

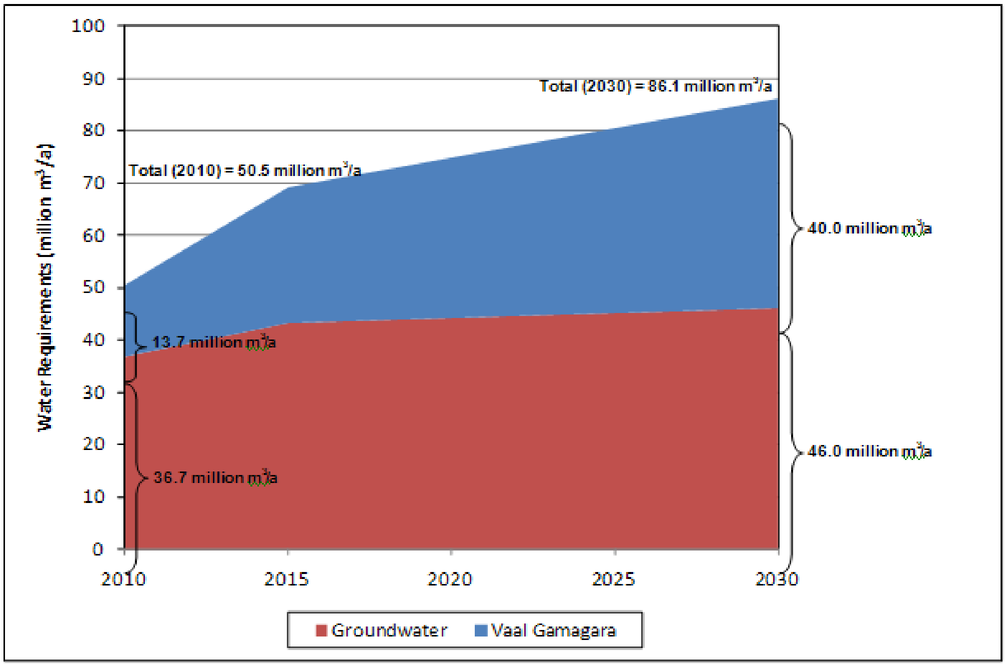

Figure 2: Water requirement projection

Table3: Vaal Gamagara Scheme water use summary according to users

Water Use Sectors	Surface Water (Vaal Gamagara Scheme)		
	2010	**2015**	**2030**
Local Authority	2 707 319	3 229 380	9 812 200
Governmental	786 569	2 300 617	8 817 875
Agricultural Other	87 812	92 167	97 036
Agricultural Kalahari East	2 140 015	3 250 433	3 250 433
Industry	52 641	55 273	63 923
Mining	7 931 300	17 036 010	18 021 225
TOTAL	**13 705 665**	**25 963 890**	**40 062 703**

Water Sources - Groundwater

As the water requirements were agreed upon through a workshop held with the water users the next step was to determine the sustainable yield of existing local groundwater supplies. This was to establish if future augmentation of VGG water is required for a specific areas served solely or partially by groundwater.

Secondly the groundwater study focused on the identifying of resources for additional source development to augment the VGG water supplies in the short to medium term (2010 to 2015).

It was found that the local groundwater source of the towns of; Schmidsdrift, Campbell, Griekwastad, Danielskuil, Lime Acres, Papkuil, Jenhaven, Skeyfontein, Dibeng, Kuruman Cluster and Heuningvlei Cluster will be sufficient and sustainable for the planning horizon of 20 years and do not require additional water from the VGG scheme.

It is however recommended that the community of Metsimatale (Groenwater) receive VGG water due to poor groundwater quality. The VGG water should be used to blend water with existing boreholes to meet the required quality and future demands.

Based on the resource potential of resource groupings and shortfalls identified in the short to medium term capacity of the VGG pipeline scheme, four large scale source development target areas were identified. Details regarding the development of these additional sources are explained under the *Existing System Capacity and Comparison with Current Demand.*

Water Source – Vaal Gamagara Scheme

With the VGG scheme water demand quantified (areas not to be solely served by groundwater) the next phase was to firstly determine the physical condition of the current scheme and associated cost. This was done since the scheme's majority of assets are approximately older than 35 years. As a result the assets not yet replaced are generally old and are operating over or very near to the expected useful life.

The second step was to analyse the scheme's hydraulic characteristics and capacity by calibrating the existing hydraulic model. This hydraulic model was then used to conduct several current and future demand scenarios from a hydraulic perspective. It was found to be very useful in recommending short to medium term interventions, upgrades and refurbishments of the scheme as well as the phasing thereof.

Existing Infrastructure Condition Analysis

From information received from a resent Asset Management Study done, the Cumulative Depreciated Replacement Cost of the existing scheme amounts to *R 1 786 936 238.00* which include: Pipeline and Reservoirs, Precipitation and Dosing and Supporting Infrastructure (Buildings etc.). Theoretically it would cost the mentioned amount to replace the scheme and give an indication of what the cost would be (excluding future demand) should no upgrading be allowed for. This is however a generalised statement as no detail cost estimate and practicalities regarding the construction were done for such a replacement.

The ratio of Cumulative Depreciated Replacement Cost over Cumulative Current Replacement Cost gives an indication of the age of the assets. In the case of the Vaal Gamagara scheme the ratio is 0.12 (12%). This means that generally the assets have "used up" approximately 88% of its

Expected Useful Life (EUL). By converting these percentages to years it is expected that the scheme need to be replace within the following 4 to 5 years (before 2015).

Several condition assessments were conducted on the existing scheme namely:

- The electrical, mechanical and electronic aspects of the existing pump stations, control- and telemetry systems.
- External mechanical integrity of the pipeline through:
  - Pipeline potential and cathodic protection status survey
  - Coating integrity surveys
- Internal condition evaluation via drained and live CCTV inspections

The objective of these studies was to establish if the existing scheme could be cost effectively refurbish to form part of the future scheme as well as to establish which segments and/or components of the system require urgent refurbishment/upgrading to ensure effective water supply on a day to day basis.

From the electrical/mechanical investigation it was found that most of the electrical and mechanical equipment at Delportshoop, Kneukel and Trewil is in a functional condition, although some pumps are being upgraded at the time the survey was conducted. These three pump stations have spare pumpset positions for future expansion. However, future extensions will require new electrical and mechanical equipment as well as design work.

The pump stations at Kathu and Mamatwane are not in use at present. In order to re-commission these pump stations in future, a considerable lead-time will have to be allowed for design work and procurement. Several items of mechanical, electrical and electronic system components require servicing and maintenance. Several control and telemetry components require upgrading as well. Local instrumentation on pump station equipment requires upgrading and repair.

Several surveys and investigation were conducting regarding the Cathodic Protection (CP) system and the external coating integrity of the VGG scheme. From the gathered information and studies/investigations conducted the following general conclusion could be drawn:

- In general, the ground conditions are non-corrosive.
- The major threat to the pipeline, from an external corrosion perspective, is the extremely high stray current activity in the area.

- There has been a recent upgrade to the cathodic protection system in that the capacity of the system was increased. However, there have been no modifications to the original 1984-1985 CP design, despite significant changes in the surrounding infrastructure.

- It would appear that the reported incidents of pipeline leaks are primarily related to the scour valves, where evidence of electrical discontinuities (no continuity bonding) have been observed, resulting in interference corrosion across the joints.

- Several of the surveys indicated that there were regular discontinuities and/or coating defects – these are most likely attributable to missing continuity bonds and unwrapped joints during pipe installation.

- It has been confirmed, during the surveys, that when the CP system is non-operational, the pipeline goes positive. This highlights the critical importance of maintaining continuous operation of the cathodic protection system.

- Since the primary corrosion mechanism can be attributed to stray current activity, the regions of the pipeline at highest risk of corrosion are those in regions of stray current discharge.

From the external integrity surveys and investigations it is recommended that the Cathodic Protection system be redesigned from first principles to meet the current demand to adequately protect the pipeline(s) regardless of which refurbishment/upgrading scenario are to be implemented. It is envisage that this will result in an increased number of locations for CP stations using traditional ICCP rectifiers and associated groundbeds. Regular maintenance and repairs to the CP System are essential to maintain the integrity of the existing and future pipelines.

The drained and live CCTV inspections on selected sections of the Vaal-Gamagara scheme yielded very meaningful results. The overall result is that the internal lining is in an advanced state of degradation. Although the degree and type of failure vary from section to section, the entire pipeline will require re-lining. Further investigation as outlined below may be justified if prioritisation of the re-ling operation is required.

The re-ling process will be significantly more cost effective if it is undertaken once a new line is operational, as no temporary bypasses will be required and the lining contract can proceed un-interrupted.

Existing System Capacity and Comparison with the Current Demand

The existing system capacity and comparison with current water demand projections was done as the second step to determine the feasibility of the current scheme. For the purposes of evaluating the sufficiency of the existing Vaal Gamagara scheme the current capacity is compared with the current (so-called 2010) demand and done per pipe segments as indicated.

It is likely that the scheme would be able to supply the anticipated current demand (2010) between the abstraction works to Clifton reservoir. This after the refurbishment of the pump sets and if the pumps run 24 hours per day.

For the supply to Gloucester the optimal utilization of the existing system capacity and sources requires from Beeshoek under peak demand periods will results in an available net supply to Gloucester, for which the hydraulic capacity of the existing system is sufficient.

The required supply downstream of Gloucester under anticipated peak demand conditions should be sufficient since the deficit can be made up by the supply from Sishen.

The section of the scheme between Gloucester and Kathu pump station can supply more than the required demand. The deficit currently anticipated North of Kathu can be made up if the Kathu pump station is in operation with the pumps having similar characteristics than before with at least one pump operating 18 hours per day during peak day. The flow velocity in the feeder pipe northwards, however, reaches values up to 1.9 m/s.

Effect of the short term (2011 to 2015) demand scenario and potential measures

As previously indicated four large scale source development target areas were identified initially to augment the water demand in the short to medium term. The four sources are located in the Danielskuil area (SD 1), Postmasburg area (SD 2), Kathu area (SD 3) and Hotazel area (SD 4) as illustrated in **Annexure D, Map 7**.

To utilize these groundwater resources to augment the current VGG scheme, detail investigations and surveys are required. It is anticipated that the total yield of the four proposed groundwater sources could be 20.3 million m^3/a consisting out of 66 production boreholes. The cost to develop these sources as well as the EIA and licence application processes is estimated at R 34.4 million and could be completed within 12 to 18 months. The study team did not investigated the long terms benefit or the reduction in size of the proposed new scheme by developing these groundwater sources and recommend that this is investigated.

A first order cost estimate was done to equip the boreholes on the conceptual position of the production boreholes assuming equal yields. The cost amount to R 249.0 million for the four sites excluding VAT and the source development cost of R 34.4 million.

Since the development of these groundwater sources will probably not be achieved in time to alleviate the situation the short term as well as updated information received from the second workshop held with the water users, solution will depend on the potential to utilize and accommodate the water produce by mines in their dewatering programmes.

As has been indicated above the pumped sector between Delportshoop and Clifton is currently running at capacity. To accommodate any growth in demand immediate measures will therefore have to be taken. The anticipated 2015 demand is approximately double that of the 2010 demand. If a linear growth in demand is assumed the 2011 peak demand will be 60 Mℓ/d growing to a peak demand of 106.7 Mℓ/d in 2015.The anticipated volume of water to potentially be discharged into the VGG scheme by Sishen and Kolomela mines grows from 49 Mℓ/d in 2011 to 75 Mℓ/d in 2015.

Given the existing scheme's pumping capacity of 33.2 Mℓ/d it thus appears that theoretically the short term demand can be served with a combination of the mines and the Vaal river source, the total supply being 82.2 Mℓ/d and 108.2 Mℓ/d in 2011 and 2015 respectively. This is valid for the sector between Delportshoop and Kathu pump station, given that the modifications as described below be made, but the capacity of the sector north of Kathu pump station is projected to be insufficient to provide the supply in 2012.

In order to utilize the water provided by the mines as effectively as possible the following modification referred to above are required:

- The Beeshoek Phase 1 pumps must be upgraded by installing the original designed for additional stages to allow pumping from Beeshoek pump station to Clifton reservoir. According to the pump curves this should result in a pump rate of 700 kℓ/h or 16.8 Mℓ/d;
- The Kathu pump station must be re-commissioned to boost the supply northwards;
- Additional pumps must be installed at Kathu pump station to allow pumping southwards up to the Khumani off-take. The detail of this installation needs to be investigated, but an initial evaluation indicates that a pump rate of 1 900 kℓ/h (45.6 Mℓ/d) at a head of 140 m can be achieved;
- The detail arrangement and controls to be able to accommodate operating of the system with the above modifications need to be established;
- In order to provide a backup for the mine water source the potential for the development of the identified ground water sources should be considered.

Given that the above mentioned mortifications are provided the results can be summarized as follows:

- The hydraulic capacity of the section of the VGG scheme north of the Kathu booster pump station is insufficient to convey the 2015 demand and would require up grading over its full length if the full demand is to be delivered from a southern source. If, however, the groundwater source identified in the Hotazel area (SD4 with reference to Annexure D, Map 7) could be developed to supply close to its indicated potential of 15.6 Mℓ/d under peak demand conditions, no upgrading of the northern sector is required before 2015. In this case the supply from SD4 should be directly into the scheme's pipe system in the vicinity of the Hotazel off-take. To reduce the head at which the supply must occur the supply point can be downstream of the PRV to the north of the Hotazel off-take but with a by-pass and check valve on the PRV to allow supply southwards during peak demand conditions.

Planning for Future (2030) Demand

Since the demand of the VGG scheme is projected to increase substantially from 13.7 million m^3/a to 40.1 million m^3/a, the condition assessment confirmed the urgent need for refurbishment and the results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand, upgrading options were investigated for proposed 20 year design horizon.

It was assumed that the scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater sources to be developed as a short to medium term measure as well as de-watering water from mining operations would therefore only provide relief in terms of operational and water cost. This assumption was made due the difficulty in obtaining agreements from the mining houses in supplying a constant yield of de-watering water and the uncertainties/variables regarding the additional groundwater sources to be developed.

The planning that was performed for three options were:

- Option 1: Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.
- Option 2: Add capacity to the existing scheme to supply the anticipated 2030 demand by an additional pipeline.
- Option 3: Replace the existing scheme with a double pipeline with sufficient capacity to supply the anticipated 2030 demand.

For all three options the basis was that pumping occurs from Delportshoop to Clifton and that the rest of the scheme is supplied from there under gravity with no booster pumps required.

In all three options it was assumed that over the pumped sector the scheme would operate at the same pressures than the existing scheme. For the sector supplied under gravity, aspects such as pressure control need to be addressed as part of optimised detailed design and costing. Proposed pressure control measures are described further herein under the paragraph dealing with operation of the proposed scheme.

In all three options it is required that Gloucester is supplied from Clifton at uncontrolled pressure. Therefore, since the Beeshoek pumps cannot deliver at Clifton pressure it is proposed for all three options that the existing pipeline from the Beeshoek connection to Gloucester be refurbished and utilized as a dedicated pump line for the Beeshoek pumps.

The major objectives pursued in the evaluation and planning of the Vaal Gamagara supply system can be summarised as follows:

- Conformity with operational requirements and criteria adopted for this study
- Optimal use of existing facilities with excess capacity
- Optimisation with regards to capital -, maintenance - and operational cost

The specific criteria pertaining to the hydraulic evaluation and optimal planning of the system were identified and planed accordingly.

All the strategic and technical alternatives studied for this report were compared on mainly economic grounds, with a view to establishing a "master plan" which will result in the lowest present value of capital works, operations and maintenance. A costing and engineering economic analyses was conducted by means of a Unit Reference Value (URV) for each technical alternative and comparing the cost.

From the calculations it was evident that Option 1 has the lowest URV and thus from an engineering economic point of view, Option 1 - Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand, is the recommended way forward.

The estimated cost to implement Option 1 for the 2030 water demand projections are estimated at *R 7 165 223 602.90* (VAT excluded).

Option 1 can be implemented with the existing scheme as a backup system but was not investigated. If the backup system is considered, it is recommended that the long term sustainability (operation and maintenance) of the existing scheme (backup system) be investigated.

Should Option 1 be taken to replace the existing pipeline with a single larger diameter pipeline and abandon the existing pipeline, the new pipeline must be designed so as to be CP compatible. In addition, the existing pipeline should not be abandoned in the ground but removed completely or form part of the CP design, as it may compromise the integrity of the replacement pipeline by acting as a parallel conductor and aggravating stray current interference effects.

Due to the anticipated rapid growth of the demand over the entire length of the VGG scheme and current lack of spare capacity in large sections it is evident that the proposed upgrading of all components should proceed as soon as possible. However the development of groundwater sources or the utilization of water produced by mines in their dewatering programmes could drastically influence the urgency of upgrading of certain sections. The most prominent of these cases are:

- As indicated the pumped sector from Delportshoop to Clifton reservoir is under peak demand conditions already running at full capacity with 24 hour operating time, therefore at very high risk of failure. The high demand from Finsch mine on this sector and the anticipated rapid growth of this demand plays a major role in this situation. This sector therefore needs to be upgraded as a matter of urgency or as alternative the potential groundwater source from the mine dewatering program as well as new sources should be developed.
- The sector of the scheme northwards of Kathu is currently operating close to capacity and will have to be upgraded to meet the anticipated 2015 demand. As indicated the alternative is to develop the potential groundwater source near Hotazel to supply directly into the scheme.

It is however recommended that a forth option is investigating determining the effect, cost as well as operational, to have the additional groundwater sources be developed and operated by Sedibeng Water.

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ABBREVIATIONS

AADD	Average Annual Daily Demand
BIF	Banded Iron Formations
CIPPS	Close-Interval Polarised Potential Survey
CP	Catholic Protection
DCVG	Direct Current Voltage Gradient
DMR	Department of Mineral Resources
DWA	Department: Water Affairs
WRPS	Water Resource Planning Systems
GIS	Global Information System
GMA	Groundwater Management Areas
GMU	Groundwater Management Unit
GPS	Global Positioning System
GRU	Groundwater Resource Unit
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
LED	Local Economic Development
LM	Local Municipality
LOS	Levels of Service
MAP	Mean Annual Precipitation
RDP	Reconstruction and Development Programme
RWQO	Resource Water Quality Objectives
PRV	Pressure Relief Valve
PSV	Pressure Safety Valve
SDF	Spatial Development Framework
TDS	Total Dissolve Solids
ToR	Terms of Reference
TWL	Top Water Level
UARL	Unavailable Annual Real Loss

URV	Unit Reference Value
VGG	Vaal Gamagara
WARMS	Water Authorization and Registration Management System
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WTP	Water Treatment Plant
WQMS	Water Quality Management System
WUA	Water User Association
WWTW	Wastewater Treatment Works

1. INTRODUCTION

Background and purpose of the study

In the process of compiling the Internal Strategic Perspectives (ISPs) for all the Water Management Areas (WMAs) in the country, the Department of Water Affairs (DWA) identified the need to develop strategies that will ensure adequate future reconciliation of water requirements and water availability in the main metropolitan areas, as well as in smaller municipal areas and towns. Some basic reconciliation options were addressed as part of the ISPs, but at the time it became clear that more detailed strategies needed to be developed. This would ensure effective and efficient management of the water resources supplying the economic hubs and smaller urban areas in the country, while at the same time managing their water requirements to ensure water use efficiency. To this end, DWA developed strategies for all the towns in the country, of which the Development of Reconciliation Strategies for All Towns in the Central Region [1] is a product.

The purpose of the All Town Reconciliation strategies [1] were to gather information about the bulk water balance situation of all towns in the country, to select the towns that are most in need of strategies for reconciliation of water availability with future water requirements, and to identify the most appropriate series of interventions that will form part of such strategies.

During the first phase of the study for the Central planning region (Vaal River and Orange River catchments) existing information regarding the water requirements, water supply infrastructure and water availability of all the towns in the study area have been gathered. The towns or grouping of towns to be studied further were then selected and prioritised. The next phase was to develop the actual reconciliation strategies for the selected towns. It became evident during this phase of the study that the towns that are being supplied from the Vaal Gamagara Scheme (refer to **Figure 4.1**) cannot be studied in isolation from the other users from this pipeline, because of the interaction between these users and the complications around the way water is being supplied from the pipeline and groundwater, mostly from the dewatering of mines. This area was therefore selected for more detailed reconciliation strategy development.

Sedibeng Water and DWA decided that the best way to achieve the above would be to develop reconciliation strategies for the area at large and through the development of a Water Master Plan and management information system for Sedibeng Water's infrastructure system at Vaal Gamagara, which is in line with current best practice. KV3 Engineers as Lead

Consultant was appointed in association with a multi disciplinary consulting team for the *Development of Reconciliation Strategies for the Area Served/Interacting by/with Sedibeng Water's Vaal Gamagara Scheme as well as a Water Master Plan*.

The multi disciplinary team consisting out of KV3 Engineers, Kayamandi Development Services, WRP Consulting Engineers, Golder Associates, GLS Consulting, Isinyithi Cathodic Protection (ICP), Delport Du Preez Consulting Engineers (DPA) commenced with the study in November 2009 and was completed August 2011.

Study Area

The Study Area falls within the Northern Cape Province and is mostly located within Water Management Area (WMA) 10 with some extension to WMA 14. It covers the area served/interacting by/with Sedibeng Water's Vaal Gamagara Scheme, as well as possible extension to the Mier area, two rural settlements at Skeifontein and Groenwater (Metsimatale). Local authorities included in the study but not served by the VGG scheme were Heuningvlei, Dibeng, Campbell, Danielskuil and Kuruman. Additional domestic water users, not initially included in the Terms of Reference (ToR) were also identified and were included in the study (Campbell, Griekwastad and Schmitsdrift). Other water users served by the scheme included mines (existing, possible new mines and prospecting mines), industries, Governmental and agricultural users. The possibility to supply Botswana either via the extension of the Kalahari East water scheme and/or with an off-take from Blackrock was also analysed.

The Vaal Gamagara (VGG) Government Water Supply Scheme (**Figure 4.1**) was completed in 1968 with the purpose to deliver Vaal River water to the area. It consists of a purification works that can purify 13.27 million m³/a water, pumps, 11 reservoirs and 370 km of pipes to deliver this water to users in the study area. The pipeline has the capacity to convey/import approximate 15 million m³/a into the D41J and D41K catchments (refer to **Annexure D, Map 1**).

De-watering of mines in proximity to Postmasburg (D73A catchment) and Kathu (D41J), and distribution of this water via the Vaal Gamagara pipeline can increase the volume of water imported to the northern part of the scheme (D41J, D41K and D41L catchments).

The Kalahari East Pipeline currently exports water at approximately 1.8 million m³/a from the D41J catchment (with the off-take from the Vaal Gamagara pipeline north of Sishen mine) for stock-farming and related domestic purposes to areas where no potable groundwater prevails, the so-called salt block areas in the D42C catchment.

The objectives of the study can be summarised as follows:

- Establish water demand and use.
- Investigate the quality and quantity of the two available water sources namely groundwater and the Vaal Gamagara scheme.
- Investigate the capacity of existing infrastructure and the need for upgrading, as well as the economic viability thereof. The calibration of the existing hydraulic model form part of this objective.
- Investigate possible augmentation options.
- Determine the economic viability of possible conveyance options.
- Develop reconciliation strategies for all municipalities and the bulk water users.
- Develop a Master Plan for the Vaal Gamagara water supply scheme.

Consulting Team and main tasks

The team for the study consists of the consulting firm KV3 Engineers with sub-consultants; WRP Consulting Engineers, GLS Consulting, Golder Associates Africa, Isinyithi Corrosion Engineering, DelportduPreez Consulting, MDA and Kayamandi Development Services.

The contributions from the associated firms, in broad terms, include the following:

- KV3 Engineer: Lead Consultant and management of multi-disciplinary team, overall co-ordination, data collection, liaison with stakeholders, costing and engineering economic evaluation.
- WRP Consulting Engineers: Surface water resources (yield/system analyses), water conservation, water demand management and water requirements.
- GLS Consulting: Compiling and calibration of hydraulic model and analyses of current and future scenarios.
- Golder Associates Africa: Groundwater resources, water quality aspects, purification and re-use.
- Isinyithi Corrosion Engineering: Condition assessment of existing pipeline.
- DelportduPreez: Pump stations and associated works (telemetry, control systems, etc.).

- Kayamandi Development Services: Demography, social and economic aspects.
- MDA: Environmental aspects.

Conceptualisation of the Assignment

The approach that was followed for the assignment is best illustrated through the list of the tasks in **Table 1.1.**

Table 1.1: Proposed Task Layout

No.	Task Description	Sub-Tasks
1	Inception Phase	Inception Report
2	Summary of Previous and Current Studies	Gather information, stakeholder consultation
		Analyse existing information and make preliminary recommendations
		Water Requirements and water related constrains
3	Preliminary Screening Workshop	Preliminary Screening Workshop
4	Calibration of existing hydraulic model	Calibrate existing hydraulic model
5	Current and Future Water Requirements of Water Users	Demographic and Economic Growth Scenarios
		Estimate future water requirements and WC/WDM
6	Current Water Sources and Possible Augmentation Options	Surface and Groundwater Options
		Comparison of Availability and Water Requirements
7	Development of Reconciliation Strategy	Water resource/options
		Reconciliation Strategies
8	Development of a Water Master Plan	Water demand analysis
		Establish monitoring system for UAW
		Establish internal condition of existing pipe line
		Compilation of strategy and master plan
		Data and information of existing infrastructure
		Criteria for the evaluation and planning of the system
		Computer modeling of the water distribution system
		Strategy and master plan for extensions and upgrade of the system
9	Stakeholder Participation	Inception meeting
		Workshops, meetings and one on one consultations

Table 1.1 is illustrated graphically in **Figure 1.1** with reference to the Supporting Reports to where the tasks' details and findings are documented.

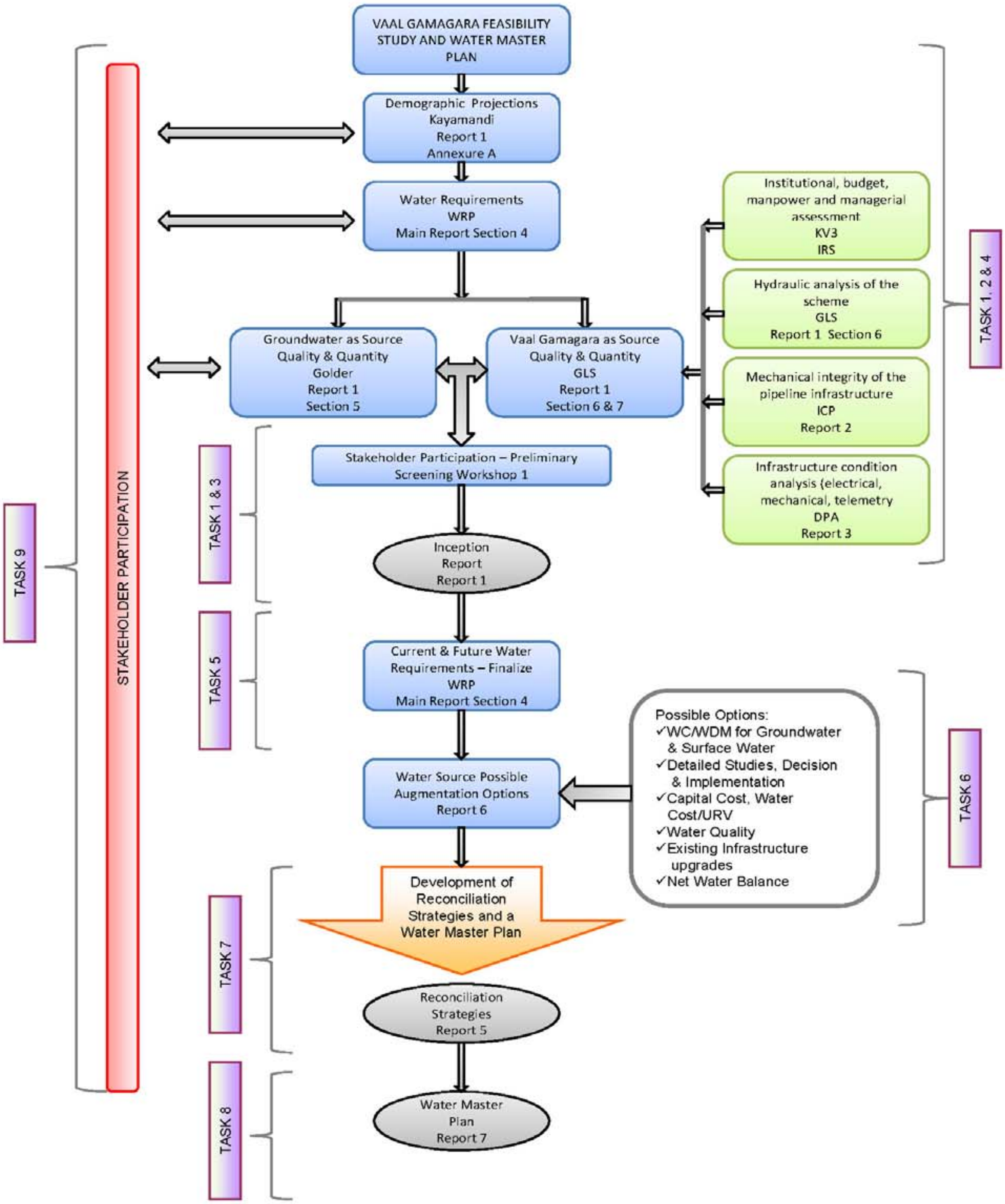

Figure 1.1: Study flow chart

2. INCEPTION REPORT

After obtaining and studying all the existing information, previous reports relating to this study and a Workshop with the water users and possible new user, the Inception Report was compiled based on the original Terms of Reference. During this phase of the study the requirements of the assignment, work processes and programmes, budget, study management and administration functions as well as individual responsibilities of the key members of the study team were re-evaluated and finalised. All of this was consolidated into the coherent Inception Report which served as the baseline against which progress of each task was monitored and evaluated.

For more detail on this task including figures, tables and Annexure not included in this report, please refer to supporting report *245460/01: INCEPTION REPORT.*

3. DEMOGRAPHIC PROJECTIONS

The demographics study, undertaken by Kayamandi Development Services (Pty) Ltd, entailed refining, updating and extending information relating to economic growth and population size of the following water users in the identified towns/areas: households, mining, agricultural and government development initiatives.

For more detail on this task including figures and tables not included in this report, please refer to supporting report *245460/01: INCEPTION REPORT – ANNEXURE A.*

3.1. Methodology and approach

The methodology followed in the undertaking of this study entailed the following steps:

Step 1: Orientation

The first step was used for orientation purposes and included delineating the study area, identifying, sourcing and reviewing all background information as well as revisiting the results of the population estimation undertaken by Kayamandi in the Reconciliation Strategies for All Towns in the Central Region (All Town Study) [1].

Step 2: Base population refinement

The purpose of this step was to ensure that the base data from the All Towns Study [1] is refined and updated.

The data utilised by the All Towns Study was ground-truthed (tested on the ground for reliability and accuracy), refined, confirmed and updated. This was done by reviewing the latest municipal documents (IDPs, SDFs, LEDs, Housing Sector plans, etc), undertaking personal interviews with the LMs to obtain latest development plans and subsidy housing plans, identifying the housing plans of strategic water users, and undertaking limited on the ground settlement surveys. The limited settlement surveys were undertaken to refine, verify and confirm information and to augment the existing database through obtaining updated data on household size per homogenous areas, growth prospects, migratory patterns, estimated size of settlements, degree of second dwelling rentals, etc. Interviews were also conducted with local informants in the field as part of the primary information gathering process. Key informants were asked a series of questions pertaining to the population dynamics, housing typologies and other relevant issues.

With the exception of some towns/settlements where adjustments to the base were made, similar to that noted in the All Towns Study [1], many settlement informants revealed that the estimated size of settlements is either unknown or based on Stats SA and in most cases do not have any future growth scenarios. Were relevant adjustments to the All Towns Study [1] were made based on ground-truthed information relating to latest housing developments, for example adjustments to household size, etc.

The outcome of this step entailed identification of additional settlements on the ground, updated number of households, refined average household size, and refined base population.

Step 3: Growth scenarios refinement and future assumptions

Once the base population was refined, confirmed and updated, scenario assumptions were tested based on up-to-date mining related population growth/decline expectations and associated population migration (in and out) in search of employment opportunities.

In terms of future natural growth, two scenarios were derived based on a high and a low population growth. Growth scenarios for the study area were based on a review of historic and recent growth indicators, local information relating to income groups, proposed housing applications, urbanization and migration trends, existing demographic knowledge and models, and discussions with the affected municipalities regarding development dynamics/potential relating to the affected towns/settlements, etc.

In addition to the natural growth, existing and future strategic water users were consulted for their future plans with the aim of identifying the resultant impact on the demographics of the study area. Development scenarios were also applied to prospecting mines in order to anticipate growth of potential future mines.

All future growth and expansion plans of existing and future mines were identified to take place prior to 2015.

The Department of Mineral Resources (DMR) list of prospecting mines and mining rights for the Northern Cape was utilised in order to obtain an indication of possible future mining developments.

Based on numerous assumptions, approximately 250 mining permit applicants were assumed to impact towns/settlements within the study area. In order to obtain future plans in terms of timing, size, employment and housing requirements, numerous assumptions were applied, as all potential prospectors could not be contacted individually within the study scope.

Spin-off developments from growth in economic activity were also factored into the towns/settlements impacted by existing and known future mining developments.

The outcome of the demographic and economic growth analysis was refinement of growth scenarios, attainment of housing plans of existing and known future mines, and attainment of population growth prospects/expectations and related migratory patterns. Resulting in two projection scenarios, i.e. a low and a high based on demographic and economic growth, which was applied to the refined base demographics.

3.2. Demographic Projections

Based on the historic population growth trends, on the ground interviews, secondary data sources, etc, the projected number of households and population for the town/settlements are provided hereunder.

The demographic results contained in this report are utilised as the basis for undertaking the base water demand analysis.

Table 3.2.1: Future projected households, 2010 to 2030

GROUPING	BASE	PROJECTED LOW HOUSEHOLDS				PROJECTED HIGH HOUSEHOLDS			
	2010	2015	2020	2025	2030	2015	2020	2025	2030
Koopmansfontein	43	44	45	46	47	44	45	46	47
Vaal Gamagara	61	62	64	65	67	63	64	66	67
Delportshoop & Longlands	3969	4155	4431	4671	4883	4184	4690	5094	5418
Danielskuil	2979	3053	3175	3275	3358	3091	3363	3575	3742
Lime Acres & Papkuil	1905	1952	1998	2041	2083	1960	2013	2065	2116
Campbell	549	563	586	605	620	566	613	648	674
Griekwastad	1374	1408	1492	1556	1603	1419	1622	1766	1864
Schmidsdrift	635	850	891	932	973	850	896	941	987
Postmasburg & Beeshoek	6 624	7 341	7 773	8 173	8 550	7 450	8 141	8 758	9 321
Metsimatale	594	609	623	637	650	610	626	641	656
Skeyfontein	83	85	87	89	91	86	88	90	92
Jenhaven	166	170	174	177	181	170	174	179	183
Kathu, Sesheng & Dingleton	5 154	9 963	10 394	10 788	11 154	10 316	11 048	11 699	12 291
Olifantshoek	2 101	1 948	2 045	2 120	2 179	1 963	2 183	2 343	2 457
Dibeng	1818	1 863	1 916	1 964	2 008	1 877	1 967	2 044	2 111
Hotazel	380	1 330	1 416	1 493	1 564	1 373	1 524	1 653	1 766

Table 3.2.2: Future projected population, 2010 to 2030

GROUPING	BASE	PROJECTED LOW POPULATION				PROJECTED HIGH POPULATION			
	2010	2015	2020	2025	2030	2015	2020	2025	2030
Koopmansfontein	176	181	185	189	193	181	186	190	195
Vaal Gamagara	250	256	262	267	273	256	263	269	276
Delportshoop & longlands	16 101	16 835	17 940	18 894	19 733	16 950	18 990	20 607	21 901
Danielskuil	13 405	13 737	14 287	14 737	15 109	13 908	15 133	16 090	16 841
Lime acres & papkuil	6 386	6 545	6 696	6 842	6 983	6 569	6 747	6 919	7 089
Campbell	2 588	2 652	2 761	2 849	2 922	2 665	2 887	3 052	3 174
Griekwastad	5 992	6 140	6 506	6 783	6 989	6 186	7 074	7 700	8 126
Schmidsdrift	2 616	3 502	3 673	3 841	4 008	3 502	3 691	3 879	4 068
Postmasburg & beeshoek	30 169	33 770	35 755	37 595	39 330	34 271	37 449	40 285	42 876
Metsimatale	2 674	2 740	2 803	2 865	2 923	2 747	2 817	2 886	2 953
Skeyfontein	208	213	218	223	228	214	219	225	230
Jenhaven	712	730	747	763	779	732	750	769	786
Kathu, Sesheng & Dingleton	19 459	36 863	38 457	39 916	41 271	38 169	40 876	43 287	45 478
Olifantshoek	9 603	8 903	9 345	9 690	9 959	8 970	9 978	10 710	11 230
Dibeng	8 813	9 030	9 290	9 522	9 733	9 098	9 534	9 908	10 233
Hotazel	1 558	5 452	5 804	6 121	6 413	5 630	6 248	6 777	7 240

Towns that formed part of the study but were found not to be make use of water from the Vaal Gamagara scheme, apart from of the reasons were: Seven Miles, Magojaneng & Seoding, Mothibistad, Mapoteng, Kuruman, Bankhara-bodulong and the Heuningvlei area. These towns had either sufficient local water sources or not feasible to extend the scheme to serve them, other sources need to be investigated. For a detailed analysis refer to supporting report *245460/01: INCEPTION REPORT – ANNEXURE A.*

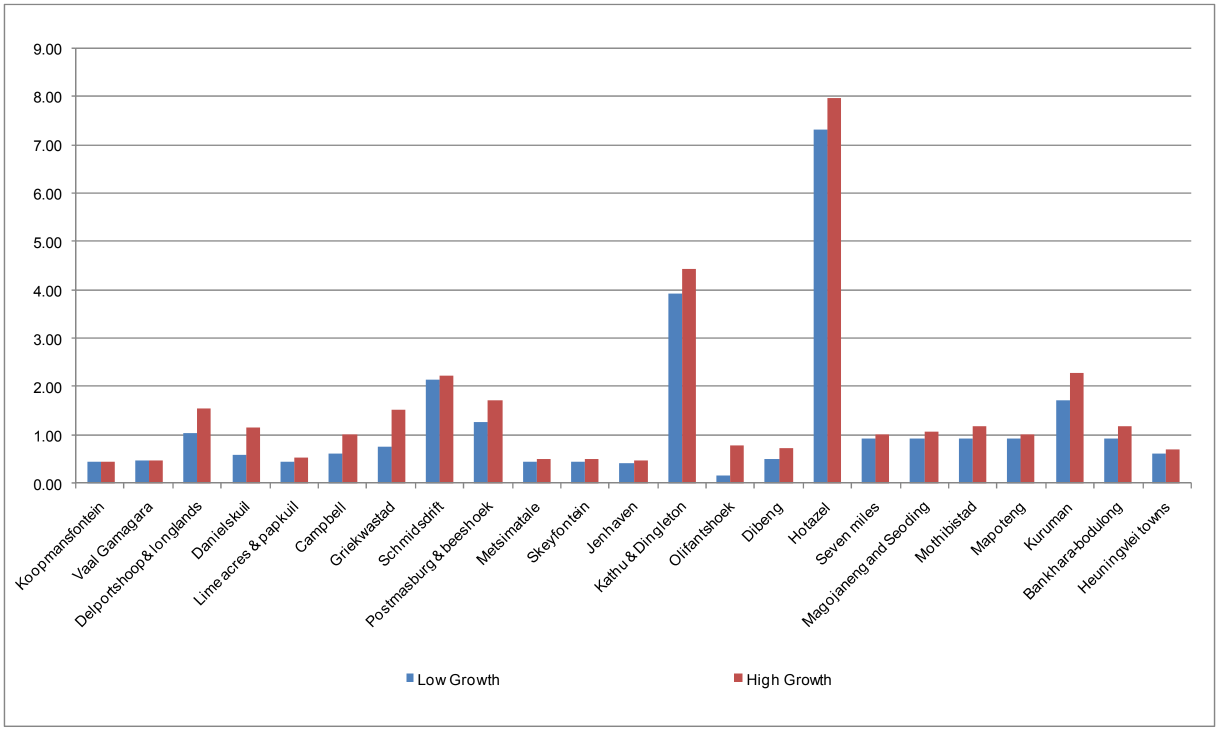

Figure 3.2.1: Average per annum population growth, 2010 to 2030

Figure 3.2.1 indicates the average population growth per annum for 2010 to 2030 including all towns that form part of the initial study.

3.3. Conclusions

Based on the historic population growth trends, on the ground interviews, secondary data sources, etc, the projected number of households, population and growth rates for the towns/settlements the study outcomes entailed:

- Determining the 2010 base population per settlement/town
- Low & High growth scenarios per settlement/town
- Socio-economic breakdown of dwelling typologies
- Demographic information per 8 water user categories

The demographic results contained in this report are utilised as the basis for undertaking the base water demand analysis.

For a detailed breakdown per settlement of the 2010 population figures as well as the projected figures up to 2030, please refer to supporting report *245460/01: INCEPTION REPORT – ANNEXURE A.*

4. WATER REQUIREMENTS

The study area was divided into segments of the existing Vaal Gamagara Scheme pipeline route (Refer to **Figure 4.1**). Each of the individual water users were divided into the same segments and clustered into three main categories (mining, local authority and other users). The current and future water requirements were estimated for each of the users in three categories, namely local authority, mines and other water users.

The local authority water users include the following Local Municipalities (LM): Dikgatlong, Kgatelopele, Siyancuma, Tsantsabane, Gamagara, Ga-Segonyana, Joe Morolong (previously known as Moshaweng) and Kgalagadi. These LM’s were included in the initial investigation but it was found that some of them will not utilize Vaal Gamagara water because of either sufficient local water source or not feasible to extend the scheme to serve them.

Mining includes mine houses: Assmang, De Beers, BHP Billiton, Kumba Iron Ore and smaller mining houses such as Kgalagadi Manganese, National Manganese, PMG Mining, Kudumani Manganese Resources, Tarnisani, Dynamic Mining Company, Diro Minerals, United Manganese of Kalahari, Sedibeng Iron Ore, Tshi pi e Ntle Manganese and Amari Resources.

The other users included agriculture, (mainly stock watering along the scheme and farmer domestic use), the Kalahari East Water Scheme (also stock watering and farmer domestic use), Governmental water supply (Lohatla Military Base and Koopmansfontein Experimental Farm among others), potential Solar Power projects and international cross border users, namely Botswana. Botswana can be supplied via the Kalahari East water scheme and through an off-take at Blackrock. In both cases the Vaal Gamagara scheme will have to make provision for this water requirement.

The water requirement projections for each of the water use segments were developed through public participation process. The approach or methodology used to derive the water use requirement projections for each of the water use sectors as well as the results are discussed in **Section 4.1** and **Section 4.2** respectively.

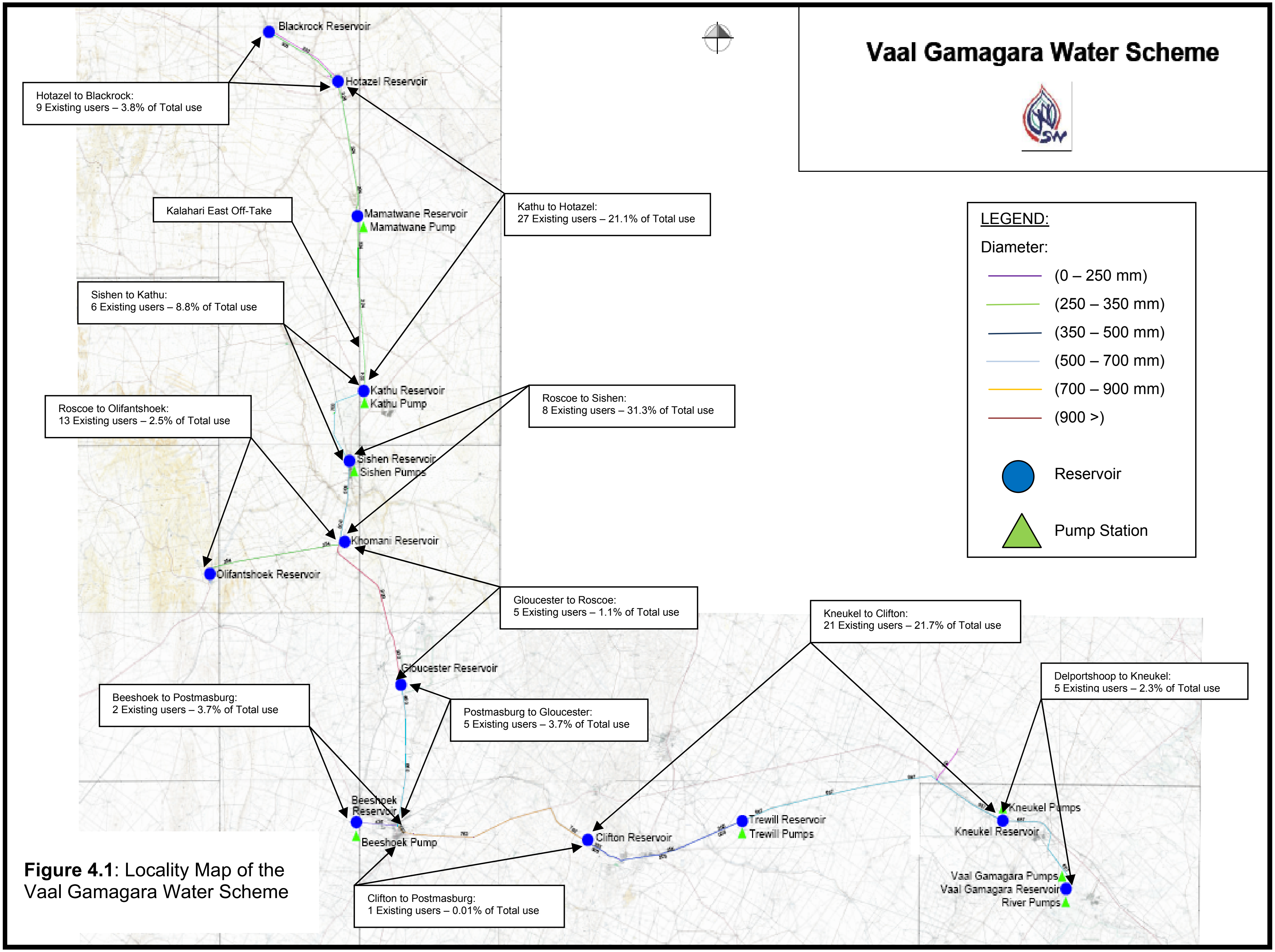

Figure 4.1: Locality Map of the Vaal Gamagara Water Scheme

4.1. Approach

This task involved the collation of available water requirements data and the estimation of future water requirement scenarios for current and potential future water users of the Vaal Gamagara Scheme. The water users were divided into three water use sectors:

I. Local Authorities

II. Mining

III. Other (remaining water users not included in the above two categories i.e. agriculture, industrial etc.)

Local Authorities

The current and projected water demands data were sourced from Sedibeng Water, Municipalities, Department of Water Affairs (DWA) and previous studies for the municipalities where available. The projected water requirements were evaluated and updated. The water use categories as developed by Directorate: WRPS (DWA) were modified and used to set-up a spreadsheet model to calculate water requirements. The water use categories as well as the average theoretical unit consumptions per category are shown **Table 4.1.1**

Table 4.1.1: Updated water use categories and per capita use

Category	Dwelling Type		Average Water Consumption	Maximum Water Consumption
			l/capita/day	l/capita/day
1	Flats		226	255
2	Clusters		255	322
3	Single Residential	Low Income	101	172
4		Medium Income	189	273
5		High Income	304	436
6		Very High Income	442	693
7	Informal	RDP Level	40	50
8		No Services	12	20

The water requirements were calibrated for each of the towns based on the demographic information obtained from the study, the levels of service (LOS) and further information obtained from the study questionnaires (actual water consumption, losses, etc). Future water use profiles were estimated based on historical trends on the one hand, and on two scenarios of likely changes in service provision based on current service levels, Departmental policies, economic trends and population growth prospects. Water Requirement Projections were derived according to each of the town's population projections for two scenarios:

- Scenario 1: Low population projection. Level of Service (LOS) assumed to be a minimum of "Single Residential – Low Income" by 2025 with a 5% growth in "Single Residential – Medium Income" by 2025. A further 5% growth in the "Single Residential – Medium Income" was assumed by 2030 (total growth in the "Single Residential – Medium Income" of 10%).
- Scenario 2: High population projection. Level of Service (LOS) assumed to be a minimum of "Single Residential – Low Income" by 2015 with a 5% growth in "Single Residential – Medium Income" by 2015. A further 5% growth in the "Single Residential – Medium Income" was assumed by 2030 (total growth in the "Single Residential – Medium Income" of 20%).

Because of the importance of the mining area to the economy of the Northern Cape, and the crucial role adequate water supply plays in to the development of this area, it was assumed that future economic growth will happen along the Vaal Gamagara pipeline and it was therefore decided to adopt Scenario 2 which is the worst case scenario for planning purposes. A theoretical water requirement projection was derived using the average water consumption figures from **Table 4.1.1**, which were applied to the population estimates split into the water use categories according to the percentages for each of the towns. The water requirement projections derived form the actual historic water use information was assessed against the theoretical projection. A summary of the water requirement results (Scenario 2) for the municipal users are discussed in **Section 4.2**.

Mining

The current and projected water demands were sourced from existing and future proposed mines using water requirement questionnaires. The list of existing and potential future mines was prepared based on information received from various sources including Sedibeng Water, Department of Minerals and Resources (DMR) and newspaper notices. In total 25 mines were taken into account in the study. The type of information requested from the mines included the following:

- Historical annual water usage data per water source. (i.e. Vaal Gamagara Scheme, dewatering, boreholes or other sources).

- Future projected water requirements for a high and best scenario from 2010 to 2030. Mines were requested to indicate their water requirement per water source.

- Internal metered consumption. Mines were requested to indicate what volume of water is accounted for through internal metering at the mine. The difference between the input volume to the mine and the accounted-for-water was used to calculate the un-accounted for water.

- Type of commodity and expected annual production. The annual production was used to calculate the estimated volume of water used to produce one tonne of ore.

Based on spreadsheet received from the Department of Minerals and Resources (DMR) there are also a number of mining applicants with prospecting rights which are located in the study area and which may become mines in the future. Based on advice received from some of the larger mining companies the estimated future water requirement for these potential mines could be between 25kℓ and 75kℓ per day. For planning purposes it was decided to use the higher volume of 75kℓ/day. A total of 128 applicants with prospecting rights met the criteria below and was taken into account in the study:

- Applicants which were located within 10km from the pipeline were taken into account. It was decided that it will normally not be feasible for applicants which are further away to obtain water from the pipe.

- Applicants with prospecting rights for minerals, diamonds, iron ore and manganese ore were taken into account. This excluded companies with prospecting rights for gravel, sand, clay, aggregate, shale, limestone and other lesser known commodities – because it was assumed that water requirement at these type of mining operations would be mostly for domestic use and therefore fairly low.

- Applicants with prospecting rights (accepted, granted, renewed or in process) were taken into account. This excluded applicants for which prospecting rights which were cancelled, closed, rejected or withdrawn.

- Applicants with prospecting rights on a land size of larger than 1.5 ha were taken into account.

For the best estimate water requirement scenario it was assumed that 45% of all 128 applicants with prospecting rights will start mining and as a high scenario 60% was used. These percentages were chosen based on the assumption that only a portion of applicants will eventually start mining. The water requirements for these prospecting companies were grouped and form part of the total of 25 mines that were taken into account in the study.

Based on the information received from mines and the estimated use from mining applicants with prospecting rights the following two scenarios were concluded:

- Scenario 1: Best estimate water requirement projection.

- Scenario 2: High water requirement projection.

A summary of the water requirement results for the mines are discussed in **Section 4.2**

<u>Other</u>

Information on the current and projected water demands for the water users falling within this category were sourced from Sedibeng Water, Municipalities, DWA and previous studies for the municipalities where available.

4.2. Results

<u>Local Authorities</u>

A list of the existing and the identified potential future municipal water users of the Vaal Gamagara Transfer Scheme is provided in the **Table 4.2.1** below.

Table 4.2.1: Existing and Potential Future Municipal Users

Category	District Municipality	Local Municipality	Town	
			Exiting VGG User	Potential Future VGG User
1	Frances Baard	Dikgatlong	Koopmansfontein	
2			Delportshoop&Longlands	
3			Vaal Gamagara	
4	John Taolo Gaetsewe	Gamagara	Kathu	
5			Olifantshoek	
6				Deben
7		Kgalagadi CB DM	Hotazel	
8		Joe Morolong		Heuningvlei
9		Ga-Segonyana		Kuruman&Wrenchville
10				Bankhara-Budulong
11				Magojaneng&Seoding
12				Mapoteng
13				Mothibistad
14				Seven Miles
15	Siyanda	Kgatelopele		Danielskuil
16				Lime Acres
17		Tsantsabane	Postmasburg	
18				Jenhaven
19				Metsimatale/Groenwater
20				Skeyfontein
21	Pixley ka Seme	Siyancuma		Campbell
22				Griekwastad
23				Schmidsdrift

A summary of the water requirement results (Scenario 2) for the municipal users are illustrated in **Figure 4.2.1** to **Figure 4.2.5**. A comparison of the 2010 actual water use figures to the average theoretical water use figures is illustrated in **Figure 4.2.2**. The average theoretical water use estimates were calculated by using the average water consumption figures from **Table 4.1.1** and applying them to the population estimates split into the water use categories for each of the towns.

The average unit consumptions calculated for the total water use (domestic + non domestic) and only the domestic component are illustrated in **Figure 4.2.3**. It can be seen that the average unit consumptions for some of the towns are excessive (generally towns where the theoretical water use estimates are much lower than the actual water use estimates). These can and need to be reduced through the implementation of water conservation and water demand management (WC/WDM) initiatives, which would result in significant water use savings as discussed in each of the reconciliations strategies (supporting report *245460/05: RECONCILIATION STRATEGIES*). The formal (LOS categories 1-6) and informal (LOS categories 7&8) components of the 2010 population estimates (percentage based)) are illustrated in **Figure 4.2.3**.

Without taking any savings that can be achieved through the implementation of WC/WDM measures into account the water requirement projections and the average compounded water requirement growth rates calculated over the 2010 to 2030 period for Scenario 2 are illustrated in **Figure 4.2.4** and **Figure 4.2.5** respectively. The higher rate of increase of the water requirement projections in the first 5 years (2010-2015) is as a result of the increase in LOS assumed over this period for Scenario 2. The average water requirement compounded growth rates are larger than the average compounded population growth rates due to the increased LOS that was applied in Scenario 2.

The reader is referred to the reconciliation strategy documents *(supporting report 245460/05: RECONCILIATION STRATEGIES)* for more detail on the water requirements and water requirement projections of each of the individual towns.

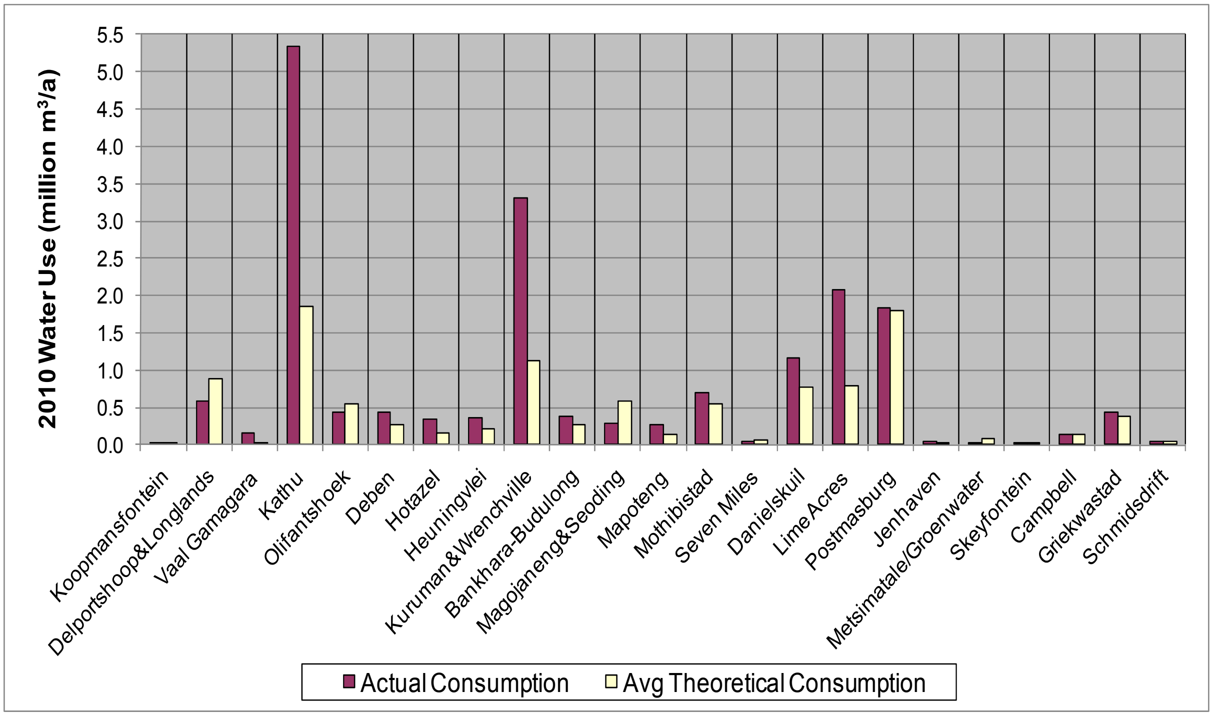

Figure 4.2.1: 2010 Water use comparison per LM

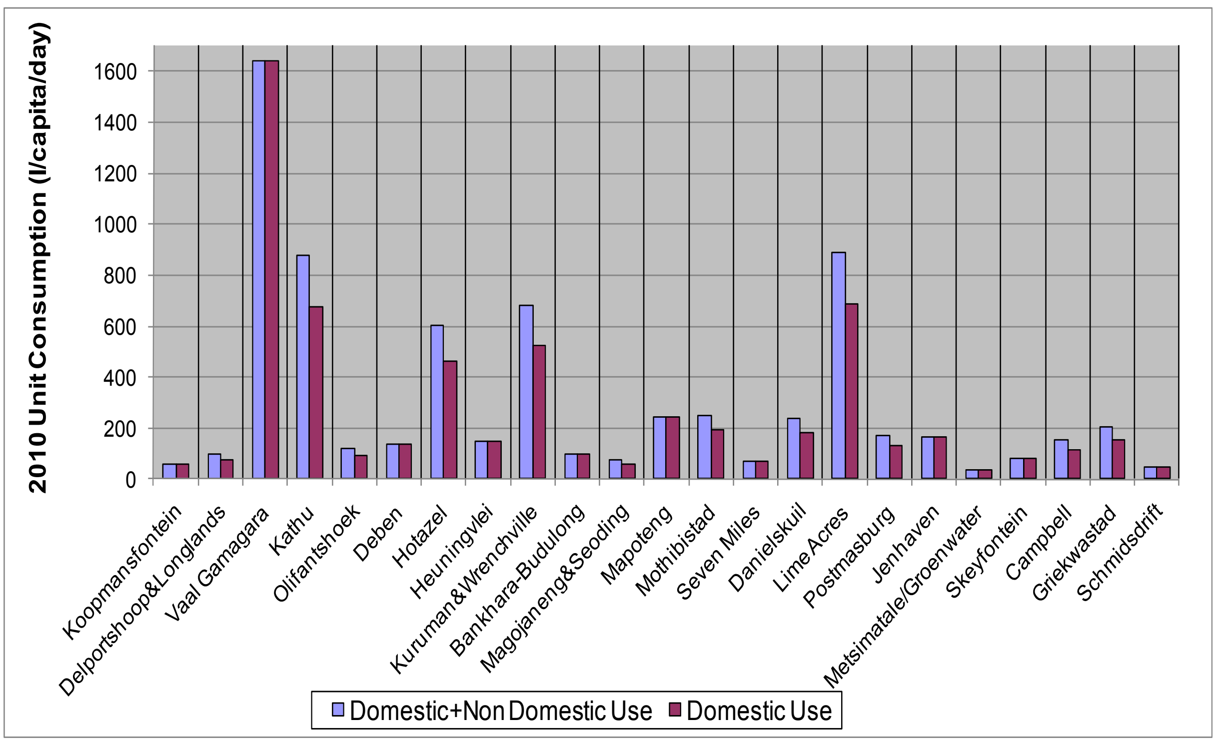

Figure 4.2.2: 2010 Water unit consumption comparison

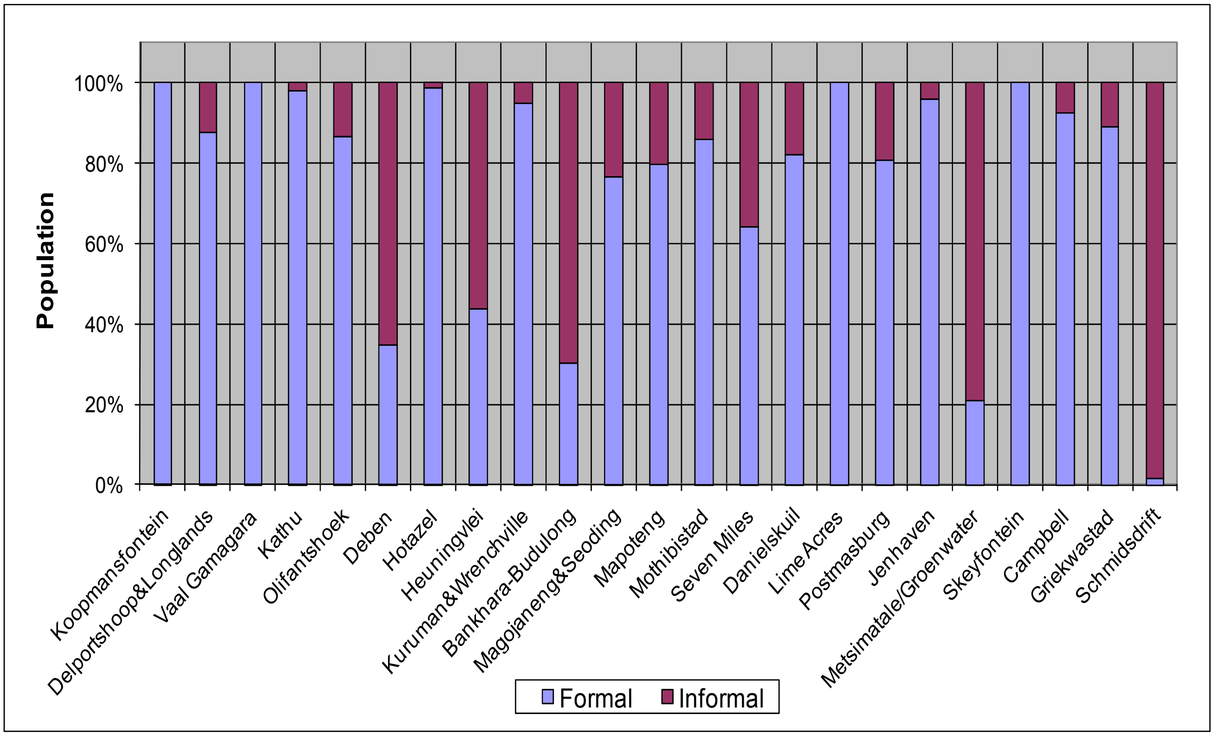

Figure 4.2.3: Summarised population distribution

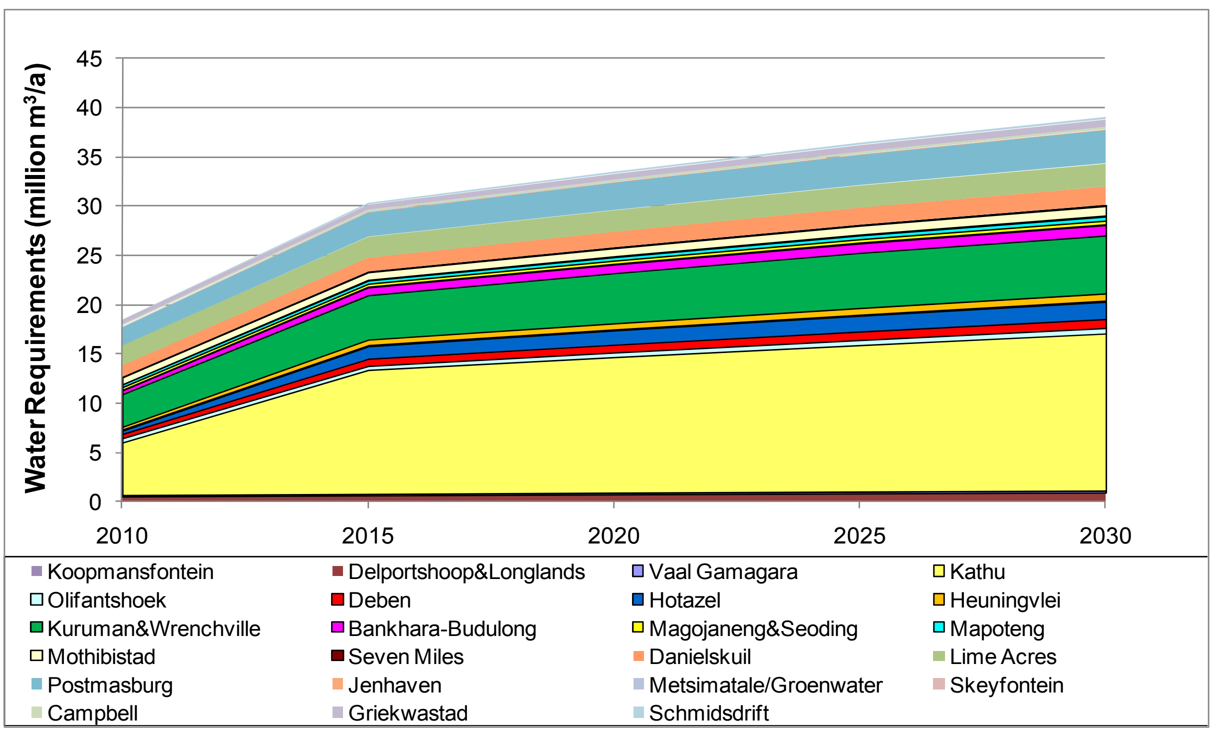

Figure 4.2.4: Water requirement projections (Scenario 2)

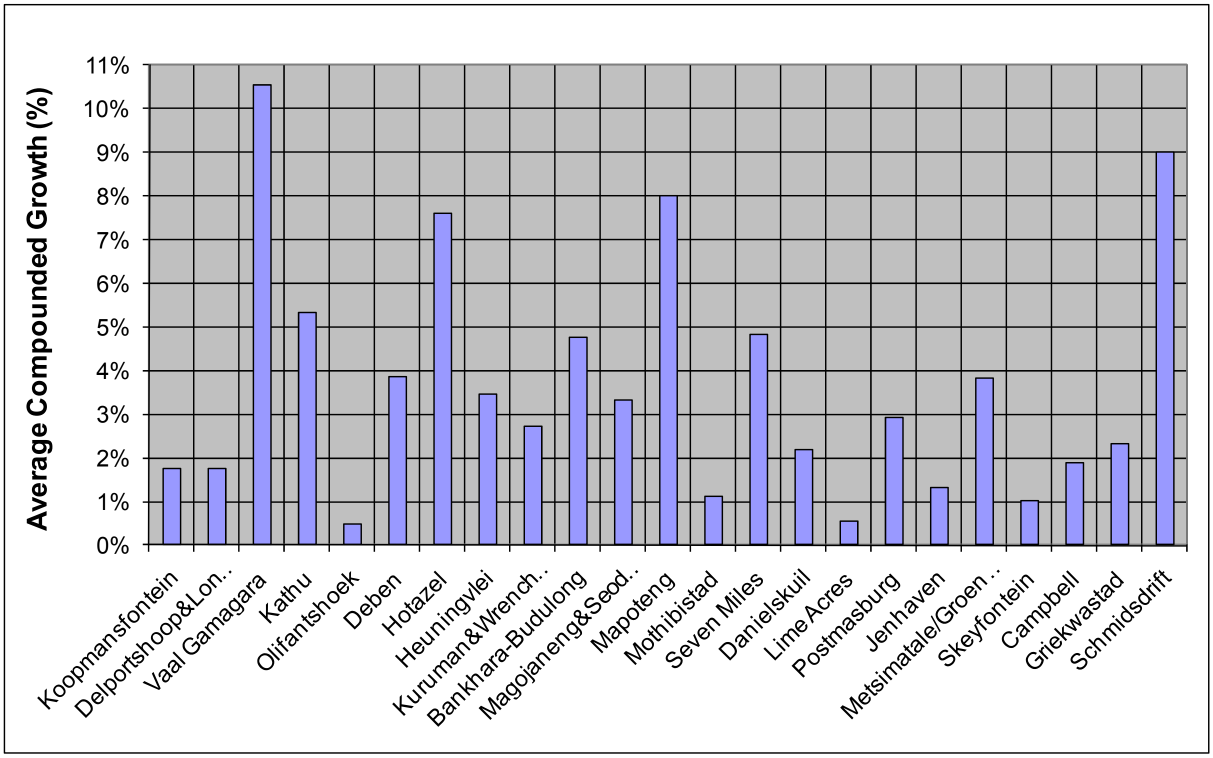

Figure 4.2.5: Average compounded water requirement growth (Scenario 2: 2010-2030)

Mining

The list of 25 mines and their current and projected future water requirements from the VGG Scheme are summarised in **Table 4.2.2** and **Table 4.2.3**. For mines, scenario 1 and scenario 4 are the same since it is expected that water conservation will not significantly influence the water requirements at mines, as discussed in Section 4.1. Graphs indicating the total water use requirements from mines including and excluding groundwater are shown in **Figure 4.2.6** and **Figure 4.2.7**.

Table 4.2.2: Summary of Scenario 2 Water Requirement (High Estimate) for all mines from the VGG scheme (excluding groundwater)

No	Company	Mine	Water Loss	Production (tonne/yr)	VGG Scheme Water Requirement (m³/a) 2009	2010	2015	2020	2025	2030
1	Assmang	Black Rock	11%	2 000 000	730 092	803 000	1 460 000	1 606 000	1 788 500	1 934 500
2	Assmang	Beeshoek	1%	1 100 000	Beeshoek may require water from VGG if Kolomela drops groundwater level significantly					
3	Assmang	Khumani	5%	10 000 000	2 409 000	4 745 000	7 665 000	8 760 000	9 490 000	9 490 000
4	De Beers	Finsch	No Info	n/a	2 654 547	2 420 200	4 105 972	1 980 000	1 980 000	1 980 000
5	Kalagadi Manganese	Kalagadi Manganese	No Info	3 000 000		219 000	1 277 500	1 277 500	1 277 500	1 277 500
6	National Manganese	Marokwa	Low Use	No Info	548	3 650	18 250	18 250	18 250	18 250
7	BHP Billiton	Wessels	No Info	1 000 000	150 000	150 000	150 000	98 550	98 550	98 550
8	BHP Billiton	Mamatwan	No Info	2 500 000	350 000	350 000	350 000	350 400	200 750	200 750
9	Kumba Iron Ore	Sishen & Kolomela	No Info	No Info	No Water from VGG					
10		McCarty Black Rock	Low Use	240 000			5 000	5 000	5 000	5 000
11		Lohatla	New	240 000			5 000	5 000	5 000	5 000
12		Kareepan	New	1 680 000			390 550	390 550	390 550	390 550
13		Kapstewel	New	1 680 000			390 550	390 550	390 550	390 550
14	PMG Mining	Bishop	New	No Info		36 400	182 000	182 000	182 000	182 000
15	Kudumane Manganese Resources	Kudumane Manganese Resources	Est 10%	1 500 000		36 500	361 350	361 350	361 350	361 350
16		Lemoteng	Low Use	No Info	No Water from VGG					
17	Tamisani	Tamisani	New	No Info		41 600	208 000	208 000	208 000	208 000
18	Dynamic Mining Company	Pensfontein	New	600 000			5 000	5 000	5 000	5 000
19	Diro Minerals	Burk	New	2 000 000		51 100	200 000	200 000	200 000	200 000
20	United Manganese of Kalahari	United Manganese of Kalahari	New	2 000 000	51 100	176 000	384 000	945 000	945 000	945 000
21	Sedibeng Iron Ore	Sedibeng Iron Ore	New	2 000 000		48 000	480 000	480 000	480 000	480 000
22	SA Smelter & Kalahari Lab	SA Smelter & Kalahari Lab	New	n/a			44 400	44 400	44 400	44 400
23	Tshipi e Ntle Manganese	Tshipi e Ntle Manganese	Est 3%	2 400 000		339 450	339 450	657 000	657 000	657 000
24	Amari Resources	Amari Resources	New	1 500 000			500 050	500 050	500 050	500 050
25	BHP Billiton	Old Hotazel	No Info	No Info			150 000	150 000		
26	Prospecting Companies that may become small mines		New	No Info			1 215 450	1 823 175	2 430 900	2 430 900
		TOTAL			**6 345 287**	**9 419 900**	**19 737 522**	**20 287 775**	**21 658 350**	**21 804 350**

Table 4.2.3: Summary of Scenario 1 or 4 Water Requirement (Best Estimate) for all mines from the VGG scheme (excluding groundwater)

No	Company	Mine	VGG Scheme Water Requirement (m^3/a)					
			2009	2010	2015	2020	2025	2030
1	Assmang	Black Rock	730 092	730 000	1 350 500	1 496 500	1 642 500	1 788 500
2	Assmang	Beeshoek						
3	Assmang	Khumani	2 409 000	3 650 000	5 840 000	6 935 000	7 373 000	7 373 000
4	De Beers	Finsch	2 654 547	2 420 200	4 105 972	1 980 000	1 980 000	1 980 000
5	Kalagadi Manganese	Kalagadi Manganese		182 500	949 000	949 000	949 000	949 000
6	National Manganese	Marokwa	548	3 650	18 250	18 250	18 250	18 250
7	BHP Billiton	Wessels	150 000	150 000	150 000	98 550	98 550	98 550
8	BHP Billiton	Mamatwan	350 000	350 000	350 000	350 400	200 750	200 750
9	Kumba Iron Ore	Sishen & Kolomela	No Water from VGG					
10		McCarty Black Rock			5 000	5 000	5 000	5 000
11		Lohatla			5 000	5 000	5 000	5 000
12		Kareepan			390 550	390 550	390 550	390 550
13		Kapstewel			390 550	390 550	390 550	390 550
14	PMG Mining	Bishop		36 400	182 000	182 000	182 000	182 000
15	Kudumane Manganese Resources	Kudumane Manganese Resources		36 500	361 350	361 350	361 350	361 350
16		Lemoteng	No Water from VGG					
17	Tamisani	Tamisani		41 600	208 000	208 000	208 000	208 000
18	Dynamic Mining Company	Pensfontein			5 000	5 000	5 000	5 000
19	Diro Minerals	Burk		51 100	200 000	200 000	200 000	200 000
20	United Manganese of Kalahari	United Manganese of Kalahari	51 100	176 000	384 000	945 000	945 000	945 000
21	Sedibeng Iron Ore	Sedibeng Iron Ore		48 000	480 000	480 000	480 000	480 000
22	SA Smelter & Kalahari Lab	SA Smelter & Kalahari Lab			44 400	44 400	44 400	44 400
23	Tshipi e Ntle Manganese	Tshipi e Ntle Manganese		54 750	54 750	73 000	73 000	73 000
24	Amari Resources	Amari Resources			500 050	500 050	500 050	500 050
25	BHP Billiton	Old Hotazel			911 638	1 367 456	1 823 275	1 823 275
26	Prospecting Companies that may become small mines				150 000	150 000		
		TOTAL	**6 345 287**	**7 930 700**	**17 036 010**	**17 135 056**	**17 875 225**	**18 021 225**

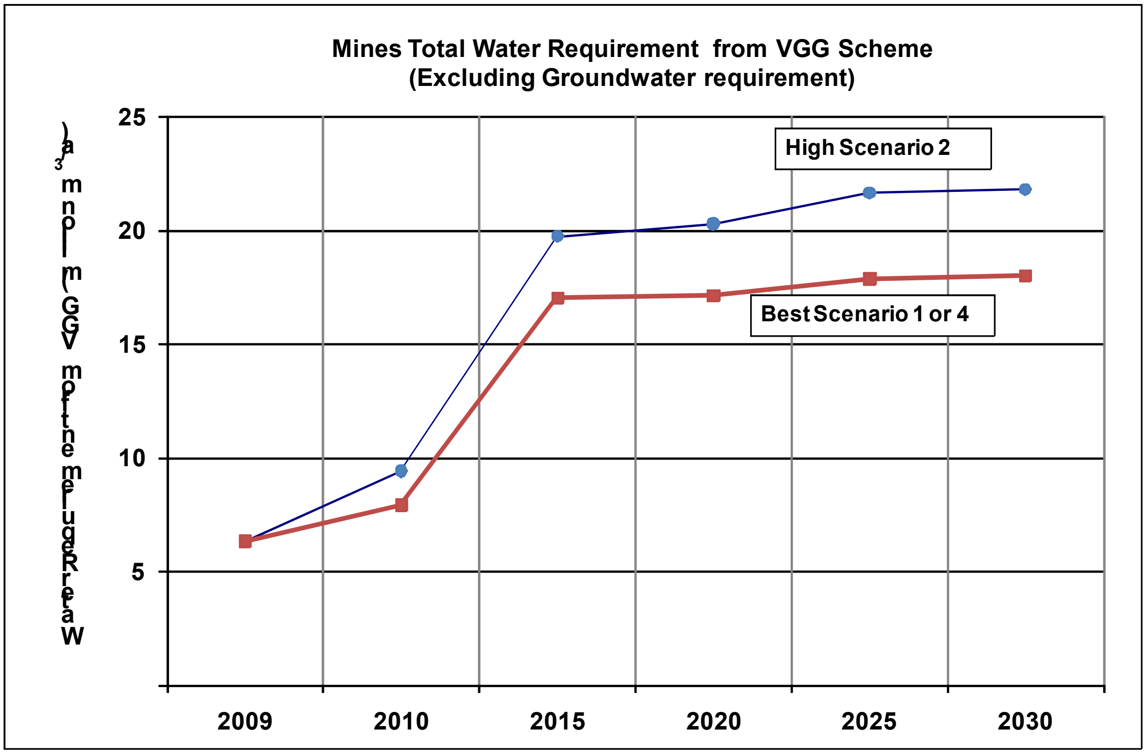

Figure 4.2.6: Mines water requirement from VGG Scheme (Excluding groundwater requirement)

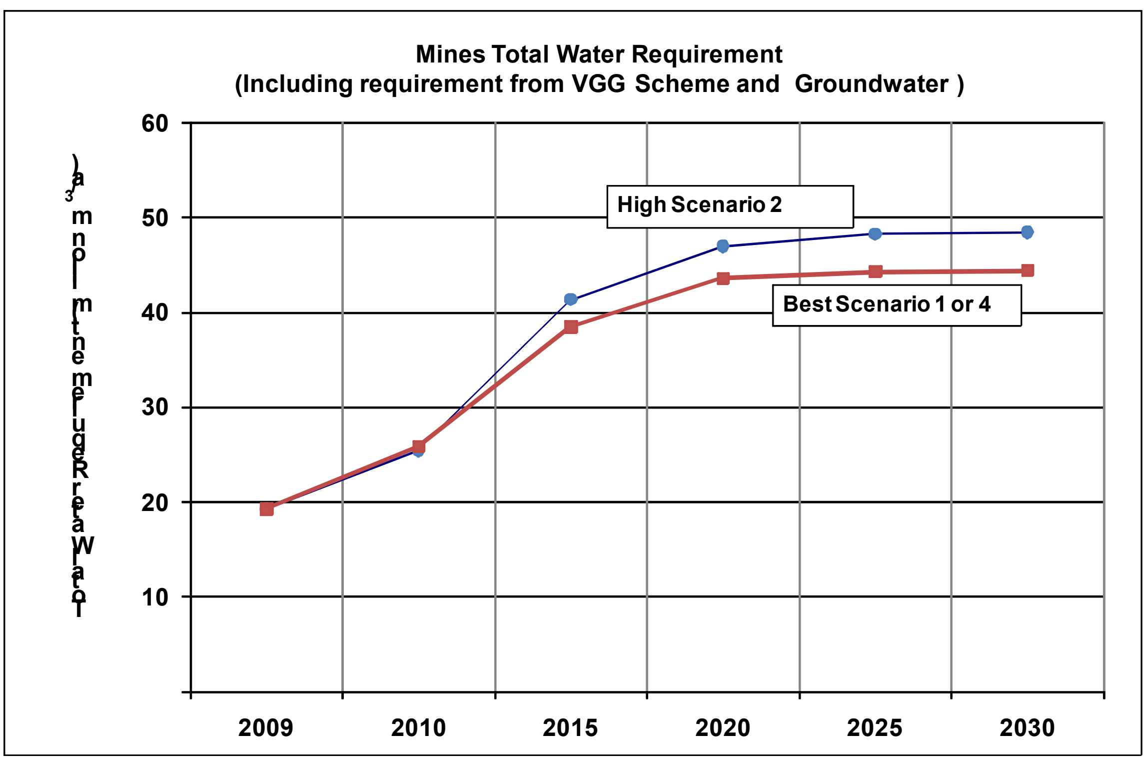

Figure 4.2.7: Mines Total water requirement – (from VGG Scheme and Groundwater)

Others

A list of the existing and the identified potential future other water users of the Vaal Gamagara Transfer Scheme is provided in the **Table 4.2.4** below.

Table 4.2.4: Existing and Potential Future Municipal Users

Category	User	
	Exiting VGG User	Potential Future VGG User
1	Kalahari East WUA	
2	Agriculture (Livestock watering)	
3	Dep. Of Public Works: Lohatla	
4	Dep. Of Public Works: Police & Agric Exp Station	
5	Transnet	
6	Eskom	
7		Proposed/Possible Solar Project
8		Botswana (excluding Kalahari East Component)

The potential future water users include the proposed solar power projects in the Kathu area and the Botswana government, who have entered discussions with DWA requesting water supply to villages located close to the South African border. A summary of the water requirement results for both the existing and potential future other users are illustrated in **Table 4.2.5**. The water requirements illustrated for the potential future water users are the maximum volumes that were indicated by the potential users.

Table 4.2.5: Existing and Potential Future Municipal Users

Other Users	2010	2015	2020	2025	2030
Kalahari East WUA	2.140	3.250	3.250	3.250	3.250
Farmers	0.091	0.095	0.100	0.105	0.110
Dep. Of Public Works: Lohatla	0.757	0.818	0.883	0.954	1.030
Dep. Of Public Works: Police & Agric Exp Station	0.029	0.031	0.032	0.034	0.036
Transnet	0.049	0.051	0.054	0.056	0.059
Eskom	0.003	0.003	0.004	0.004	0.004
Proposed/Possible Solar Project	0.000	1.452	2.752	2.752	2.752
Botswana (excluding Kalahari East Component)	0.000	5.000	5.000	5.000	5.000
TOTAL	**3.069**	**10.701**	**12.076**	**12.156**	**12.242**

4.3. Water Conservation and Water Demand Management

WC/WDM - Municipal

In recent years there has been a clear move away from the traditional approach of resource development to one of water demand management. The reasoning is: If water can be saved in one area it will be available for use elsewhere. Some areas of South Africa are already experiencing water shortages and this will become more pronounced in the future as the demand for water outstrips the available resources. In this regard DWA requires all municipalities to prepare a water conservation and water demand management strategy (WC/WDM) and to implement the measures proposed in the strategy in reasonable time.

Municipalities represent a significant portion of the water requirement on the VGG Scheme. In this regard, if the water requirement at municipalities can be reduced through WC/WDM it will lower the overall load on the VGG scheme. Two additional demand scenarios were considered that included the potential impact of WC/WDM for municipalities:

Scenario 3: This scenario was based on the demands derived for Scenario 2 (High Scenario) with general water conservation potential taken into account for all towns. The focus of water conservation is to reduce physical water loss.

Scenario 4: In this scenario the potential impact of WC/WDM was considered separately for towns where the per capita consumption was acceptable and for towns where the per capita consumption was excessively high. A) For towns with excessive high per capita consumption the theoretical water requirements were calculated based on the maximum theoretical unit consumptions, plus 20% for water losses. B) For towns with acceptable and/or low per capita consumption the general water conservation potential was taken into account as described in Scenario 3.

A more detailed explanation of the calculations undertaken for Scenario 3 and 4 are described below.

Scenario 3

In Scenario 3 the potential reduction in water loss (physical leakage) was calculated with the following steps for all towns in the study area:

Step1: The Real Loss in each town was calculated. The difference between system input volume and metered property consumption is equal to the total loss. The total loss is split in real loss and apparent loss. It was assumed that the apparent loss typically vary between

20% and 40% of the total loss. The real loss was then calculated as the difference between the total loss and the apparent loss. For towns where no billing was undertaken or where billing data appeared suspect a total loss of 30% was assumed.

Step 2: The unavoidable annual real loss (UARL) was calculated per town based on a theoretical formula developed through the burst and background leakage research undertaken in the UK. The UARL is seen as a theoretical minimum level of leakage in any reticulation system.

$$UARL\left(\frac{kl}{day}\right) = [(18 litre\ per\ km\ pipe) + (0.8 litre\ per\ connection)] * pressure/1000$$

Step 3: It was assumed that realistically the real loss could be reduced to a level double that of the calculated UARL. This meant that the Water Savings achievable = Real Loss - 2 x UARL.

Step4: It was assumed that the WC/WDM initiates could be implemented over 10 years from 2011 to 2021. The potential savings as a result of WC/WDM was subtracted from the water requirement estimate.

Scenario 4

In Scenario 4 the potential impact of WC/WDM was considered separately for towns where the per capita consumption was acceptable and for towns where the per capita consumption was excessively high:

A) For towns with excessive high per capita consumption the theoretical water requirements were calculated based on the maximum theoretical unit consumptions1 , plus 20% for water losses. The calculation resulted in water requirements that were significantly lower than those calculated for Scenario 2 (as shown in **Figure 4.2.4**). Six towns in the study area had excessive unit consumptions, these were: Vaal-Gamagara Village, Kathu, Hotazel, Kuruman and Lime Acres PPC.

B) For towns with acceptable and/or low per capita consumption the general water conservation potential was taken into account as described in the steps for Scenario 3.

[1] Maximum Theoretical Unit Consumptions: Cat1: 255litre/capita/day, Cat2: 322l/c/d, Cat3: 172l/c/d, Cat4: 273l/c/d, Cat5: 435l/c/d, Cat6: 693l/c/d, Cat7: 50l/c/d, Cat8: 20l/c/d. (See Table 4.1.1 for explanation of categories).

A graph showing the potential reduction in demand for the water conservation scenarios is shown in **Figure 4.3.1**.

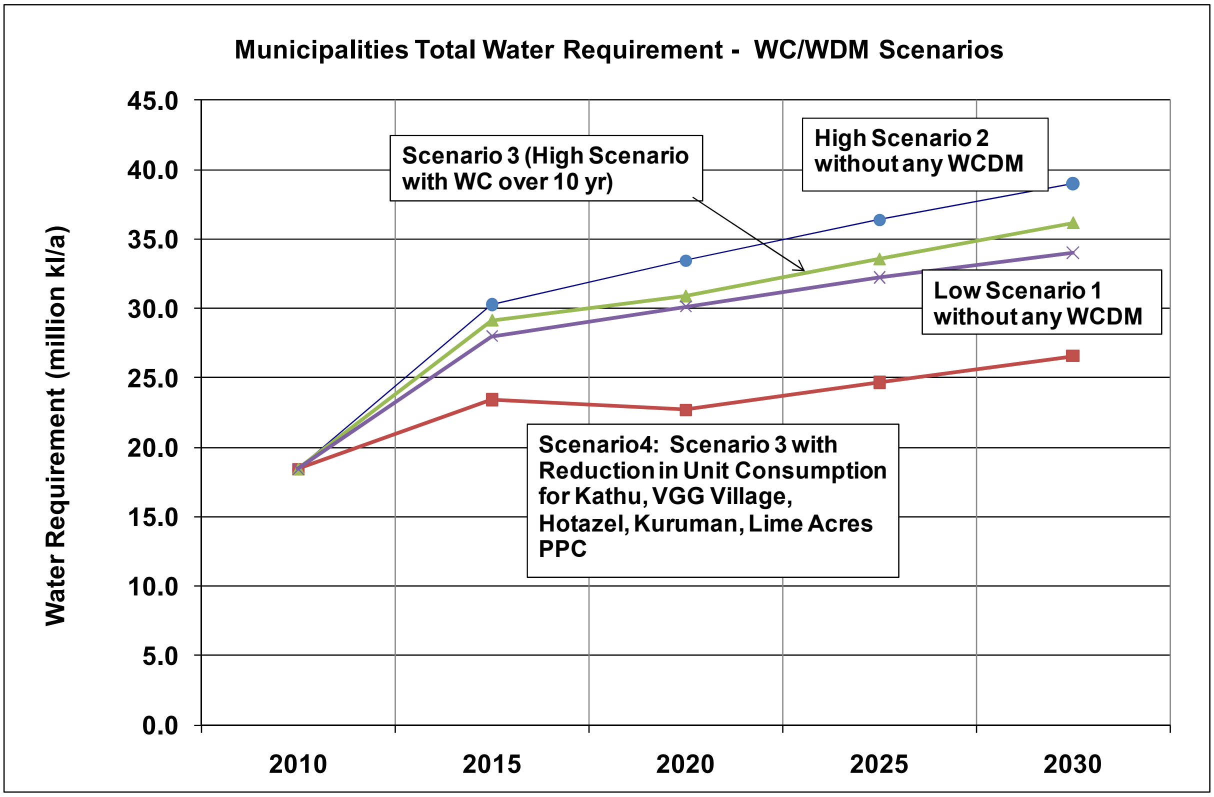

Figure 4.3.1: Municipal Water Requirement Scenarios with and without WC/WDM

<u>WC/WDM Recommendation for Municipalities</u>

Scenarios 3 and 4 provide useful insight on the potential for water demand reduction in municipalities through water conservation.

Of the municipalities that are included in this study only Gamagara and Ga-Segonyana have already prepared WC/WDM strategies. Based on feedback received from these two municipalities it appears that some of the measures that were proposed in the WC/WDM strategies have been implemented but that many actions are still outstanding. The Kgatelopele Municipality has also recently requested proposals for the preparation of a WC/WDM strategy.

The following recommendations regarding WC/WDM at municipalities were made:

- For short/medium term planning purposes (before a potential new/upgraded VGG scheme will come into operation) it is recommended to use Scenario 4 because the existing VGG scheme will not be able to handle any other higher scenario.

- DWA should consider assisting municipalities which have excessive high per capita consumption to reduce their demand to more acceptable levels. In the study area these towns include: Vaal-Gamagara Village, Kathu, Hotazel, Kuruman and Lime Acres PPC.

- DWA should request all municipalities to submit a water demand management plan and annual water balances. Once their WC/WDM strategies are complete the municipalities should start implementing measures to reduce demand and water leakage.

WC/WDM - Mines

Mines were requested to indicate what volume of water is accounted for through the internal metering at each mine. The difference between the input volume to the mine and the accounted for water was used to calculate the un-accounted for water. Unfortunately only three mines supplied this information and for these three mines un-accounted for volumes ranged from 5% to 14%. Based on the information received it seems that an un-accounted for volume of less than 10% should be attainable for a mine.

Most mines that were included in the study have implemented or are planning to implement some measures to reduce water demand and water leakage. These measures include: water metering, water balancing, wastewater re-use, process water re-use, stormwater harvesting, awareness campaigns for personnel, use of dry processes to minimise water use, replacement of old steel water pipelines, use of methods to increase water recovery from tailings disposal and planned maintenance.

Existing mines in the study area were requested to complete a water demand management scorecard that was developed for this project. The scorecard consisted of 10 questions all relating to the different water demand management and water conservation aspects. Mines were requested to score their water conservation efforts out of a maximum 50 points. The scores varied between 33 and 37 with an average of 38 which also indicates that most mines have already implemented some WC/WDM actions.

Based on the information supplied by mines the water usage to produce one tonne of ore (manganese and iron ore) varied between 200 litre/tonne and 400 litre/tonne. Although this range cannot be used to specify an exact water use (because the processes at mines are different and because mines vary in size), it does provide a useful indication of what seems to be an attainable water use target for manganese ore and iron ore mines. Only three mines reported figures in excess of 400litre/tonne. These were: United Manganese of Kalahari

(500 litre/tonne), Tshipi e Ntle Manganese (900litre/tonne in high scenario and 500litre/tonne in low scenario) and Beeshoek (3 200 litre/tonne).

- The usage per tonne for Beeshoek was exceptionally high. (The water usage component for Beeshoek village was already subtracted in this calculation). Further discussion will be required between DWA and Beeshoek to identify why their water usage per tonne is so high. Fortunately, Beeshoek is using only groundwater and will, therefore, not impact on the hydraulic modelling of the existing or future pipe system.

- The usage per tonne for UMK and Tshipi was not as high as Beeshoek, but because these mines require water from the VGG scheme it was considered appropriate to evaluate what the impact will be if the usage at these two mines can be reduced to 400litre/tonne. The calculation indicated that the combined water requirement for UMK and Thsipi would reduce by 0.5mil kℓ/yr which seems significant but which is still small in comparison with the overall water requirement for mines from the VGG scheme (0.5mil kℓ/yr represents only 3% of the total High Estimate Water Requirement for mines in 2030 from the VGG scheme). Due to the limited potential impact it was, therefore, not considered worthwhile to create a separate water requirement scenario for mines where WC/WDM is taken into account.

WC/WDM Recommendation for Mines

- For mines, scenario 1 and scenario 4 are essentially the same since it is expected that water conservation will not significantly influence the water requirements at mines. For short/medium term planning purposes (before a potential new/upgraded VGG scheme will come into operation) it is recommended to use Scenario 4 because the existing VGG scheme will not be able to handle any other higher scenario.

- Mines which have indicated that they use/require a higher than average volume of water per tonne of ore produced should give an explanation thereof in their water demand management plan that will be submitted to DWA.

- DWA should request all medium and large mines to submit a water demand management plan and an annual water balance. A pre-requisite to prepare an annual water balance will be to meter all internal buildings and processes. DWA should consider developing a standard template for the annual water balance of mines.

4.4. Water Requirement Conclusion

The results of the total current and projected water use summarised per Vaal Gamagara Scheme segment is presented in **Table 4.4.1**. The total water currently used from the Vaal Gamagara Scheme is 13.7 million m³/a, which is projected to increase substantially to 40.1 million m³/a by 2030. The water use currently supplied from ground water is 36.7 million m³/a and is currently projected to increase to 46.0 million m³/a by 2030 (refer to Section 5 – Groundwater Resources). The results from **Table 4.4.1** are illustrated graphically in **Figure** 4.4.1, and the future water required from both the Vaal Gamagara Scheme and ground water is clearly illustrated. From the figure it can be seen that additional ground water resources will be developed up to a point where all the available ground water resources are utilised (2015) (refer to Section 5), after which the further growth in water use will need to be supplied from the Vaal Gamagara Scheme.

Table 4.4.1: Water demand summary according to the Vaal Gamagara Scheme pipe segments

Segment	Water Demand [m³/a]					
	2010			2030		
	Vaal Gamagara	Ground-water	Total	Vaal Gamagara	Ground-water	Total
	A	B	C	D	E	F
Delportshoop to Kneukel	662 885	69 000	731 885	1 019 411	69 000	1 088 411
Kneukel to Clifton	2 463 160	5 217 979	7 681 139	2 204 132	6 081 364	8 285 496
Clifton to Postmasburg	745	0	745	99 371	0	99 371
Beeshoek to Postmasburg	638 431	7 082 533	7 720 964	2 351 533	7 821 570	10 173 103
Postmasburg to Gloucester	805 543	180 000	985 543	2 525 848	180 000	2 705 848
Gloucester to Roscoe	114 861	102 550	217 411	618 515	102 550	721 065
Roscoe to Olifantshoek	449 379	0	449 379	585 637	0	585 637
Roscoe to Sishen	3 720 732	0	3 720 732	7 730 150	0	7 730 150
Sishen to Kathu	2 776 119	16 999 259	19 775 378	11 090 580	20 051 746	31 142 326
Kathu to Hotazel	1 181 175	6 532 856	7 714 031	4 813 357	10 801 040	15 614 397
Hotazel to Blackrock	892 636	561 095	1 453 731	7 024 168	900 095	7 924 263
TOTAL	**13 705 665**	**36 745 272**	**50 450 937**	**40 062 703**	**46 007 365**	**86 070 068**

Note: The water use presented in **Table 4.4.1** includes all users according to the TOR, as well as possible new water users identified through the study. The groundwater use (Column B &

E) includes localized sources and does not necessarily require surface water. The total water demand (surface water and groundwater) is indicated in Column C for 2010 and Column F for 2030 i.e. *A + B = C & D + E = F.*

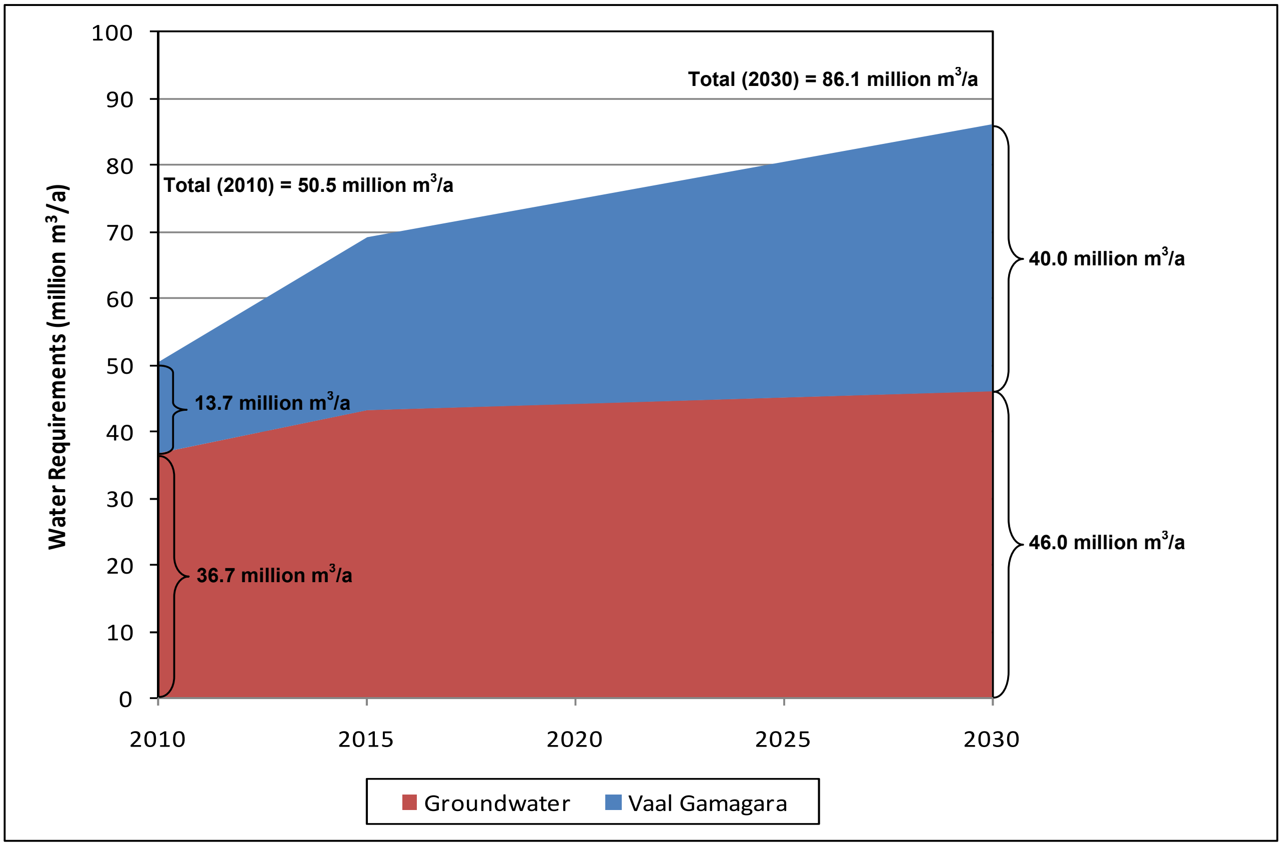

Figure 4.4.1: Water requirement projection

The total current and projected water use from the Vaal Gamagara Scheme, according to the different water use sectors, is presented in Table 4.4.2. From the table it can be deduced that the mining sector currently utilises the most water (63.5%) of the Vaal Gamagara Scheme, whereas the local authorities and other water users currently utilise 14.7% and 21.8% of the total scheme's water use respectively. The reader is referred to **Annexure A, Water Demand Table** for the detailed information used to derive **Table 4.4.2**.

Table 4.4.2: Vaal Gamagara Scheme water use summary according to users

Description	Surface Water (Vaal Gamagara Scheme)		
	Required Water Use Scenario 4		
	2010	2015	2030
Total Local Authority	**2 707 319**	**3 229 380**	**9 812 200**
Exp. Farm and Police Stations	29 267	30 730	35 574
SANDF (Lohatla)	757 302	817 886	1 030 301
Possible Solar Projects	0	1 452 000	2 752 000
International (Botswana)	0	0	5 000 000
Total Governmental	**786 569**	**2 300 617**	**8 817 875**
Agriculture: Other	**87 812**	**92 167**	**97 036**
Agriculture: Kalahari East	**2 140 015**	**3 250 433**	**3 250 433**
Transnet	48 409	50 830	58 884
Eskom	3 311	3 476	4 024
Private industries	921	967	1 015
Total Industry	**52 641**	**55 273**	**63 923**
Existing Mining	7 714 050	13 497 722	13 553 050
New Mining	217 250	2 626 650	2 644 900
Prospecting Mines	0	911 638	1 823 275
Total Mining	**7 931 300**	**17 036 010**	**18 021 225**
TOTAL	**13 705 665**	**25 963 890**	**40 062 703**

5. GROUNDWATER RESOURCE

5.1. Introduction

Mining expansion programs are planned in the Northern Cape, by major mining. These mining expansion programs depend on water being available for mining water needs and related increased demands for domestic water supply. Current water supplies consist of local ground water resources (boreholes and mine dewatering) and bulk water supplies from the Vaal Gamagara (VGG) Pipeline Scheme. Many rural communities in the area rely solely on groundwater for their everyday domestic and agricultural water supply needs.

This section of the report documents the groundwater feasibility component of the study.

The main objective of the groundwater component of the study is to conduct a desk top based, feasibility study, to determine the sustainable yield of existing water supplies and secondly identify resources for additional source development to augment water supplies.

The objectives can be summarised as follows:

- Assess sustainable local groundwater resources;
- Map/confirm Groundwater Units (GU) and Groundwater Management Units (GMU);
- Collect information on existing and future use;
- Assess contribution GW can make to:
  - Augment pipeline water in the short to medium term;
  - Provide a source to an area thus diminish reliance of pipeline – conjunctive use;
  - Provide an independent source which could obviate need for pipeline extensions, e.g. into Kuruman and Heuningvlei areas.

The scope of work for the groundwater study component entailed the following main activities:

- Preliminary delineate and assess the sustainable resource potential of significant groundwater management units (GMU) in proximity to local users and the VGG pipeline;
- Identify existing groundwater sources and sustainable yield capacity based on previous studies;
- Preliminary assess aquifer storage of GMU's based on previous studies;
- Based on projected water demands identify areas where future source development can be implemented to meet or augment short to medium term demands;
- Compile preliminary cost estimates for areas identified for future source development options to meet/augment these water demands.

5.2. General Description of Study Area

The study area falls in the Northern Cape Province and covers the area served/interacting by/with Sedibeng Water's Vaal Gamagara Scheme, as well as possible extension to the Mier area, two rural settlements (Skeifontein and Metsimatale), Heuningvlei and Kuruman town clusters, Dibeng, Campbell, Danielskuil, and also Botswana via the existing Kalahari East WUA and with an off-take from Blackrock (refer to **Table 4.2.1**).

The study area encompasses quaternary catchments D41H; D41L; D41J; D41K; D73A; D71B; C33C, C92A, C92B and C92C. The regional setting of these catchments, towns, and VGG pipeline route are shown in Map 1 (**Annexure D**). The area includes the John Taolo Gaetsewe and portions of the Frances Baard and Pixley ka Seme District Municipalities.

For a detailed description of the Morphology, drainage, climate, rainfall, vegetation and land use, please refer to supporting report *245460/04: GROUNDWATER RESOURCES.*

5.3. Resource Exploitation Potential

Two main aspects are involved in any groundwater resource assessment / utilization study:

- Sustainable yield: - considered as the amount of water which can be abstracted from an area over the long term without a constant lowering of the water table or a negative effect on borehole yield and water quality. The sustainable yield is dependent on the groundwater recharge, effective storage capacity, permeability of the aquifer and aquifer boundaries, with the emphasis on recharge (water balance) and aquifer boundaries.

- Resource potential or aquifer characteristics: – dependant on the effective storage capacity and permeability of the aquifer, aquifer recharge and economic aspects such as borehole yield and water quality. The resource potential can be considered as the amount of water being available for abstraction without consideration of any long or short-term lowering of the water table.

5.4. Water Quality

Groundwater samples analysed over the last 40 years from the area were used. The water quality is indicative of excellent class 0 water being present in the upper recharge area of the catchments, poorer class 1 water in the intermediate middle catchment areas and poor class 2 and 3 water in the discharge area of the catchment. The water is suitable for all use with the exception of the class 3 water in isolated areas.

The dolomite and banded iron formations (BIF) water from boreholes in the study area is generally very hard which will cause scaling of pipes, hot water cylinders and other appliances. Water for domestic purposes in Kathu is treated by a softening plant to reduce hardness before distribution to the communities.

The groundwater quality in the Heuningvlei area is highly variable, ranging from Class 0 to Class 4, with salinity and nitrate the main chemical elements which impact on water potability. The nitrate content may increase over time, originating from stock farming and on-site sanitation. This is due to the low rainfall in the area with limited dilution potential of contaminants. Areas underlain by lava rocks have very high nitrates, with most boreholes not suitable for human use (Madibeng Community).

The Metsimatale (prevoisly known as Groenwater) community is underlain by lava rocks with poor recharge characteristics with often gradually increasing nitrate content from stock watering and on site sanitation. The possibility to blend VGG pipeline water with existing boreholes and meet future water demands will have to be considered and was allowed for (refer to **Annexure A, Water Demand Table**).

5.5. Groundwater Water Supply Sources

The groundwater supply sources for municipal use in the study area and production and standby boreholes presented to large scale mine users are discussed in detail in the supporting report *245460/04 GROUNDWATER RESOURCES*. To follow are a brief description of the groundwater use profile of the study area.

5.5.1. Domestic Water Requirements

The current and future domestic water requirements were assessed and projected based on updated community demographics determined through the study. The base year for assessing current water requirements was 2010, and growth estimates were used to project future water needs at 5 year intervals from 2010 to 2030.

Communities that only or mainly use VGG water include: Delportshoop & Longlands, Vaal Gamagara, Koopmansfontein, Lohatla Military base (Public Works), Olifantshoek, and Hotazel.

Postmasburg is currently the only town that uses both groundwater and VGG pipeline water. The Kathu and the Sisheng communities will in future use VGG pipeline water conjunctively with groundwater sources. Communities or town clusters which currently solely use groundwater include: Schmidsdrift, Campbell, Griekwastad, Danielskuil, Lime Acres & Papkuil, Metsimatale, Jenhaven, Skeyfontein, Dibeng, the Kuruman and Heuningvlei Clusters.

The largest projected domestic water users in 2030 (Scenario 4 requirements with reference to Section 4) are Kathu (5.02 million m^3/a) and the Kuruman Cluster (9.023 million m^3/a). Moderate domestic users (1.0 to 3.0 million $m^3/$ a) dependent on groundwater resources in 2030 include Danielskuil as well as Lime Acres & Papkuil.

The total domestic water requirements according to Scenario 4 water demand projections increase from:

- 18.4 million m^3/a in 2010 to,
- 23.5 million m^3/a in 2015 to,
- 26.8 million m^3/a in 2030.

The rapid increases from 2010 to 2015 relate to increased mining activities and upgrading to higher service levels in communities. A lesser increase is projected from 2015 to 2030 due to the implementation of WC/WDM strategies.

Local groundwater resources are estimated to supply 75% of the 2030 domestic water demand. This includes the all domestic water users in the study area, existing VGG users and potential VGG users (refer to **Table 4.2.1**).

5.5.2. Mining Water Use

Water use and borehole yield information were sourced from the mines by means of questionnaires as well as several workshops and consultations with the mines. Groundwater information submitted by the mines was very limited and very general.

Mine Dewatering

Several mines are dewatering groundwater for mining purposes (according to Section 21 J of the National Water Act), the largest dewatering being at Sishen mine near Kathu. Mines that reported dewatering of groundwater include:

- De Beers - Finsch Diamond Mine are licensed to dewater the mining pit, with a registered mining water use of 1.126 million m^3/a. The mine reapplied to abstract additional water from the Bonza Quarry Dolomite compartment that was approved. The total dewatering licence amount to 4.4 million m^3/a. The mine is currently still obtaining the balance of their mining water needs from the VGG pipeline scheme.
- Assmang Iron Ore – Beeshoek Mine. Reported dewatering of groundwater for mining purposes of 6.518 million m^3/a. The registered water use on WARMS of 4.039 million m^3/a, was closed in June 2007. No water for future mining required from VGG pipeline scheme.

- BHP Billiton – Wessels Manganese Mine. Reported dewatering of groundwater for mining purposes of 0.2 million m^3/a. The balance of the mines water needs are obtained from the VGG pipeline scheme. The mine (Samancor) had a registered groundwater use of 0.493 million m^3/a since 1988, which was closed in June 2007.

- BHP Billiton – Mamatwan Manganese Mine. Reported dewatering of groundwater for mining purposes of 0.3 million m^3/a. The balance of the mines water needs are obtained from the VGG pipeline scheme. The mine (Samancor) had a registered groundwater use of 0.493 million m^3/a since 1988, which was closed in June 2007.

- McCarthy – Black Rock Manganese Mine. Reported dewatering of groundwater for mining purposes of 0.031 million m^3/a. The balance of their mining water needs is obtained from the VGG pipeline scheme.

- Lohatla Manganese Mine. Reported dewatering of groundwater for open pit mining purposes of 0.031 million m^3/a. No water for future mining required from VGG pipeline scheme.

- Tshipi eNtle Managanese Mine. Reported dewatering of open pit mine of 1.244 million m^3/a.

- Kumba Iron Ore – Sishen (Kathu Area). The mine is licensed to dewater groundwater for open pit mining purposes of up to 24 million m^3/a. The average dewatering abstraction is 13 million m^3/a. A mining water use from the Sishen aquifer of 7.124 million m^3/a, is registered on WARMS with a water use date from 1994. The excess dewatering water is currently supplied to the VGG pipeline scheme and Kathu Municipality. The authorised allocation for Kathu from the mine dewatering activities at Sishen Iron Ore is 4.005 million m^3/a. Increasing water requirements for planned expansion of mining activities at Sishen would have been met by reducing the amount of water supplied to Kathu. Updated mine dewatering and mine water use projections, received from Kumba Iron Ore in January 2011, indicate that the 4.383 million m^3/a available for Kathu in 2010 will actually increase to 5.260 million m^3/a in 2015. Projections for 2020 indicate larger volumes becoming available from mine dewatering based on numerical aquifer modelling, which may be over stated.

As a conservative approach the 2015 projection is considered applicable up to 2030.

- Kumba Iron Ore – Kolomela Mine (Beeshoek Area). The mine is licensed to dewater groundwater for open pit mining purposes of up to 17 million m^3/a, from the GMU D73A-07. The average dewatering abstraction is estimated at 13 million m^3/a. A total mining water use of 3.563 million m^3/a, is registered on WARMS with a water use date of May 2006. The excess dewatering water is currently supplied to the VGG pipeline at Beeshoek. No water for future mining required from VGG pipeline scheme.
- No dewatering info was submitted by the Assmang Black Rock mine.

The total average dewatering of groundwater for mining purposes in the study area amounts to 25.77 million m^3/a for 2030.

Mines that require no VGG pipeline water in the future (2030) and are responsible for their own water supplies from local groundwater sources include:

- Assmang Iron Ore – Beeshoek Mine;
- Kumba Iron Ore – Sishen Mine (Kathu Area);
- Kumba Iron Ore – Sishen South Mine (Beeshoek Area);
- Lohatla Manganese Mine;
- Lemoteng Manganese Mine.

Augmentation of VGG Pipeline Scheme from Mine Dewatering

Available water from mine dewatering for the VGG pipeline scheme include:

- 10.5 million m^3/a available at Beeshoek VGG Reservoir from the Beeshoek and Sishen South Mines, abstracting water from GMU D73A-07.
- 1.3 million m^3/a currently available from Sishen Mine (Kathu Area), increasing to 6.6 million m^3/a in 2015 and onwards till 2030.

5.6. Groundwater Potential to Augment VGG Pipeline

Preliminary hydrological modelling of the overall VGG pipeline capacity indicated that the high water demand for the Finsch Mine in 2015 of 5.18 million m^3/a (**Table 4.2.2**), should preferably be supplied from local groundwater resources. Another area with a critical shortfall in the short term VGG supply capacity is Kathu with a 2015 demand of 8.459 million m^3 /a.

5.6.1. Resource Grouping and Median Recharge

The groundwater potential of GMU's were grouped together to identify larger scale water sources near the VGG pipeline which are or could be developed for direct water supply to users or for augmentation. A total of ten resource groupings were identified of which the layout and location is presented in **Annexure D: Map 6**. A resource grouping comprise of one or more GMU's. Summary resource information is listed in **Table** 5.6.1.1

The registered water use presented in **Table 5.6.1.1** is based on WARMS information using registered coordinates to link to listed GMU's. The total storage volume in the upper 4 meters of the aquifers amounts to 406 million m^3 /a and the total average recharge is 109 million m^3 /a, approximate 25 per cent of storage.

The D41L-K10 GMU delineated by Wiegmans (2006) is also identified as a potential source of local water supply. This is based on median recharge of the GMU unit and cumulative water balance of median recharge in upstream GMU's. The total available amount listed in 2006 was 11.909 million m^3. Preliminary hydrological modelling of the overall VGG pipeline capacity indicated a shortfall of 5.7 million m^3 /a in the Hotazel area, which is 48 per cent of the total volume of available groundwater – Refer **Annexure D - Map 6**.

Table 5.6.1.1: Summary resource information of groupings

RESOURCE GROUPING REF	GMU NUMBER/S	AREA	AQUIFER STORAGE : 4m	RECHARGE FROM RAINFALL million m^3 /a		REGISTERED USE	COMMENT
		km^2	million m^3	average	median	million m^3 /a	
VGG CLIFTON EAST	C92A-03, C92A-04, C92A-06, C92A-07.	1 095	74.7	14.085	5.289	0.106	Identified to supply Finsch mine
DANIELSKUIL	C92A-01, C92A-02.	439	35.1	7.407	3.311	1.621	Used by Danielskuil and Idwala mine
FINSCH LIME ACRES	C92C-01	204	16.3	3.182	1.362	1.196	Use by Finsch & Lime Acres & Papkuil
VGG POSTMASBURG EAST	D73A-01, D73A-02, D73A-03.	732	50.0	12.084	5.34	0.173	Identified to augment VGG scheme
BEESHOEK SISHEN SOUTH	D73A-07	162	9.7	2.333	0.950	12.947	Dewatering by mines
KATHU	D41J-G1, D41J-G2, D41J-G3.	1 815	98.6	23.534	10.264	8.252	Identified to augment supply to Kathu
SISHEN (KATHU AREA)	D41J-G4, D41J-G5, D41J-G6	841	39.1	9.127	2.899	7.202	Dewatering by Sishen mine
DIBENG	D41J-G7	1 268	25.4	9.211	2.189	0.079	Use by Dibeng
KURUMAN CLUSTER	D41L-K4, D41L-K5, D41L-K6.	621	57.0	27.905	16.533	4.86	Used by Kuruman community cluster
TOTAL		**7 177**	**405.9**	**108.868**	**48.137**	**36.436**	

5.6.2. Large Scale Source Development Options

Based on the resource potential of resource groupings and shortfalls in the current capacity of the VGG pipeline scheme four large scale source development target areas were identified (SD1 to SD4) – refer to **Annexure D - Map 7**. Conceptual production boreholes, all with a 10 ℓ/s for 24 hours per day yield, are indicated in Map 7.

The targeted water supply volumes and conceptual production boreholes for the source development target areas are:

- SD1 15 production boreholes 4.5 million m³ /a to supply Finsch Mine
- SD2 17 production boreholes 5.1 million m³ /a to augment VGG Pipeline Scheme
- SD3 16 production boreholes 5.0 million m³ /a for short term supply to Kathu

- SD4 18 production boreholes 5.7 million m³ /a to augment VGG Pipeline Scheme

Total 66 production boreholes 20.3 million m³ /a

The risk for source development of target areas SD1 to SD3 is low, provided appropriate geophysical surveys are conducted by highly experienced karst source development specialists. The source development risk for SD4 is considered moderate, which may reduce once detailed hydrocensus surveys and appropriate geophysical surveys are completed.

5.6.3. Costing of Source Development Options

An indicative costing (VAT exclusive) of the source development for target areas SD1 to SD4 is estimated for budget purposes.

The costs presented below include:

- detailed hydrocensus surveys of existing boreholes in use within resource groupings;
- forty chemical samples from existing boreholes per resource grouping;
- geophysical surveys to investigate aquifer conditions and site pilot and production boreholes;
- Drilling of 1.5 pilot boreholes for every conceptual production borehole;
- Drilling of production boreholes to yield at least 10 ℓ/s for 24 hours per day;
- Test pumping (48 hour constant discharge test) of new boreholes including chemical analysis of tested boreholes;
- 3D numerical groundwater model per target area, using Feflow software;
- Compilation of technical report per target area.

The costs for public participation, EIA’s and license applications are excluded. A lump sum per target area of R 850 000.00 is considered sufficient for these activities.

Indicative costing for the source development component of target areas is:

• SD1	15 boreholes	4.5 million m³ /a	R 7,100,000
• SD2	17 boreholes	5.1 million m³ /a	R 7,800,000
• SD3	16 boreholes	5.0 million m³ /a	R 7,700,000
• SD4	18 boreholes	5.7 million m³ /a	R 8,500,000
Total	**66 boreholes**	**20.3 million m³ /a**	**R31,100,000**

The total cost of the development of the additional groundwater sources amounts to R 34 500 000.00 excluding VAT.

The source development of listed target areas can be implemented simultaneously. The estimated duration, from date of order, for each target area is:

- SD1 15 boreholes 12 months
- SD2 17 boreholes 12 months
- SD3 16 boreholes 18 months
- SD4 18 boreholes 18 months

6. EXISTING INFRASTRUCTURE CONDITION ANALYSIS

This section of the report summarises the information obtained on the existing infrastructure in the areas that fall within the study area. For more information regarding the existing infrastructure in the study area, please refer to supporting reports *245460/01, INCEPTION REPORT, ANNEXURE K – CATHODIC PROTECTION STATUS SURVEY AND ANNEXURE L – COATING INTEGRITY SURVEY, REPORT 245460/02 SAHARA CCTV INSPECTION OF SELECTED PIPELINE SECTIONS AND REPORT 245460/03 STATUS QUO REPORT ON THE FUNCTIONALITY OF THE MECHANICAL, ELECTRICAL AND ELECTRONIC SYSTEMS*

6.1. Description of the existing scheme

System layout and operation

The layout of the Vaal Gamagara water supply scheme is shown on **Figure 6.1.1**. The scheme comprises a total pipeline length of approximately 370 km from Delportshoop to Black Rock. Water is extracted from the Vaal River at the Sedibeng Water treatment plant (WTP) at Delportshoop. From the WTP water is pumped via a 20 km long 687 mm diameter pipeline to the Kneukel sump and pump station from where it is pumped via a 48.7 km long 687 mm diameter pipeline to the Trewill sump and pump station. From the Trewill pump station the water is pumped in two 29.45 km long parallel pipelines, a 508 mm and a 355 mm diameter pipeline, to the Clifton reservoir.

From Clifton reservoir water is conveyed in a 36.6 km long 762 mm diameter and 23.5 km long 660 mm diameter pipeline to Gloucester reservoir under gravity. Gloucester reservoir serves as a pressure break tank. From Gloucester water is conveyed under gravity to the rest of the system, initially through a 27.1 km long 900 mm pipeline up to the Olifantshoek branch, then a 14.1 km long section of 508 mm diameter pipeline and a 15.9 km section of 700 mm diameter pipeline up to Kathu from where the supply to Hotazel is via a 52.2 km long 324 mm diameter pipeline. From Hotazel to Blackrock it is a 14.7 km, 305 mm diameter pipeline with an additional 220 mm diameter pipeline in parallel.

There are several branch pipelines serving large consumers, most being relatively short and with small diameter, with the 23.5 km long 254 mm diameter pipeline serving Olifantshoek from a connection on the main line at Roscoe. The length of the 110 mm Koopmansfontein off-take is 6.5 km.

Booster pump facilities are located at Kathu and Mamatwan, both currently out of commission. The Kathu facility is planned to be re-commissioned.

Bulk water is also supplied from two areas: Beeshoek and Sishen. The water is generated through the dewatering actions of the mines by abstracting from nearby borehole fields. The water is utilized by the mines in their processes but surplus water can be pumped into the Vaal Gamagara system.

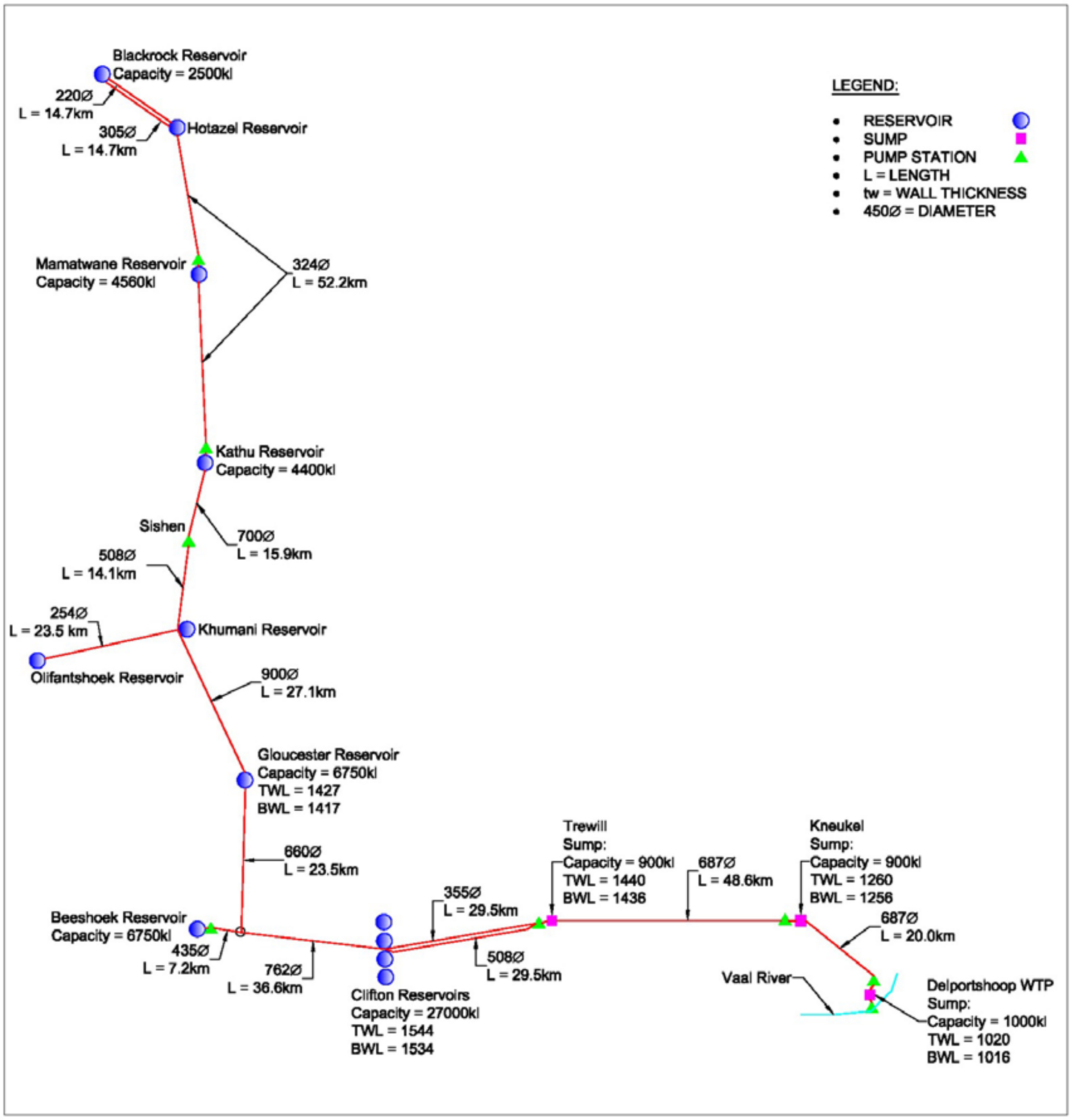

Figure 6.1.1: Existing Vaal Gamagara Scheme

The existing supply from Beeshoek is via a 7.2 km long 435 mm diameter pipeline that connects to the main pipeline at Postmasburg. This system is currently being upgraded with a new pump station and 650 mm diameter supply line. Pressure control is applied in the main line upstream of the connection point as described below. The Sishen pump station delivers directly into the main pipeline that passes the mine. This pump station is to be decommissioned with a new pumping facility to be established that delivers the Sishen ground water through the Kathu supply line.

Pressure control is applied at four points on the main pipeline: Approximately 3.3 km upstream of the Beeshoek pump line connection to the main line a PRV with setting 110 m reduces the pressure in order to avoid the Beeshoek pumps having to pump at the static head provided by the Clifton reservoir level. Approximately 4.5 km south of the existing Sishen pump station a PRV with setting 65 m reduces the pressure against which the Sishen pumps have to operate. The pressure against which the Kathu pumps have to operate is reduced by a PRV with setting 65 m directly upstream of the pump station. The northernmost section of the scheme is protected against excessive static pressure by a PRV with setting 60 m directly north of the connection to Hotazel. At the latter three PRV locations pressure sustaining is also applied directly upstream.

Pressure control is applied on several of the off-takes to consumers.

Reservoirs and sumps

The reservoirs and sumps forming part of the VGG scheme are listed in **Table 6.1.1**. The main reservoir clusters are at Clifton, located 98 km from Delportshoop along the pipeline, where four identical structures provide total storage of 27 Mℓ and Gloucester reservoir, located a further 60 km along the pipeline, with a capacity of 6.75 Mℓ. Clifton reservoir is supplied by the pump system from Delportshoop. Gloucester reservoir is supplied from of the Clifton reservoirs under gravity as well as from Beeshoek pumps and serves as a pressure break tank for downstream supply. The 10 Mℓ Delportshoop WTP clearwell serves as a sump for the Delportshoop pump station.

The 4.4 Mℓ Kathu reservoir serves as a sump for the Kathu booster pump station, which is currently not in operation but in the process to be commissioned again.

The 4.56 Mℓ Mamatwan reservoir is used as a sump for the Mamatwan booster pump station, currently not in commission.

The 2.5 Mℓ Black Rock reservoir is located at the northernmost point of the scheme.

Identical 0.9 Mℓ sumps are located at Kneukel and at Trewill pump stations.

Table 6.1.1: Reservoirs and Sumps

Reservoir/Sump	Volume (Mℓ)	Elevation (m asl)	TWL (m asl)
Delportshoop sump	10	1016	1020
Kneukel sump	0.9	1256	1260
Trewill sump	0.9	1436	1440
Clifton 1	6.75	1534	1544
Clifton 2	6.75	1534	1544
Clifton 3	6.75	1534	1544
Clifton 4	6.75	1534	1544
Gloucester	6.75	1417	1427
Kathu	4.40	1200	Unknown
Mamatwan	4.56	1120	Unknown
Black Rock	2.50	1040	Unknown

Pump stations

The pump stations forming part of the VGG scheme are listed in **Table 6.1.2**. The main pump stations supplying to Clifton reservoir are located at Delportshoop, Kneukel, 20 km along the pipeline and Trewill a further 48.7 km along the pipeline, each with three pumps, one of which is a standby. These pumps are currently being refurbished to deliver to their original specifications, in the order of 1 520 kℓ per hour. Booster pump stations are located at Kathu and Mamatwan, both currently not in commission. The Kathu pump station is currently in the process of being put back into commission.

External pump stations that affect the operation of the scheme are those located at Beeshoek and Sishen that supply groundwater into the main pipeline and the Kalahari East pumps that extract directly from the main pipeline. The recently upgraded Beeshoek pump station is capable of delivering up to 1 800 kℓ per hour to Gloucester reservoir at a point on the main pipeline located 23.5 km upstream of the reservoir. The Sishen pump station delivers up to 150 kℓ per hour directly into the main pipeline at a point located approximately 15.9 km upstream of the Kathu take-off along the pipeline. The section of the pipeline between this point and Kathu as well as the pump station are currently planned to be relocated to accommodate mining activities, with the new delivery point located on the supply line to Kathu.

Table 6.1.2: Pump Stations

Pump station	No of pumps	Delivery rate (ℓ/s)	Comments
Delportshoop	3	420	
Kneukel	3	420	
Trewill	3	420	
Beeshoek 1	2	135	
Beeshoek 2	4	500	
Sishen BR	3	25	
SishenOli	3	16	
Kathu	2	170	Bypassed
Mamatwane	1	135	Bypassed

Control valves

The control valves that affect the operation of the scheme are listed in **Table 6.1.3** and their functioning described in above sections.

Table 6.1.3: Control Valves

Location	Type	Setting	Comment
Chamber 29	PRV	110 m	Downstream of Clifton reservoirs
Chamber 31	PSV	110 m	Between Khumani off-take andSishen pump station
	PRV	65 m	
Kathu	PSV	50 m	Directly upstream of Kathu booster pump station
	PRV	65 m	
Hotazel	PSV	40 m	Directly downstream of Hotazel off-take
	PRV	60 m	

6.2. Replacement Value of the existing scheme

The original Vaal Gamagara Scheme was constructed during 1968 and again upgraded in 1976 the majority of the assets are therefore approximately 35 years and older. As a result the assets not yet replaced are generally old and are operating over or very near to the expected useful life. The following discussion provides an overview of the replacement value of the scheme:

The Depreciated Replacement Cost (DRC) of the scheme in the three assets classes are:

Table 6.2.1: Depreciated Replacement Cost of the scheme

Asset Class	Depreciated Replacement Cost
Pipeline and Reservoirs	R 1 665 374 479
Precipitation and Dosing	R 2 314 000
Supporting Infrastructure (Buildings etc.)	R 119 247 759
TOTAL	**R 1 786 936 238**

The ratio of Cumulative DRC over Cumulative Current Replacement Cost (CRC) gives an indication of the age of the assets. In the case of the Vaal Gamagara scheme the ratio is 0.12 (12%). This means that generally the assets have “used up” approximately 88% of its Expected Useful Life (EUL).

6.3. Condition Analysis of the Scheme

This section report on the functional status of the mechanical, electrical and electronic equipment installed and in use at the Vaal-Gamara Water Scheme. This task forms part of the Data Capturing and Verification process with the aim of compiling the Water Master Plan.

In response to the Terms of Reference, data and information was gathered regarding the existing infrastructure of the Scheme, with particular reference to the electrical, mechanical and electronic aspects of the existing Pump Stations, Control Systems and Telemetry Systems.

6.4. Assessment of equipment

6.4.1. General

i. The pump stations at Delportshoop, Kneukel and Trewil have pump positions available for future extensions. New electrical and mechanical equipment will, however, be necessary to expand the pumping capacity.

ii. At present, the pump stations at Kathu and Mamatwane are not in use. In addition, various system components such as pumps have been removed for various operational reasons. As a result, there would be a considerable lead-time to make these pump stations operational again should they be re-commissioned in future. At Beeshoek pump station the building is currently being extended to provide for extra pumps due to changes in consumer demands.

iii. Some particular aspects, which require attention as far as maintenance is concerned, have been noted at the various sites:

iv. The power supply transformers should be serviced. (This also applies to Kneukel and Trewil Pump Stations). There was oil leakages noticed.

v. For the Abstraction works the containment of the variable speed drives in a separate air-conditioned building is recommended.

vi. Water Treatment Works: Various rusting pipes and flanges, as well as water leaks must be repaired. Several instances of repairs required to buildings, such as refurbishing and re-painting of walls, have been noted.

6.4.2. Pump Stations

i. Delportshoop, Kneukel and Trewil Pump Stations

- The pumps are currently being replaced with new ones.
- The 6,6kV motors are very old and are of the slip-ring type, which presents a high maintenance problem, especially as far as the replacement of brush-gear is concerned. The motors utilize resistor bank starting, as the incoming supply to the premises originally required that the starting current of the motors should be kept as low as possible. It is recommended that the motors be replaced with squirrel-cage

induction motors and that variable speed drives (VSD's) or MV soft starters be installed to limit the starting current to the acceptable level.

- To comply with safety regulations, the VSD's and 6,6kV switchgear should be enclosed in a separate bricked room.

ii. Beeshoek Pump station

- The existing pump sets were installed in 2004 and are still in good condition.
- Consideration should be given to replacing the pump control console with a more modern design to ensure compatibility with the starting arrangement at the other pump stations.
- The pump station is currently being extended to accommodate new plant, of which the details were not available at the time of the visit to the site.

iii. Sishen Pump station

- The interior of the pump station was not inspected, but according to the operations personnel, the plant is still in good condition.

iv. Kathu Pump station

- This pump station is not in use at present and it is not clear whether it will be required in the near future.
- The pumps have been removed and the motors disconnected. Considerable expenditure will be required to re-commission this pump station.

v. Mamatwane Pump station

- This pump station is not in use at present.
- Operating personnel have reported that the plant is not in a good condition and refurbishment work will be necessary should this pump station be re-commissioned.

6.4.3. Monitoring, control and communication equipment

The general impression of the Communication, SCADA and other monitoring systems is that the systems are in a state of transition with incomplete migration. Lack of serious maintenance is evident.

6.4.4. Communication networks

The communication networks seem to be operating to a fair degree of satisfaction. It was not possible during the inspection to determine with any degree of accuracy what the real state of reliability was. It can be assumed that the GSM network is very stable with a very high rate of availability and reliability.

The broadband radio network equipment appeared to be operating well. However if the technical parameters and radio profiles are considered it can be concluded that communication outages will be experienced. The paths are reasonably long for the low power equipment and no evidence of space or frequency diversity was noted.

6.4.5. SCADA

The SCADA master station server arrangement was functioning reasonably well with current versions of the software. The installation quality was however very substandard and needs serious upgrading.

The Allen Bradley PLC network is reasonably new and the installation standard was acceptable. The on-plant systems seemed to operate very well. A serious lack of documentation was noted and no manuals of the system were found on site. This needs to be rectified.

The Prodesign TS161 RTU network seemed to be operating verily well. Full documentation was found on site. The scheme was in the process of migrating the major pump stations from the TS161 RTU's to Allen Bradley PLC based stations. At Beeshoek pump station it was said that the planning was to replace the Schneider PLC with Allen Bradley units and to integrate the station into the central system. During the inspection the station was still connected via the TS 161 equipment.

6.4.6. Other systems

At all the pump stations the local instrumentation was found to be in a serious state of disrepair with a number of units either disconnected from the system or de-mounted from the plant. It was not really possible to assess the functional state of most units.

6.4.7. Summary and conclusions

i. Most of the electrical and mechanical equipment at Delportshoop, Kneukel and Trewil is in a functional condition, although some pumps are being upgraded. These three pump stations have spare pumpset positions for future expansion. However, future extensions will require new electrical and mechanical equipment as well as design work.

ii. The pump stations at Kathu and Mamatwane are not in use at present. In order to re-commission these pump stations in future, a considerable lead-time will have to be allowed for design work and procurement.

iii. Several items of mechanical, electrical and electronic system components require servicing and maintenance. Several control and telemetry components require upgrading as well.

iv. Local instrumentation on pump station equipment requires upgrading and repair.

In conclusion, it must be stressed that the continued availability of pumping capacity and operation of the water supply system was under serious threat at the time the investigations was conducted due to the lack of routine maintenance and the age of some components.

6.5. Mechanical Integrity of the Pipeline

This section provides a brief summary of the salient results from the various investigations and a general conclusion on the status of the pipeline.

6.5.1. Integrity Investigation Methodology:

The Vaal Gamagara pipeline system comprises a number of discrete, identifiable sectors which have different characteristics related to the pipeline construction methods, age and operational history. For example; the section of the system north of Sishen was supplied with water from Sishen itself prior to the installation of the pipeline from Posmasburg to Sishen. As a result, a section of this pipeline lay unused, filled with “dead” water for several years prior to being commissioned.

The Vaal Gamagara pipeline parallels the 3kV DC rail system for most of its length, and is subject to some of the worst stray current influence in South Africa due to the heavy traffic on the rail line and the relatively poorly insulating bitumen coating on the pipeline.

The pipeline has the highest current rating CP system of all DWA pipelines in the country, which is further complicated by the use of regenerative braking on the rail system. The pipeline is equipped with some 14 natural drainage bonds rated in excess of 400A each between Kneukel and Lime Acres alone. Electrical continuity of this pipeline is one of the most critical factors in the successful implementation of stray current interference mitigation. Further investigation in the late nineteen eighties confirmed the presence of un-coated Viking Johnson couplings on the Delportshoop – Posmasburg section with bonding straps excluding the body of the coupling.

The pipeline may be divided into discrete sections for evaluation of corrosion risk as follows:

- Delportshoop – Kneukel
- Kneukel – Lime Acres (Clifton Reservoir)
- Lime Acres – Posmasburg
- Beeshoek branch
- Posmasburg – Olifantspoort Tee (Roscoe)
- Olifantspoort branch
- Olifantspoort Tee – Sishen
- Sishen – Hotazel
- Hotazel – Black Rock

The status of the cathodic protection system is best evaluated by means of synchronised potential and current recordings. Pipeline potential provides the most commonly used parameter for determining whether active corrosion is occurring on a structure. Simultaneous measurement of the operating parameters of the forced and natural drainage units, impressed current cathodic protection rectifiers and the rail potential complete the picture.

Efficient operation of the cathodic protection system is only possible if the pipeline is electrically isolated from pump stations and reservoirs. The infrastructure status survey would include verification of the operational status of all cathodic protection hardware on the pipeline system.

It is possible to evaluate the condition of the external coating of a pipeline as well as the efficacy of the cathodic protection system using non-destructive overland survey techniques such as CIPS/DCVG. A significant advantage of these techniques is that they can be used without taking any of the pipeline sectors out of service. Defects in a pipeline coating where no CP is experienced by the pipeline will result in regions of high risk of perforation, particularly in the event of increased operation pressures.

This information, in conjunction with the pipeline leak history can provide valuable insight and information regarding the status of a given pipeline.

Once the data has been evaluated it can be compared with the results of calibration digs to correlate the survey data with the field condition. The locations are usually determined by leak history, route conditions as well as the results of the overview CIPS/DCVG survey.

During the field digs, visual and physical evaluation of the pipe coating as well as ultrasonic wall thickness measurements further complement the survey data, providing a detailed picture of the pipeline condition. Wherever possible, the digs should include the exposure of a field joint, as these are the locations most susceptible to coating failure and subsequent corrosion, both internal and external.

Internal Condition Evaluation can be conducted by means of CCTV inspection of up to 400 m sections of pipeline accessed through air valve or access tees. Such inspections often require the pipeline to be de-commissioned and partially drained. Evaluation of the video footage obtained can provide an overview of the status of the internal lining of the pipeline which assists in estimating the remaining life of the internal lining.

In summary, the following scope of work was concluded. Not all the originally proposed activities could be completed due to various operational restrictions, as noted:

- Potential survey of the entire pipeline route at CP monitoring points. (60 locations surveyed)
- Status survey and measurement of operating parameters of all CP installations.
- Inspection and testing of insulating flanges at all pump stations and reservoirs.

- Coating integrity survey of 15 sections of pipe identified according to pipeline characteristics, potential survey results, topography and leak history.
- (No external excavation and inspection work was undertaken.)
- Internal CCTV inspection at 14 locations using a tethered camera under live flow conditions, plus 1 CCTV crawler inspection of the abandoned line between Kneukel and Trewill.
- Report on infrastructure condition based on the results of all survey work.

6.5.2. Pipeline Potential and Cathodic Protection Status Survey

A preliminary route survey was conducted during the first week of January 2010 and continued in February 2010 after CP maintenance work had been completed. Background information was obtained from DWA monitoring reports, CP system installation details and anecdotal leak history reports. The results of the survey are reflected in supporting report *REPORT 245460/01 INCEPTION REPORT ANNEXURE K – CATHODIC PROTECTION STATUS SURVEY.*

The following general conclusions can be drawn:

- Average pipe-to-soil potential recordings on the majority of the pipeline indicated that CP system is not providing adequate protection of the entire pipeline.
- Severe stray current influence was evident from amplitude calculated on pipe-to-soil recordings.
- Rail system characterisation has been established from rail-to-soil potentials, rail current recordings, and traction sub-station locations. Rails exhibit extreme positive and negative potentials
- Rectifier current recordings and diode integrity have been established from survey results. On paper, the CP equipment appears to be adequately rated for service conditions, but the installations do not appear to be sufficiently robust to withstand site conditions.
- Insulating flanges, where they could be found, were generally non-functional.

6.5.3. Coating Integrity Surveys

The CIPPS/DCVG, DCVG and PCM© coating integrity surveys commenced 12 April 2010. Locations for the calibration digs will be determined from these surveys.

The survey locations were determined based on historical data and location of rectifier units. The intent was to cover sections representative of the different stages of pipeline construction.

A number of CP units were found to be non-functional. Accordingly, survey locations and techniques were modified to accommodate the site conditions.

Table 6.5.3.1: Modification to accommodate site conditions

TEST POINT NO.	UNIT	GPS CO-ORDINATE	COMMENTS
04 FDU	Kneukel	S 28 16 16.3 E 24 08 49.9	Rail cable burnt off (Reconnected by ICP)
32 FDU	Clifton	S 28 16 50.2 E 23 23 14.3	Thyristor blown
39 FDU	Manganor	S 28 09 13.0 E 23 04 52.7	Electronic card blown
49 FDU	Sishen	S 27 46 27.4 E 22 58 53.5	Unit burnt out
57 FDU	Hotazel	S 27 13 55.9 E 22 58 01.9	Bypass diode blown

The sections selected for surveying are listed in **Table 6.5.3.2** below.

Table 6.5.3.2: Sections selected for surveying are listed below.

TEST POINT NO.	SWITCH	ROUTE	SURVEY TECHNIQUE	ALTERED SURVEY RECHNIQUE
04 TRU	Kneukel	Kneukel towards Koopmansfontein	CIPPS/DCVG	
04 TRU	Kneukel	Kneukel towards Koopmansfontein	DCVG	
32 FDU	Clifton	Lime Acres towards Trewill	CIPPS/DCVG	PCM
32 FDU	Clifton	Clifton towards Postmasburg	CIPPS/DCVG	PCM
32 FDU	Clifton	Lime Acres towards Trewill	DCVG	
32 FDU	Clifton	Clifton towards Postmasburg	DCVG	
39 FDU	Manganor	Manganor towards Postmasburg	CIPPS/DCVG	PCM
39 FDU	Manganor	Glouster towards Olifantshoek T	CIPPS/DCVG	PCM
46 MC		Olifantshoek T towards Olifantshoek	PCM	
48 TRU	Vaal Gamagara	Olifantshoek T towards Sishen	CIPPS/DCVG	
55 FDU	Mamatwan	Mamatwan towards Kathu	CIPPS/DCVG	
55 FDU	Mamatwan	Mamatwan towards Hotazel	CIPPS/DCVG	
55 FDU		Mamatwan towards Kathu	PCM	
57 FDU	Hotazel	Hotazel towards Blackrock	CIPPS/DCVG	PCM
57 FDU		Hotazel towards Blackrock	PCM	

The survey techniques and interpretation of results are detailed in *REPORT 245460/01 INCEPTION REPORT ANNEXURE L – COATING INTEGRITY SURVEY*. The general conclusions from these surveys are given below:

- From site observations and CIPPS/DCVG surveying, cathodic protection levels along sections of the pipeline are inadequate.

- Many coating defects were identified. However, few of them can be classified as requiring immediate attention. In many instances the number of defects identified can be considered commensurate with the age of the pipeline.
- Along some of the pipe sections (such as from Mamatwan to Hotazel) regularly spaced defects were logged. These are most likely attributable to uncoated couplings. However, in the presence of adequate CP levels, these are unlikely to cause significant concern.
- Flanges which had recently been replaced near Lime Acres were found to be uncoated and no continuity bonding was evident.
- The Vaal Gamagara CP system was designed during 1980s during which time no rural power network was available hence, extensive use of power from the rail was used. Although the capacity of the CP system has recently been increased, insufficient spread of protective current is being noted. In addition, the CP System does not seem to be robust enough to withstand the stray current conditions. “OFF” potentials were frequently recorded below the criterion for protection.
- From the surveys, coating degradation is evident throughout the pipeline route with defects at regular intervals indicating uncoated flanges. However, extensive coating refurbishment alone is unlikely to achieve desired results with the present stray current and cathodic protection situation.
- During the survey, several locations were identified where the pipeline has been exposed. At some locations VJ couplings without continuity bonds were noted. These should be prioritized for continuity bonding, re-wrapping and re-burial.

6.6. Internal Condition Evaluation

The drained and live CCTV inspections on selected sections of the Vaal-Gamagara scheme yielded very meaningful results. The overall result is that the internal lining is in an advanced state of degradation referring to *REPORT 245460/02 SAHARA CCTV INSPECTION OF SELECTED PIPELINE SECTIONS.*

Although the degree and type of failure vary from section to section, the entire pipeline will require re-lining. Further investigation as outlined below may be justified if prioritisation of the re-ling operation is required.

- The visual inspections provide clues as to the presence and possible type and mode of corrosion taking place inside the pipelines. It is however not possible to determine actual metal loss and the resultant impact on the structural integrity, or remaining life expectancy of the pipelines.

- The old pipeline is in an advanced state of disrepair and has seemingly suffered severe corrosion damage during the period that it was out of service. Additional sampling and possible detailed ultrasonic (or other) testing would need to be performed to confirm the structural integrity of the pipe barrel. If found to be structurally sound, the pipeline must be completely re-lined to render it serviceable.

- The condition of the in service pipe sections inspected with the Sahara® CCTV system varied considerably from one location to the next.

- Based on the inspection findings, it is clear that corrosion is taking place inside all the pipelines. The type/mode and severity of the corrosion differs. Apart from the risk that this poses to the structural integrity of the pipelines and possible increased system losses, it potentially also has a significant impact on the operation of the scheme due to increased pipeline friction losses leading to higher operating costs and lower efficiency. Over time, the cost implication of this could be vast.

- It is recommended that more detailed investigations be performed on selected sections of the pipelines where severe corrosion product and tuberculosis is present. This will require man entry into the pipelines where possible/practical. The aim of the physical inspections should be the following:

  – To take samples of corrosion products to confirm the type and mode of corrosion, and to confirm whether Microbiologically Influenced Corrosion (MIC) is taking place.

  – To determine the extent of metal loss and pitting that has taken place in areas with different types and severity of corrosion product and tuberculation build up.

  - To determine the extent of damage to the lining and the underlying pipe barrel where cracking and blistering has taken place.
  - Physically verifying the integrity of the lining in areas that are not showing signs of active corrosion to inform future upgrading and refurbishment decision making processes.

- Performing selected detailed inspections will also significantly increase the value of the CCTV footage gathered during the inspections as it will assist in interpreting and classifying the CCTV findings on the remainder of the scheme.
- Based on the observations made on the rising mains, it is recommended that Sedibeng Water carefully consider the impact of operational changes on pressure surges in the system. The current approach and alleviating measures do not seem to provide adequate protection as it seems to be causing damage to the internal pipe lining. It is possible to compile a calibrated dynamic model of the pumping system to accurately predict the stresses that the pipelines are exposed to and decide on the most effective means of protecting the system.
- The presence and frequency of leaks is a valuable indicator of the structural integrity of pipelines. A detailed leak detection and location program could be considered to inform the prioritisation and decision making process and at the same time reduce system losses.

6.7. Conclusions

The following comments can be made, regarding the mechanical integrity of the Vaal Gamagara Pipeline network:

- In general, the ground conditions are non-corrosive.
- The major threat to the pipeline, from an external corrosion perspective, is the extremely high stray current activity in the area.
- There has been a recent upgrade to the cathodic protection system in that the capacity of the system was increased. However, there have been no modifications to the original 1984-1985 CP design, despite significant changes in the surrounding infrastructure.

- It would appear that the reported incidents of pipeline leaks are primarily related to the scour valves, where evidence of electrical discontinuities (no continuity bonding) have been observed, resulting in interference corrosion across the joints.

- Several of the surveys indicated that there were regular discontinuities and/or coating defects – these are most likely attributable to missing continuity bonds and unwrapped joints during pipe installation.

- It has been confirmed, during the surveys, that when the CP system is non-operational, the pipeline goes positive. This highlights the critical importance of maintaining continuous operation of the cathodic protection system.

- Since the primary corrosion mechanism can be attributed to stray current activity, the regions of the pipeline at highest risk of corrosion are those in regions of stray current discharge.

- Internal inspection has revealed that there has been comprehensive failure of the internal lining of the pipeline and general internal corrosion was noted.

- It is not possible at this stage to predict residual life expectancy. This will require physical inspection

6.8. Recommendations

- Regardless of the pipeline scenario finally selected, it is recommend that the Cathodic Protection system be redesigned from first principles to meet the current demand to adequately protect the pipeline(s). We envisage that this will result in an increased number of locations for CP stations using traditional ICCP rectifiers and associated groundbeds.

- Regular maintenance and repairs to the CP System are essential to maintain the integrity of the existing and future pipelines.

- Pipeline Scenarios:

- Should the decision be taken to replace the existing pipeline with a single larger diameter pipeline and abandon the existing pipeline, the new pipeline must be designed so as to be CP compatible. In addition, the existing pipeline should not be abandoned in the ground but removed completely, as we believe that it may compromise the integrity of the replacement pipeline by acting as a parallel conductor and aggravating stray current interference effects.

- Should the decision be taken to refurbish the existing pipeline and have two parallel pipelines, the new pipeline must be designed so as to be CP compatible. Once construction is complete, the existing pipeline should be refurbished in its entirety by means of cement mortar lining, valve refurbishment, ensuring continuity bonding and undertaking selective coating repairs.
- The re-lining process will be significantly more cost effective if it is undertaken once a new line is operational, as no temporary bypasses will be required and the lining contract can proceed un-interrupted.

7. RECONCILIATION STRATEGIES

The main objective of this part of the study was to develop reconciliation strategies for the bulk water users and municipalities served/interacting by/with the Vaal Gamagara Scheme, in order to identify measures that are necessary to ensure that the current and future water requirements of the water users can be supplied from the available water resources on a sustainable basis. The various reconciliation strategies were used to develop a water master plan for the Vaal Gamagara water supply scheme.

The development of these strategies involved the following components:

- Establish water demand and use.
- Investigate the potential water savings achievable through water conservation and water demand management (WC/WDM).
- Investigate the quality and quantity of available water sources i.e. ground water and/or the Vaal Gamagara scheme.
- Investigate the capacity and condition of existing infrastructure and the need for upgrading, as well as the economic viability thereof.
- Investigate possible augmentation options.
- Determine the economic viability of possible conveyance options.

Stand alone reconciliation strategies were developed for 10 towns or town clusters and 7 bulk users (mines).

7.1. Towns

Stand alone reconciliation strategies were developed for 10 towns or town clusters. The towns and villages included in each of the town clusters are illustrated in **Table 7.1.1**.

Table 7.1.1: Town cluster strategies

District Municipality	Local Municipality	Town	Strategies
			Town Cluster
Frances Baard	Dikgatlong	Koopmansfontein	Delportshoop
		Delportshoop&Longlands	
		Vaal Gamagara	
John Taolo Gaetsewe	Gamagara	Kathu	Kathu
		Olifantshoek	Olifantshoek
		Deben	Deben
	Kgalagadi CB DM	Hotazel	Hotazel
	Joe Morolong	Heuningvlei	No Strategy
	Ga-Segonyana	Kuruman&Wrenchville	Kuruman
		Bankhara-Budulong	
		Magojaneng&Seoding	
		Mapoteng	
		Mothibistad	
		Seven Miles	
Siyanda	Kgatelopele	Danielskuil	Danielskuil
		Lime Acres	No Strategy
	Tsantsabane	Postmasburg	Postmasburg
		Jenhaven	
		Metsimatale/Groenwater	
		Skeyfontein	
Pixley ka Seme	Siyancuma	Campbell	Campbell
		Griekwastad	Griekwastad
		Schmidsdrift	No Strategy

Stand alone strategies were not developed for the following towns:

- Heuningvlei: Heuningvlei has been investigated in significant detail in a separate study i.e. Feasibility Study of the Heuningvlei Water Services Supply Scheme (Joe Morlolong Local Municipality, 2009). At the time of the study a decision had also already been made that additional groundwater resources will be developed to supply Heuningvlei with the additional water required.

- Lime Acres: The demographic, water requirement projection and WC/WDM information derived as part of the project was used in the development of the water master plan. Since Lime Acres is privately owned (owned by PPC and De Beers), a standalone reconciliation strategy document was not developed for the town.

- Schmitsdrift: Schmitsdrif is located next to the Vaal River. At the time of the study a decision was made the additional water required will also be sourced directly from the Vaal River and not from the Vaal Gamagara Scheme.

The reconciliation strategy documents are structured as follows:

- Section 1: Introduction
- Section 2: Demography
- Section 3: Water Requirements
- Section 4: Water supply infrastructure
- Section 5: Water conservation and water demand management
- Section 6: Sanitation
- Section 7: Water resources
- Section 8: Water balance
- Section 9: Reconciliation options to meet shortages
- Section 10: Conclusions and strategy recommendations

The reader is referred to *REPORT 245460/05 RECONCILIATION STRATEGIES* for the stand alone reconciliation strategy documents for each of the town or town clusters, where the details of each of the sections are presented.

7.2. Mines

Stand alone reconciliation strategies were developed for 7 large mines which have existing or future water requirement from the VGG scheme of 0.5m^3/a or more. The mines for which strategies were developed included:

- Amari Resources Mine
- Assmang, Black Rock Mine
- Assmang, Khumani Mine
- De Beers, Finsch Mine
- Kalagadi Manganese Mine
- Tshipi e Ntle Manganese Mine
- United Manganese of the Kalahari Mine

Stand alone strategies were not developed for the following mines:

- Kumba Iron Ore Limited (KIOLTD) and Assmang, Beeshoek Mine. Kumba and Beeshoek are large mines with high water requirements but all their water is obtained from groundwater.
- Mines with water requirements of less than 0.5 million m^3/a from the VGG scheme were not considered for stand alone water reconciliation strategies.

The reconciliation strategy documents are structured as follows:

- Section 1: Introduction
- Section 2: Water Requirements
- Section 3: Water supply infrastructure
- Section 3: Water conservation and water demand management
- Section 5: Water resources
- Section 6: Water balance

- Section 7: Reconciliation options to meet shortages
- Section 8: Conclusions and strategy recommendations

The reader is referred to *REPORT 245460/05 RECONCILIATION STRATEGIES* for the stand alone reconciliation strategy documents, where the details of each of the sections are presented.

One of the key issues mentioned in the reconciliation strategy for Finsch mine is the potential groundwater availability from Bonza Quarry which is located at Finsch mine. According to Finsch mine there is an adjacent quarry at PPC mine with excess water that can potentially be used to augment the water in Bonza Quarry. Between 2001 and 2005 the abstraction by Finsch mine from Bonza Quarry varied between 1.2 mil m^3/a to 3.0 mil m^3/a while water was pumped from the PPC quarry into Bonza quarry. Finsch mince has indicated that Sedibeng Water has since requested them to stop using excess groundwater from PPC. It is recommended to determine the current potential of the Bonza Quarry with supply from PPC in a separate follow-up study. If the water volume required by Finsch mine from the VGG scheme can be lowered by between 1.0 mil m^3/a to 3.0 mil m^3/a it will assist Sedibeng Water to supply other water users in the period before a new/upgraded VGG scheme comes into operation.

8. EXISTING SYSTEM CAPACITY AND COMPARISON WITH THE CURRENT DEMAND

For the purposes of evaluating the sufficiency of the existing Vaal Gamagara scheme the current capacity is compared with the current (so-called 2010) demand.

Pumped supply to Clifton reservoir

The refurbished pump sets delivering water to Clifton reservoir should according to the original design supply at a rate of 420 ℓ/s. The supply rates obtained in the model for Delportshoop and Kneukel pump stations closely resemble the design rate but not for Trewill pump station which, according to the modelled results, supply at a maximum rate of 385 ℓ/s when all three pumps are running. This has been confirmed by actual measurements. The result is that the pumped supply to Clifton reservoir after the refurbishment of the pumps has been completed will be in the order of 33.2 Mℓ/d if the pumps run 24 hours per day. This represents a maximum supply of approximately 12.1 million m³ per year that can be supplied up to Clifton reservoir, or in the existing situation, up to where the Beeshoek supply occurs.

The total anticipated required current peak day supply for the Vaal Gamagara scheme is 56.3 Mℓ/d. Of this volume 12.9 Mℓ/d is abstracted between Delportshoop and Clifton reservoir and 43.5 Mℓ/d is required downstream of Clifton reservoir. Of the 12.9 Mℓ/d that is required between Delportshoop and Clifton reservoir 9.9 Mℓ/d is supplied to Finsch mine and Lime Acres. This implies that the net supply to Clifton reservoir during the 2010 peak day demand will be 20.3 Mℓ/d. That is if the refurbished pumps run at 24 hours per day, and in the case of Trewill pump station all three pumps.

Supply to Gloucester reservoir

The difference between what is required downstream of Clifton reservoir and the net supply rate to Clifton under peak supply conditions as determined above is 23.2 Mℓ/d. If only currently available sources are to be considered this deficit needs to be made up by the supply from Beeshoek and Sishen. Of the required supply rate of 43.5 Mℓ/d downstream of Clifton reservoir 37.5 Mℓ/d is required downstream of Gloucester reservoir.

The optimal utilization of the existing system capacity and sources requires a supply in the order of 37.5 Mℓ/d (1 562 m³/h) from Beeshoek under peak demand periods. This results in an available net supply of 32.0 Mℓ/d from Gloucester, for which the hydraulic capacity of the existing system is sufficient.

Supply from Gloucester to Black Rock

The required supply downstream of Gloucester under anticipated peak demand conditions is 37.5 Mℓ/d. The difference between this required rate and the net supply rate to the reservoir under peak supply conditions as determined above is therefore 6.8 Mℓ/d (283 m^3/h). If only currently available sources are to be considered this deficit needs to be made up by the supply from Sishen.

According to the modelled results the section of the scheme between Gloucester and Kathu pump station can supply 60 Mℓ/d under gravity, which is more than sufficient. The maximum that can be supplied further north under gravity is 6.7 Mℓ/d before the delivery head drops below 20 m. The required supply on this section is 8.5 Mℓ/d, which implies a deficit of 1.8 Mℓ/d under gravity supply. If the Kathu pump station is in operation with the pumps having similar characteristics than before it can provide the required supply rate of 8.5 Mℓ/d with at least one pump operating 18 hours per day during peak day. The flow velocity in the feeder pipe northwards, however, reaches values up to 1.9 m/s.

Effect of the short term (2011 to 2015) demand scenario and potential measures

As has been indicated above the pumped sector between Delportshoop and Clifton is running at capacity. To accommodate any growth in demand immediate measures will therefore have to be taken. Since the development of groundwater sources will probably not be achieved in time to alleviate the situation the short term solution will depend on the potential to utilize and accommodate the water produce by mines in their dewatering programmes.

The anticipated 2015 demand is approximately double that of the 2010 demand. If a linear growth in demand is assumed the 2011 peak demand will be 60 Mℓ/d growing to a peak demand of 106.7 Mℓ/d in 2015.The anticipated volume of water to potentially be discharged into the VGG scheme by Sishen and Kolomela mines grows from 49 Mℓ/d in 2011 to 75 Mℓ/d in 2015.

Given the existing scheme's pumping capacity of 33.2 Mℓ/d it thus appears that theoretically the short term demand can be served with a combination of the mines and the Vaal river source, the total supply being 82.2 Mℓ/d and 108.2 Mℓ/d in 2011 and 2015 respectively. This is valid for the sector between Delportshoop and Kathu pump station, given that the modifications as described below be made, but the capacity of the sector north of Kathu pump station is projected to be insufficient to provide the supply in 2012.

In order to utilize the water provided by the mines as effectively as possible the following modification referred to above are required:

- The Beeshoek Phase 1 pumps must be upgraded by installing the original designed for additional stages to allow pumping from Beeshoek pump station to Clifton reservoir. According to the pump curves this should result in a pump rate of 700 kℓ/h or 16.8 Mℓ/d;
- The Kathu pump station must be re-commissioned to boost the supply northwards;
- Additional pumps must be installed at Kathu pump station to allow pumping southwards up to the Khumani off-take. The detail of this installation needs to be investigated, but an initial evaluation indicates that a pump rate of 1 900 kℓ/h (45.6 Mℓ/d) at a head of 140 m can be achieved;
- The detail arrangement and controls to be able to accommodate operating of the system with the above modifications need to be established;
- In order to provide a backup for the mine water source the potential for the development of the identified ground water sources should be considered.

A possible scenario for supply under the 2015 demand conditions given the above modifications is provided in **Annexure E**. The results can be summarized as follows:

- The hydraulic capacity of the section of the VGG scheme north of the Kathu booster pump station is insufficient to convey the 2015 demand and would require upgrading over its full length if the full demand is to be delivered from a southern source. If, however, the SD4 groundwater source could be developed to supply close to its indicated potential of 15.6 Mℓ/d under peak demand conditions, no upgrading of the northern sector is required before 2015. In this case the supply from SD4 should be directly into the scheme's pipe system in the vicinity of the Hotazel off-take. To reduce the head at which the supply must occur the supply point can be down stream of the PRV to the north of the Hotazel off-take but with a by-pass and check valve on the PRV to allow supply southwards during peak demand conditions.

8.1. Costing of Source Development Options

An indicative in **Section 5** the source development cost for target areas SD1 to SD4 is estimated to be R 34 422 000.00 (refer to **Table 8.1.1**) which comprises of the development of 66 proposed boreholes with an estimated sustainable yield of 20.3 million m³/a.

The 66 borehole that where identified are conceptual holes and this will have to be confirmed by means of the detailed source development steps as indicated in **Section 5**.

Table 8.1.1: Groundwater Source Development Cost

Groundwater Source	Yield (m m³/a)	Source Development Cost	EIA, Public Participation & Licence Applications	No. of Holes	Time to Complete Development
SD1 - Finsch & Lime Acres	4.5	R 7 252 000.00	R 850 000.00	15	12
SD2 - Postmasburg	5.1	R 7 420 000.00	R 850 000.00	17	12
SD3 - Kathu	5.0	R 8 400 000.00	R 800 000.00	16	18
SD4 - Hotazel	5.7	R 7 980 000.00	R 870 000.00	18	18
TOTAL	**20.3**	**R 31 052 000.00**	**R 3 370 000.00**	**66**	
GRAND TOTAL		**R 34 422 000.00**			

A first order cost estimate was done to equip the proposed boreholes and associated pipeline systems to convey the groundwater to the recommended delivery point as indicated in Section 8 above. Since the groundwater sources are conceptual the following assumptions were made:

- Servitudes and the buying out of land were excluded from the calculations.
- Co-ordinates of the concept borehole were used to determine pipe lengths.
- 60% of all excavations are to be in hard rock.
- The yield of all boreholes in a specific area is equal.
- A lump sum amount to equip boreholes with electricity and a pump system was used.
- No purification is needed for the groundwater to be utilized.

From **Table 8.1.2** it is evident that the cost to utilize the groundwater resource for the 2015 demand scenario is in the order of R 214 603 266.00. If an agreement with the mine group in the Kathu area can be reach to supply a constant volume of dewatering, the need to develop SD3 can be reconsider.

The advantage that will exist if the proposed groundwater sources is developed and owned by Sedibeng water was not investigated.

Table 8.1.2: Cost to Develop and Equip Groundwater Sources

Component	Cost
Finsch - SD 1	
Equipping boreholes 17 holes @ R 100 000/hole Pipelines (Excavation & Pipe installation)	R 1 700 000.00 R 35 477 900.00
Sub Total 1: SD 1	**R 37 177 900.00**
Postmasburg - SD 2	
Equipping boreholes 17 holes @ R 100 000/hole Pipelines (Excavation & Pipe installation)	R 1 700 000.00 R 30 288 540.00
Sub Total 2: SD 2	**R 31 988 540.00**
Kathu - SD 3	
Equipping boreholes 20 holes @ R 100 000/hole Pipelines (Excavation & Pipe installation)	R 2 000 000.00 R 28 341 220.00
Sub Total 3: SD 3	**R 30 341 220.00**
Hotazel - SD 4	
Equipping boreholes 19 holes @ R 100 000/hole Pipelines (Excavation & Pipe installation)	R 1 900 000.00 R 34 074 200.00
Sub Total 4: SD 4	**R 35 974 200.00**
Sub-Total A	***R 135 481 860.00***
Preliminary and General (20% of Sub-Total A)	R 27 096 372.00
Sub-Total B	***R 162 578 232.00***
Contingencies (20% of Sub-Total B)	R 32 515 646.00
Sub-Total C	***R 195 093 878.00***
Planning Design and Supervision (10% of Sub-Total C)	R 19 509 388.00
Total Project Cost (Excluding VAT)	***R 214 603 266.00***

The total cost in developing and equipping the additional groundwater source amount to R 249 025 266.00 (R 214 603 266.00 plus R 34 422 000.00).

The study team did not investigated the long terms benefit or the reduction in size of the proposed new scheme by developing these groundwater sources and recommend that this is investigated.

9. PLANNING FOR FUTURE (2030) DEMAND

For planning purposes a 20 year design horizon (2010 to 2030) was used. The results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand. A condition assessment of the existing pipelines also confirmed the need for refurbishment.

It was assumed that the scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater sources to be developed as a short to medium term measure as well as de-watering water from mining operations would therefore only provide relief in terms of operational and water cost. This assumption was made due the difficulty in obtaining agreements from the mining houses in supplying a constant yield of de-watering water and the uncertainties/variables regarding the additional groundwater sources to be developed.

The possibility to separate the supply of potable and process water was also considered. It is, however, evident that both the anticipated potable and process water demand will exceed the existing system capacity up to Clifton reservoir. The current condition and high cost of refurbishing the existing system could also exclude the possibility to utilize it at all.

Planning was performed for three options:

- Option 1: Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.
- Option 2: Add capacity to the existing scheme to supply the anticipated 2030 demand by an additional pipeline.
- Option 3: Replace the existing scheme with a double pipeline with sufficient capacity to supply the anticipated 2030 demand.

For all three options the basis was that pumping occurs from Delportshoop to Clifton and that the rest of the scheme is supplied from there under gravity with no booster pumps required.

In all three options it was assumed that over the pumped sector the scheme would operate at the same pressures than the existing scheme. For the sector supplied under gravity aspects such as pressure control need to be addressed as part of optimised detailed design and costing. Proposed pressure control measures are described further herein under the paragraph dealing with operation of the proposed scheme.

In all three options it is required that Gloucester is supplied from Clifton at uncontrolled pressure. Therefore, since the Beeshoek pumps cannot deliver at Clifton pressure it is proposed for all three options that the existing pipeline from the Beeshoek connection to Gloucester be refurbished and utilized as a dedicated pump line for the Beeshoek pumps.

9.1. Planning criteria

The major objectives pursued in the evaluation and planning of the Vaal Gamagara supply system can be summarised as follows:

- Conformity with operational requirements and criteria adopted for this study
- Optimal use of existing facilities with excess capacity
- Optimisation with regards to capital -, maintenance - and operational cost

The specific criteria pertaining to the hydraulic evaluation and optimal planning of the system are described below.

9.1.1. Water demand and peak factors

Peak factors

In evaluating the existing system performance peaks in the supply from the system were based on actual measured values. However, for the purposes of planning future extensions to the system it was assumed that at least the large users will provide their own storage to deal with hourly peaks and that supply to these users will not exceed peak day demand. For this purpose the assumption was made that flow to large users will be restricted to not more than 1.5 x AADD. This factor was applied to both residential consumers, such as towns, and large industrial consumers, such as mines.

Water demand patterns

Actual measurements of typical water use patterns were available for some consumers. These patterns, as well as measured patterns for similar users obtained from other sources and patterns constructed from information provided by large users, were used to establish typical peak week demand patterns for different user types. For the large mines the observed consumption pattern indicates that allowance must be made for the peak day demand being required over prolonged periods during the peak months. This in essence implies that planning for the future capacity of the Vaal Gamagara scheme must allow for constant delivery at 1.5 x AADD of the total demand.

9.1.2. Operational criteria

Maximum and minimum pressures

The maximum pressures that can be allowed in the existing system depend on the pipe class and current condition. Information on the actual pipe class for the different pipe sections on the scheme was not available and it was assumed that future pressures in the existing pipes should be limited to the current maximum pressures occurring. In order to allow for cross connection between existing and future components this implies that pressures in future sections should be in accordance with existing maximum pressures.

In general the planning was done to ensure a minimum pressure in the supply system of 40 m. However, a supply pressure of 20 m at a consumer reservoir site was considered acceptable.

Flow velocities

Flow velocities must be limited in order to protect pipeline coatings and reduce the effects of water hammer. The preferred maximum allowed is 1.8 m/s, but an absolute maximum of 2.2 m/s is acceptable where only intermittent peak flows occur.

Pump stations

Pump stations should always have one standby pump available.

The planning of the pump, pipe line and storage capacity was done by allowing for not more than 16 out of 24 hour pumping time under peak day supply conditions.

Redundancy

In general it is ideal for bulk supply systems to have redundancy in the form of parallel pipes and separated reservoirs. To a large extent this is not the case for the Existing Vaal Gamagara scheme. The required upgrading of the scheme provides the opportunity to address this aspect.

Ease of operation and maintenance

In order to minimize additional load on operational and maintenance requirements on the upgraded scheme it was attempted to as far as possible propose new components at existing corresponding locations, therefore at current positions of reservoirs and pump stations and along current pipeline routes.

It is proposed and planning was done accordingly, that operation of pumps is automated as far as possible.

9.1.3. Reservoir supply rates and storage capacities

The required storage capacity in the Vaal Gamagara system should ideally be determined in conjunction with the planning of storage capacity of the large water users and consideration of the risks related to failure of the various system components and power supply. Since the proposed supply capacity of the scheme is equal to the maximum supply rate, which is proposed to be limited to 1.5 x AADD, reservoir storage capacity is in theory not required for balancing purposes but only for emergency supply. However, since the principle that pumps should run only 16 hours per day is proposed, storage capacity of at least 8 hours peak day demand will be required for balancing purposes.

The current combined storage volume at Clifton and Gloucester reservoirs is 33.75 Ml, which represents approximately 24 hours of the maximum supply capacity of the scheme. If this principle is adhered to the reservoir storage in the scheme has to be planned with sufficient capacity to provide 24 hours of peak day demand.

9.1.4. Economic optimisation and cost functions

All the strategic and technical alternatives studied for this report were compared on mainly economic grounds, with a view to establishing a "master plan" which will result in the lowest present value of capital works, operations and maintenance.

The cost functions used for cost estimates, cost comparisons and economic optimisation, are presented in *REPORT 245460/06 COSTING AND ENGINEERING ECONOMIC ANALYSES.*

9.2. Future components

The future components of the VGG scheme that need to be established under the three options are listed in **Table 9.2.1** to **Table 9.2.3**

Table 9.2.1: Existing and proposed Pipelines

Sector	Length (km)	Existing Diameter (mm)	Option 1 Diameter (mm)	Option 2 Diameter (mm)	Option 3 Diameter (mm)
Delportshoop to Kneukel	20.00	687	1 700	1 500	2 x 1 300
Kneukel to Trewill	48.70	687	1 600	1 500	2 x 1 200
Trewill to Clifton	29.45	508 & 355	1 600	1 500	2 x 1 200
Clifton to Beeshoek Connection	36.60	762	1 300	1 100	2 x 1 100
Beeshoek Connection to Gloucester	23.50	660	1 200	1 100	2 x 900
Gloucester to Olifantshoek Off-Take	27.10	900	1 100	800	2 x 800
Olifantshoek Off-Take to Sishen	14.10	508	900	850	2 x 650
Sishen to Kathu Off-Take	15.90	700	900	850	2 x 650
Kathu Off-Take to Hotazel Off-Take	52.20	324	700	700	2 x 550
Hotazel Off-Take to Blackrock	14.70	305 & 220	550	500	2 x 450

Table 9.2.2: Existing and Proposed Reservoirs and Sumps

Sector	Existing Capacity (kℓ)	Option 1 Capacity (kℓ)	Option 2 Capacity (kℓ)	Option 3 Capacity (kℓ)
Delportshoop	10 000	10 000	10 000	10 000
Kneukel	900	7 500	7 500	7 500
Trewill	900	7 500	7 500	7 500
Clifton	27 000	210 000	210 000	105 000
Beeshoek	6 750	6 750	6 750	6 750
Gloucester	6 750	60 000	60 000	30 000
Kathu	4 400	4 400	4 400	4 400
Mamatwane	4 560	4 560	4 560	4 560
Blackrock	2 500	20 000	20 000	10 000

Table 9.2.3: Existing and Proposed Pump Stations

Pump Station	Existing duty point		Option 1 duty point		Option 2 duty point		Option 3 duty point	
	Flow (ℓ/s)	Head (m)	Flow (ℓ/s)	Head (m)	Flow (ℓ/s)	Head (m)	Flow (ℓ/s)	Head (m)
Delportshoop	471	284	2929	258	2929	270	2929	258.5
Kneukel	442	271	2856	240.5	2856	240	2856	248.5
Trewill	390	234	2856	136	2856	160	2856	141

9.3. Storage capacity

Since the future scheme is planned to supply peak day demand with pumps running not more than 16 hours out of 24, the theoretical total balancing storage required is 8 hours of peak day demand. The total storage required will be dependent on the time required to repair component failure. The current average down time during component failures on the scheme is in the order of 48 hours. If it is assumed that in total balancing plus emergency storage of 48 hours peak day demand (equal to 72 hours AADD) is to be provided additional storage of 290 Mℓ (depending on reliance on pump sumps and smaller reservoirs) must be established in the VGG scheme.

The logical location for the bulk of this storage is at the highest point, which is the Clifton reservoir site. At least two sites, however, require additional storage. The one is at Gloucester where volume should be provided for receiving water from Beeshoek and the other is at Blackrock from which Botswana will be supplied by pumping.

It could be argued that for Option 2 and 3 where the ultimate scheme will consist of a double pipeline the added redundancy could allow the emergency storage to be reduced, probably to 50% of the volume calculated above. This was in the costing exercise applied for Option 3 but not for Option 2 due to the relatively low capacity of the existing scheme compared to the demand and the fact that during refurbishing of the existing pipeline the scheme still will be supplying through a single pipeline.

The required sizes of the pump sumps at the three main pump stations should be determined in conjunction with the design of the pumps. If it is assumed that the sump volume should be equal to at least one hour of the maximum pump rate, the additional volume that should be established at each of Kneukel and Trewill pump stations is in the order of 7.5 Mℓ.

9.4. Operation

Planning of the proposed future scheme options was done on the basis that the scheme will largely be operated in the same way than is currently the case. Over the different main sectors this can be summarized as follows:

Pumped sector Delportshoop to Clifton

The three main pump stations are to be controlled by the levels in the sumps and reservoir that they deliver to. It is preferred that the control is automatic. The sumps and reservoir are to be top-fed and bottom-outlet. For Options 2 and 3 the parallel pipes are to be interlinked.

Gravity sector Clifton to Gloucester

Clifton reservoir will supply Gloucester reservoir under gravity without any pressure control. For all three options the existing 660 mm diameter pipeline from the Beeshoek connection to Gloucester should be refurbished and utilized as a dedicated supply pipeline to extend the Beeshoek pump station supply system to Gloucester. It should be considered if the potential for pumping from Beeshoek back to Clifton should be retained. This is not required if the system is upgraded as per the ultimate planning.

Gravity sector Gloucester to Black Rock

The northern section of the scheme will be supplied from Gloucester under gravity. The top water level of Gloucester reservoir is 1 427 m.a.s.l. This implies that if uncontrolled the static pressure in the pipeline(s) will exceed 250 m from just north of Kathu and reach more than 407 m at the lowest point on the scheme south of Black Rock.

It is proposed that pressure control is applied at least at one point on the pipeline. The location of this point or points will be determined by the pressure that can be allowed in the pipeline(s). If pressure control is to be applied at two points the current positions at Kathu pump station and north of the Hotazel off-take respectively, would be appropriate.

The static pressure in the section of pipeline between Sishen and Kathu that is currently being planned to be re-routed will be 230 m if uncontrolled. This would then also be the level at which the new Sishen pumps must operate to supply water into the VGG scheme. The pressure in this section of pipeline can be controlled, but with a static head not less than 120 m.

10. COSTING AND ENGINEERING ECONOMIC ANALYSES

The purpose of this section is to identify the most economical viable option. In order to compare for example an option with a significant capital expenditure (CAPEX) and low operation and maintenance expenditures (OPEX) with another option with a low CAPEX and significant OPEX, all costs must be converted/escalated to a common base date (Net Present Value). These costs serve as input into the calculation of the unit reference values (URV), i.e. the costs will be discounted at three values for the discount rate and the net present costs and URV's will be calculated. The option with the lowest URV will be the preferred option from an engineering economic point of view.

Costing of the various components of the identified options, including operation and maintenance costs, were based on the assumptions and measurement methodologies as described in the Guidelines for Preliminary Sizing, Costing and Engineering Economic Evaluation of Development Options prepared for the VAPS study and updated, by KV3 Engineers, for the Vaal River Eastern Sub-System and Western Highveld Region studies and recently for the Mokolo Crocodile Water Augmentation Project [67].

Cost estimates were done for the components of the proposed options. The costs of the options were escalated to a common base date, i.e. December 2010.

10.1. URV Costing & COSTING PARAMETERS

For the purposes of this study the following parameters were utilised in the engineering economic analyses:

Table 10.1.1: Costing Parameters

Description	Note / Assumption
Energy Tariff	Eskom Megaflex
Discount rate (real)	6, 8 and 10%
Annual increase in Energy Tariffs	25% compounded for initial 3 years, inflation thereafter
Construction Period	Commencement: Start 2012 Completion: End 2015
Analysis Period	45 years (from 2016 until 2060)

Table 10.1.2: Eskom Megaflex

Megaflex (300 to 600 km Transmission Zone)		
	Rate: c/kWh (incl. rural subsidy and excl. VAT)	
Rate	**Summer**	**Winter**
High	45.22	148.86
Standard	29.67	42.45
Off peak	22.28	25.05
Months per season	9	3

Energy Charge Daily Rate Allocation - Megaflex			
	Weekdays	Saturday	Sunday
High	5	0	0
Standard	11	7	0
Off Peak	8	17	24
Other Costs (R/day)	Daily charge	Monthly cost	Once Off Cost
Service & Admin charge	R 121.31		
Network Access Charge (R/kVa)		R 6.72	
Network Demand Charge (R/kVA/month)		R 12.73	
Reactive Energy Charge (R/kVaRh)		R 0.0589	
Transmission Netw Charge (R/kVA/month)		R 3.38	

10.2. Construction Values

The Construction Value was calculated as follows for the various components.

Pipelines:

The cost estimates include road crossings, excavations, bedding material, supply and installation of steel pipes, etc. Steel pipe manufacturer provided rates for the various pipe diameters, including the delivery costs to Postmasburg.

Refurbishment of Existing Pipeline

Costs associated with the refurbishment of the internal relining are based on the following:

Not included for temporary bypass arrangements, assume that a second pipeline are installed.

The relining process is done with a cement mortar lining (CMℓ). The cost estimated was done on an average pipeline diameter of 500mm throughout the length of the scheme. Variations in diameter will affect a refined budget but this was considered adequate for these cost-estimates.

Cathodic Protection (CP)

Based on the results of the various CP surveys undertaken, there is no evidence that significant refurbishment of the external coating is required. Regardless of whether the pipeline is refurbished or replaced, a single pipeline or two parallel pipelines, the cathodic protection system for the pipeline will need to be redesigned.

Isinyithi Cathodic Protection performed the cathodic protection investigation and provided amounts for the CP survey and design, as well as the installation of a cathodic protection system. The design and installation cost are estimated and included in the calculations.

Reservoirs and Sumps

The rates (R/Mℓ) provided by GLS for the reservoirs and sumps were used.

Pump Stations (Mechanical, Electrical and Civil)

The mechanical, electrical and civil costs for pump stations were calculated as a function of the power required at peak flow and were divided as follows:

Mechanical Cost	50%
Electrical Cost	20%
Civil Cost	30%

Mechanical (further breakdown of costs)

Pumps and motors:	60% of Total Mechanical Cost
Valves:	25 % of Total Mechanical Cost
Pipework:	15% of Total Mechanical Cost

The following percentages were used in the cost models as obtained from the costing and sizing guideline to compare the options on the same basis:

SUB-TOTAL A - CONSTRUCTION VALUE
Landscaping (5% of sub-total A)
Miscellaneous (10% of sub-total A)
SUB-TOTAL B
Preliminary and General (30% of Sub-total B)
SUB-TOTAL C
Contingencies (20% of Sub-total C)
SUB-TOTAL D
Planning, design and supervision fees (15% of Sub-total D)

10.3. Operation and Maintenance Costs

Annual operation and maintenance (O&M) costs are based on percentages of capital cost as laid out hereunder:

- 0,5% of the pipeline cost;
- 4% of the electrical and mechanical installation of a pump station;

- 0,25% of the capital cost of civil structures, including the civil portion of the pump stations.

Pumps and motors (major overhaul every 15 years)

- 15% of initial capital cost of pump and motor

10.4. Environmental Studies

A cost equal to 1% of the Total Project Cost has been allowed for Environmental Studies. This cost is accrued one year before the commencement of the construction project. The Environmental Services will be performed over a period of 5 years, i.e. one year in advance of construction (start 2011) up to the completion of construction (end 2015).

Once cost streams had been calculated for each component, they were discounted, along with the demand deficit curve and URV's calculated.

10.5. Escalation of Unit Rates

For the purpose of this study the rates obtained for the options were escalated (if necessary) to the base date, December 2010. The information for escalation/inflation data was received from SAFCEC.

The formula used in the Civil Engineering Industry for Contract Price Adjustment (CPA) has four coefficients which represents the proportionate values of Labour, Material, Plant and Fuel. The proportions will vary depending upon the nature of the work, whether it is plant or labour intensive for instance. For the purpose of this study the proportions were assumed as follows:

Labour	:	32.5%
Materials	:	25.0%
Plant	:	32.5%
Fuel	:	10.0%
Total		100.0%

The base date for rates utilised from previous studies is 2008. CPA Indices obtained from the South African Federation of Civil Engineering Contractors (SAFCEC) were used to calculate factors to adjust/escalate rates to the base date.

10.6. Assumptions

The costing and engineering economic analyses for this study were based on the following assumptions.

- The existing power supply at each pump station is sufficient for the proposed new installations and no upgrading is required. Since it is common to all three options it will not influence the ranking of the URV's.
- The existing access roads to pump stations and reservoir sites are adequate and provision was made for only 0,5 km access roads per reservoir and pump station site.
- No upgrading of the Abstraction Works and Water Treatment Plant at Delportshoop is required. Since it is common to all three options it will not influence the ranking of the URV's.
- Provision was made for new pump station buildings at Delportshoop, Kneukel and Trewilll.
- The booster pump facilities at Kathu and Mamatwane will be decommissioned.
- Standard pipe diameters from the manufacturers' product catalogues were used.
- It was assumed that the existing infrastructure for Option 2 will have no financial and economic implications, except the refurbishment costs.
- No provision was made for the Socio-Economic impacts of the proposed options. It was further assumed that no land will be purchased and that the existing servitudes are adequate. No allowance was made for the compensation of land owners due to the temporary loss of land.

- Only projected water requirements for segments of the Vaal Gamagara System for the years 2010, 2015 and 2030 were available. The demands for the intermediate years were linearly interpolated.

10.7. Conclusions and Recommendations

Table 10.7.1 contains a summary of the economic analyses of the options investigated and discounted at a rate of 8%.

Table 10.7.1: Summary of Economic Analyses

Description	Capital Cost	O&M Cost	Total Cost	Total Water Delivered ($m^3 \times 10^6$)	URV R/m^3
Option 1: Single Pipeline	4 784 386 870	660 567 256	5 444 954 126	289.39	18.815
Option 2: Augment Current Scheme	5 100 594 712	682 020 021	5 782 614 733	289.39	19.982
Option 3: Two Pipelines	6 223 466 992	722 931 745	6 946 398 737	289.39	24.004

- From the above it is evident that Option 1 has the lowest Unit Reference Value (URV). There are however other factors to be taken into consideration before a decision can be made on which option to implement.

- The information in **Table 10.7.1** gives preference in terms of cost but does not address any risk regarding the water supply to individual stakeholders. The way forward must take cognisance of the major consumers. By evaluating the different criteria and associated risk of each option the most suitable option which is acceptable to all major consumers will have to be selected.

- From an engineering economic point of view, Option 1 - Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand, is the recommended way forward.

11. COMPARISON OF INFRASTRUCTURE OPTIONS

Based on the premise that the ultimate Vaal Gamagara scheme should be able to supply the required demand with water extracted from the Vaal River only, three options were investigated and planned in sufficient detail to establish acceptably accurate costs. In this section the three options are discussed with respect to the main infrastructure components and related advantages and disadvantages.

In all three options the principle was maintained that the pipeline will be constructed along the exiting route and main components, such as reservoirs and pump stations be positioned at the existing locations. The system components are in all cases sized based on optimization of costs related to required supply service levels.

11.1. Proposed Infrastructure Option 1

Option 1 comprises replacing of the existing system with a single pipeline over its full length.

Advantages:

Implementation of the single pipeline option results in the optimal ratio of hydraulic capacity and pipe material. It would also imply the simplest operation.

Disadvantages:

The main disadvantage of the single pipeline option is the lack of redundancy, both in the case of component failure and maintenance procedures requiring component shut-down.

11.1.1. Electrical and Electronic Aspects Regarding Option 1 - 2030

The worst case as far as the electrical supply is concerned, is "For peak day 16 hours" with Botswana included. The flows and electrical input power requirements calculated with an overall mechanical and electrical efficiency of 72% are then:

- Delportshoop – Kneukel: 2 064 ℓ/s and 7 987kW
- Kneukel – Trewill: 2 032 ℓ/s and 7 503kW

- Trewill – Clifton: 2 022 ℓ/s and 6 447 kW

The present electrical systems at the three pump stations are not adequate to cater for the requirements listed above.

The present installations are as follows:

Delportshoop:

2 x 3000kVA transformers (1 duty, 1 stand-by) fed at 11kV from Eskom. This feeds the high lift pump station (3 x 760kW motors at 6,6kV), the Abstraction Works (3 x 90kW motors at 400V) as well as the Purification Plant, the Workshop, auxiliary power and the staff village via minisubs on a 6,6kV cable distribution system.

Kneukel

2 x 2 500kVA transformers (1 duty, 1 stand-by) fed at 11kV from Eskom. This feeds the pumps (3 x 760kW at 6,6kV), and staff houses and auxiliary power via a minisub.

Trewill

2 x 2 500kVA transformers (1 duty, 1 stand-by) fed at 22kV from Eskom. This feeds the pumps (3 x 760kW at 6,6kV), and staff houses and auxiliary power via a minisub.

The 2030 installations require the following:

The total new power requirements for Option 1, i.e. replacing the existing scheme with additional pumps at the Abstraction Works, extensions to the Purification Works and adding new pump stations will then be:

Delportshoop

High Lift Pumps	8 000kVA
Abstraction Works	600kVA
Purification Works	500kVA
Workshop	100kVA
Housing, etc.	100kVA
Total	**9 300kVA**

It is recommended that a new infeed substation be built, equipped with 2 x 10MVA transformers, 11kV/6,6kV and that new 6,6kV switchgear be installed in the new pump station building for the new pumpsets. The existing switchgear of the supplies to the minisubs, feeding the Abstraction Works, Purification Plant, Workshop and Housing, can then be swung over to the new transformers.

Kneukel

High Lift Pumps: 7 500kVA

No extra power will be required for the housing and auxiliary supplies.

It is recommended that a new infeed substation be built, equipped with 2 x 10MVA transformers, 11kV/6,6kV and that new 6,6kV switchgear be installed in the new pump station building for the new pumpsets. The switchgear of the supplies to the minisubs feeding the housing and auxiliaries, can then be swung over to the new transformers.

Trewill

High Lift Pumps: 7 500kVA

No extra power will be required for the housing and auxiliary supplies.

It is recommended that a new infeed substation be built, equipped with 2 x 10MVA transformers, 22kV/6,6kV and that new 6,6kV switchgear be installed in the new pump station building for the new pumpsets. The switchgear of the supplies to the minisubs feeding the housing and auxiliaries, can then be swung over to the new transformers.

Regarding the adequacy of supply, it must be noted that Delportshoop and Kneukel are fed from 11kV Eskom lines and Trewil from a 22kV Eskom line, and the final selection of pump sizes and starting methods should be discussed with Eskom at the detail design stage to ascertain whether the inrush current of the pumpsets and the voltage-drops caused by motor starting are within the capacity of the power lines. However, soft starters or variable speed drives are recommended for the pumpsets.

11.1.2. Hydraulic Aspects

Hydraulically the new scheme is proposed to be operated largely similar to the existing scheme.

Over the pumped section to Clifton reservoir the pump head is close to or the same as is currently the case.

Over the section from Clifton reservoir to Gloucester reservoir it is proposed that the new scheme is operated at Clifton level to maximise the potential flow rate under gravity. This implies that no pressure reduction will be applied to accommodate the Beeshoek pumps operating head. It is rather proposed that the existing pipeline from the Beeshoek connection to Gloucester be refurbished and applied as a dedicated feed line for the Beeshoek pumps.

Downstream of Gloucester reservoir pressure reduction will be required at one or more positions to avoid excessive static heads. The exact positions should be determined in the optimized detail design. A specific in requirement in this respect, though, is that the pressure directly upstream of Sishen should not be reduced below 120m.

11.1.3. Operation and Control

As all three options include the laying of a new pipeline from Delportshoop to Clifton, it is proposed that a fibre-optic cable be installed along the new pipeline route (as was done in the case of recent similar projects, such as VRESAP and MCWAP) to provide reliable communications between all the pump stations, reservoirs and cathodic protection stations with the Control Room at Delportshoop.

It is envisaged that the new pump stations will be equipped with programmable logic controllers (PLCs) and Human Machine Interface (HMI) panels, as well as networked instrumentation systems, and these systems can be easily integrated via the fibre-optic cable into an overall automation system, providing control and monitoring from not only the Control Room, but at all stations. Thus pumps can be started and stopped by using the system parameters, without operator intervention. The fibre-optic cable can also be used for the security system as well as for speech communication between stations.

All existing telemetry stations from Delportshoop to Clifton can be modified to operate over the fibre-optic cable and the existing radio network can be used for the other stations as well as to act as a back-up with limited functions for the three pump stations at Delportshoop, Kneukel and Trewill.

The final Operation and Control philosophy can only be developed at the final design stage, but it should provide for a simple, yet reliable control system which is robust enough to ensure that the scheme can be operated within its design parameters, such as pressures and flows.

A PLC should be utilised at each pump station to control the pumpsets and should communicate via the fibre optic link with PLCs at other pump stations and reservoirs/storage tanks, as well as with the control Room at Delportshoop. The PLCs at reservoirs/storage tanks should monitor flows and levels at these sites and should also control inlet and outlet valves as necessary. This will allow easy control of the levels and will prevent over-filling and over-drawing of the reservoirs and storage tanks.

The control system should also cater for local and remote control modes of operation to facilitate maintenance, testing and operating in manual or automatic modes.

11.2. Proposed Infrastructure Option 2

Option 2 comprises supplementing the existing system with a single pipeline over its full length.

Advantages:

Implementation of the additional pipeline results in increased redundancy, both in the case of component failure and maintenance procedures requiring component shut-down.

Disadvantages:

The disadvantage of the additional pipeline option is the requirement that the existing pipeline will have to be refurbished. When this occurs the probability is high that the demand will already be at a level where the new pipeline could not provide sufficient supply and under-supply will occur.

11.2.1. Electrical and Electronic Aspects Regarding Option 2 - 2030

As Option 2 and 3 are identical from an electrical point of view, they will be considered on the same basis, i.e. Add additional pumping capacity and re-use existing pump stations.

As the existing pump stations will remain in operation, it is necessary to calculate the extra flow and power required to reach the target flow.

Comparing the required power for Option 1 and the added power requirements for Options 2 and 3, it can be seen that a new infeed substation will be required at all three sites anyway and it is recommended that a new substation such as required in Option 1 be erected at the three sites respectively. This is further substantiated by the fact that the existing infeed transformers were manufactured in 1972 already, which plays a large part in the security of supply when a risk analysis is performed.

In the case of Options 2 and 3 it will be required to replace all existing 6,6kV motors, as these are of the slip-ring type and requires a lot of maintenance on the brush-gear. In addition, the starter panels for the motors need to be replaced, as these are resistance starters, which are not suitable for starting squirrel-cage motors. It is recommended that new MV soft-starters be installed for the new motors.

11.2.2. Hydraulic Aspects

Refer to Section 11.2.2

11.2.3. Operation and Control

Refer to Section 11.2.3

11.3. Proposed Infrastructure Options 3

Option 3 comprises replacing the existing system with two identical pipelines over its full length.

Advantages:

Implementation of the two new pipelines results in increased redundancy, both in the case of component failure and maintenance procedures requiring component shut-down. This could also result in the required emergency storage being substantially reduced.

Disadvantages:

The disadvantage of the two new pipelines option is that the ratio of hydraulic capacity to pipe material is not as good as for a single new pipeline, resulting in a more expensive solution.

11.3.1. Electrical and Electronic Aspects Regarding Option 3 - 2030

Refer to Section 11.3.1

11.3.2. Hydraulic Aspects

Refer to Section 11.4.2

11.3.3. Operation and Control

Refer to Section 11.2.3

11.4. Cost Comparison of Infrastructure Options

The estimated costs of the three options are set out in the **Table 11.4.1**.

Table 11.4.1: Cost Comparison of 2030 Options

Component (Used for URV Calculations)	Option 1 - Single pipeline system	Option 2 - Augment current scheme	Option 3 - Double pipeline system
Pump Stations:			
Delportshoop	101 707 918	103 490 108	101 729 540
Kneukel	93 934 981	95 061 195	95 463 503
Trewill	65 407 855	67 458 527	66 430 130
Sub Total 1: Pumpstations	**261 050 754**	**266 009 830**	**263 623 173**
Rising Mains:			
Delportshoop to Kneukel	333 861 598	313 582 284	450 106 062
Kneukel to Trewill	671 634 333	714 859 904	915 315 608
Trewill to Clifton	371 527 593	419 813 281	559 215 945
Sub Total 2: Rising Mains	**1 377 023 524**	**1 448 255 469**	**1 924 637 615**
Gravity Mains:			
Clifton to Beeshoek Connection	333 426 888	317 387 089	447 961 918
Beeshoek Connection to Gloucester	183 683 366	202 655 542	256 727 984
Gloucester to Khumani Off-Take	186 831 403	161 003 896	242 261 459
Khumani Off-Take to Kathu Off-Take	147 489 630	180 119 969	199 980 680
Kathu Off-Take to Hotazel Off-Take	197 915 043	273 731 553	343 140 588
Hotazel Off-Take to Blackrock	49 402 657	85 730 728	76 892 640
Sub Total 3: Gravity Mains	**1 098 748 987**	**1 220 628 777**	**1 566 965 269**
Reservoirs and Sumps:			
Delportshoop Sump	8 325 000	8 325 000	8 325 000
Kneukel Sump	8 325 000	8 325 000	8 325 000
Trewill Sump	8 325 000	8 325 000	8 325 000
Clifton Reservoir	168 000 000	168 000 000	84 000 000
Gloucester Reservoir	48 000 000	48 000 000	24 000 000
Blackrock Reservoir	17 600 000	17 600 000	8 800 000
Sub Total 4: Reservoirs and Sumps	**258 575 000**	**258 575 000**	**141 775 000**
Sub-Total A	***2 995 398 265***	***3 193 469 076***	***3 897 001 057***
Landscaping and EIA Remediation (5% of Sub-Total A)	149 769 913	159 673 454	194 850 053
Miscellaneous (10% of Sub-Total A)	299 539 827	319 346 908	389 700 106
Sub-Total B	***3 444 708 005***	***3 672 489 437***	***4 481 551 216***
Preliminary and General (30% of Sub-Total B)	1 033 412 401	1 101 746 831	1 344 465 365
Sub-Total C	***4 478 120 405***	***4 774 236 268***	***5 826 016 581***
Contingencies (20% of Sub-Total C)	895 624 081	954 847 254	1 165 203 316
Sub-Total D	***5 373 744 486***	***5 729 083 522***	***6 991 219 897***

Component (Used for URV Calculations)	Option 1 - Single pipeline system	Option 2 - Augment current scheme	Option 3 - Double pipeline system
Planning Design and Supervision (15% of Sub-Total D)	806 061 673	859 362 528	1 048 682 985
Environmental Services/Studies	53 737 444	57 290 835	69 912 199
Sub-Total E	***6 233 543 603***	***6 645 736 885***	***8 109 815 081***
Components Simialar for Options (Not included in URV's):			
Upgrading of substations at Delportshoop, Kneukel and Trewil: 2 x 10MVA transformers each	12 000 000	12 000 000	12 000 000
6,6kV switchgear at Delportshoop, Kneukel and Trewil	630 000	630 000	630 000
Abstraction pumps at Delportshoop with motor control panel	3 750 000	3 750 000	3 750 000
Pumps, starters and PLC/HMI equipment at Delportshoop, Kneukel and Trewil	42 500 000	42 500 000	42 500 000
SCADA/Telemetry equipment	1 000 000	1 000 000	1 000 000
Fibre-optic cable laid with pipeline	7 500 000	7 500 000	7 500 000
Electrical/mechanical work required for the extension of the Purification works	445 550 000	445 550 000	445 550 000
Refurbishment of Olifantshoek Gravity Main	33 750 000	33 750 000	33 750 000
Gravity Main from Blackrock to Botswana border	385 000 000	385 000 000	385 000 000
Sub-Total E	***931 680 000***	***931 680 000***	***931 680 000***
Total Project Cost (Excluding VAT)	**7 165 223 603**	**7 577 416 885**	**9 041 495 081**

12. PREFERRED OPTION AND PHASING OF IMPLEMENTATION

As can be seen in the previous section the option that should be the cheapest to implement is Option 1, thus replacing the existing scheme with a single pipeline and associa6ted components. The second cheapest option is that of installing an additional pipeline and associated components and refurbishing the existing system. However, the probability of under-supply due to the rapid anticipated growth in demand when implementing this option probably rules out its implementation. The most expensive option, namely that of the installation of a new dual system provides significantly more redundancy than the single system. In addition the implementation of groundwater sources on a permanent basis could be viable in any of the three options. In order to evaluate the most viable scheme taking all these factors into consideration it could be considered to perform an overall risk analysis in conjunction with the large consumers, incorporating their infrastructure component characteristics and consequences of failure of components of the scheme.

12.1. Phasing of Implementation

Due to the anticipated rapid growth of the demand over the entire length of the VGG scheme and current lack of spare capacity in large sections it is evident that the proposed upgrading of all components should proceed as soon as possible. However, as discussed in previous sections the development of groundwater sources could drastically influence the urgency of upgrading of certain sections. The most prominent of these cases are:

- As indicated the pumped sector from Delportshoop to Clifton reservoir is under peak demand conditions already running at full capacity with 24 hour operating time, therefore at very high risk of failure. The high demand from Finsch mine on this sector and the anticipated rapid growth of this demand plays a major role in this situation. This sector therefore needs to be upgraded as a matter of urgency or as alternative the potential groundwater source from the mine dewatering program as well as new sources should be developed.

- The sector of the scheme northwards of Kathu is currently operating close to capacity and will have to be upgraded to meet the anticipated 2015 demand. As indicated the alternative is to develop the potential groundwater source near Hotazel to supply directly into the scheme

13. CONCLUSION

Key Findings

The key findings made through this study are summarised below.

- The total water currently used from the Vaal Gamagara Scheme is 13.7 million m³/a, which is projected to increase substantially to 40.06 million m³/a by 2030. The interim water demand projections for 2015 are 25.9 million m³/a.
- The water use currently supplied from ground water is 36.7 million m³/a and is currently projected to increase to 46.0 million m³/a by 2030
- The mining sector currently utilises the most water (63.5%) of the Vaal Gamagara Scheme, whereas the local authorities and other water users currently utilise 14.7% and 21.8% of the total scheme's water use respectively.
- Based on the resource potential of resource groupings and shortfalls in the current capacity of the VGG pipeline scheme four, large scale source development target areas were identified.
- The targeted water supply volumes and conceptual production boreholes for the source development target areas are:
  - SD1 15 boreholes 4.5 million m³ /a to supply Finsch Mine
  - SD2 17 boreholes 5.1 million m³ /a to augment VGG Pipeline Scheme
  - SD3 16 boreholes 5.0 million m³ /a for short term supply to Kathu
  - SD4 18 boreholes 5.7 million m³ /a to augment VGG Pipeline Scheme
- The original Vaal Gamagara Scheme was constructed during 1968 and extended in 1976 and therefore the majority of the assets are therefore approximately 35 years old and older. As a result the assets not yet replaced are generally old and are operating over or very near to the expected useful life.
- The Cumulative Depreciated Replacement Cost of the existing scheme amounts to R 1 786 936 238.00 (**Table 6.2.1**) which include: Pipeline and Reservoirs, Precipitation and Dosing and Supporting Infrastructure (Buildings etc.).
- The ratio of Cumulative Depreciated Replacement Cost over Cumulative Current Replacement Cost gives an indication of the age of the assets. In the case of the Vaal

Gamagara scheme the ratio is 0.12 (12%). This means that generally the assets have "used up" approximately 88% of its Expected Useful Life (EUL).

- Most of the electrical and mechanical equipment at Delportshoop, Kneukel and Trewill is in a functional condition, although some pumps are being upgraded. These three pump stations have spare pumpset positions for future expansion. However, future extensions will require new electrical and mechanical equipment as well as design work.
- The pump stations at Kathu and Mamatwane are not in use at present. In order to re-commission these pump stations in future, a considerable lead-time will have to be allowed for design work and procurement.
- Several items of mechanical, electrical and electronic system components require servicing and maintenance. Several control and telemetry components require upgrading as well.
- Local instrumentation on pump station equipment requires upgrading and repair.
- Regardless of the pipeline scenario finally selected, it is recommended that the Cathodic Protection system be redesigned from first principles to meet the current demand to adequately protect the pipeline(s). It is envisage that this will result in an increased number of locations for CP stations using traditional ICCP rectifiers and associated groundbeds.
- Regular maintenance and repairs to the CP System are essential to maintain the integrity of the existing and future pipelines.
- Should the decision be taken to replace the existing pipeline with a single larger diameter pipeline and abandon the existing pipeline, the new pipeline must be designed so as to be CP compatible. In addition, the existing pipeline should not be abandoned in the ground but removed completely, as we believe that it may compromise the integrity of the replacement pipeline by acting as a parallel conductor and aggravating stray current interference effects.
- Should the decision be taken to refurbish the existing pipeline and have two parallel pipelines, the new pipeline must be designed so as to be CP compatible. Once construction is complete, the existing pipeline should be refurbished in its entirety by means of cement mortar lining, valve refurbishment, and ensuring continuity bonding and undertaking selective coating repairs.

- The re-ling process will be significantly more cost effective if it is undertaken once a new line is operational, as no temporary bypasses will be required and the lining contract can proceed un-interrupted.
- For the purpose of evaluating the sufficiency of the existing VGG scheme the current capacity is compared with the current (so-called 2010) demand The refurbished pump sets delivering water to Clifton reservoir should according to the original design supply at a rate of 420 ℓ/s. The supply rates obtained in the model for Delportshoop and Kneukel pump stations closely resemble the design rate but not for Trewill pump station which, according to the modelled results, supply at a maximum rate of 385 ℓ/s when all three pumps are running. This has been confirmed by actual measurements. The result is that the pumped supply to Clifton reservoir after the refurbishment of the pumps has been completed will be in the order of 33.2 Mℓ/d if the pumps run 24 hours per day. This represents a maximum supply of approximately 12.1 million m^3 per year that can be supplied up to Clifton reservoir, or in the existing situation, up to where the Beeshoek supply occurs.
- The total anticipated required current peak day supply for the Vaal Gamagara scheme is 56.3 Mℓ/d. Of this volume 12.9 Mℓ/d is abstracted between Delportshoop and Clifton reservoir and 43.5 Mℓ/d is required downstream of Clifton reservoir. Of the 12.9 Mℓ/d that is required between Delportshoop and Clifton reservoir 9.9 Mℓ/d is supplied to Finsch mine and Lime Acres. This implies that the net supply to Clifton reservoir during the 2010 peak day demand will be 20.3 Mℓ/d. That is if the refurbished pumps run at 24 hours per day, and in the case of Trewill pump station all three pumps.
- For the supply to Gloucester reservoir the difference between what is required downstream of Clifton reservoir and the net supply rate to Clifton under peak supply conditions as determined above is 23.2 Mℓ/d. If only currently available sources are to be considered this deficit needs to be made up by the supply from Beeshoek and Sishen. Of the required supply rate of 43.5 Mℓ/d downstream of Clifton reservoir 37.5 Mℓ/d is required downstream of Gloucester reservoir.The optimal utilization of the existing system capacity and sources requires a supply in the order of 37.5 Mℓ/d (1 562 m^3/h) from Beeshoek under peak demand periods. This results in an available net supply of 32.0 Mℓ/d from Gloucester, for which the hydraulic capacity of the existing system is sufficient.
- For the supply from Gloucester to Black Rock, the required supply downstream of Gloucester under anticipated peak demand conditions is 37.5 Mℓ/d. The difference between this required rate and the net supply rate to the reservoir under peak supply

conditions as determined above is therefore 6.8 Mℓ/d (283 m³/h). If only currently available sources are to be considered this deficit needs to be made up by the supply from Sishen.

- According to the modelled results the section of the scheme between Gloucester and Kathu pump station can supply 60 Mℓ/d under gravity, which is more than sufficient. The maximum that can be supplied further north under gravity is 6.7 Mℓ/d before the delivery head drops below 20 m. The required supply on this section is 8.5 Mℓ/d, which implies a deficit of 1.8 Mℓ/d under gravity supply. If the Kathu pump station is in operation with the pumps having similar characteristics than before it can provide the required supply rate of 8.5 Mℓ/d with at least one pump operating 18 hours per day during peak day. The flow velocity in the feeder pipe northwards, however, reaches values up to 1.9 m/s.
- Effect of the short term (2011 to 2015) demand scenario and potential measures. To accommodate any growth in demand immediate measures will therefore have to be taken. Since the development of groundwater sources will probably not be achieved in time to alleviate the situation the short term solution will depend on the potential to utilize and accommodate the water produce by mines in their dewatering programmes.
- The anticipated 2015 demand is approximately double that of the 2010 demand. If a linear growth in demand is assumed the 2011 peak demand will be 60 Mℓ/d growing to a peak demand of 106.7 Mℓ/d in 2015.The anticipated volume of water to potentially be discharged into the VGG scheme by Sishen and Kolomela mines grows from 49 Mℓ/d in 2011 to 75 Mℓ/d in 2015.
- Given the existing scheme's pumping capacity of 33.2 Mℓ/d it thus appears that theoretically the short term demand can be served with a combination of the mines and the Vaal river source, the total supply being 82.2 Mℓ/d and 108.2 Mℓ/d in 2011 and 2015 respectively. This is valid for the sector between Delportshoop and Kathu pump station, given that the modifications as described below be made, but the capacity of the sector north of Kathu pump station is projected to be insufficient to provide the supply in 2012.
- In order to utilize the water provided by the mines as effectively as possible the following modification referred to above are required:
  - The Beeshoek Phase 1 pumps must be upgraded by installing the original designed for additional stages to allow pumping from Beeshoek pump station to Clifton reservoir. According to the pump curves this should result in a pump rate of 700 kℓ/h or 16.8 Mℓ/d;

- The Kathu pump station must be re-commissioned to boost the supply northwards;
- Additional pumps must be installed at Kathu pump station to allow pumping southwards up to the Khumani off-take. The detail of this installation needs to be investigated, but an initial evaluation indicates that a pump rate of 1 900 kℓ/h (45.6 Mℓ/d) at a head of 140 m can be achieved;
- The detail arrangement and controls to be able to accommodate operating of the system with the above modifications need to be established;
- In order to provide a backup for the mine water source the potential for the development of the identified ground water sources should be considered.

- A possible scenario for supply under the 2015 demand conditions given the above modifications is provided in Annexure E. The results can be summarized as follows:
  - The hydraulic capacity of the section of the VGG scheme north of the Kathu booster pump station is insufficient to convey the 2015 demand and would require upgrading over its full length if the full demand is to be delivered from a southern source. If, however, the SD4 groundwater source could be developed to supply close to its indicated potential of 15.6 Mℓ/d under peak demand conditions, no upgrading of the northern sector is required before 2015. In this case the supply from SD4 should be directly into the scheme's pipe system in the vicinity of the Hotazel off-take. To reduce the head at which the supply must occur the supply point can be down stream of the PRV to the north of the Hotazel off-take but with a by-pass and check valve on the PRV to allow supply southwards during peak demand conditions.

- As previously indicated four large scale source development target areas were identified initially to augment the water demand in the short to medium term. The four sources are located in the Danielskuil area (SD 1), Postmasburg area (SD 2), Kathu area (SD 3) and Hotazel area (SD 4) as illustrated in **Annexure D, Map 7**.
- To utilize these groundwater resources to augment the current VGG scheme, detail investigations and surveys are required. It is anticipated that the total yield of the four proposed groundwater sources could be 20.3 million m^3/a consisting out of 66 production boreholes. The cost to develop these sources as well as the EIA and licence application processes is estimated at R 34.4 million and could be completed within 12 to 18 months. The study team did not investigated the long terms benefit or

the reduction in size of the proposed new scheme by developing these groundwater sources and recommend that this is investigated.

- A first order cost estimate was done to equip the boreholes on the conceptual position of the production boreholes assuming equal yields. The cost amount to R 249.0 million for the four sites excluding VAT and the source development cost of R 34.4 million.
- For planning purposes a 20 year design horizon (2010 to 2030) was used. The results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand. A condition assessment of the existing pipelines also confirmed the need for refurbishment.
- It was assumed that the scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater sources to be developed as a short to medium term measure as well as de-watering water from mining operations would therefore only provide relief in terms of operational and water cost. This assumption was made due the difficulty in obtaining agreements from the mining houses in supplying a constant yield of de-watering water and the uncertainties/variables regarding the additional groundwater sources to be developed.
- Since the demand of the VGG scheme is projected to increase substantially from 13.7 million m³/a to 40.1 million m³/a, the condition assessment confirmed the urgent need for refurbishment and the results of the hydraulic analyses indicated that the existing infrastructure has insufficient capacity to accommodate the anticipated 2030 demand, upgrading options were investigated for proposed 20 year design horizon.
- It was assumed that the scheme must be capable of providing the total demand from the Vaal River source. The addition of groundwater sources to be developed as a short to medium term measure as well as de-watering water from mining operations would therefore only provide relief in terms of operational and water cost. This assumption was made due the difficulty in obtaining agreements from the mining houses in supplying a constant yield of de-watering water and the uncertainties/variables regarding the additional groundwater sources to be developed.
- Planning was performed for three options:
  - Option 1: Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand.

  - Option 2: Add capacity to the existing scheme to supply the anticipated 2030 demand by an additional pipeline.

  - Option 3: Replace the existing scheme with a double pipeline with sufficient capacity to supply the anticipated 2030 demand.

- For all three options the basis was that pumping occurs from Delportshoop to Clifton and that the rest of the scheme is supplied from there under gravity with no booster pumps required.

- In all three options it was assumed that over the pumped sector the scheme would operate at the same pressures than the existing scheme. For the sector supplied under gravity, aspects such as pressure control need to be addressed as part of optimised detailed design and costing. Proposed pressure control measures are described further herein under the paragraph dealing with operation of the proposed scheme.

- In all three options it is required that Gloucester is supplied from Clifton at uncontrolled pressure. Therefore, since the Beeshoek pumps cannot deliver at Clifton pressure it is proposed for all three options that the existing pipeline from the Beeshoek connection to Gloucester be refurbished and utilized as a dedicated pump line for the Beeshoek pumps.

- All the strategic and technical alternatives studied for this report were compared on mainly economic grounds, with a view to establishing a "master plan" which will result in the lowest present value of capital works, operations and maintenance. A costing and engineering economic analyses was conducted by means of a Unit Reference Value (URV) for each technical alternative and comparing the cost.

- From the calculations it was evident that Option 1 has the lowest URV and thus from an engineering economic point of view, Option 1 - Replace the existing scheme with a single pipeline with sufficient capacity to supply the anticipated 2030 demand, is the recommended way forward.

- The estimated cost to implement Option 1 for the 2030 water demand projections are estimated at R 7 165 223 602.90 (VAT excluded).

- Option 1 can be implemented with the existing scheme as a backup system but was not investigated. If the backup system is considered, it is recommended that the long term sustainability (operation and maintenance) of the existing scheme (backup system) be investigated.

- Should Option 1 be taken to replace the existing pipeline with a single larger diameter pipeline and abandon the existing pipeline, the new pipeline must be designed so as to be CP compatible. In addition, the existing pipeline should not be abandoned in the ground but removed completely or form part of the CP design, as it may compromise the integrity of the replacement pipeline by acting as a parallel conductor and aggravating stray current interference effects.

- Due to the anticipated rapid growth of the demand over the entire length of the VGG scheme and current lack of spare capacity in large sections it is evident that the proposed upgrading of all components should proceed as soon as possible. However the development of groundwater sources or the utilization of water produced by mines in their dewatering programmes could drastically influence the urgency of upgrading of certain sections. The most prominent of these cases are:

  – As indicated the pumped sector from Delportshoop to Clifton reservoir is under peak demand conditions already running at full capacity with 24 hour operating time, therefore at very high risk of failure. The high demand from Finsch mine on this sector and the anticipated rapid growth of this demand plays a major role in this situation. This sector therefore needs to be upgraded as a matter of urgency or as alternative the potential groundwater source from the mine dewatering program as well as new sources should be developed.

  – The sector of the scheme northwards of Kathu is currently operating close to capacity and will have to be upgraded to meet the anticipated 2015 demand. As indicated the alternative is to develop the potential groundwater source near Hotazel to supply directly into the scheme.

- It is however recommended that a forth option is investigating determining the effect, cost as well as operational, to have the additional groundwater sources be developed and operated by Sedibeng Water.

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Annexure A: Water Demand Table

Annexure B: Water Demand Summary according to pipe segments

Annexure C: Water Demand Summary according to Users Groups

Annexure D: Groundwater Maps

Annexure E: Supply scenarios under 2015 demand conditions