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REVIEW, EVALUATION AND OPTIMISATION OF THE SOUTH AFRICAN WATER RESOURCES MONITORING NETWORK

Implementation Strategy

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IMPLEMENTATION STRATEGY

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LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
ARC	Agricultural Research Council
CBR	Cost-benefit Ratio
CD: WIM	Chief Directorate: Water Information Management
CMA	Catchment Management Agency
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
EWR	Ecological Water Requirement
IT	Information Technology
KZN	KwaZulu-Natal
NWRS-2	National Water Resources Strategy 2
O&M	Operation and Maintenance
PMC	Project Management Committee
PSP	Professional Service Provider
RQIS	Resource Quality Information Services
RQO	Resource Quality Objective
RWI	Regional Water Institute

SAEON	South African Environmental Observation Network
SAWS	South African Weather Service
TOR	Terms of Reference
WMA	Water Management Area
WMO	World Meteorological Organisation
WSA	Water Services Authority
WSP	Water and Sanitation Programme
WUA	Water User Association

1. INTRODUCTION

1.1 BACKGROUND

The applications of water resources data and information are many and varied. Reliable data and information on the status and trends of the water resources in South Africa allow for informed decisions on best practices to manage and protect available water resources for human and environmental health. This includes data on quantity, quality and on events such as floods, droughts, chemical composition and pH amongst other factors.

The National Water Act (Act No. 36 of 1998) requires the establishment and management of national monitoring programmes to facilitate the continued and coordinated monitoring of water resources by collecting relevant data and information that are adequate and responsive to the present and future challenges of efficient management of the country's water resources. The second National Water Resources Strategy (NWRS-2) (DWS, 2013) states that "*Monitoring is necessary to collect sufficient and accurate data to inform decision-making, and reduce and manage risk. Therefore, the ultimate goal is to provide information needed for planning, decision making and operational water management and related infrastructure at local, regional and national level*".

The overall responsibility for all national water resources monitoring programmes lies with the Department of Water and Sanitation (DWS). However, other associated institutions such as the South African Weather Service (SAWS), the Agricultural Research Council (ARC), Catchment Management Agencies (CMAs), water boards, bulk water suppliers and local authorities, amongst others, have developed and maintained several external monitoring networks to address their water resource management needs.

Within this context, the DWS, Chief Directorate: Water Information Management (CD: WIM) commissioned a three-year technical study for the *Review, Evaluation and Optimisation of the South African Water Resources Monitoring Network*. The study focused on the 10 national monitoring programmes for which the DWS is directly responsible, but also considered (although more superficially) other programmes, such as the SAWS rainfall monitoring network, the ARC agro-meteorological network and the South African Environmental Observation Network (SAEON).

1.2 OBJECTIVES OF THE STRATEGY

In essence the Implementation Strategy provides a plan for implementing and maintaining an optimal South African Water Resources Monitoring Network. As such the Strategy includes a number of key aspects considered for each of the surface water, groundwater and water quality monitoring programmes, as summarised below:

- Finalising the optimal monitoring network design, including the location, the variables/constituents being monitored, the frequency of observations, as well as the implementation priority for each monitoring site.
- Identifying opportunities for the integration of processes involved in the implementation process, such as the coordinated development or upgrading of monitoring sites based on physical location and other practical considerations.
- Developing preliminary implementation, operation and maintenance cost estimates for each monitoring site.
- Developing the sequencing, grouping and programming of the relevant implementation steps for monitoring sites within each monitoring programme.
- Developing preliminary implementation timelines and cash flow estimates, both provided per site, monitoring programme, defined implementation area (such as a Water Management Area, WMA) and for the National Network.
- Providing recommendations and the action list for achieving Strategy implementation
- Identifying Strategy implementation risks and possible mitigation strategies, including the need for Strategy implementation support.

1.3 PURPOSE AND STRUCTURE OF DOCUMENT

The purpose of this document is to present the strategy for implementing and maintaining an optimal South African Water Resources Monitoring Network and includes:

- An introduction with background information and describes the objectives of the Implementation Strategy (this section).
- An overview of the Strategy development process (**Section** Error! Reference source not found.).

- The Strategy for surface water quantity monitoring (**Section 3**).
- The Strategy for groundwater monitoring (**Section 4**).
- The Strategy for water quality monitoring (**Section 5**).
- The scheduling and national cash flow estimates for the Implementation Strategy, across all monitoring programmes (**Section 6**).
- A high-level indication of the cost-benefit characteristics of the Strategy (**Section 7**).
- Strategy implementation risks and possible mitigation strategies (**Section 8**).
- Strategy implementation actions (**Section** Error! Reference source not found.)

1.4 ACKNOWLEDGEMENTS

The Study Team would like to acknowledge everyone involved in the development of this Implementation Strategy. Without their support the Strategy would not have become a reality. More specifically the Study Team would like to thank the following individuals:

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- The Project Management Committee (PMC) for their valuable and continuous support and contributions to the development of the Strategy.
- The external reviewer, Dr Thinus Basson.

2. DEVELOPMENT OF THE STRATEGY

The Implementation Strategy was developed based on an extensive process of stakeholder liaison, technical investigations and scientific analysis. At the core of this process was an assessment of specific monitoring objectives that formed the basis for defining and optimising the Monitoring Network design.

A summary of the steps involved in this process is provided in the following subsections, including an assessment of user requirements, the development of a network inventory, a data integrity assessment, a scientific review and the development of a strategy for implementing an optimal Water Resources Monitoring Network.

2.1 USER REQUIREMENTS

A key step in the development of the Strategy was identifying user requirements for the South African Water Resources Monitoring Network and to prioritise these requirements based on the strategic monitoring objectives of DWS and other important stakeholders and data users. This process involved a national stakeholder engagement process with representatives from the DWS, Chief Directorate: Water Information Management, other DWS Chief Directorates, DWS Provincial Operations, CMAs, municipalities, water boards, bulk water suppliers, consultants and research institutions, as well as other important data users.

Interaction with stakeholders was facilitated in a number of ways, aimed at ensuring that all important users are adequately consulted. This included a series of dedicated workshops, interviews with key stakeholders, as well as email correspondence allowing users to provide feedback by completing a questionnaire. Important user requirements were also identified by consulting reports available from earlier hydrological, water resources and water quality studies undertaken by the DWS, Chief Directorate: Integrated Water Resource Planning and other organisations. Other sources of information included minutes of the DWS National Water Monitoring Committee meetings and Gauge Assessment Reports developed by the DWS, Directorate: Hydrological Services, providing detailed information on specific stream flow gauging stations.

A final workshop was held with DWS and other important stakeholders to identify and prioritise strategic objectives for the South African Water Resources

Monitoring Network. The results are summarised below, in descending order of priority (from 1 to 4). Note that the objectives are not programme-specific, but rather represent the national perspective, which is strategic in nature and cuts across multiple monitoring programmes.

Table 2.1 Summary of prioritised strategic national monitoring objectives

Priority class	Objective	Description
1	**Resource and Infrastructure Planning**	To provide adequate monitoring data for determining the availability and quality of current and future water resources, aimed at the equitable and sustainable allocation of these resources to the population, environment and other economic sectors of society through planned infrastructure development and other interventions.
2	**Resource Operations and Management**	To provide timeous monitoring data for the efficient operation and management of water resources to ensure the protection of resources and water users and to allocate water equitably and sustainably.
3	**Compliance and Auditing**	To provide water quality and quantity monitoring data to ensure compliance and auditing functions required for water use licensing, complying with Reserve and Resource Quality Objectives (RQOs) requirements and international obligations.
4	**Risk Mitigation**	To provide timeous water resources monitoring data for early-warning systems to mitigate negative impacts on humans, infrastructure, the economy and riverine and coastal ecosystems.

Subsequently, user requirements were assessed and prioritised as outlined below:

- Each identified user requirement was classified according to the prioritised strategic national monitoring objectives.
- The user requirement was then assigned the same priority as for the strategic objective in question.
- In some instances the user requirement was considered to support multiple (or all) strategic objectives, in which case the highest relevant priority was assigned.
- In other instances the user requirement was considered not to specifically support any of the strategic objectives, in which case a low priority was assigned.

The process is discussed in detail in the *User Requirements Report* of this study (DWS, 2015) and a database of prioritised user requirements is provided (in spreadsheet-format). These requirements are applicable to specific monitoring sites or stations and have been linked directly to the key strategic monitoring objectives for the purpose of prioritisation.

2.2 NETWORK INVENTORY

The current status of the South African Water Resources Monitoring Network was assessed and documented in a detailed network inventory. The inventory includes the 10 DWS national monitoring programmes, as well as the SAWS rainfall and ARC agro-meteorological monitoring networks. The inventory was developed based on information obtained through extensive engagement with the relevant DWS Database Managers, Regional Monitoring Managers and other stakeholders. It includes, among others, the variables/constituents being monitored, frequency of observations, storage of data sets, the current status of stations, as well as the spatial distribution and coverage (density) of stations across the country.

The inventory is structured according to the following main data categories:

- Surface water quantity.
- Surface water quality.
- Groundwater levels and quality.
- Rainfall quality.
- Biophysical data.
- Hydro-meteorology (including rainfall and evaporation).

The inventory is available in the following formats:

- An electronic **Data Catalogue** providing detailed information on each individual monitoring station across all monitoring networks.
- A **Map Book** showing the spatial distribution of monitoring stations within each of the nine recently-defined Water Management Areas (WMAs).
- Summaries of the **Current** Status of the national monitoring network based on the number of open monitoring stations.
- **Historical Trends** in the national status of monitoring based on the total number of stations actively recording data at any given time.

In order to ensure that the inventory remained relevant, updated and effectively contributed to the development of the Strategy:

- The inventory was made available to all monitoring data users for verification. These users include, in particular, the DWS Database Managers and Regional Monitoring Managers. Feedback obtained from data users was continually collated, checked and then used to update the catalogue.
- Once verified, custodianship of the inventory was transferred to DWS for continued maintenance as part of their line function duties.
- Since the basic information used for developing the inventory was the metadata sets for each monitoring programme, it was recommended that all revisions as a result of the verification process should be used by DWS for correcting the relevant metadata sets of the monitoring programmes themselves.

The network inventory is presented in the study report *Network Inventory Volume 1: Main Report* (DWS, 2015) and *Volume 2: Map Book* (DWS, 2015), including an electronic database with each individual existing gauging stations (in spreadsheet-format) and maps per WMA covering each of the data categories.

2.3 DATA INTEGRITY ASSESSMENT

The purpose of this step was to assess the data integrity (also referred to as “data quality”) of the National Monitoring Network. This included the surface water quantity, water quality, groundwater levels, biophysical data and hydro-meteorology data categories. The assessment involved the formulation of integrity indicators with support of DWS Monitoring Network Managers and based on available metadata at active monitoring sites.

Water resources monitoring data integrity indicators should include all steps (or elements) in a typical monitoring process. This criterion, however, proved to be difficult to comply with due to limited metadata in several of the monitoring networks. It was therefore necessary to assess which functions and processes of the monitoring cycle are currently sufficiently covered by the available metadata. As such, the following main categories of data integrity indicators were adopted:

- **Source indicators**: These include the status and accuracy of infrastructure/ equipment to measure at source. Together with the experience and expertise of the data collector and technician and to a lesser extent any potential issues related to data retrieval and transmission for the source to the database.

- **Analysis and data audit**: These include data management issues such as data storage, data validation and verification, data analysis accuracy and implementation of quality control measures, for example laboratory accreditation and the flagging of exceedances or suspect values.
- **Data record quality**: This includes an expression of the integrity of the entire record based analysis of the record and described by factors, such as gaps, frequency, number of flagged values, consistency and other factors.

A detailed description of the data integrity assessment and its outcomes are provided in the study report *Data Integrity Assessment* (DWS, 2015). The report includes a multitude of data category-specific recommendations, as well as a number of integrated recommendations as summarised below:

- **More comprehensive integrity indicators**: Some areas and alternative indicators were identified that would contribute towards a clearer description of the integrity of the relevant datasets. Implementation of these indicators in quality management systems and databases will support technicians, data auditors and users with identifying problem areas, unreliable datasets and stations.
- **Infrastructure and equipment**: For water quantity and hydro-meteorological data the accuracy and status of monitoring infrastructure and equipment is of primary importance for data integrity assessments. Metadata should be updated with every change in conditions captured and dated so that the data record can be associated with potential monitoring issues. This includes observations during visits, recalibrations and after flood events.
- **Training of technicians and samplers**. The maintenance and, particularly in the case of water quality, the actual monitoring/sampling is largely dependent on the capabilities of the field technicians and samplers. DWS should provide continuous practical training of field technicians and samplers to ensure consistency and accurate monitoring.

- **Expansion of quality management systems**: The Hydstra system provides tools to support quality control for surface and hydro-meteorological data. However, the need exists for the existing knowledge of auditing and error detection offered by experienced DWS specialists to be applied in quality management systems for use by all technicians and data managers. Furthermore a range of (automated) tests and associated training in interpretation of these test need to be developed to support data auditing.

2.4 SPECIALISED MONITORING NEEDS

Specialised monitoring information may be required at certain sites to support the management of processes that present a unique set of requirements. This includes, most importantly, the possible impacts on national water resources of:

- Hydro-fracking.
- Acid mine drainage (AMD).
- Climate change.
- Transboundary stream flow and aquifer water quantity and quality obligations.

Within this context the need for specialised monitoring programmes was assessed and incorporated into the development of the Strategy. This was achieved by ensuring that such needs are included as part of the Scientific Review outcomes (discussed below) and considered explicitly in the theoretical network design.

More information in this regard is provided in the *Scientific Review Report* of the study (DWS, 2016).

2.5 SCIENTIFIC REVIEW AND NETWORK DESIGN

The National Monitoring Network should provide adequate national and regional spatial coverage and scientifically sound measurement of the quantity, quality and biophysical properties of water resources at appropriate time intervals. Within this context, a scientific review was undertaken to develop an optimised National Monitoring Network design. This was achieved, in essence, based on the process outlined below:

- The design of a **theoretical monitoring network** that provides the required distribution of sites, monitored variables/constituents and frequency of observations.
- Comparing the theoretical network with **existing monitoring activities**. These were identified, evaluated and documented in the network inventory and data integrity assessment described earlier.
- Assigning **importance and functions** to existing monitoring sites.
- Identifying **redundancies and problems** at existing sites (such as vandalism, structural problems, etc.).
- Identifying **gaps** in the existing spatial coverage.
- Identifying possible **physical constraints** of new sites (such as founding conditions, accessibility, etc.).

The process was supported by extensive engagement with stakeholders, in particular a national Spatial Design Workshop, followed by a series of Regional Spatial Design Workshops. Each workshop considered the extent of the theoretical and existing monitoring network for a particular area (typically a WMA) and, based on the outcomes of this assessment, make recommendations on network optimisation. This included the identification of new sites, existing sites that should be replaced or improved, sites that are not considered to be of national importance, redundant sites, etc.

Patently, a key step in the scientific review process was the design of a theoretical monitoring network. This involved the following three main aspects:

- Review defined prioritised strategic national monitoring objectives (as outlined in **Section 2.1**).
- Develop optimal site positioning criteria for theoretical sites.
- Apply optimal positioning criteria to spatial data sets to select theoretical sites. This was achieved based on hydrological, geo-hydrological, environmental considerations and anthropogenic spatial data sets.
- Importantly, a deliberate approach was followed to develop the theoretical network independently of existing monitoring activities to ensure an unbiased outcome.

The relative importance of existing and proposed monitoring sites was determined based on a priority scoring system that uses prioritised strategic national monitoring objectives and additional defined sub-objectives. The score represents the relative importance of a site and is calculated as the sum of the objective scores assigned to that site. A summary is provided below.

Table 2.2 Priority scoring system

Objective	Score
Resource and infrastructure planning	4
Resource operations and management	3
Early warning systems	2
Compliance and auditing	1
Sub-objectives	0.5 per sub-objective

Note: While compliance is of great importance, from a national monitoring perspective this should not be the main objective for monitoring at a specific site. However where sites contribute towards compliance monitoring such as EWR sites, additional importance is associated with this consideration.

A summary of the optimised National Monitoring Network is presented in **Appendix A**, including the following:

- A national map of the **optimal surface water monitoring network**, including the location of new sites, sites for water quality monitoring, sites for water quantity monitoring, sites for both water quality and quantity monitoring and sites that are considered to be redundant or not of national importance (**Figure A.1**).
- A national map of the **optimal groundwater monitoring network**, including existing and new baseline sites, existing and new trend sites and sites that are considered to be redundant or not of national importance (**Figure A.2**).
- Tables providing **summaries of the number of sites per WMA** for surface water quantity, reservoirs, estuaries and groundwater, distinguishing between the various categories as outlined above (**Tables A.1** to **A-5**).

A detailed description of the scientific review and its outcomes are provided in the *Scientific Review Report* of the study (DWS, 2016).

2.6 IMPLEMENTATION

a) Context for the development of an Implementation Strategy

The Strategy presented in this document must ensure that the relevant institutional gaps and barriers are adequately considered and addressed for successful implementation. The implementation of the Strategy must therefore be underpinned by the institutional framework suggested in the "Institutional Vision" of the National Water Resource Strategy (NWRS-2) as shown in Figure 2.1.

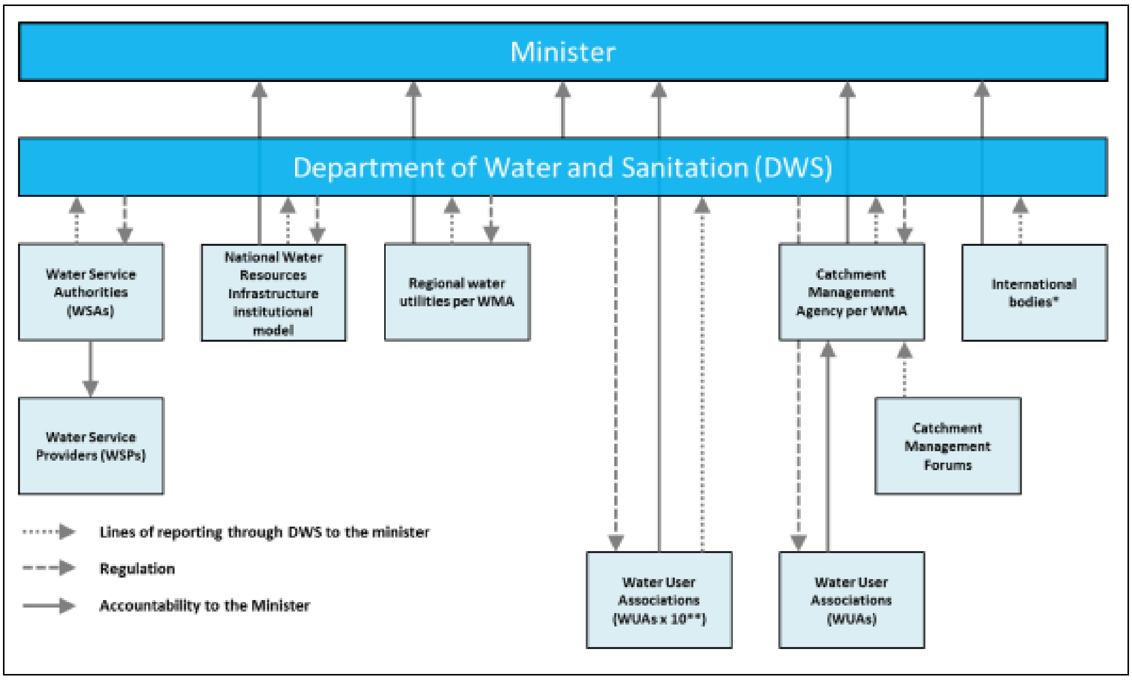

Figure 2.1 Institutional Vision of the NWRS-2

According to the NWRS-2 this Institutional Vision is based on the following key principles:

- **Water resources management at the appropriate level**: The vision makes provision for the protection, use, development, management and control of water resources to be carried out at the appropriate level, considering efficiency benefits related to economies of scale.

- **Clear definition of roles and responsibilities**: The roles and responsibilities of the three spheres of government (i.e. national, provincial and local) as well as of the water resources and water service institutions must be clearly defined. Overlapping mandates should be eliminated, whenever and wherever possible. **Coherence between national and local water related strategies and plans**: All water resources management and water service strategies, plans and instruments at local, provincial and national level must be aligned to achieve coherence.
- **Separation of regulatory and operational responsibilities**: The responsibilities and authorities for regulation differ from those of operations in the water sector. Water Service Authorities (WSAs) and all other users of water, such as Regional Water Institutes (RWIs), Water User Associations (WUAs) and Water and Sanitation Programmes (WSPs) are not party to decision making in relation to water use authorisations. This is apparent in the separation of regulatory or water use authorisation functions from operational or water user functions. Regulation aims to protect the integrity of the water resources and aquatic ecosystems for future sustainable use, while ensuring that water resources are available for supplying the justifiable needs for growing and sustaining the socio-economy of the country.
- **Collaboration and partnership**: The importance of collaboration and partnership between all stakeholders and beneficiaries is recognised, including between all spheres of government, as well as private and civil society.
- **Alignment**: Institutions will be aligned throughout the water value chain to ensure the efficient, equitable and sustainable protection, use, development, conservation and control of water resources as well as the provision of improved and sustainable water services, taking cognisance of the need to reflect the cultural, gender and racial diversity in South Africa. Realignment of institutions promotes economies of scope and scale in support of sustainability in the water sector.
- **Financial sustainability**: Realignment must enable institutions to make optimal use of available funds for water infrastructure and sustainable management.

Within this context the financial considerations in the implementation of the Strategy must, in conjunction with the financial sustainability principle highlighted in NWRS-2, take into consideration the physical, as well as the operation and maintenance components of water monitoring. Cost drivers range from feasibility studies, site investigations and mobilisation of construction equipment through to the operation and maintenance costs after monitoring stations are commissioned.

Certain cost drivers are common to all monitoring networks, however, water quality and groundwater monitoring networks have unique additional drivers, such as the need for laboratory analysis for water quality and the cost of yield testing for groundwater. Therefore, in order to ensure that the Implementation Strategy is practically achievable, with realistic time frames, cost estimates and cash flow projections, the implementation plan was developed with the assistance of specialists within DWS and other organisations. These individuals have extensive experience in the development and implementation of monitoring stations across the surface water quantity, groundwater levels and surface water and groundwater quality programmes.

Furthermore, the implementation plan follows a prioritised approach aimed at achieving a balance between technical requirements, financial constraints and institutional processes. In this way, the plan provides a robust basis for addressing budget compromises and operational and management mechanisms to ensure the effectiveness and sustainability of the desired outcomes.

b) Components of the Implementation Strategy

The process involved a number of distinct components, each of which was addressed within the various monitoring programmes, as appropriate. These are described below:

- **Planning**: This involves the identification of the various project phases and tasks that must be completed for the establishment of a monitoring station. This may include project scope definition, environmental impact assessments (EIAs), design and procurement, construction and commissioning. However, project phases and tasks differ considerably depending, for example, on the type of programme in question or whether the site requires a new station or rehabilitation of an existing one.

- **Programming**: Programming requires for estimates to be made of the duration of each project phase and task as defined in planning above. Programming must take into account opportunities for concurrent activities, both in terms of multiple tasks within one project, as well as multiple projects. Furthermore, programming must consider implementation risks associated with all the project tasks and allow for time contingencies (float) where appropriate.
- **Capital costs**: These are defined as a one-time expenses associated with the establishment of a monitoring station. This includes mainly the construction and installation of monitoring equipment and related planning and approval processes. Capital costs are also incurred with the upgrade or rehabilitation of existing stations to an optimal operable status.
- **Operation and maintenance (O&M) costs**: These are incurred subsequent to the commissioning of a monitoring station and includes the costs of human resources, maintenance, inspections and evaluations, light structural work, instrumentation, security of installations and sampling and laboratory analyses (specifically in the case of water quality monitoring).
- **Cost estimation**: A number of costing tools were developed for the Strategy to allow for the determination of costs relating to both the capital expenditure and O&M at a monitoring site, as outlined above. The tools were designed based a combination of practical experience and the actual costs of recent projects and are therefore considered provide realistic cost estimates. However, for the purpose of the Implementation Strategy numerous assumptions have been made and, as such, all cost estimates provided are considered to be indicative only.
- **Scheduling and cash flow**: Once the planning, programming and cost estimation had been completed for all monitoring stations scheduling and cash flow tools were developed for each monitoring programme. The tool allows for the sequencing and grouping of multiple projects across a selected area (such as a WMA), resulting in an overall programme schedule and cash flow for the projects in question. Again, the tool incorporates a number of assumptions and, as such, all cash flow estimates are for illustrative purposes only.

- **Assumptions**: The assumptions mentioned above for both the cost estimation and the scheduling and cash flow tools, are discussed later in this document under the relevant sections. Note that, as mentioned earlier, the assumptions were made in consultation with experienced specialists and are therefore considered to be realistic. However, all tools allow for assumptions to be revised and/or the values replaced with confirmed information, resulting in more accurate cost estimates.
- **Implementation risks**: Significant risks exist that may delay or result in a failure to implement the Strategy. These risks have been identified and (in some cases) quantified for incorporation into the costing and scheduling tools discussed above. Furthermore, recommendations are also provided on possible mitigation strategies to limit potential impacts. Recommendations in this regard are also included in this document.

It is important that all cost calculations that are presented in the Implementation Strategy, including, capital and O&M costs, are in current rand value (2016) and neither escalation nor discounting have been applied.

The following sections provide a description of the above components for each of the monitoring programmes, namely surface water quantity, groundwater levels and surface water and groundwater quality.

3. SURFACE WATER QUANTITY

The development of the Implementation Strategy for the surface water monitoring programme takes into consideration the technical, financial and institutional aspects of the programme. Furthermore, the Strategy is based on the technical evaluation conducted as part of the Scientific Review analysis (described in **Section 2.5**).

The purpose of this section is to describe the process undertaken and the factors taken into consideration for the development of the implementation cost estimates and institutional recommendations for the optimal surface water quantity monitoring network. The recommendations made regarding the institutional framework are based on the institutional arrangement recommendations made as part of NWRS-2 as well as input from DWS (as discussed in **Section 2.6 (a)**).

3.1 PLANNING

The Planning phase for the implementation of the optimal surface water quantity monitoring network is divided into seven tasks. These are tasks that must be completed for each of the projects identified in the Scientific Review analysis before the design, construction and implementation phases can commence. The tasks are described below:

- **Site visit**: The Scientific Review analysis, conducted as part of this study, is a desktop analysis and does not accurately capture the topographical conditions at the proposed sites. Topographical and geotechnical conditions will affect the costing, technical requirements and project schedule. A site visit is required in order to revise the indicative cost reported in this Strategy.
- **Topographical surveys**: Topographical surveys will be required and may be included in the site visit or as a separate process. This decision must be made in the implementation stage of the Strategy.
- **Geotechnical investigation**: Geotechnical investigations will be required and may have significant impacts on the technical and financial requirements for each identified project.

- **Land acquisition**: This is an important factor to consider for the capital costing of the implementation phase. As part of the planning stage, project teams must identify which of the proposed project sites will require additional land acquisition. Note that this factor is not included in the indicative costs reported in **Section 3.3**.
- **Access roads**: Provision has been made as part of the indicative capital costing for the development of access roads in the implementation of the identified projects. This is, similarly to the Scientific Review analysis, a high-level estimate that must be revised though detailed costing and design. Note that it was assumed that an average access road length of 2.5 km would be required for each surface water project. The actual length of the access road must be verified and revised to the individual projects in the implementation stage.
- **Feasibility study requirements**: The site visit, topographical surveys and geotechnical investigations required in the planning phase will, for each project, determine whether further feasibility investigations are required to determine the optimal site.
- **Indicative capital cost**: These are provided in **Section 3.3** based on the approach and assumptions discussed above.

The completion of these tasks would allow for work to commence on the Design, Construction, Implementation and operation and maintenance phase.

3.2 PROGRAMMING

As discussed in **Section 2.6 (b)** the programming aspect of each surface water project must take into consideration the associated risks with all tasks. An indicative schedule for an individual surface water project has been developed by the study team in consultation with DWS based on their expertise and experience in this field. The results are presented in **Table B.1** of **Appendix B**, including the estimated number of months required to complete the relevant project tasks, both for a new station and the upgrading of an existing station.

3.3 INDICATIVE CAPITAL COSTS

Factors considered for the development of a capital cost estimate for the implementation of a surface water monitoring site are presented in this section. This includes the one-time expenses incurred on the purchase of land, construction and the installation of monitoring equipment. It is the total cost needed to construct or upgrade the associated monitoring sites to an optimal operable status. Any costs incurred after reaching the optimal operable status, such as costs of human resources and maintenance, are included under the indicative O&M costs discussed in **Section 3.4**.

The cost variables and rates directly associated with the construction of new gauging weirs are presented in **Table B.2**. There are also additional costs associated with the commissioning of a new gauging weir such a dewatering, overheads and the rehabilitation of the surrounding area. These items are, for the purposes of the Strategy, calculated as a percentage of the construction costs.

The calculation procedure for construction material volumes is presented in **Table B.3**. It should be noted that the variables in the table exclude the material required for the construction of the instrumentation hut and these are shown in **Table B.4**. The material quantities calculated as summarised in the above tables are then summarised per material type (i.e. concrete, reinforced concrete, rebar, etc.) and multiplied by the rates per unit to determine a total cost estimate for the construction material only. The results are shown in **Table B.5**.

The total cost of construction material is calculated as the sum of all the component amounts in **Table B.6** and shown as “Sub-total A”. However, this only accounts for about 50% of the total amount required for the construction and commissioning of new gauging weirs. Other factors, such as landscaping and rehabilitation, are calculated as a percentage of sub-total A and account for the remaining 50% of the implementation costs. The total construction costs are equal to the sum of the products of the material volumes by the relevant rate, as shown in **Table B.7**. These are the calculations of the cost estimates not directly associated with the size of the gauging weir. Based on calculations reported in **Tables B.6** and **B.7**, as well as the cumulative nature of these calculations, the total cost of constructing and commissioning a gauging weir can be estimated as the sum of variables [39], [40] and [41].

Based on the procedure described above the total indicative capital cost was calculated for all new monitoring stations required for the implementation of the optimal surface water quantity monitoring network. The results of this analysis are presented in **Tables B.8** to **B.16** in **Appendix B** and summarised in **Table 3.1** below.

Note that the cost estimates were based on three cross-sections within the vicinity of each new site, resulting in a low, medium and high cost. However, due to the inherent uncertainties associated with this method of cost calculation, the highest, geometric mean and arithmetic mean are all presented in **Table 3.1**.

Table 3.1 Summary of indicative capital cost for surface water quantity projects

WMA	Number of proposed stations	Arithmetic average cost estimate	Geometric average cost estimate	Maximum cost estimate
Limpopo	20	R 515 600 000	R 504 326 138	R 616 900 000
Olifants	20	R 350 400 000	R 344 900 724	R 407 600 000
Inkomati-Usuthu	10	R 167 719 048	R 166 211 207	R 188 842 857
Pongola-uMzimkhulu	15	R 192 266 668	R 191 523 910	R 209 800 000
Vaal	23	R 586 733 333	R 573 245 428	R 739 700 000
Orange	31	R 377 778 562	R 373 915 079	R 431 408 431
Mzimvubu-Tsitsikamma	25	R 296 673 333	R 264 637 435	R 397 500 000
Breede-Gouritz	15	R 476 933 333	R 434 198 197	R 654 200 000
Berg-Olifants	5	R 62 270 833	R 62 156 694	R 65 843 750
Total	**164**	**R 3 026 375 111**	**R 2 915 114 812**	**R 3 711 795 039**

Note: (1) In current (2016) rand-value.

It should be noted that the capital costs shown above exclude the cost of conducting an Environmental Impact Assessment (EIA) for the proposed sites. The costs of an EIA would vary for the various sites depending on the geology, topography and environmental sensitivity of the region. However, an average cost of R300 000 per EIA was recommended by DWS based on their experience in the construction of flow monitoring stations. This additional cost results in the indicative total implementation costs presented in **Table 3.2**.

Table 3.2 Indicative capital cost for surface water quantity projects with EIAs

WMA	Total number of new sites	Total cost of EIA	Maximum cost estimate	Total Implementation cost
Limpopo	20	R 6 000 000	R 616 900 000	R 622 900 000
Olifants	20	R 6 000 000	R 407 600 000	R 413 600 000
Inkomati-Usuthu	10	R 3 000 000	R 188 842 857	R 191 842 857
Pongola-uMzimkhulu	15	R 4 500 000	R 209 800 000	R 214 300 000
Vaal	23	R 6 900 000	R 739 700 000	R 746 600 000
Orange	31	R 9 300 000	R 431 408 431	R 440 708 431
Mzimvubu-Tsitsikamma	25	R 7 500 000	R 397 500 000	R 405 000 000
Breede-Gouritz	15	R 4 500 000	R 654 200 000	R 658 700 000
Berg-Olifants	5	R 1 500 000	R 65 843 750	R 67 343 750
Total	164	R 49 200 000	R 3 711 795 039	R 3 760 995 039

Note: (1) In current (2016) rand-value.

(2) At an assumed R300 000 per EIA.

3.4 INDICATIVE O&M COSTS

The operation and maintenance (O&M) costs associated with surface water monitoring extend far beyond the maintenance of dams and river monitoring stations. The Strategy also takes into account stations at springs, lake/estuary/pan and for flood monitoring. It should be noted that the cost estimates provided in this chapter were developed and provided to the Study Team by DWS.

The focus of this section is the evaluation of the operation and maintenance cost estimates for the optimal surface water quantity monitoring network. Unlike the capital cost analysis, this is not driven only by new stations and stations to be upgraded, but by all stations included in the optimal network.

For this purpose a cost estimate tool was developed in consultation with DWS and populated by the DWS Regional Offices in the Free State Province, George, Mpumalanga, Boskop, Limpopo and KwaZulu-Natal with information as shown in Table C.1 of Appendix C. The type of monitoring station evaluated is further classified into size categories based on the width of the river, as shown in Table C.2.

The calculation of the O&M cost estimates are further broken down into the sub-components for each of the activities listed under variable “A2” in Table C.1. This allows for the operation and maintenance cost estimates to be reported per region and structure size for the factors shown in Table C.3.

Instead of generating unique O&M cost estimates for the different Regions or WMAs, the Study Team was advised by DWS to use the data provided in the various Regional O&M cost estimations for generating a national O&M unit cost. This national unit cost was then applied to all stations on the optimal surface water quantity monitoring network. On this basis the national O&M unit cost were determined as follows:

- The total annual maintenance cost/ structure size is summarised per Region / WMA as shown in Table C.4.
- The unit cost per structure size, per region is calculated by dividing the total annual cost for the different structure sizes by the total number of stations for the respective structure sizes (see Table C.5).
- The unit costs/ structure size are then ranked from the highest to the lowest unit cost as indicated in Table C.5.
- The two highest and two lowest unit costs are then eliminated for the different structure sizes (assumed to be outliers).
- The average and geometrical mean of the remaining 5 unit cost / structure sizes is then taken as the National O&M unit cost / structure size

This procedure results in an overall national O&M unit cost for all structure sizes. The information received for the different regions and monitoring structure types is summarised in Table C.6 with details provided in Tables C.8 to C.12 at the end of Appendix C. It should be noted that not all regions provided information of this kind, therefore, there are uncertainties inherent in the indicative O&M cost in the Strategy. An example is the Northern Cape Province, where it is possible that the low spatial density of monitoring stations would result in higher travelling costs. This, amongst other factors, must be reviewed in the implementation of the Strategy.

The O&M unit costs in Table C.6 are then ranked and used to calculate the national O&M unit cost per monitoring structure as per the process described earlier. The results are presented in **Table C.7**. The comparison of the arithmetic mean to the geometric mean indicates that the use of the geometric mean to calculate the national unit O&M cost results in an average percentage decrease of 18.5%. To further compare the impact that this would have on the annual O&M costs, the total annual O&M cost estimate is calculated for surface water quantity monitoring stations using both approaches. The results are summarised in **Table 3.3**. In this regard the following assumptions must be noted:

- When the Strategy was developed there was no clear and immediate distinction between the number of river flow monitoring stations used for flood measurement purposes compared to regular flow measurement structures. It is assumed that all river flow stations are "River (structure)" monitoring stations. This assumption must be reviewed in the implementation phase of the Strategy.
- The national unit O&M cost determined for W-components is higher than that for dams and is thus applied to all reservoirs.
- The O&M costs associated with the registration and maintenance of servitudes was not included in this analysis but must be accounted for in the implementation phase of the Strategy.

Table 3.3 Indicative annual O&M cost per surface water quantity station

Type	Number of stations	O&M unit cost (arithmetic mean)	O&M unit cost (geometric mean)	Annual O&M cost (arithmetic mean)	Annual O&M cost (geometric mean)
River stations	601	R 222 627	R 217 743	R 133 798 827	R 130 863 543
Reservoirs	389	R 146 473	R 141 029	R 56 977 997	R 54 860 281
Total	**990**	**-**	**-**	**R 190 776 824**	**R 185 723 824**

Note: (1) In current (2016) rand-value.

4. GROUNDWATER

The development of the implementation strategy for the groundwater monitoring programme considered the technical, financial and institutional aspects of the programme. The technical evaluation, conducted as part of the Scientific Review analysis (discussed in **Section 2.5**) is incorporated into the integrated strategy recommendations presented here.

The purpose of this section is to describe the process undertaken and factors taken into consideration for the development of implementation cost estimates, as well as, institutional recommendations for the optimal groundwater monitoring network. Recommendations made regarding the institutional frameworks associated with groundwater monitoring are based on an evaluation of the status quo of groundwater provision and shortcomings in South Africa's National Water Policy, presented in **Table D.1** as well as further shortcomings identified in the NWRS-2 in **Table D.2** of **Appendix D** (Pietersen, et al., 2012).

The information in **Table D.2** provides the over-arching principles for recommendations on the institutional requirements for the optimal groundwater monitoring network. However, special attention must be given to the hydrocarbon potential of South Africa's main Karoo Basin as indicated in **Figure D.1**. Due to the growing interest in specialised programmes such as hydraulic fracking (as mentioned in **Section 2.4**), monitoring points have been identified in the Scientific Review to monitor around potential onshore exploration areas. However, in line with the principle of coherence within the Institutional Vision reported in NWRS-2, any recommendations made for the specialised monitoring programmes were integrated with the national implementation plan such that mandates do not overlap and roles and responsibilities are clear.

4.1 PLANNING

The implementation of the optimal groundwater monitoring network has planning requirements that differ from those of surface water quantity or water quality monitoring networks. These requirements affect the programming and the cost estimates associated with the implementation phase. The factors that were considered in the Strategy for implementing the optimal groundwater monitoring network are discussed in this section. It is proposed that in the implementation phase of the Strategy this is divided into two tasks, namely Development and

Operation. In the development task the planning requirements associated with the start-up and implementation of the optimal groundwater monitoring network must be evaluated. Planning requirements identified for the development task of the planning stage are as follows:

- **Geological exploration**: The Scientific Review was a desktop analysis. Before the implementation of the Strategy, this must be supported by site visits, exploration and detailed evaluation of the feasibility of the proposed sites.
- **Ground geophysics analysis**: This analysis is an aspect of geological exploration that uses geophysical methods such as seismic, gravitational, magnetic, electrical and electromagnetic to measure the physical properties of the subsurface along with the anomalies in the earth properties.
- **Drilling and establishment of infrastructure**: This element is equivalent to the construction phase associated with the surface water quantity monitoring network. Various factors, all of which are shown in **Table D.3**, must be evaluated in the implementation phase of the Strategy.
- **Installation of monitoring equipment**: The monitoring and collection of information requires the installation of certain equipment and data loggers. The time and cost associated with this task is crucial to the planning stages.
- **Security of installation**: Provision must be made in the planning and programming tasks for practicalities such as vandalism and theft. This could be through the installation of fencing and security gates or the development of subsurface instrumentation which would be integrated with the borehole. The former would reduce the cost of instrumentation and installation as it would allow for the use of above-ground instrumentation. This would however increase the risk of theft and vandalism compared to the use of subsurface instrumentation

Finally, the planning task must allow for the technical, human resources and financial risks associated with the aforementioned tasks.

4.2 PROGRAMMING

The programming aspect of each of the identified projects must take into consideration three main factors, namely:

- **Financial constraints**: The financial constraints and cash flow are important drivers of the scheduling of a given project. Factors to be considered include:
  - Time over which the funds will be available
  - Total budget available per project
  - Cost of equipment, installation and human resources, adjusted for annual inflation
- **Human resources constraints**: Constraints on human resources not only affect how long a given project would take to be completed, but also how many of the identified projects can be conducted parallel to each other.
- **Technical requirements**: The technical requirements and potential challenges on the identified projects would not only affect the time required to complete the development and implementation, but also the type of equipment required for the implementation. The different geological features would, for the groundwater implementation, influence the type of drilling rig required, the time it takes to drill to a given depth and possibly the type of material required for the instrumentation casing.

Taking these into consideration, and using their expertise and experience, the study team developed an indicative schedule for the implementation of the optimal groundwater monitoring network and the results are presented in **Table D.4** for a single defined spatial grouping of sites. Note that the implementation of the optimal groundwater monitoring network must be conducted per WMA or per Region as opposed to per site. For this purpose, Task 21 in **Table D.4** must be revised based on information gathered in implementation phase of the Strategy.

4.3 INDICATIVE START-UP COSTS

A start-up phase is required for the optimal groundwater monitoring network before drilling and establishment of the monitoring infrastructure can commence. This phase consists of two tasks, namely the geological exploration and ground geophysics exploration tasks.

The Study Team has, through consultation with DWS, third party stakeholders and their experience and expertise in this field, compiled indicative cost estimates associated with technical and human resources needs associated with the start-up phase of the implementation project. These are presented in **Table 4.1** for the purposes of this Strategy, applied across all groundwater monitoring stations across the different WMAs. There are however practicalities, such as the procurement of equipment, training and availability of human resources that must be considered by DWS prior to the implementation of the Strategy.

Table 4.1 Indicative unit start-up costs for a groundwater monitoring site

Task description	Resources required	Unit	Rate (R)
Exploration (geology, remote sensing etc.)	Professional	hour	R850
	Registered professional	hour	R1 200
Ground geophysics	Professional	hour	R500
Hire of geophysical instrumentation	Magnetometer	day	R320
	EM	day	R750
	Resistivity (Lund)	day	R4 750

Note: (1) In current (2016) rand-value.

4.4 INDICATIVE CAPITAL COSTS

This section discusses the factors taken into consideration for the development of a capital cost estimates for the implementation of the optimal groundwater monitoring network. This represents the total cost needed to construct or upgrade the associated monitoring sites to an optimal operable status. Any costs incurred after achieving the optimal operable status (i.e. maintenance and costs of human resources) are discussed under O&M costs in **Section 4.5**.

The capital cost of implementing new groundwater monitoring sites is, as indicated before, dependent on various factors ranging from establishment costs to the yield testing procedures required prior to the commissioning of new groundwater monitoring sites. There are also critical sub-factors such as the depth and diameter of the borehole, as well as the type of material from which the equipment casing will be made. These are summarised in **Table D.5**.

It should be noted that the Scientific Review conducted was a desktop study. Provision must be made in the drilling and establishment cost estimates for different geological features and the technical risks associated with them. The geology of the proposed site will have an effect on the allowable borehole depth and rate at which the drilling can occur. The indicative costs discussed earlier take into consideration two types of geological formations, metamorphic and carbonate rocks, and assume a constant borehole depth of 100 m for all the projects identified in the Scientific Review.

Bearing in mind the aforementioned assumptions, these cost estimates must be revised and adjusted to meet the needs of the various projects. These changes can, however, only be made after the results of the start-up phase have been evaluated.

The implementation of the optimal groundwater monitoring network will not be conducted on a single borehole basis, but rather per spatial grouping. This means that the unit rates must also be applied to stations depending on their spatial grouping. However, the preferred spatial grouping for the implementation phase has not been determined, resulting in uncertainties within the cost estimation exercise.

The study team has, based on expertise from DWS and groundwater experts developed an average standard cost for the drilling and implementation of a 100 m deep borehole. This cost was the applied to the total number of new boreholes per WMA to determine a national indicative capital cost of implementing the optimal groundwater monitoring network. The results are summarised in **Table 4.2**.

Table 4.2 Indicative capital costs for implementing groundwater monitoring sites

Factor			Value	
Average cost of implementing a 100m deep borehole			R 60 000	
WMA	**New baseline**	**New trend**	**Total new stations**	**Total cost**
Berg-Olifants	28	177	205	R 12 300 000
Breede-Gouritz	40	111	151	R 9 060 000
Inkomati-Usuthu	35	113	148	R 8 880 000
Limpopo	48	367	415	R 24 900 000
Mzimvubu-Tsitsikamma	48	295	343	R 20 580 000
Olifants	23	229	252	R 15 120 000
Orange & Lesotho	86	489	575	R 34 500 000
Pongola-Mzimkulu	56	127	183	R 10 980 000
Vaal	63	814	877	R 52 620 000
Total	**427**	**2 722**	**3 149**	**R 188 940 000**

4.5 INDICATIVE O&M COSTS

The operation and maintenance costs associated with groundwater monitoring extend far beyond just the maintenance of borehole monitoring stations. Also taken into consideration are the costs of data collection, reporting and security maintenance. It should be noted that the cost estimates provided in here were developed and provided to the Study Team by DWS and consultation with specialist service providers and the results are shown in Table 4.3. Also, similarly to the indicative capital costs discussed earlier, O&M operation and maintenance unit rates must be reviewed in the implementation phase of the Strategy.

Table 4.3 Indicative O&M costs for groundwater monitoring sites

Task description	Level of skill	Unit	Rate (R)
Monitoring of water levels	Technician	hr	R350
Monitoring of water quality	Technician	hr	R350
Cleaning and maintaining above-ground infrastructure	Technician	hr	R350
Cleaning and maintaining boreholes	Technician	hr	R350
Security of installations	-	No	
Reporting	Professional	hr	R750
Borehole inspections and rehabilitation	Professional	hr	R1 800

Note: (1) In current (2016) rand-value.

5. WATER QUALITY

This section provides the required tasks, proposed scheduling timeframes and initial estimated costs of implementing the optimal water quality monitoring network. The implementation strategy takes into consideration the technical, financial and institutional aspects of the network. The technical evaluation, conducted as part of the Water Quality Monitoring Review Workshops, is incorporated into the integrated strategy recommendations.

5.1 PLANNING

The phases and planning tasks required for the implementation of the optimal water quality monitoring network are discussed below.

a) Management phase

This phase makes provision for resources to support the implementation of the Strategy. It is conceivable that a single management phase could be undertaken for all the networks. The role of the resources would be to support DWS in giving effect to the implementation phases in terms of management, secretariat and reporting functions, as well as support to procurement procedures.

b) Planning phase

This phase involves all the preparatory tasks required to refine the initial design of the network in order to ensure the most cost-effective implementation and long-term operations and maintenance.

The Implementation Strategy is based on many assumptions that must be confirmed or revised before any actual implementation can commence. This is especially true for the water quality network.

The planning phase will ensure that the desktop optimisation analysis, which was done in preparation for the Strategy, is updated to a feasibility level and that subsequently the actual implementation and O&M costs are determined. The planning phase involves multi-year assignments to undertake the following:

- **National Water Quality Data Survey**. The objective of this assignment will be to:
  - Review all the available water quality data to assess what constituents are of concern at each site.
  - Undertake sampling and analyses at some sites for the new constituent groupings that have not previously been measured at the site.
  - Undertake full sampling at new proposed sites.
  - Refine the proposed constituents initially, their frequencies and their priorities.
- **WMA-based Feasibility Studies**: The objectives of these assignments will be to:
  - Use the results from the National Survey to further refine the spatial distribution of sites by assessing their constituents' serial relationships and to undertake the final optimisation of the WMA's number of sites.
  - Evaluate each site in terms of value of the information through a multi-disciplinary team approach
  - Determine the exact locations of all new sites.
  - Define the new sampling procedures for all sites based on its constituents.
  - Determine the optimal human resource structure for the management, analysis and sampling of all the sampling in the WMA.
  - Undertake path analyses to determine the quickest routes to ensure sampler efficiency.
- A National Water Quality Monitoring Structural Options Analysis. This assignment will develop:
  - Options for national implementation of the network with regards to centralisation, decentralisation or hybrid options for analysis and management of laboratories in terms of capital and O&M costs.
  - Skills and audit capabilities of South African laboratories.
  - Recommendations based on option costs for all or some of the WMA based Feasibility Studies.

c) Design and review phase

The planning phase would have updated the cost estimates for the Strategy and details of each site's constituents and frequencies to a feasibility level. This will allow for a revision of the Strategy for approval by DWS before the installation and implementation phases commence.

d) Construction and installation phase

This phase will depend on the outcome of the *National Water Quality Monitoring Structural Options Analysis*. If this assignment finds that there is upscaling required in terms of the DWS centralised laboratories, or more laboratories needs to be constructed at other sites in South Africa, then the construction and installation phase will involve the appointment of contractors for laboratory upgrading, construction and specialised equipment installation.

e) Implementation phase

This phase will give effect to all the outcomes from the planning phase. It will involve the roll-out of the new network in terms of contracting of external laboratories, assigning new constituents and frequencies to new and existing sites, as well as any required modification of IT systems.

To gain the maximum benefit of a sample, a skilled technician is required. Extensive training of samplers will have to be undertaken on new techniques and sample preservation methods to gain maximum benefit from the proposed sampling network.

One of the major risk factors to implementation is the procurement system. Sampling and analytical procedures require specialised equipment and supplies. Therefore, the procurement section should include at least two officials with appropriate technical or scientific qualifications and relevant experience, in addition to their financial skills.

f) Maintenance phase

This phase involves ongoing auditing of sampling, training and accreditation of existing and new staff, maintenance of laboratories and outsourced services, as well as data management activities.

5.2 PROGRAMMING

An indicative schedule for the implementation of the optimal water quality monitoring network is provided in **Table E.1** of **Appendix E**.

5.3 COST ESTIMATION CONSIDERATIONS

During the development of the Strategy, outcomes of the Scientific Review (described in **Section 2.5**) and other assumptions made at the time, resulted in a description of the optimal water quality monitoring network in terms of:

- The optimal spatial positioning of sites.
- Identification of the constituents required to meet the national monitoring objectives in term of fitness for use reporting.
- Assumptions regarding the frequency of sampling.
- Likely options for sample analysis by laboratories.
- The organisations responsible for undertaking sampling.

The frequency of sampling and the constituents to be analysed are the most important factors during costing of the optimal water quality monitoring network, especially O&M costs. Determining the exact frequency and constituents per site will involve a substantial investigation that would span several years. The decision regarding centralisation, decentralisation or partial to full-outsourcing of laboratories will be the main consideration for capital costs, but will also influence O&M costs. All these issues must be resolved as in the implementation phase of the Strategy.

For the purposes of the initial costing of the optimised water quality monitoring network the following assumptions were made:

- The water quality site review process will adequately address most of the hydrological, ecological and anthropogenic considerations for the country (see **Table A.5** in **Appendix A** for the proposed spatial distribution per WMA).
- All constituents in each grouping of identified constituents need to be monitored at every type of site to cover all required fitness for use reporting. These are listed in **Table E.2**.
- The frequency of sampling would be following historically accepted intervals.
- All samples will be taken by DWS at current-day estimates for sampling per year

- Two possible options for laboratory analysis would be considered involving either the upscaling and decentralisation of the current DWS laboratory facilities or the full outsourcing of all analyses to external laboratories. These options are further discussed in subsequent subsections.

Most of the assumptions are considered to be reasonable, although clarity will have to be obtained about which constituents need to be measured at each site, since, for example, not all expected constituents will necessarily occur at a given site. As a result it is anticipated that the assumptions regarding the constituents and the frequency will likely result in the indicative costs presented in the Strategy to be relatively high.

Regarding the two possible models for laboratories, the full-outsourcing model may require a separate institutional entity for monitoring management, while the RQIS will probably be largely involved in technical problem resolution. Monitoring management requires a multidisciplinary team involving scientists, legal staff, administrative staff and a standards inspectorate. A critical consideration, however, would be whether the expansion of the RQIS can be accommodated under the existing DPSA structure. In either scenario the development of technical skills will have to be the initial priority. Outsourcing is the quickest route to implementing monitoring on such a large scale and could be implemented within two to three years if administrative impediments are timeously addressed.

The indicative cost estimates for the implementation of the optimal water quality monitoring network are evaluated in terms of two elements, namely; the capital costs and the O&M costs. These two costs are addressed in the sections that follow, after which a summary of annual costs for some specialised monitoring programmes are discussed.

5.4 INDICATIVE CAPITAL COSTS

Capital cost estimates depend on the selected options for laboratory analysis (mentioned earlier), as outlined below.

a) Option 1: Upscaling DWS laboratory facilities

The estimated capital expenditure required to upscale the amount of laboratory equipment at the RQIS and build and equip two additional laboratories (say in Bloemfontein and Cape Town) has been estimated at R280 million (in 2016 rand-value), of which R 80 million would be for equipment. The latter would include equipment like gas chromatography and high performance liquid chromatography machines for organic compounds and microplate systems for quick analysis of unusual compounds.

b) Option 2: Full outsourcing to external laboratories

In this case no capital expenditure would be required since the capital and replacement costs would be included in the costing of analyses.

5.5 INDICATIVE O&M COSTS

a) Option 1: Upscaling DWS laboratory facilities

The estimated O&M required to upscale the amount of laboratory equipment at the RQIS and build and equip two additional laboratories were based on a simple upscaling of the total current annual O&M cost of approximately R40 million for 15 000 surface water samples. This amounts to R533 million per year for approximately 212 000 samples a year (refer to Option 2 below for clarification on the number of samples used for this calculation).

Furthermore, sampling costs were estimated to be R60 million per year (the same value was assumed for Option 2 discussed below). Also the cost of groundwater quality analysis costs was estimated to be 23% of the same costs under Option 2. On this basis the groundwater water analysis costs was estimated at R160 million per year.

This results in a total analysis cost for Option 1 of R694 million per year.

b) Option 2: Full outsourcing to external laboratories

A spreadsheet-based costing model was developed for this option, based on the following datasets:

- The number of sites per type of monitoring site type within each WMA (see **Table A.5** in **Appendix A**).
- The cost of individual constituent analysis by external laboratories (based on a recent survey), aggregated up to constituent groups as provided in **Table E.3**.
- The average cost for DWS to take a sample twice a month per site for a year, estimated at R35 000.

5.6 INDICATIVE ANALYSIS COSTS

The number of samples per site type per year, and therefore the annual cost per WMA, is then calculated by adjusting any of the following three variables:

- The frequency of monitoring per site type. This has statistical implications.
- The constituent group order of priority. This has interpretation implications.
- The fraction of samples to which each group of constituents is applied.

The fraction of samples to which each group of constituents is applied, the total number of annual samples and the associated total annual costs are provided in **Table E.4** and **Table E.5** for the surface water quality and groundwater quality networks, respectively.

Finally, annual sampler costs were calculated based on reference costs (K) as follows:

K = R.month/2.sites.year

Where: K = Reference cost

R.month = R 35 000 per year, for twice a month per site

The actual sampling cost per annum (C) is then calculated as:

C = (F/24) x K x N

Where: K = Reference cost

F = Frequency

N = Number of sites

Even though costing of water quality sampling is included with the surface water quantity cost estimates for sites with water quantity measurements, all the sites were used for N and not only the ones without quantity monitoring. This approach was followed since several changes will have to be phased into the prevailing sampling practices, such as the preservatives to be used and sampling methods. This might entail specialist samplers that will have to travel certain routes within specific timeframes.

A summary of the total sampling costs for both surface and groundwater monitoring is provided in **Table E.6**.

5.7 INDICATIVE COSTS FOR SPECIALISED MONITORING

a) National estuarine monitoring

Estuaries, the surface water interface between rivers and the ocean, represent a specific water use, as well as a resource with unique aesthetic and ecological characteristics. About 40 priority estuaries of national importance have been identified. Annual estuary monitoring costs have been estimated as follows:

- Single estuary operational costs based on 24 sample runs and 5 sites per estuary equate to R144 000 per year. This includes costs associated with personnel (R3 000), sample analyses and transport (R2 000) as well as boat and vehicle costs (R1 000).
- Single estuary capital costs for three loggers over a 4-year period, recalculated to annual costs are R160 000/4, or R40 000 per year.
- Single estuary capital costs for boat and handheld instruments shared across four estuaries over a 4-year period are R 380 000/(4x4), or R 23 750 per year.

In this way the total annual cost per estuary was calculated as R207 750 and the total cost for 40 estuaries, therefore, as R8 310 000.

b) Continuous monitoring

Continuous monitoring of physico-chemical attributes provides ancillary information for filling gaps in the records of constituents sampled at discrete intervals, as well as defining certain types of water use events. Infilling missing values involves an informatics approach and is often used in conjunction with water quality modelling to obtain a finer resolution in fitness for use assessments. The ideal network would include a few carefully selected sampling sites equipped with data loggers with a range of selected electronic sensors. The current proposal is to have continual water quality monitoring at 35 sites nationally.

The annual maintenance and capital cost for one site, including instrument depreciation and human resources, is R180 000. The annual cost for 35 sites is, therefore, R6 300 000.

c) Biometrics

Biomonitoring is the only monitoring activity that currently aims to obtain a direct estimate of the condition of a river. This program is currently largely carried out by WSAs and private institutions, but has great potential for assessing the state of the surface water ecosystem. It also differs from the other fitness for use programmes in that it requires highly trained technicians and scientists to perform all field visits. At a cost of approximately R6 000 per sample and an estimated of 150 samples per province per year, the estimated annual cost is R9 000 000.

5.8 SUMMARY OF INDICATIVE COSTS

The total indicative capital and annual O&M costs of water quality monitoring was estimated based on the approaches and assumptions discussed in the preceding sections. The results are summarised in **Table 5.1** for the optimal water quality monitoring network and for both Option 1 (i.e. upscaling DWS laboratory facilities) and Option 2 (i.e. full outsourcing to external laboratories).

Table 5.1 Indicative capital and O&M costs for water quality monitoring sites

Item	Option 1(1)	Option 2(2)
Capital costs(3)		
Laboratory and equipment upgrading	R 280 000 000	Included in analysis costs
Total capital cost	**R 280 000 000**	**R 0**
Annual costs(3)		
a) Surface water		
Analysis	R 533 000 000	R 822 403 620
Sampling	R 37 082 500	R 37 082 500
Sub-total (a)	*R 570 082 500*	*R 859 486 120*
b) Groundwater:		
Analysis	R 160 612 702	R 247 820 765
Sampling	R 23 207 917	R 23 207 917
Sub-total (b)	*R 183 820 619*	*R 271 028 682*
c) Specialised Monitoring		
Estuaries	R 8 310 000	R 8 310 000
Biomonitoring	R 9 000 000	R 9 000 000
Continuous monitoring	R 6 300 000	R 6 300 000
Sub-total (c)	*R 23 610 000*	*R 23 610 000*
Total annual cost	**R 777 513 119**	**R 1 154 124 802**

Note: (1) Upscaling DWS laboratory facilities.
(2) Full outsourcing to external laboratories
(3) Annual costs, in current (2016) rand value.

Note the following regarding the summary of costs presented above:

- The frequency of sampling and the constituents to be analysed have the most significant impact on cost estimates (especially O&M costs).
- Determining the exact frequency and constituents per site will require extensive research during the next few years.
- The decision regarding the two options for laboratory analysis (i.e. upscaling DWS facilities or full outsourcing to external laboratories) will be the main consideration for capital costs, but will also influence O&M costs.

Furthermore, the costs reflected in Table 5.1 are based on assumption that may result in the indicative costs to be an overestimation. Specifically, some assumptions may not be nationally applicable, such as the following:

- Not all constituents would be of concern in all areas across the country.
- Lower frequencies may be acceptable in drier areas.
- The information yield from consecutive sites on a river may not differ significantly, making some sites redundant.

Based on the cost estimates presented here it appears that Option 1 is preferable. However, Option 2 would be much quicker to implement and there is also a significant risk that DWS would not be able to appoint personnel with the required expertise to undertake some of the specialised analyses. However, a final decision on the preferred option would only be possible in the implementation phase of the Strategy.

6. SCHEDULING AND CASH FLOW

As discussed in **Section 2** a number of spreadsheet-based costing tools were developed for the Strategy to develop indicative capital and O&M costs for implementing and maintaining an optimal Water Resources Monitoring Network. As part of this process, a set of scheduling and cash flow tools were also developed to allow for these aspects to be considered in the implementation of the Strategy.

Separate tools were designed for the surface water quantity, groundwater and water quality programmes, specifically to:

- Enable the sequencing and grouping of multiple monitoring sites/stations based on technical priority scores and other user-selected considerations.
- Estimate capital and O&M costs for individual monitoring sites/stations based on the assumptions and methodologies discussed in the preceding sections.
- Allow for assumptions (such as unit costs or the duration of tasks) to be revised based on more reliable information if available.
- Schedule project phases and tasks for individual monitoring sites/stations, based on selected start dates, durations and inter-dependencies.
- Based on the above, calculate monthly expenditure and cash flow projections for the selected area.
- Generate a Gantt chart of the scheduled projects and phases.

Furthermore, the tools were designed in such a way that they are completely scalable to allow for analyses across any number of monitoring sites/stations and across any area, such as a selected catchment, WMA, province or nationally. Furthermore, the tools were developed based on input from DWS, as well as various assumptions derived from the technical experience of both DWS officials and members of the Strategy development team. These assumptions, as well as limitations are discussed below and must be kept in mind when applying the tools.

- If the construction sites are within a radius less than 100 km and adequate access roads are in place it is assumed that a construction unit can work on the construction/refurbishment of four surface water quantity monitoring stations simultaneously. This is defined as a “station grouping”.

- The costs of construction material and activities are calculated explicitly, while costs associated with the planning, management and design phases are calculated as a percentage of the construction cost. The user of the tool can overwrite these values with more accurate estimate should they be available.
- EIA costs are assumed to be R300 000 per surface water quantity monitoring station.
- Each phase of a project (such as design or construction) will only commence once the previous phase has been completed. However, the user can define time shifts as outlined below.
- A time shift can be applied to an individual or grouping of monitoring sites/stations, thereby moving the commencement date of projects and phases (as shown in **Figure F.1** of **Appendix F**). These time shifts may, for the design and construction phases, be less than zero (to move the phase up), greater than zero (to move the phase out) or equal to zero to maintain the default assumption.
- The time shifts must, for the planning and management phase, always be greater or equal to zero.
- The start date of individual monitoring stations within a "station grouping" can also be changed by changing values in spreadsheet column H on the user input tab (as shown in as shown in **Figure F.2**). This value must always be greater or equal to one.
- Planning on the WMA-scale occurs on a monthly time-step.
- A single WMA scheduling tool cab be used for a maximum of 40 monitoring stations and up to a maximum project duration of 1 200 months (100 years).
- The formulas used to generate the Gantt chart output (as shown in **Figure F.3**) can be dragged horizontally to increase the maximum project duration, but cannot be dragged vertically to cater for more than 40 monitoring stations.
- The spreadsheet file must be saved after any changes are made to the time shifts or on the user input tab. Failure to do so will result in the projected cash flow and Gantt chart to not update accordingly.
- The prioritisation of monitoring sites/station is defined in the first row of the user input tab (see **Figure F.4**).

Once the cash flows for all selected areas, such as the nine WMAs, have been completed, the output is used in a separate tool to generate a national implementation timeline for the Strategy. Specifically, the monthly totals generated below the Gantt chart (shown in **Figure F.5**) must be copied by the user and pasted as text next to the relevant WMA and monitoring programme (shown in **Figure F.6**). The second tool then generates a national timeline on an annual time step.

The tool does allow for changes in the start year per WMA (as shown in **Figure F.7**). All values in these cells must always be greater or equal to 1. Note that one national timeline tool is used that incorporates output from the three monitoring networks and generates an integrated national schedule and cash flow projection.

Finally, note that all of the costing, cash flow and scheduling tools developed for the Strategy are provided electronically with this document, on a CD included at the end of **Appendix F**.

7. COST-BENEFIT ANALYSIS

A key aspect of the implementation of the Strategy is the potential associated benefits and, therefore, motivation for the significant expenditure required (as discussed in earlier sections). For this purpose, the outcomes from an earlier study, *Cost Benefit Analysis for Water Monitoring and Information* (DWA, 2012) was used to provide a preliminary indication of the financial benefit that could be realised by implementing the Strategy.

Based on extensive calculations and analyses the study produced a cost-benefit ratio (CBR) for expenditure on the national water resources monitoring network of 10.77. This ratio indicates the return, in rands, expected as a result of every one rand invested in the monitoring network. By adopting this CBR and applying it to the indicative capital costs of the optimal National Monitoring Network the financial benefit of the Implementation Strategy could be calculated. The results are presented in Table 7.1.

Table 7.1 Total capital cost-benefit for optimal National Monitoring Network

Monitoring programme	Option	Cost(3) (R million)
Surface water flow	N/A	3 761
Groundwater	N/A	189
Water Quality	Option 1(1)	280
	Option 2(2)	0
Total capital cost	Option 1	3 950
	Option 2	4 230
Benefit parameter	**Option**	**Benefit (R million)**
CBR	N/A	10.77
Benefit	Option 1	38 591
	Option 2	41 327

Note: (1) Upscaling DWS laboratory facilities.
(2) Full outsourcing to external laboratories
(3) Annual costs, in current (2016) rand value.

8. IMPLEMENTATION RISKS

Any institutional recommendations made as part of this study must be aligned with the National Water Act (Act No. 36 of 1998) and the National Water Resources Strategy (NWRS-2). These documents provide guiding principles to ensure that the implementation of the Strategy contributes to the goal of the NWRS-2, which is to ensure that water is efficiently and effectively managed for equitable and sustainable growth and development.

However, in the implementation of the Strategy, three over-arching risks must be considered for all monitoring networks. These risks are briefly described in **Sections** Error! Reference source not found.**,** Error! Reference source not found. and Error! Reference source not found., but must be further investigated and taken into consideration in the implementation phase.

8.1 HUMAN RESOURCES

The human resources risks associated with the implementation of the Strategy relate to obtaining the skills required to successfully implement its recommendations. This will require that DWS equips itself with a variety of technical and project management skills.

The available resources within DWS must be evaluated in detail in the planning stages of the implementation phase. This evaluation will determine which implementation tasks can be implemented by the Department and which will either require recruitment of adequately skilled staff or will have to outsourced to third party professional service providers (PSPs).

The outsourcing of projects and tasks to PSP may impede the scheduling of the implementation phase. The outsourcing process would require, amongst others, the development of Requests for Proposals, preparation of tender documents and the relevant procurement processes before the selected PSP can start work. These factors are applicable to all the monitoring networks and are triggered by the human resources risks associated with each monitoring network.

Likewise, recruiting new staff would involve a substantial human resources procedure for DWS – assuming that individuals with the requisite skills and capabilities are available in the marketplace.

8.2 CONSTRUCTION AND TECHNICAL IMPLEMENTATION

Construction and technical implementation risks are specific to each monitoring network. These risks are not evaluated as part of this Strategy, but have to be evaluated in the planning stages of the implementation phase.

The evaluation of these risks should include site visits, geological explorations, geophysics evaluations and geotechnical investigations, as well as other reconnaissance exercises. The purpose of these activities is to identify factors that may delay or otherwise affect the implementation, construction or installation of monitoring stations.

An example of construction risks that must be considered is the geology and topography of the proposed monitoring sites. These factors could affect the location and duration of construction of both surface water quantity monitoring stations and groundwater monitoring boreholes. Not only will the effects be different for the different monitoring programmes, but the regional variations in South Africa’s geology and topography must also be considered at each stage of the implementation phase.

8.3 FINANCIAL RESOURCES

The lack of financial resources poses a significant risk to the implementation of the Strategy both with regard to the significant expenditure required, as well as the budgeting and cash flow challenges faced by DWS and other responsible institutions. These challenges will affect both the scheduling and the period over which the Strategy can be implemented. These constraints should be evaluated and updated during the planning stages of the implementation phase in order to develop a realistic implementation schedule.

9. STRATEGY IMPLEMENTATION ACTIONS

Programme-specific implementation actions for surface water quantity, groundwater and water quality are provided in **Sections 3**, **4** and **5** of this document, respectively. There are however a number of overarching actions that are required both to review the outcomes of this study and ensure that the Strategy is implemented accordingly. These are summarised below:

- Implementation support from a PSP must be procured as soon as possible. It is unlikely that DWS will have all the required resources to implement the Strategy thus making it crucial that a Terms of Reference (TOR) is developed prior to the start of the implementation phase.
- DWS must begin establishing a project management team for the implementation phase of the Strategy. This team will be at the forefront of all procurement, management, scheduling and administrative requirements. Having such a team in place will make the transition from Strategy development to implementation much more effective.
- All outcomes of the Scientific Review must be verified. This task would include site visits, ground explorations, surveys and various other investigations to confirm the locations of all proposed monitoring points.
- All indicative capital and O&M costs must be updated based on the outcomes of the above verification process. Capital costs of gauging weirs are particularly sensitive to topography amongst other factors. It is crucial that accurate data be acquired in order to generate realistic cost estimates.
- For the purposes of sharing the knowledged developed in this study and strategy, it is recommended that the full study be submitted to the WMO for review and publishing.
- Sufficient funding support must be secured for the implementation of the Strategy.
- Once this is in place the scheduling and the period over which the Strategy can be implemented must be reviewed and updated.
- Long-term capital and O&M funding must also be secured to ensure that high-quality data is collected across all monitoring programmes and over many years.
- Additional monitoring points must be implemented as soon as possible to provide the additional information required for a meaningful understanding of the status and trends in our water resources.

- Highly productive sources (high rainfall areas, high-yielding aquifer systems, high recharge systems, etc.) should be prioritised.
- Protocols for the identification of new sites must be developed to ensure proper integration into the existing monitoring network. This includes, for example, guidelines for borehole construction.
- The implementation of the optimal water quality monitoring network must first give effect to all the outcomes from the Planning Phase. It will involve the roll-out of the new network in terms of contracting of external laboratories, assigning new constituents and frequencies to new and existing sites as well as any required adaptation to IT systems.
- To gain the maximum benefit from water quality sample, skilled technicians are required. Substantial training of samplers will have to be undertaken on new techniques and preservatives to be used.
- Sampling and analytical procedures require specialised equipment and supplies. The DWS procurement section should therefore include at least two officials with, in addition to their financial skills, appropriate technical or scientific qualifications and relevant experience.

10. REFERENCES

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APPENDIX A:

Optimal monitoring network design

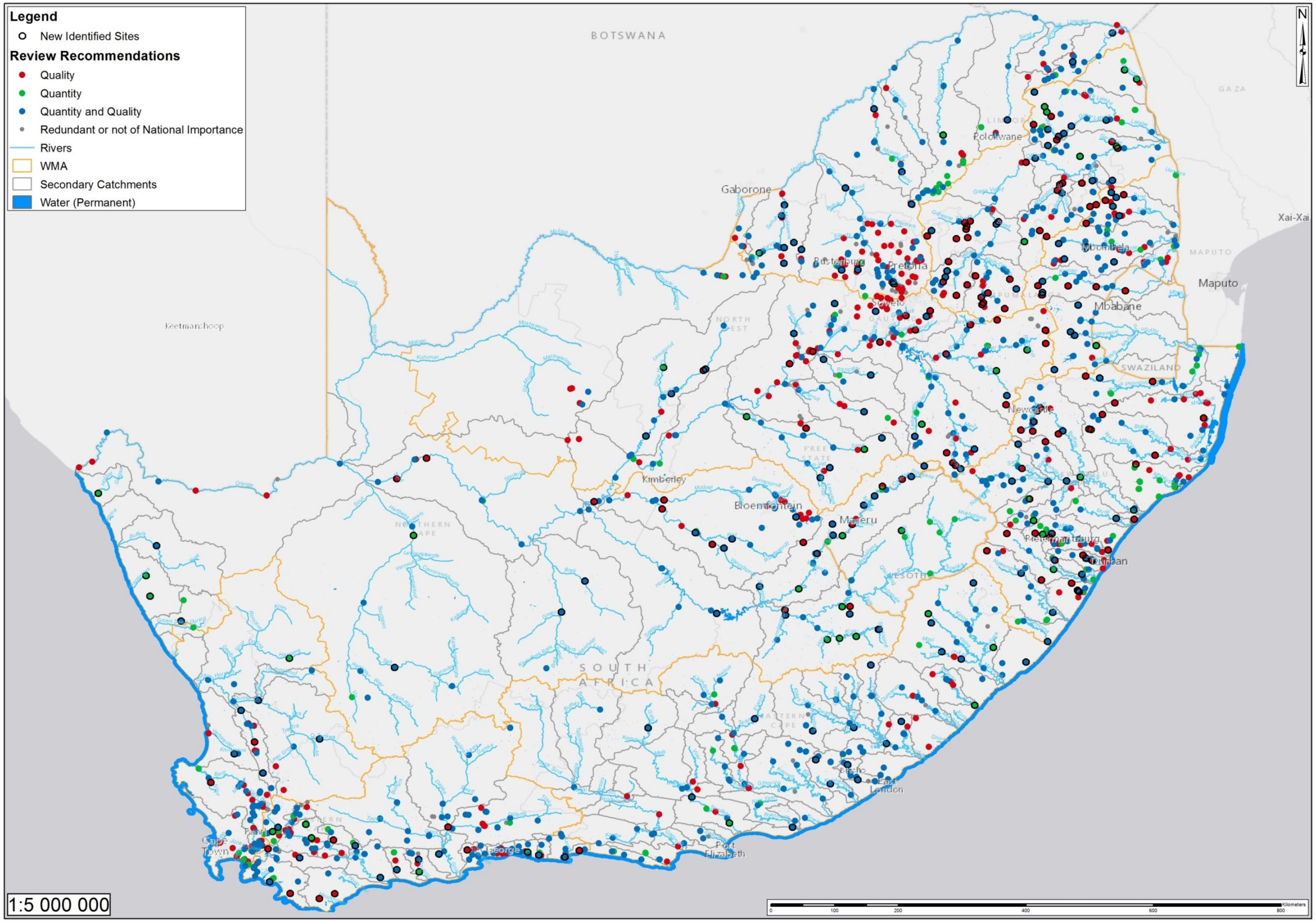


Figure A.1 **Optimal monitoring network design: surface water quantity and quality sites**

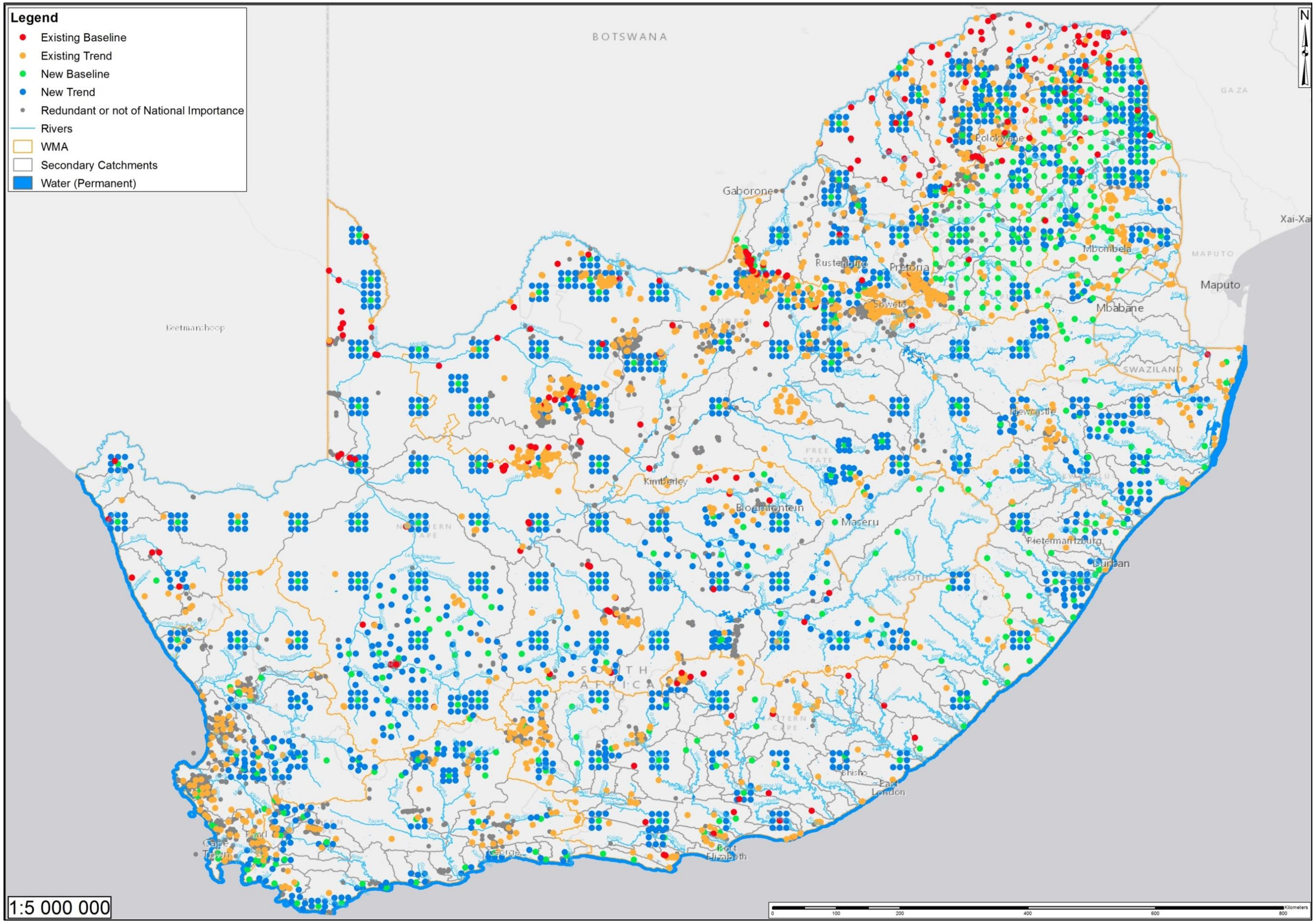


Figure A.2 Optimal monitoring network design: groundwater sites

Table A.1 Optimal monitoring network design for surface water quantity monitoring sites

WMA	Workshop recommendations[1]					Total
	New Site	Investigate improvement / replacement	Maintain Site	Not of national importance	Possibly redundant	
Limpopo	11	34	30	10	11	75
Olifants	13	17	23	8	5	53
Inkomati-Usuthu	9	3	41	1	2	53
Pongola-Mzimkhulu	13	9	61	1	4	83
Vaal	22	31	27	10	9	80
Orange and Lesotho	25	18	23	2	1	66
Mzimvubu-Tsitsikamma	17	19	44	4	7	80
Breede-Gouritz	13	14	45	7	8	72
Berg-Olifants	4	7	28	5	7	39
National	**127**	**152**	**322**	**48**	**54**	**601**

Notes: (1) From the national and regional Spatial Design Workshops as discussed in ***Section 2.5****.*

Table A.2 Optimal monitoring network design for reservoir monitoring sites

WMA	Workshop recommendations[1]					Total
	New Site	Investigate improvement or replacement	Maintain Site	Not of national importance	Possibly redundant	
Limpopo	9	18	31	0	1	58
Olifants	7	13	29	0	1	49
Inkomati-Usuthu	1	2	24	0	0	27
Pongola-Mzimkhulu	2	4	53	0	0	59
Vaal	1	7	25	4	0	33
Orange and Lesotho	6	8	18	0	0	32
Mzimvubu-Tsitsikamma	8	7	43	0	0	58
Breede-Gouritz	2	1	56	0	0	59
Berg-Olifants	1	0	13	1	0	14
National	**37**	**60**	**292**	**5**	**2**	**389**

Notes: (1) From the national and regional Spatial Design Workshops as discussed in ***Section 2.5****.*

Table A.3 Comparison of existing and optimal monitoring network design for surface water and reservoir monitoring sites

WMA	Existing number of sites[(1)]		Proposed number of sites		Total number of sites	
	Surface water quantity	Reservoirs	Surface water quantity	Reservoirs	Existing[(1)]	Proposed
Limpopo	98	30	75	58	128	133
Olifants	71	24	53	49	95	102
Inkomati-Usuthu	64	15	53	27	79	80
Pongola-Mzimkhulu	98	36	83	59	134	142
Vaal	77	28	80	33	105	113
Orange and Lesotho	51	18	66	32	69	98
Mzimvubu-Tsitsikamma	94	31	80	58	125	138
Breede-Gouritz	95	40	72	59	135	131
Berg-Olifants	56	8	39	14	64	53
Totals:	**704**	**230**	**601**	**389**	**934**	**990**

Notes: (1) Analysis of existing sites based on the status in 2014.

Table A.4 Comparison of existing and optimal monitoring network design for groundwater sites

WMA	Existing[(1)] number of sites for baseline monitoring	Proposed number of sites for baseline monitoring	Existing[(1)] number of sites for trend monitoring	Proposed number of sites for trend monitoring	Total
Berg-Olifants	0	28	0	177	205
Breede-Gouritz	0	40	54	111	205
Inkomati-Usuthu	2	35	0	113	150
Limpopo	82	48	41	367	538
Mzimvubu-Tsitsikamma	25	48	0	295	368
Olifants	164	23	0	229	416
Orange & Lesotho	76	86	127	489	778
Pongola-Mzimkulu	3	56	52	127	238
Vaal	40	63	47	814	964
Total	**392**	**427**	**321**	**2 722**	**3 862**

Notes: (1) Analysis of existing sites based on the status in 2014.

Table A.5 Comparison of existing and optimal monitoring network design for water quality sites

Site type	Existing[1] or total recommended	Vaal	Orange	Limpopo	Olifants	Inkomati-Usuthu	Pongola-Mzimkhulu	Mzimvubu-Tsitsikamma	Breede-Gouritz	Berg-Olifants	Total	% Difference	Number of sites with quality only
Reservoir/Barrage/Lake	Existing	32	17	32	24	14	36	27	28	4	214	0%	29
	Total recommended	28	18	36	26	14	28	27	31	7	215		
River (W-Comp)	Existing	7	4	15	10	8	15	14	3	1	77	53%	1
	Total recommended	9	7	19	18	12	15	21	13	4	118		
River (GenFFU)	Existing	86	42	87	57	43	70	79	62	35	561	9%	207
	Total recommended	94	62	61	67	57	87	77	66	42	613		
River (Hum,LS,Rec Only)	Existing	15	7	32	10	13	16	9	17	18	137	26%	171
	Total recommended	20	7	32	27	17	26	9	17	18	173		
River (Baseline)	Existing	4	1	6	1	4	7	8	13	4	48	77%	37
	Total recommended	10	4	6	9	8	15	12	16	5	85		
Spring/Eyes	Existing	13	0	11	0	0	0	1	0	0	25	-12%	11
	Total recommended	12	0	9	0	0	0	1	0	0	22		
Groundwater (Baseline)	Existing	40	76	82	164	2	3	25	0	0	392	9%	0
	Total recommended	63	86	48	23	35	56	48	40	28	427		
Groundwater (Trend)	Existing	47	127	41	0	0	52	0	54	0	321	748%	0
	Total recommended	814	489	367	229	113	127	295	111	177	2722		
Total recommended surface water quality sites		**173**	**98**	**163**	**147**	**108**	**171**	**147**	**143**	**76**	**1226**	**15%**	**456**
Existing surface water quality sites		**157**	**71**	**183**	**102**	**82**	**144**	**138**	**123**	**62**	**1062**		
Difference (%)		10%	38%	-11%	44%	32%	19%	7%	16%	23%	15%		
Total recommended groundwater quality sites		**877**	**575**	**415**	**252**	**148**	**183**	**343**	**151**	**205**	**3149**	**342%**	
Existing groundwater quality sites		**87**	**203**	**123**	**164**	**2**	**55**	**25**	**54**	**0**	**713**		

Notes: (1) Analysis of existing sites based on the status in 2014.

APPENDIX B:

Surface water quantity monitoring capital costs

Table B.1 Indicative implementation schedule for a surface water quantity monitoring project

Phase	Task no.	Task description	Months to complete - New	Months to complete – Upgrade of stations
Management	1	Management of overall implementation project i	See General Notes	
	2	In-house / external ii	See General Notes	
	3	Project Management Office? iii	See General Notes	
	4	Engineering programme	0.25	0.25
	5	Environmental impact assessment	6	6
	6	Water use licence application iv	6	N/A
	7	Stakeholder participation v	6	6
Planning	8	Site identification, evaluation & geotechnical screening	1.5	1.5
	9	Topographical surveys	0.5	0.5
	10	Land acquisition vi	6	N/A
	11	Access roads vii	3	N/A
	12	Indicative capital cost viii	2	2
Design	13	Scope of work: RfP	3	3
	14	Request for proposals	3	3
	15	Tender documents	6	6
	16	Tender evaluation	2	2
	17	Procurement	2	2
	18	Appointment of PSP	1	1
	19	Design programme	0.25	0.25
	20	Detail design & drawings	5	3
	21	Detail cost estimate	1	1
	22	Updated implementation plan (based on cost and time frames)	1	1
Construction	23	Funding: Treasury? ix	18 - 24	18 - 24
	24	Tender documents	6	6
	25	Tender evaluation	2	2

Phase	Task no.	Task description	Months to complete - New	Months to complete – Upgrade of stations
	26	Procurement	2	2
	27	Appointment of contractor	1	1
	28	Site establishment	0.5 - 1	0.5 – 1
	29	Construction	6 - 36	6 - 36
Implementation	30	As-built surveys	2	1
	31	Commissioning	1	1
	32	Calibration	0.5	0.5
	33	Implementation	0.5	0.5
O&M	34	Operation (assume manual/s)	2 - 3	2 – 3
	35	Maintenance (assume prescribed plan)	2 - 3	2 - 3

GENERAL NOTES:

i. The above durations are based on general experience and ignore the location and size of a structure.

ii. The actual differences in durations when task descriptions for existing structures are compared to those of new structures do not always exist. The durations for most task descriptions are more or less the same irrespective of whether it is an existing structure to be modified or a completely new one to be built.

iii. The main differences between an existing weir and a new weir are regarded as the following:

a. Land matter issues;

b. Construction of access roads;

c. Application of a new water licence for a new structure (based on the assumption an existing structure does not require the same);

d. The environmental authorization might be different in case of an existing structure. However, if the changes on an existing structure are not substantial or the affected area is within a certain footprint size, exemption may be obtained or the process might be less cumbersome; and

e. Construction periods might vary substantially which will be highly dependent on construction material volumes and other construction quantities. The capacity of river diversion works has a dominant effect on the construction period: the bigger the diversion capacity the longer the construction period. River diversion capacity for existing structures is normally less than what is required for new structures because existing structures are normally used as part of a river diversion strategy.

EXPLANATION OF NOTES:

i. The durations of the following tasks (read task numbers) should be added (if not required to run sequential the task with the longest duration per phase is used): 5 or 6 or 7 + 10 or 13 to 22 + 24 to 29 + 30 + 34 or 35.

ii. If "in-house" then the duration will be the same as discussed above under "1". If "external" the duration of Tasks 24 + 15 + 16 +17 + 18 needs to be added.

iii. The duration will be as discussed in "2" above but dependent on whether "in-house" or "external" is used.

iv. Already discussed in the 3rd bullet under "c" above.

v. This aspect should run concurrently with Tasks 3, 5 and 6.

vi. If the land acquisition process takes longer than 6 months, then servitudes in favour of the department should be registered over the affected property not to delay processes beyond

6 months. It can also be decided to start off with the registering of servitudes to enable processes to commence (then the land acquisition process can run concurrently with other activities).

vii. *The length and complexity/sophistication of access roads may impact the duration negatively or positively.*

viii. *The outcome of this exercise informs budget cycles and attempts should be put in place to finalise this task earlier. In this case Task No 12 can stay where it is but then it will not be an indicative cost, but rather a more detailed cost analysis (almost an engineer's estimate).*

ix. *Task No 23 is critical but in fact can only start after Task No 12 is completed and then run concurrently with other activities to ensure funds are secured before the commencement of Task No 26. If not possible, Task No 23 has to start earlier than Task No 12. The budget cycles used by government needs to be incorporate here where funds must be requested 3 years in advance as per the MTEF. In such case the durations a suggested above will be in jeopardy*

Table B.2 Indicative capital cost estimates for a surface water quantity monitoring project

Task	Sub-factor	Unit	Rand(1) per unit
Weir construction	Excavations	m^3	100
	Foundation preparation	m^2	175
	Shuttering	m^2	975
	Reinforcing	ton	16 500
	Concrete - blinding	m^3	2 800
	Concrete - mass	m^3	2 800
	Concrete - reinforced	m^3	2 800
	Concrete – rollcrete	m^3	1 500
Fill material	Soil cement	m^3	600
	Selected material	m^3	150
	Rockfill / gabions	m^3	1 350
Service road	Service road	m	175

Note: (1) In current (2016) rand-value.

Table B.3 Calculation of construction material volumes for a surface water quantity monitoring project

ID	Variable	Unit	Calculation
[1]	Width of river at the lowest level	m	User input
[2]	Reduced level at lowest level	m	User input
[3]	Reduced level of higher point on the section	m	User input
[4]	Width of the river at reduced level	m	User input
[5]	Slope	-	$(\frac{[4]-[1]}{2})/([3]-[2])$
[6]	Level of weir crest	m	[2]+1.5
[7]	Top level of weir structure	m	[6]+2.5
[8]	Length of weir crest	m	[1]+([6]-[2])*[5]*2-2
[9]	Cross-sectional area of weir crest	m^2	$([7]-[6])*3*([6]-[2])-0.65*([7]-[6])^2$
[10]	Shutter height	m	([6]-[2])*2-([7]-[6])*0.9
[11]	Total weight dowels	kg	$((\frac{[8]}{0.5}+1)*4*(1+([6]-[2])))$
[12]	Length of the cut-off wall	m	[1]+([7]-[2])*[5]*2-[8]+12
[13]	Cut-off walls cross sectional area	m^2	(([7]-[2])*0.6+2)/2*([7]-[2])
[14]	Shutter height (cut-off wall)	m	$([7]-[2])+([7]-[2])*\sqrt{1.36}$
[15]	Total weight dowels (cut-off wall)	kg	([12]/1+1)*4*([7]-[2]+1)
[16]	Length of the flank walls	m	([7]-[6])*19
[17]	Flank walls cross sectional area	m^2	1*([7]-[2])
[18]	Shutter height (flank walls)	m	2*([7]-[2])
[19]	Total weight of reinforcement	kg	[16]*([7]-[2])*35+20*[16]
[20]	Blinding	m^3	[8]*0.2*(([7]-[6])*3+2)+0.2*[12]*(([7]-[2])*0.6+3)+[16]*0.2*2
[21]	Rip-rap	m^3	0.8*([12]+10)*20/1.6
[22]	Excavations	m^3	$((([7]-[2])*0.6+1+10)*([7]-[2])+([7]-[2])^2)*([12]+10+([7]-[2]))+(([8]+2)*(3*([7]-[6])+2))*0.3$

ID	Variable	Unit	Calculation
[23]	Selected fill	m^3	[22]/10
[24]	Foundation preparation	m^2	[8]*(([7]-[6])*3+3)+([12]+6)*(3+([7][1])*0.6)+([16]+6)*3

Table B.4 Material quantities for the construction of an instrumentation hut

ID	Variable	Units	Calculation
[25]	Concrete volume	m^3	User input
[26]	Reinforcement	kg	User input
[27]	Shuttering	m^2	User input

Table B.5 Summary calculations of volumes for a surface water quantity monitoring project

ID	Variable	Units	Calculation
[28]	Concrete volume (mass): summary	m^3	[8]*[9]+[12]*[13]
[29]	Concrete volume (reinforced): summary	m^3	[16]*[17]+[25]
[30]	Concrete volume (blinding): summary	m^3	[20]
[31]	Rebar	ton	([11]+[15]+[19]+[26])/1000
[32]	Shuttering	m^2	([8]*[10]+[12]*[14]+[16]*[18])*1.1+[27]

Table B.6 Calculation of construction material costs for a surface water quantity monitoring project

Item	Description	Unit	Rate	Quantity	Amount
1.0	Weir construction				
1.1	Excavations	m^3	100	[22]	100*[22]
1.2	Foundation preparation	m^2	175	[24]	175*[24]
1.3	Shuttering	m^2	975	[32]	975*[32]
1.4	Reinforcing	ton	1500	[31]	16 500*[31]
1.5	Concrete: blinding	m^3	800	[30]	2 800*[30]
1.6	Concrete: mass	m^3	800	[28]	2 800*[28]
1.7	Concrete: reinforced	m^3	800	[29]	2 800*[29]
1.8	Concrete: rollcrete	m^3	500	0	-
2.0	Fill material				
2.1	Soil cement	m^3	600	0	-
2.2	Selected material	m^3	150	[23]	150*[23]
2.3	Rockfill / gabions	m^3	1 350	[21]	1 350*[21]
3.0	Service roads(2)	m	175	2 500	437 500
[33]	Sub-total A				

Note: (1) In current (2016) rand-value.

(2) For the purpose of the Implementation Strategy it is assumed that the average length of required service road is 2.5 km based on input from DWS.

Table B.7 Calculation of costs not directly associated with construction of a surface water quantity monitoring project

Item no.	Description	Units	Rate	Quantity	Amount
[34]	Dewatering (% of [33])	%	[33]	4.0	[33]*(4/100)
[35]	Mechanical items (% of [33])	%	[33]	10.0	[33]*(10/100)
[36]	Landscaping & Rehabilitation (% of [33])	%	[33]	5.0	[33]*(5/100)
[37]	Sub-total B				[33]+[34]+[35]+[36]
[38]	Miscellaneous (% of [37])	%	[37]	5	[37]*(5/100)
[39]	Sub-total C				[37]+[38]
[40]	Overheads (% of [39])	%	[39]	30	[39]*(30/100)
[41]	Contingencies (% of [39])	%	[39]	10	[39]*(10/100)

Note: (1) In current (2016) rand-value.

Table B.8 Indicative capital costs for surface water quantity monitoring projects in the Limpopo WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N1	R 14 000 000	R 15 400 000	R 13 900 000	R 13 900 000	R 14 433 333	R 14 417 430	R 15 400 000
N2	R 14 700 000	R 20 600 000	R 25 800 000	R 14 700 000	R 20 366 667	R 19 842 730	R 25 800 000
N3	R 23 000 000	R 39 900 000	R 66 600 000	R 23 000 000	R 43 166 667	R 39 390 515	R 66 600 000
N4	R 24 700 000	R 25 100 000	R 37 200 000	R 24 700 000	R 29 000 000	R 28 464 564	R 37 200 000
N5	R 19 800 000	R 19 400 000	R 18 200 000	R 18 200 000	R 19 133 333	R 19 121 095	R 19 800 000
N6	R 12 800 000	R 14 100 000	R 13 600 000	R 12 800 000	R 13 500 000	R 13 489 297	R 14 100 000
N7	R 10 300 000	R 8 900 000	R 9 700 000	R 8 900 000	R 9 633 333	R 9 616 115	R 10 300 000
N8	R 9 400 000	R 8 700 000	R 9 900 000	R 8 700 000	R 9 333 333	R 9 320 247	R 9 900 000
N9	R 65 000 000	R 55 400 000	R 48 900 000	R 48 900 000	R 56 433 333	R 56 050 221	R 65 000 000
N10	R 25 500 000	R 23 900 000	R 24 100 000	R 23 900 000	R 24 500 000	R 24 489 789	R 25 500 000
N11	R 18 400 000	R 10 200 000	R 16 200 000	R 10 200 000	R 14 933 333	R 14 486 974	R 18 400 000
N12	R 51 700 000	R 55 000 000	R 58 800 000	R 51 700 000	R 55 166 667	R 55 090 518	R 58 800 000
N13	R 31 800 000	R 46 700 000	R 48 800 000	R 31 800 000	R 42 433 333	R 41 692 180	R 48 800 000
N14	R 12 600 000	R 11 900 000	R 33 700 000	R 11 900 000	R 19 400 000	R 17 159 941	R 33 700 000
N15	R 21 700 000	R 24 400 000	R 22 700 000	R 21 700 000	R 22 933 333	R 22 906 486	R 24 400 000
N16	R 9 700 000	R 10 500 000	R 12 200 000	R 9 700 000	R 10 800 000	R 10 750 788	R 12 200 000
N17	R 13 700 000	R 12 900 000	R 15 500 000	R 12 900 000	R 14 033 333	R 13 992 028	R 15 500 000

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N18	R 31 900 000	R 64 600 000	R 55 500 000	R 31 900 000	R 50 666 667	R 48 540 628	R 64 600 000
N19	R 36 100 000	R 32 500 000	R 28 200 000	R 28 200 000	R 32 266 667	R 32 103 069	R 36 100 000
N20	R 11 700 000	R 14 800 000	R 13 900 000	R 11 700 000	R 13 466 667	R 13 401 522	R 14 800 000
Total	**R 458 500 000**	**R 514 900 000**	**R 573 400 000**	**R 419 400 000**	**R 515 600 000**	**R 504 326 138**	**R 616 900 000**

Note: (1) In current (2016) rand-value.

Table B.9 Indicative capital costs for surface water quantity monitoring projects in the Olifants WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N1	R 6 300 000	R 9 400 000	R 12 600 000	R 6 300 000	R 9 433 333	R 9 070 119	R 12 600 000
N2	R 16 000 000	R 16 300 000	R 13 500 000	R 13 500 000	R 15 266 667	R 15 212 962	R 16 300 000
N3	R 24 900 000	R 26 200 000	R 31 900 000	R 24 900 000	R 27 666 667	R 27 506 190	R 31 900 000
N4	R 11 300 000	R 13 000 000	R 12 000 000	R 11 300 000	R 12 100 000	R 12 080 021	R 13 000 000
N5	R 10 100 000	R 9 400 000	R 10 100 000	R 9 400 000	R 9 866 667	R 9 861 058	R 10 100 000
N6	R 30 400 000	R 15 900 000	R 13 000 000	R 13 000 000	R 19 766 667	R 18 453 186	R 30 400 000
N7	R 23 500 000	R 34 400 000	R 12 100 000	R 12 100 000	R 23 333 333	R 21 386 377	R 34 400 000
N8	R 17 400 000	R 21 500 000	R 19 600 000	R 17 400 000	R 19 500 000	R 19 427 396	R 21 500 000
N9	R 14 000 000	R 14 400 000	R 14 500 000	R 14 000 000	R 14 300 000	R 14 298 358	R 14 500 000
N10	R 14 400 000	R 12 700 000	R 15 400 000	R 12 700 000	R 14 166 667	R 14 121 982	R 15 400 000
N11	R 15 300 000	R 15 700 000	R 19 800 000	R 15 300 000	R 16 933 333	R 16 817 138	R 19 800 000
N12	R 34 100 000	R 35 900 000	R 33 400 000	R 33 400 000	R 34 466 667	R 34 450 730	R 35 900 000
N13	R 13 400 000	R 20 700 000	R 29 200 000	R 13 400 000	R 21 100 000	R 20 082 572	R 29 200 000
N14	R 16 000 000	R 15 400 000	R 15 500 000	R 15 400 000	R 15 633 333	R 15 631 145	R 16 000 000
N15	R 16 300 000	R 14 400 000	R 13 600 000	R 13 600 000	R 14 766 667	R 14 724 131	R 16 300 000
N16	R 31 000 000	R 34 700 000	R 30 900 000	R 30 900 000	R 32 200 000	R 32 152 633	R 34 700 000
N17	R 11 600 000	R 13 900 000	R 14 200 000	R 11 600 000	R 13 233 333	R 13 180 151	R 14 200 000

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N18	R 12 300 000	R 9 700 000	R 9 700 000	R 9 700 000	R 10 566 667	R 10 499 038	R 12 300 000
N19	R 10 700 000	R 14 300 000	R 12 900 000	R 10 700 000	R 12 633 333	R 12 544 013	R 14 300 000
N20	R 11 700 000	R 14 800 000	R 13 900 000	R 11 700 000	R 13 466 667	R 13 401 522	R 14 800 000
Total	**R 340 700 000**	**R 362 700 000**	**R 347 800 000**	**R 300 300 000**	**R 350 400 000**	**R 344 900 724**	**R 407 600 000**

Note: (1) In current (2016) rand-value.

Table B.10 Indicative capital costs for surface water quantity monitoring projects in the Inkomati-Usuthu WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N1	R 13 800 000	R 12 700 000	R 19 700 000	R 12 700 000	R 15 400 000	R 15 114 125	R 19 700 000
N2	R 13 700 000	R 18 000 000	R 16 000 000	R 13 700 000	R 15 900 000	R 15 801 720	R 18 000 000
N3	R 14 200 000	R 13 100 000	R 11 800 000	R 11 800 000	R 13 033 333	R 12 996 125	R 14 200 000
N4	R 13 200 000	R 16 700 000	R 13 400 000	R 13 200 000	R 14 433 333	R 14 348 232	R 16 700 000
N5	R 17 400 000	R 17 100 000	R 15 700 000	R 15 700 000	R 16 733 333	R 16 716 615	R 17 400 000
N6	R 20 200 000	R 17 100 000	R 14 800 000	R 14 800 000	R 17 366 667	R 17 226 739	R 20 200 000
N7	R 30 700 000	R 30 400 000	R 18 200 000	R 18 200 000	R 26 433 333	R 25 705 602	R 30 700 000
N8	R 17 600 000	R 17 871 429	R 15 657 143	R 15 657 143	R 17 042 857	R 17 013 545	R 17 871 429
N9	R 17 600 000	R 17 871 429	R 15 657 143	R 15 657 143	R 17 042 857	R 17 013 545	R 17 871 429
N10	R 13 400 000	R 16 200 000	R 13 400 000	R 13 400 000	R 14 333 333	R 14 274 959	R 16 200 000
Total	**R 171 800 000**	**R 177 042 857**	**R 154 314 286**	**R 144 814 286**	**R 167 719 048**	**R 166 211 207**	**R 188 842 857**

Note: (1) In current (2016) rand-value.

Table B.11 Indicative capital costs for surface water quantity monitoring projects in the Pongola-uMzimkhulu WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N1	R 8 200 000	R 8 100 000	R 7 900 000	R 7 900 000	R 8 066 667	R 8 065 699	R 8 200 000
N2	R 11 600 000	R 15 200 000	R 13 700 000	R 11 600 000	R 13 500 000	R 13 417 576	R 15 200 000
N3	R 11 500 000	R 11 400 000	R 10 500 000	R 10 500 000	R 11 133 333	R 11 124 077	R 11 500 000
N4	R 10 400 000	R 8 300 000	R 9 100 000	R 8 300 000	R 9 266 667	R 9 226 796	R 10 400 000
N5	R 15 900 000	R 16 100 000	R 15 800 000	R 15 800 000	R 15 933 333	R 15 932 846	R 16 100 000
N6	R 8 900 000	R 9 200 000	R 9 500 000	R 8 900 000	R 9 200 000	R 9 196 738	R 9 500 000
N7	R 17 200 000	R 19 300 000	R 17 800 000	R 17 200 000	R 18 100 000	R 18 078 758	R 19 300 000
N8	R 12 600 000	R 11 600 000	R 12 300 000	R 11 600 000	R 12 166 667	R 12 159 374	R 12 600 000
N9	R 10 500 000	R 11 300 000	R 12 100 000	R 10 500 000	R 11 300 000	R 11 281 089	R 12 100 000
N10	R 9 000 000	R 10 500 000	R 11 300 000	R 9 000 000	R 10 266 667	R 10 221 236	R 11 300 000
N11	R 13 200 000	R 12 100 000	R 11 900 000	R 11 900 000	R 12 400 000	R 12 387 075	R 13 200 000
N12	R 17 200 000	R 13 400 000	R 12 700 000	R 12 700 000	R 14 433 333	R 14 304 708	R 17 200 000
N13	R 14 300 000	R 12 600 000	R 13 200 000	R 12 600 000	R 13 366 667	R 13 348 327	R 14 300 000
N14	R 17 800 000	R 15 800 000	R 15 200 000	R 15 200 000	R 16 266 667	R 16 229 565	R 17 800 000
N15	R 13 100 000	R 16 400 000	R 21 100 000	R 13 100 000	R 16 866 667	R 16 550 046	R 21 100 000
Total	**R 191 400 000**	**R 191 300 000**	**R 194 100 000**	**R 176 800 000**	**R 192 266 668**	**R 191 523 910**	**R 209 800 000**

Table B.12 Indicative capital costs for surface water quantity monitoring projects in the Vaal WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N1	R 22 200 000	R 20 600 000	R 32 600 000	R 20 600 000	R 25 133 333	R 24 611 945	R 32 600 000
N2	R 19 100 000	R 17 800 000	R 35 200 000	R 17 800 000	R 24 033 333	R 22 873 468	R 35 200 000
N3	R 7 000 000	R 7 300 000	R 6 800 000	R 6 800 000	R 7 033 333	R 7 030 344	R 7 300 000
N4	R 26 700 000	R 28 800 000	R 29 300 000	R 26 700 000	R 28 266 667	R 28 243 843	R 29 300 000
N5	R 8 000 000	R 8 500 000	R 8 800 000	R 8 000 000	R 8 433 333	R 8 426 823	R 8 800 000
N6	R 8 700 000	R 7 700 000	R 8 500 000	R 7 700 000	R 8 300 000	R 8 288 507	R 8 700 000
N7	R 19 100 000	R 17 800 000	R 35 200 000	R 17 800 000	R 24 033 333	R 22 873 468	R 35 200 000
N8	R 19 100 000	R 17 800 000	R 35 200 000	R 17 800 000	R 24 033 333	R 22 873 468	R 35 200 000
N9	R 19 100 000	R 17 800 000	R 35 200 000	R 17 800 000	R 24 033 333	R 22 873 468	R 35 200 000
N10	R 22 200 000	R 20 600 000	R 32 600 000	R 20 600 000	R 25 133 333	R 24 611 945	R 32 600 000
N11	R 22 300 000	R 19 000 000	R 32 600 000	R 19 000 000	R 24 633 333	R 23 993 413	R 32 600 000
N12	R 22 300 000	R 19 000 000	R 32 600 000	R 19 000 000	R 24 633 333	R 23 993 413	R 32 600 000
N13	R 22 300 000	R 19 000 000	R 32 600 000	R 19 000 000	R 24 633 333	R 23 993 413	R 32 600 000
N14	R 22 300 000	R 19 000 000	R 32 600 000	R 19 000 000	R 24 633 333	R 23 993 413	R 32 600 000
N15	R 54 400 000	R 33 900 000	R 38 200 000	R 33 900 000	R 42 166 667	R 41 300 374	R 54 400 000
N16	R 52 700 000	R 68 000 000	R 68 000 000	R 52 700 000	R 62 900 000	R 62 461 079	R 68 000 000
N17	R 37 500 000	R 50 500 000	R 51 900 000	R 37 500 000	R 46 633 333	R 46 149 110	R 51 900 000

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N18	R 22 300 000	R 19 000 000	R 32 600 000	R 19 000 000	R 24 633 333	R 23 993 413	R 32 600 000
N19	R 8 900 000	R 7 700 000	R 9 000 000	R 7 700 000	R 8 533 333	R 8 512 186	R 9 000 000
N20	R 12 300 000	R 11 500 000	R 15 100 000	R 11 500 000	R 12 966 667	R 12 878 342	R 15 100 000
N21	R 15 700 000	R 17 000 000	R 31 100 000	R 15 700 000	R 21 266 667	R 20 247 418	R 31 100 000
N22	R 19 100 000	R 17 800 000	R 35 200 000	R 17 800 000	R 24 033 333	R 22 873 468	R 35 200 000
N23	R 37 500 000	R 50 500 000	R 51 900 000	R 37 500 000	R 46 633 333	R 46 149 110	R 51 900 000
Total	**R 520 800 000**	**R 516 600 000**	**R 722 800 000**	**R 470 900 000**	**R 586 733 333**	**R 573 245 428**	**R 739 700 000**

Note: (1) In current (2016) rand-value.

Table B.13 Indicative capital costs for surface water quantity monitoring projects in the Orange WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N1	R 14 800 000	R 13 200 000	R 15 500 000	R 13 200 000	R 14 500 000	R 14 467 354	R 15 500 000
N2	R 10 500 000	R 13 200 000	R 14 300 000	R 10 500 000	R 12 666 667	R 12 561 257	R 14 300 000
N3	R 9 700 000	R 11 100 000	R 10 400 000	R 9 700 000	R 10 400 000	R 10 384 271	R 11 100 000
N4	R 12 100 000	R 11 300 000	R 12 400 000	R 11 300 000	R 11 933 333	R 11 924 179	R 12 400 000
N5	R 8 300 000	R 18 400 000	R 14 100 000	R 8 300 000	R 13 600 000	R 12 913 333	R 18 400 000
N6	R 8 300 000	R 18 400 000	R 14 100 000	R 8 300 000	R 13 600 000	R 12 913 333	R 18 400 000
N7	R 14 900 000	R 12 600 000	R 10 600 000	R 10 600 000	R 12 700 000	R 12 578 269	R 14 900 000
N8	R 10 900 000	R 8 600 000	R 7 900 000	R 7 900 000	R 9 133 333	R 9 047 266	R 10 900 000
N9	R 10 200 000	R 10 400 000	R 9 800 000	R 9 800 000	R 10 133 333	R 10 130 243	R 10 400 000
N10	R 10 700 000	R 12 200 000	R 9 500 000	R 9 500 000	R 10 800 000	R 10 743 746	R 12 200 000
N11	R 9 600 000	R 9 700 000	R 9 700 000	R 9 600 000	R 9 666 667	R 9 666 551	R 9 700 000
N12	R 10 200 000	R 10 400 000	R 9 800 000	R 9 800 000	R 10 133 333	R 10 130 243	R 10 400 000
N13	R 8 300 000	R 18 400 000	R 14 100 000	R 8 300 000	R 13 600 000	R 12 913 333	R 18 400 000
N14	R 10 700 000	R 12 200 000	R 9 500 000	R 9 500 000	R 10 800 000	R 10 743 746	R 12 200 000
N15	R 10 900 000	R 8 600 000	R 7 900 000	R 7 900 000	R 9 133 333	R 9 047 266	R 10 900 000
N16	R 14 900 000	R 12 600 000	R 10 600 000	R 10 600 000	R 12 700 000	R 12 578 269	R 14 900 000
N17	R 14 900 000	R 12 600 000	R 10 600 000	R 10 600 000	R 12 700 000	R 12 578 269	R 14 900 000

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N18	R 11 170 588	R 12 582 353	R 11 223 529	R 11 170 588	R 11 658 824	R 11 640 969	R 12 582 353
N19	R 10 200 000	R 10 400 000	R 9 800 000	R 9 800 000	R 10 133 333	R 10 130 243	R 10 400 000
N20	R 10 200 000	R 10 400 000	R 9 800 000	R 9 800 000	R 10 133 333	R 10 130 243	R 10 400 000
N21	R 14 900 000	R 12 600 000	R 10 600 000	R 10 600 000	R 12 700 000	R 12 578 269	R 14 900 000
N22	R 9 700 000	R 11 100 000	R 10 400 000	R 9 700 000	R 10 400 000	R 10 384 271	R 11 100 000
N23	R 9 700 000	R 11 100 000	R 10 400 000	R 9 700 000	R 10 400 000	R 10 384 271	R 11 100 000
N24	R 9 700 000	R 11 100 000	R 10 400 000	R 9 700 000	R 10 400 000	R 10 384 271	R 11 100 000
N25	R 9 700 000	R 11 100 000	R 10 400 000	R 9 700 000	R 10 400 000	R 10 384 271	R 11 100 000
N26	R 15 900 000	R 19 100 000	R 13 700 000	R 13 700 000	R 16 233 333	R 16 083 616	R 19 100 000
N27	R 15 900 000	R 19 100 000	R 13 700 000	R 13 700 000	R 16 233 333	R 16 083 616	R 19 100 000
N28	R 15 900 000	R 19 100 000	R 13 700 000	R 13 700 000	R 16 233 333	R 16 083 616	R 19 100 000
N29	R 15 900 000	R 19 100 000	R 13 700 000	R 13 700 000	R 16 233 333	R 16 083 616	R 19 100 000
N30	R 15 900 000	R 19 100 000	R 13 700 000	R 13 700 000	R 16 233 333	R 16 083 616	R 19 100 000
N31	R 11 822 353	R 13 326 078	R 11 410 784	R 11 410 784	R 12 186 405	R 12 159 263	R 13 326 078
Total	**R 366 492 941**	**R 413 108 431**	**R 353 734 314**	**R 325 481 373**	**R 377 778 562**	**R 373 915 079**	**R 431 408 431**

Note: (1) In current (2016) rand-value.

Table B.14 Indicative capital costs for surface water quantity monitoring projects in the Mzimvubu-Tsitsikamma WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N1	R 12 600 000	R 13 600 000	R 13 100 000	R 12 600 000	R 13 100 000	R 13 093 636	R 13 600 000
N2	R 12 000 000	R 12 200 000	R 15 300 000	R 12 000 000	R 13 166 667	R 13 084 109	R 15 300 000
N3	R 12 300 000	R 14 100 000	R 11 700 000	R 11 700 000	R 12 700 000	R 12 660 087	R 14 100 000
N4	R 12 200 000	R 11 100 000	R 1 200 000	R 1 200 000	R 8 166 667	R 5 457 009	R 12 200 000
N5	R 12 000 000	R 11 500 000	R 17 400 000	R 11 500 000	R 13 633 333	R 13 390 890	R 17 400 000
N6	R 9 400 000	R 10 100 000	R 9 700 000	R 9 400 000	R 9 733 333	R 9 729 122	R 10 100 000
N7	R 8 800 000	R 8 700 000	R 8 800 000	R 8 700 000	R 8 766 667	R 8 766 540	R 8 800 000
N8	R 9 200 000	R 9 200 000	R 9 400 000	R 9 200 000	R 9 266 667	R 9 266 189	R 9 400 000
N9	R 8 900 000	R 8 700 000	R 1 000 000	R 1 000 000	R 6 200 000	R 4 262 225	R 8 900 000
N10	R 8 800 000	R 7 300 000	R 8 400 000	R 7 300 000	R 8 166 667	R 8 141 322	R 8 800 000
N11	R 9 100 000	R 9 700 000	R 9 900 000	R 9 100 000	R 9 566 667	R 9 560 548	R 9 900 000
N12	R 1 000 000	R 16 200 000	R 1 700 000	R 1 000 000	R 6 300 000	R 3 019 868	R 16 200 000
N13	R 1 020 000	R 9 800 000	R 9 300 000	R 1 020 000	R 6 706 667	R 4 530 051	R 9 800 000
N14	R 14 800 000	R 14 100 000	R 1 500 000	R 1 500 000	R 10 133 333	R 6 789 806	R 14 800 000
N15	R 14 600 000	R 13 300 000	R 10 400 000	R 10 400 000	R 12 766 667	R 12 639 967	R 14 600 000
N16	R 15 400 000	R 17 300 000	R 19 700 000	R 15 400 000	R 17 466 667	R 17 378 449	R 19 700 000
N17	R 15 400 000	R 17 300 000	R 19 700 000	R 15 400 000	R 17 466 667	R 17 378 449	R 19 700 000

Site ID	Alternative 1	Alternative 2	Alternative 3	MIN	Average	Geomean	MAX
N18	R 15 600 000	R 16 500 000	R 13 400 000	R 13 400 000	R 15 166 667	R 15 109 072	R 16 500 000
N19	R 15 600 000	R 16 500 000	R 13 400 000	R 13 400 000	R 15 166 667	R 15 109 072	R 16 500 000
N20	R 93 000 000	R 11 800 000	R 10 600 000	R 10 600 000	R 38 466 667	R 22 658 106	R 93 000 000
N21	R 8 900 000	R 8 700 000	R 1 000 000	R 1 000 000	R 6 200 000	R 4 262 225	R 8 900 000
N22	R 7 200 000	R 7 700 000	R 7 400 000	R 7 200 000	R 7 433 333	R 7 430 505	R 7 700 000
N23	R 8 600 000	R 9 700 000	R 9 300 000	R 8 600 000	R 9 200 000	R 9 188 636	R 9 700 000
N24	R 10 800 000	R 10 400 000	R 10 800 000	R 10 400 000	R 10 666 667	R 10 664 986	R 10 800 000
N25	R 11 000 000	R 11 100 000	R 11 100 000	R 11 000 000	R 11 066 667	R 11 066 566	R 11 100 000
Total	**R 348 220 000**	**R 296 600 000**	**R 245 200 000**	**R 214 020 000**	**R 296 673 333**	**R 264 637 435**	**R 397 500 000**

Note: (1) In current (2016) rand-value.

Table B.15 Indicative capital costs for surface water quantity monitoring projects in the Breede-Gouritz WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N1	R 15 600 000	R 166 000 000	R 73 800 000	R 85 133 333	R 85 133 333	R 57 600 955	R 166 000 000
N2	R 35 600 000	R 71 800 000	R 107 100 000	R 71 500 000	R 71 500 000	R 64 931 381	R 107 100 000
N3	R 65 700 000	R 42 900 000	R 60 000 000	R 56 200 000	R 56 200 000	R 55 299 937	R 65 700 000
N4	R 39 300 000	R 48 400 000	R 40 500 000	R 42 733 333	R 42 733 333	R 42 549 812	R 48 400 000
N5	R 8 300 000	R 7 800 000	R 10 800 000	R 8 966 667	R 8 966 667	R 8 875 622	R 10 800 000
N6	R 10 200 000	R 9 300 000	R 8 900 000	R 9 466 667	R 9 466 667	R 9 451 289	R 10 200 000
N7	R 13 000 000	R 14 200 000	R 10 800 000	R 12 666 667	R 12 666 667	R 12 585 925	R 14 200 000
N8	R 14 500 000	R 23 400 000	R 18 600 000	R 18 833 333	R 18 833 333	R 18 479 871	R 23 400 000
N9	R 16 500 000	R 23 700 000	R 19 500 000	R 19 900 000	R 19 900 000	R 19 682 895	R 23 700 000
N10	R 25 500 000	R 25 500 000	R 42 400 000	R 31 133 333	R 31 133 333	R 30 209 862	R 42 400 000
N11	R 16 200 000	R 15 100 000	R 16 800 000	R 16 033 333	R 16 033 333	R 16 017 710	R 16 800 000
N12	R 35 600 000	R 44 000 000	R 39 000 000	R 39 533 333	R 39 533 333	R 39 384 236	R 44 000 000
N13	R 35 600 000	R 44 000 000	R 39 000 000	R 39 533 333	R 39 533 333	R 39 384 236	R 44 000 000
N14	R 19 300 000	R 25 600 000	R 2 200 000	R 15 700 000	R 15 700 000	R 10 281 899	R 25 600 000
N15	R 8 000 000	R 8 900 000	R 11 900 000	R 9 600 000	R 9 600 000	R 9 462 567	R 11 900 000
Total	**R 358 900 000**	**R 570 600 000**	**R 501 300 000**	**R 476 933 333**	**R 476 933 333**	**R 434 198 197**	**R 654 200 000**

Table B.16 Indicative capital costs for surface water quantity monitoring projects in the Berg-Olifants WMA

Site ID	Alternative 1	Alternative 2	Alternative 3	Min	Average	Geomean	Max
N1	R 11 300 000	R 11 600 000	R 12 100 000	R 11 300 000	R 11 666 667	R 11 662 024	R 12 100 000
N2	R 11 700 000	R 13 500 000	R 14 000 000	R 11 700 000	R 13 066 667	R 13 028 144	R 14 000 000
N3	R 11 500 000	R 12 550 000	R 13 050 000	R 11 500 000	R 12 366 667	R 12 345 084	R 13 050 000
N4	R 11 600 000	R 13 025 000	R 13 525 000	R 11 600 000	R 12 716 667	R 12 686 614	R 13 525 000
N5	R 11 525 000	R 12 668 750	R 13 168 750	R 11 525 000	R 12 454 167	R 12 434 827	R 13 168 750
Total	**R 57 625 000**	**R 63 343 750**	**R 65 843 750**	**R 57 625 000**	**R 62 270 833**	**R 62 156 694**	**R 65 843 750**

Note: (1) In current (2016) rand-value.

APPENDIX C:

Surface water quantity monitoring O&M costs

Table C.1 Input information for O&M costs of surface water quantity monitoring station

Variable ID	Variable	Description
A1	Type of monitoring station	The cost estimation tool makes provision for the following types of stations; • Reservoir • W-Components • Canals • River (structure) • River (flood) • Lake / estuary / pan • Meters • Meteorological • Springs • Water quality (only)
A2	Frequency	Average number of months between successive actions. Actions taken into consideration are • Major access road repairs • Major cleaning of pools • Major excavation of banks • Removal of debris • Flushing of inlet system
A3	Number of days	Average number of days or fraction of a day to complete a specific action.
A4	Vehicle used for site maintenance	These are the factors required for each vehicle used; • Type of vehicle (make and model) • Engine capacity • Average expected tariff (R/km) • Total official km expected for financial year
A5	Office and store functions	Taken into consideration under this variables are factors such as: • IT equipment • Cell phones • Tele / fax / data • Office lease • Stationery
A6	Type of instrumentation	Two categories are taken into consideration for the calculation of the operation and maintenance costs for the surface water monitoring network, namely: *Water level instrumentation* • Stage sensors • Stage data loggers • Stage communication devices *Other instrumentation* • Stage velocity instrumentation • Meteorological stations (E-station) • Instrumentation housing • Rain gauges

Table C.2 Structure size classification for surface water quantity monitoring station

Classification	River width limits
Small structures	River width < 20m
Medium structures	20 m < river width < 50 m
Large structures	River width > 50 m

Table C.3 O&M cost estimate output variables for surface water quantity monitoring stations

Category / action	Sub-component
Access road	Access road repairs
Pool cleaning	Cleaning of pool upstream of structure and river bed downstream of structure
	Excavation and stabilisation of river banks
	Removal of debris from structure
	Clean river banks of vegetation and minor pool maintenance
Light structural work	Upgrade of recorder hut
Inlet system	Flushing of inlet systems
	Upgrade of inlet systems
Instrumentation (Stage)	Sensors (replace)
	Loggers (replace)
	Communication devices (replace)
	Stage-velocity instrumentation (replace)
	Rain gauge installation: Not E-station (replace)
	Instrumentation housing (replace)
	Sensors (service)
	Loggers (service)
	Communication devices (service)
	Stage-velocity instrumentation (service)
	Rain gauge installation: Not E-station (service)
	Instrumentation housing (service)
	Mechanical recorders (service)
Instrumentation (water quality)	Sensors (replace)
	Loggers (replace)

Category / action	Sub-component
	Communication devices (replace)
	Rain gauge installation: Not E-station (replace)
	Instrumentation housing (replace)
	Sensors (service)
	Loggers (service)
	Communication devices (service)
	Rain gauge installation: Not E-station (service)
	Instrumentation housing (service)
Instrumentation (E-station)	Replace equipment
	Service equipment
	Replace scours
	Replace angle iron
	Replace gauge plates / gauge plate stands
	Small concrete repair / structural works

Table C.4 O&M cost per surface water quantity monitoring station based on structure size

Description	Number of small stations	Number of medium stations	Number of large stations	Total annual cost for small structure	Total annual cost for medium structure	Total annual cost for large structure
Region 1	X_1	Y_1	Z_1	[42]	[51]	[60]
Region 2	X_2	Y_2	Z_2	[43]	[52]	[61]
Region 3	X_3	Y_3	Z_3	[44]	[53]	[62]
Region 4	X_4	Y_4	Z_4	[45]	[54]	[63]
Region 5	X_5	Y_5	Z_5	[46]	[55]	[64]
Region 6	X_6	Y_6	Z_6	[47]	[56]	[65]
Region 7	X_7	Y_7	Z_7	[48]	[57]	[66]
Region 8	X_8	Y_8	Z_8	[49]	[58]	[67]
Region 9	X_9	Y_9	Z_9	[50]	[59]	[68]

Note: (1) Annual costs.

Table C.5 O&M cost per surface water quantity monitoring station based on structure size

Description	Total annual cost for small structure	Total annual cost for medium structure	Total annual cost for large structure	Ranking
Region 1	[42] / X_1	[51] / Y_1	[60] / Z1	Maximum unit cost
Region 2	[43] / X_2	[52] / Y_2	[61] / Z2	-
Region 3	[44] / X_3	[53] / Y_3	[62] / Z3	-
Region 4	[45] / X_4	[54] / Y_4	[63] / Z4	-
Region 5	[46] / X_5	[55] / Y_5	[64] / Z5	Median unit cost
Region 6	[47] / X_6	[56] / Y_6	[65] / Z6	-
Region 7	[48] / X_7	[57] / Y_7	[66] / Z7	-
Region 8	[49] / X_8	[58] / Y_8	[67] / Z8	-
Region 9	[50] / X_9	[59] / Y_9	[68] / Z9	Minimum unit cost

Note: (1) Annual costs.

Table C.6 O&M unit cost per region for different surface water quantity monitoring station types

Region	Dam	W-component	River (structure)	River (flood)	Lake, estuary or pan
KZN	22 244	102 352	163 949	51 575	1 720
Limpopo	133 056	215 879	207 390	157 899	0
Boskop	22 426	71 457	203 871	39 402	0
Mpumalanga	71 873	136 611	358 280	69 010	0
George	60 347	131 051	174 401	190 351	33 462
Free State	165 587	284 678	304 847	208 213	0

Note: (1) Annual costs, in current (2016) rand value.

Table C.6 National O&M unit cost for different surface water quantity monitoring station types

Region	Unit cost per structure type	Arithmetic mean	Geometric mean	% difference (Arithmetic to geometric mean)
Dams				
Free State	165 587	71 926	59 980	-16.6%
Limpopo	133 056			
Mpumalanga	71 873			
George	60 347			
Boskop	22 426			
KZN	22 244			
W-components				
Free State	284 678	146 473	141 029	-3.7%
Limpopo	215 879			
Mpumalanga	136 611			
George	131 051			
KZN	102 352			
Boskop	71 457			
River (structure)				
Mpumalanga	358 280	222 627	217 743	-2.2%
Free State	304 847			
Limpopo	207 390			
Boskop	203 871			
George	174 401			
KZN	163 949			
River (flood)				
Free State	208 213	117 209	101 700	-13.2%
George	190 351			
Limpopo	157 899			
Mpumalanga	69 010			

Region	Unit cost per structure type	Arithmetic mean	Geometric mean	% difference (Arithmetic to geometric mean)
KZN	51 575			
Boskop	39 402			
Lake / estuary / pan				
George	33 462	17 591	7 587	-56.9%
KZN	1 720			
Limpopo	0			
Boskop	0			
Mpumalanga	0			
Free State	0			
Average % difference				-18.5%

Note: (1) Annual costs, in current (2016) rand value.

Table C.7 O&M cost information provided by the DWS Free State Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	30	Number	32
Access road						
Access road repairs	19 433		64 574		23 949	
Sub-total	**19 433**		**64 574**		**23 949**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	272 469		361 275		37 420	
Excavation and stabilisation of river banks	6 510		83 045		84 195	
Removal of debris from structure	931		88 379		36 966	
Clean river banks of vegetation & minor pool maintenance	1 234 801		959 690		511 835	
Sub-total	**1 514 711**		**1 492 389**		**670 416**	
Inlet systems						
Flushing of inlet systems	2 560		3 108		1 422	
Upgrade of inlet systems	94 679		77 920		77 621	
Sub-total	**97 238**		**81 028**		**79 043**	
Instrumentation (stage)						
Sensors (replace)	217 908		184 883		157 769	
Loggers (replace)	450 208		348 548		307 884	
Communication devices (replace)	7 277 028		5 633 828		4 976 548	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	15 199		9 500		10 133	
Instrumentation housing (replace)	38 889		24 305		25 926	
Sensors (service)	61 420		33 909		40 307	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	30	Number	32
Stage-velocity Instrumentation (service)		0		0		0
Rain gauge installation: NOT E-station (service)		184 261		115 163		119 002
Instrumentation housing (service)		0		0		0
Mechanical recorders (service)		0		0		0
Sub-total		**8 244 913**		**6 350 137**		**5 637 569**
Instrumentation (water quality)						
Sensors (replace)		2 815		5 886		2 303
Loggers (replace)		35 596		74 427		29 124
Communication devices (replace)		0		0		0
Rain gauge installation: NOT E-station (replace)		0		0		0
Instrumentation housing (replace)		4 689		9 805		3 837
Sensors (service)		84 453		176 583		69 098
Loggers (service)		42 226		88 292		34 549
Communication devices (service)		0		0		0
Rain gauge Installation: NOT E-station (service)		0		0		0
Instrumentation housing (service)		8 445		17 658		6 910
Sub-total		**178 224**		**372 651**		**145 820**
Instrumentation (E-stations only)						
Replace equipment		186 552		0		0
Service equipment		243 122		0		0
Sub-total		**429 673**		**0**		**0**
Light structural works						
Upgrade of recorder hut		40 941		25 588		8 529
Replace scours		37 108		76 775		44 786
Replace angle iron		60 311		121 987		81 041

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	30	Number	32
Replace gauge plates / gauge plate stands	248 240		191 938		166 858	
Small concrete repair / structural works	118 746		191 938		102 367	
Sub-total	505 346		608 227		403 581	
Annual cost / structure size	10 989 539		8 969 005		6 960 377	
Annual cost / structure	135 673		298 967		217 512	

Note: (1) In current (2016) rand value.

Table C.8 O&M cost information provided by the DWS George Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	83	Number	33	Number	30
Access road						
Access road repairs	353 588		313 347		517 996	
Sub-total	**353 588**		**313 347**		**517 996**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	190 263		1 090 406		701 996	
Excavation and stabilisation of river banks	0		22 868		11 688	
Removal of debris from structure	5 025		20 516		20 279	
Clean river banks of vegetation & minor pool maintenance	1 321 998		1 944 115		725 803	
Sub-total	**1 517 286**		**3 077 905**		**1 459 766**	
Inlet systems						
Flushing of inlet systems	73 879		72 258		40 904	
Upgrade of inlet systems	268 559		329 384		671 994	
Sub-total	**342 438**		**401 642**		**712 898**	
Instrumentation (stage)						
Sensors (replace)	50 115		38 018		30 242	
Loggers (replace)	403 455		220 066		212 731	
Communication devices (replace)	98 286		48 603		46 983	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	31 972		17 439		28 263	
Instrumentation housing (replace)	38 184		20 828		20 133	
Sensors (service)	213 853		116 647		112 759	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	

Description of activities	Small structure	Medium structure	Large structure
	River width < 20 m	River width < 50 m	River width > 50 m
	Number 83	Number 33	Number 30
Stage-velocity Instrumentation (service)	0	0	0
Rain gauge Installation: NOT E-station (service)	213 853	116 647	104 982
Instrumentation housing (service)	0	0	0
Mechanical recorders (service)	0	0	0
Sub-total	**1 049 716**	**578 248**	**556 093**
Instrumentation (water quality)			
Sensors (replace)	0	0	0
Loggers (replace)	0	0	0
Communication devices (replace)	0	0	0
Rain gauge Installation: NOT E-station (replace)	0	0	0
Instrumentation housing (replace)	0	0	0
Sensors (service)	0	0	0
Loggers (service)	0	0	0
Communication devices (service)	0	0	0
Rain gauge Installation: NOT E-station (service)	0	0	0
Instrumentation housing (service)	0	0	0
Sub-total	**0**	**0**	**0**
Instrumentation (E-stations only)			
Replace equipment	75 027	0	0
Service equipment	285 137	0	0
Sub-total	**360 164**	**0**	**0**
Light structural works			
Upgrade of recorder hut	176 165	96 090	22 421
Replace scours	72 580	97 206	31 754
Replace angle iron	76 036	152 073	47 523

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	83	Number	33	Number	30
Replace gauge plates / gauge plate stands	285 137		194 411		339 572	
Small concrete repair / structural works	228 109		194 411		72 580	
Sub-total	**838 029**		**734 192**		**513 850**	
Annual cost / structure size	**4 461 221**		**5 105 334**		**3 759 894**	
Annual cost / structure	**53 750**		**154 707**		**125 330**	

Note: (1) In current (2016) rand value.

Table C.9 O&M cost information provided by the DWS Mpumalanga Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	68	Number	54	Number	54
Access road						
Access road repairs	499 567		1 258 660		654 562	
Sub-total	**499 567**		**1 258 660**		**654 562**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	339 868		1 352 465		320 088	
Excavation and stabilisation of river banks	0		279 146		365 835	
Removal of debris from structure	893 591		3 529 071		1 656 902	
Clean river banks of vegetation & minor pool maintenance	637 813		732 098		465 881	
Sub-total	**1 871 272**		**5 892 780**		**2 808 706**	
Inlet systems						
Flushing of inlet systems	192 823		299 495		153 779	
Upgrade of inlet systems	110 356		215 261		356 169	
Sub-total	**303 179**		**514 756**		**509 948**	
Instrumentation (stage)						
Sensors (replace)	166 474		315 696		340 794	
Loggers (replace)	226 368		314 599		321 069	
Communication devices (replace)	515 893		755 478		727 351	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	38 640		60 440		59 885	
Instrumentation housing (replace)	36 585		59 547		102 461	
Sensors (service)	38 823		59 899		59 899	
Loggers (service)	38 823		59 899		56 849	
Communication devices (service)	38 823		68 773		93 176	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	68	Number	54	Number	54
Stage-velocity Instrumentation (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	18 302		32 168		74 874	
Instrumentation housing (service)	25 513		19 079		59 233	
Mechanical recorders (service)	0		0		0	
Sub-total	**1 144 245**		**1 745 577**		**1 895 591**	
Instrumentation (water quality)						
Sensors (replace)	0		0		0	
Loggers (replace)	0		0		0	
Communication devices (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	0		0		0	
Instrumentation housing (replace)	0		0		0	
Sensors (service)	0		0		0	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	0		0		0	
Instrumentation housing (service)	0		0		0	
Sub-total	**0**		**0**		**0**	
Instrumentation (E-stations only)						
Replace equipment	17 235		0		0	
Service equipment	0		0		0	
Sub-total	**17 235**		**0**		**0**	
Light structural works						
Upgrade of recorder hut	63 692		126 363		123 542	
Replace scours	52 134		129 411		83 193	
Replace angle iron	144 201		412 637		238 764	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	68	Number	54	Number	54
Replace gauge plates / gauge plate stands	114 621		157 142		257 898	
Small concrete repair / structural works	130 336		329 075		371 595	
Sub-total	**504 985**		**1 154 628**		**1 074 993**	
Annual cost / structure size	**4 340 482**		**10 566 402**		**6 943 798**	
Annual cost / structure	**63 831**		**195 674**		**128 589**	

Note: (1) In current (2016) rand value.

Table C.10 O&M cost information provided by the DWS Limpopo Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	16	Number	45
Access road						
Access road repairs	1 261 668		236 563		1 093 526	
Sub-total	**1 261 668**		**236 563**		**1 093 526**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	377 761		188 511		487 911	
Excavation and stabilisation of river banks	119 021		135 284		221 778	
Removal of debris from structure	687 139		186 343		524 089	
Clean river banks of vegetation & minor pool maintenance	634 730		326 100		943 360	
Sub-total	**1 818 650**		**836 238**		**2 177 137**	
Inlet systems						
Flushing of inlet systems	59 397		19 799		53 574	
Upgrade of inlet systems	439 964		132 592		325 453	
Sub-total	**499 360**		**152 391**		**379 026**	
Instrumentation (stage)						
Sensors (replace)	318 536		78 185		221 304	
Loggers (replace)	639 683		125 534		353 908	
Communication devices (replace)	2 189 032		430 324		1 211 130	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	32 755		18 717		68 594	
Instrumentation housing (replace)	104 932		18 864		53 056	
Sensors (service)	106 565		30 281		73 372	
Loggers (service)	110 641		32 610		68 830	
Communication devices (service)	110 641		32 610		73 372	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	16	Number	45
Stage-velocity Instrumentation (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	65 220		37 269		104 818	
Instrumentation housing (service)	110 641		32 610		68 714	
Mechanical recorders (service)	0		0		0	
Sub-total	**3 788 647**		**837 004**		**2 297 099**	
Instrumentation (water quality)						
Sensors (replace)	19 799		6 211		17 470	
Loggers (replace)	48 767		12 821		43 272	
Communication devices (replace)	18 712		6 211		17 470	
Rain gauge Installation: NOT E-station (replace)	46 999		30 693		86 324	
Instrumentation housing (replace)	60 130		18 864		53 056	
Sensors (service)	118 793		37 269		104 818	
Loggers (service)	118 793		37 269		104 818	
Communication devices (service)	118 793		37 269		104 818	
Rain gauge Installation: NOT E-station (service)	118 793		37 269		104 818	
Instrumentation housing (service)	118 793		37 269		104 818	
Sub-total	**788 374**		**261 144**		**741 681**	
Instrumentation (E-stations only)						
Replace equipment	92 748		0		0	
Service equipment	174 696		0		0	
Sub-total	**267 444**		**0**		**0**	
Light structural works						
Upgrade of recorder hut	246 443		23 580		60 130	
Replace scours	285 337		174 696		244 575	
Replace angle iron	366 862		244 575		349 393	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	81	Number	16	Number	45
Replace gauge plates / gauge plate stands	125 781		55 903		90 260	
Small concrete repair / structural works	638 224		349 393		454 210	
Sub-total	**1 662 647**		**848 147**		**1 198 567**	
Annual cost / structure size	**10 086 792**		**3 171 486**		**7 887 036**	
Annual cost / structure	**124 528**		**198 218**		**175 267**	

Note: (1) In current (2016) rand value.

Table C.11 O&M cost information provided by the DWS KwaZulu-Natal Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	115	Number	48	Number	56
Access road						
Access road repairs	168 843		173 386		235 671	
Sub-total	**168 843**		**173 386**		**235 671**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	991 977		4 539 050		2 020 666	
Excavation and stabilisation of river banks	0		1 922		34 786	
Removal of debris from structure	496 930		368 900		273 309	
Clean river banks of vegetation & minor pool maintenance	556 554		960 956		672 669	
Sub-total	**2 045 461**		**5 870 828**		**3 001 430**	
Inlet systems						
Flushing of inlet systems	210 582		289 659		131 598	
Upgrade of inlet systems	36 361		69 001		79 060	
Sub-total	**246 943**		**358 660**		**210 658**	
Instrumentation (stage)						
Sensors (replace)	161 401		190 526		216 674	
Loggers (replace)	505 887		539 613		629 549	
Communication devices (replace)	9 009		9 610		11 211	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	9 496		10 130		11 818	
Instrumentation housing (replace)	15 140		16 149		18 840	
Sensors (service)	36 036		38 438		44 845	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	115	Number	48	Number	56
Stage-velocity Instrumentation (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	108 108		115 315		127 327	
Instrumentation housing (service)	0		0		0	
Mechanical recorders (service)	0		0		0	
Sub-total	**845 077**		**919 781**		**1 060 264**	
Instrumentation (water quality)						
Sensors (replace)	4 645		5 766		2 883	
Loggers (replace)	0		0		0	
Communication devices (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	0		0		0	
Instrumentation housing (replace)	2 790		3 463		1 731	
Sensors (service)	139 339		172 972		86 486	
Loggers (service)	69 669		86 486		43 243	
Communication devices (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	0		0		0	
Instrumentation housing (service)	13 934		17 297		8 649	
Sub-total	**230 376**		**288 984**		**142 992**	
Instrumentation (E-stations only)						
Replace equipment	261 523		0		0	
Service equipment	208 207		0		0	
Sub-total	**469 730**		**0**		**0**	
Light structural works						
Upgrade of recorder hut	20 182		21 528		9 418	
Replace scours	34 434		76 877		58 859	
Replace angle iron	56 643		121 721		104 104	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	115	Number	48	Number	56
Replace gauge plates / gauge plate stands	144 143		192 191		190 590	
Small concrete repair / structural works	110 190		192 191		134 534	
Sub-total	365 592		604 508		497 505	
Annual cost / structure size	**4 372 021**		**8 213 146**		**5 148 519**	
Annual cost / structure	**38 018**		**171 107**		**91 938**	

Note: (1) In current (2016) rand value.

Table C.12 O&M cost information provided by the DWS Boskop Regional Office

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	157	Number	40	Number	49
Access road						
Access road repairs	479 428		367 815		165 041	
Sub-total	**479 428**		**367 815**		**165 041**	
Pool cleaning						
Cleaning of pool u/s of structure & river bed downstream of structure	644 609		756 064		315 413	
Excavation and stabilisation of river banks	342 449		535 004		117 954	
Removal of debris from structure	614 290		482 421		146 786	
Clean river banks of vegetation & minor pool maintenance	548 075		633 134		62 130	
Sub-total	**2 149 423**		**2 406 623**		**642 283**	
Inlet systems						
Flushing of inlet systems	60 019		28 192		25 602	
Upgrade of inlet systems	207 289		115 603		0	
Sub-total	**267 308**		**143 795**		**25 602**	
Instrumentation (stage)						
Sensors (replace)	488 618		350 630		335 646	
Loggers (replace)	682 738		435 694		417 074	
Communication devices (replace)	62 299		258 095		0	
Stage-velocity Instrumentation (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	33 081		0		103 969	
Instrumentation housing (replace)	0		19 932		0	
Sensors (service)	0		0		0	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	157	Number	40	Number	49
Stage-velocity Instrumentation (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	0		0		0	
Instrumentation housing (service)	0		0		0	
Mechanical recorders (service)	594 673		346 153		207 100	
Sub-total	**1 861 409**		**1 410 503**		**1 063 789**	
Instrumentation (water quality)						
Sensors (replace)	138 103		208 948		0	
Loggers (replace)	115 378		188 805		0	
Communication devices (replace)	0		0		0	
Rain gauge Installation: NOT E-station (replace)	0		0		0	
Instrumentation housing (replace)	8 503		2 180		0	
Sensors (service)	532 543		6 177 495		0	
Loggers (service)	0		0		0	
Communication devices (service)	0		0		0	
Rain gauge Installation: NOT E-station (service)	0		0		0	
Instrumentation housing (service)	0		0		0	
Sub-total	**794 527**		**6 577 428**		**0**	
Instrumentation (E-stations only)						
Replace equipment	285 105		0		0	
Service equipment	183 431		0		0	
Sub-total	**468 536**		**0**		**0**	
Light structural works						
Upgrade of recorder hut	0		155 466		0	
Replace scours	127 810		0		0	
Replace angle iron	39 053		128 698		0	

Description of activities	Small structure		Medium structure		Large structure	
	River width < 20 m		River width < 50 m		River width > 50 m	
	Number	157	Number	40	Number	49
Replace gauge plates / gauge plate stands	438 756		187 869		190 828	
Small concrete repair / structural works	19 527		147 337		0	
Sub-total	**625 146**		**619 370**		**190 828**	
Annual cost / structure size	**6 645 774**		**11 525 534**		**2 087 543**	
Annual cost / structure	**42 330**		**288 138**		**42 603**	

Note: (1) In current (2016) rand value.

APPENDIX D:

Groundwater monitoring costs

Table D.1 Groundwater provisions in South Africa's National Water Policy

Topic	Groundwater provision
Rights and access to groundwater	• All water part of interdependent water cycle - a resource common to all. • Equity in access for all South African citizens to water services, water resources and benefits from usage. • No ownership but only a right for environmental and basic human needs (Reserve) and authorization for its use.
Groundwater allocation	• Allocation licensing policy (registration of new wells, drillers; groundwater use in context of catchment management plan).
Protection of water resources	• Resource direct measures – setting clear objectives for protection of resources (classification, Reserve determination and resource quality objectives, RQOs; DWAF, 2000) • Source-directed measures: control and ensure that objectives are met • Artificial recharge strategy
Climate change impacts and adaptation	• Develop pro-active and pre-emptive approaches in water-related disaster prevention.
Conjunctive use and management	• Water conservation and utilization policy • Water development in accordance with integrated environmental management
Groundwater monitoring	• Detailed account of resources monitoring and information management
Water pricing	• Water pricing policy
Transboundary water management	• Southern Africa Development Community (SADC) Protocol on shared Water Course Systems
Institutions of water management	• National (DWA), Regional (CMAs) and local (Irrigation Boards)
Stakeholder participation	• Integral part of South Africa's water sector reform

Note: (1) From (Pietersen, et al., 2012)

Table D.2 Shortcomings in groundwater provision in NWA and NWRS-2

Topic	Shortcomings in groundwater provisions
Controlling groundwater use	• Licensing of groundwater unclear (regulation of local government) • Only 20% of applications processed • Limited capacity within DWS
Regulating construction of wells and boreholes	• No explicit regulation • Only technical guidelines and procedures for drilling, testing and sampling.
Controlling groundwater pollution	• Waste discharge charge system not yet implemented • Inadequate groundwater monitoring networks
Linkages with other legislation, National Environmental Management Act (1998) and Minerals and Petroleum Resources Development Act (2002)	• DWS and Department of Environmental Affairs (DEA) may require groundwater users to obtain a licence and environmental authorisation • The two departments follow different procedures for assessment • No effective co-operative governance procedures in place • Mines operating without water use-licences • Mining permits issued without due consideration for water use consequences.

Note: (1) From (Pietersen, et al., 2012)

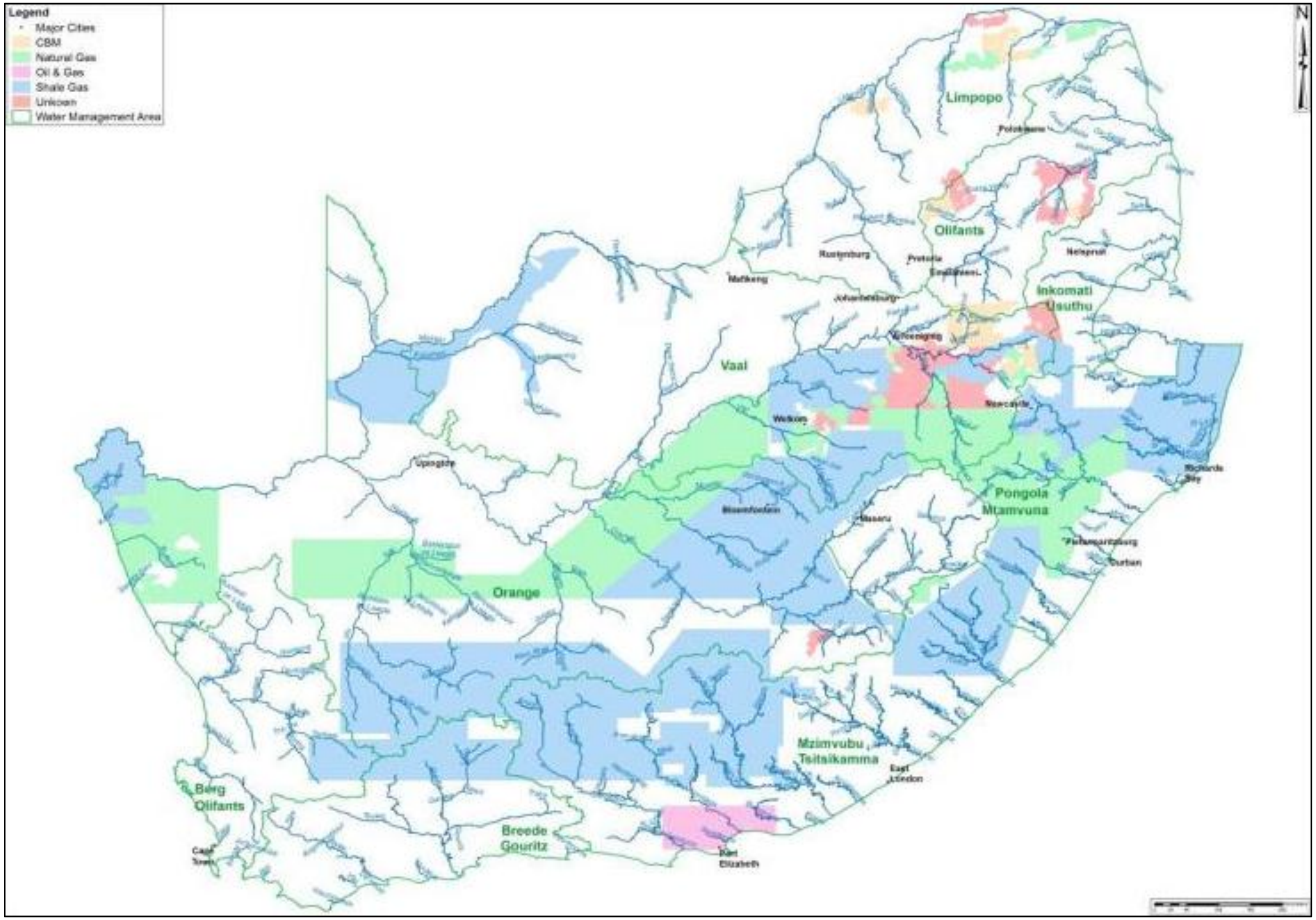


Figure D.1 On-shore exploration areas for oil and gas

Table D.3 Factors taken into consideration for the drilling and establishment stage of the groundwater implementation

Task	Description
Establishment	Mobilisation of the drilling rig and supporting equipment to site and ready to drill.
Drilling (e.g. air percussion or mud rotary)	The method employed to progress a hole to the required depth and diameter. Air percussion is the method most used in South Africa. Mud rotary is used in unconsolidated formations. Factors such as geology, climate and distance from base of operations all affect cost.
Casing	Boreholes are constructed by inserting lengths of protective casing. This can be steel casing or plastics. In deeper boreholes steel casing is preferred,
Screen	Screens are placed alongside the water bearing formations to allow movement of water into the borehole. These perforated sections come in sizes and joints similar to casing, so can be interconnected with suitable plain casing (steel or plastic) in any combination.
Reaming of boreholes	Enlarging of an existing borehole.
Formation stabilizer (gravel pack)	The annular space between the well screen, well casing, and borehole wall is filled with gravel or coarse sand. The gravel pack prevents sand and fine sand particles from moving from the aquifer formation into the well.
Concrete collar	The uppermost section of the annulus is normally sealed with a bentonite clay and cement grout to ensure that no water or contamination can enter the annulus from the surface.
Sanitary seal	The sanitary seal is intended to provide protection from leakage and to keep runoff from entering the wellhead.
Borehole disinfection	-
Development time	After the well screen, well casing, and gravel pack have been installed, the well is developed to clean the borehole and casing of drilling fluid and to properly settle the gravel pack around the well screen. A typical method for well development is to surge or jet water or air in and out of the well screen openings
Interhole move	Moving to the next hole to drill.

Table D.4 Indicative schedule for implementation of a single spatial grouping of groundwater monitoring sites

Phase	Task no.	Task description	No of months
Management	1	Management of overall implementation project	4
	2	In-house / external	-
	3	Project Management Office	-
	4	Engineering programme	-
	5	Environmental impact assessment	6
	6	Water use licence application	6
	7	Stakeholder participation	-
Planning	8	Site visit	3
	9	Topographical surveys (Groundwater exploration)	6
	10	Geotechnical investigations (Geophysics)	10
	11	Land acquisition	-
	12	Access roads	-
	13	Feasibility study	6
	14	Indicative capital cost	2
Design	15	Scope of work: RfP	1
	16	Request for proposals	0.5
	17	Tender documents	0.5
	18	Tender evaluation	6
	19	Procurement	6
	20	Appointment of PSP	4
	21	Design programme	4
	22	Detail design	6
	23	Detail cost estimate	4
	24	Updated implementation plan (based on cost and timeframes)	2
Construction	25	Funding: Treasury?	-
	26	Tender documents	4
	27	Tender evaluation	6

Phase	Task no.	Task description	No of months
	28	Procurement	6
	29	Appointment of Contractor	4
	30	Site establishment	-
	31	Construction (drilling programme)	42
Implemen-tation	32	Commissioning	1
O&M	33	Operation	2
	34	Maintenance	2

Table D.5 Cost drivers for the implementation of a groundwater monitoring site

Task description	Assumption/specification	Unit	Rate (R)
Establishment costs		Sum	5 200
Drilling (air percussion) in metamorphic or carbonate rocks	165 mm diameter	m	295
Casing steel	165 mm inner diameter, 4 mm wall thickness	m	620
Casing steel slotted	165 mm inner diameter, 4 mm wall thickness	m	680
Reaming of boreholes		m	300
Formation stabilizer		kg	4.1
Concrete collar		No	4 000
Sanitary seal		m	280
Borehole disinfection		No,	100
Development time		hr	1 400
Interhole move		km	7.5

Note: (1) In current (2016) rand value.

APPENDIX E

Water quality monitoring costs

Table E.1 Indicative schedule for the implementation of a water quality monitoring site

Phase	Task description	Months
Management	Division of in-house / external appointment work load for management phase	3
	Appointment of service provider	8
	Management of overall implementation project	Duration of project
	Establishment of a Project Management Office	3
	Manage engineering programme	Duration of project
	Management of environmental impact assessments	Duration of project
	Facilitate water use licence application	Duration of project
	Stakeholder participation	Duration of project
Planning	Refine initial optimization of sites and variables	6
	Identify sites and / or visit sites	6
	Feasibility study (including appointment of PSPs)	12
	Update indicative capital cost estimate	4
Design	Updated implementation plan (based on cost and timeframes)	6
Construction/ Installation	Funding	12
	Tender documents	2
	Tender evaluation	2
	Procurement	4
	Appointment of contractors / suppliers	2
	Construction / installation	8
Implemen-tation	Implementation	24
O&M	Operation	Ongoing
	Maintenance	Ongoing

Table E.2 Constituents to be considered for fitness for use monitoring

Group	Abbreviation	Description	Unit	Equipment
Bio	AlgID	Algal id	Name	flowCam, microscope
Bio	BOD5	BOD5	mg O_2/L	BOD5 analysis system
Bio	Chla	Chla	µg/L	UV Vis/ centrifuge
Bio	DaphToxAc	Diaphnia acute	LC_{50}	
Bio	FishToxAc	Fish test	LC_{50}	
Bio	MicCys	Mycrocystin	µg/L	Microplate reader
Bio	SelAGI	Selenastrum AGI		
Bio	VibTox	Vibrio	LC_{50}	Luminometer
Bio	YES	Yeast	µgEE/L	Ultra low freezer
ChEmC	2EE	2-Ethynyl-estradiol	µg/L	GCxGC TOFMS
ChEmC	Cl2Benz	1,4-Dichlorobenzene	µg/L	GC-MS
ChEmC	Cl2Benz	1,3-Dichlorobenzene	µg/L	GC-MS
ChEmC	ClBenz	Chlorobenzene	µg/L	GC-MS
ChEmC	Dioxins	Polychlorinated dibenzo-p-dioxins ("dioxins") and polychlorinated dibenzofurans	µg/L	GCxGC TOFMS
ChEmC	PFOS	Perfluorooctanesulfonic acid (PFOS), its salts and perfluorooctanesulfonyl fluoride (PFOSF)	µg/L	GCxGC TOFMS
ChEmC	PhOH	Phenols (Total)	µg/L	GC-MS
ChEmC	Tol	Toluene	µg/L	GC-MS
DrWater	Br2ClMe	Dibromochloromethane	µg/L	GC-MS
DrWater	BrCl2Me	Bromodichloromethane	µg/L	GC-MS
DrWater	CCl4	Carbon Tetrachloride	µg/L	GC-MS
DrWater	CHBr3	Bromoform	µg/L	GC-MS
DrWater	ChCl3	Chloroform	µg/L	GC-MS
DrWater	Cl2Et	1,2-Dichloroethane	µg/L	GC-MS
DrWater	Cl2Prop	1,2-Dichloropropane	µg/L	GC-MS
DrWater	Cl3Et	1,1,1-Trichloroethane	µg/L	GC-MS
DrWater	Cl3Et	Trichloroethylene	µg/L	GC-MS
DrWater	Cl4Et	Tetrachloroethylene	µg/L	GC-MS

Group	Abbreviation	Description	Unit	Equipment
DrWater	SOG	Soap, Oil and grease	mg/L	GC-MS
DrWater	THM	Trihalomethanes (THMs)	µg/L	GC-MS
DrWater	VOC	Volatile organic compounds (VOCs)	µg/L	GC-MS
GenChem	CaDiss	Calcium	mg/L	ICP/ICP-MS
GenChem	ClDiss	Chloride	mg/L	Gallery Plus
GenChem	COD	COD (Chemical oxygen demand)	mg O_2/L	COD analyser
GenChem	DO	Dissolved Organic Content (DOC)	mg/L	TOC Analyser
GenChem	EC	EC (Electrical Conductivity)	mS/m at 25°C	Conductivity Meter
GenChem	Ftot	Fluoride (total & soluble)	mg/L	FIA
GenChem	Kdiss	Potassium	mg/L	ICP/ICP-MS
GenChem	MgDiss	Magnesium	mg/L	ICP/ICP-MS
GenChem	NaDiss	Sodium	mg/L	ICP/ICP-MS
GenChem	NH4Diss	Ammonia as N	mg/L	Gallery Plus
GenChem	NOxDiss	Nitrate + nitrite as N	mg/L	Gallery Plus
GenChem	ORP	Redox Potential	mV	Bench top analyser
GenChem	pH	pH (measured with a glass electrode)	pH units	pH Meter
GenChem	SiDiss	Silicates as Si (total & soluble)	mg/L	Gallery Plus
GenChem	SO4Diss	Sulphate	mg/L	Gallery Plus
GenChem	SRP	Orthophosphate as P	mg/L	Gallery Plus
GenChem	TAlk	Total alkalinity	mg $CaCO_3$/L	Gallery Plus
GenChem	TOC	Total Organic Content (TOC)	mg/L	TOC Analyser
GenChem	TP	Total phosphate as P	mg/L	Gallery Plus
GenChem	TSS	Suspended solids	mg/L	Oven
GenChem	Turbidity	Turbidity	NTU	Turbidity Meter
MicBio	Clostridia	Clostridia	count	Incubators
MicBio	Ecoli	E. coli	count	Quanti-tray sealer
MicBio	Enetroviruses	Enterovirusses	count	PCR
MicBio	Fcoli	Faecal coliforms	count	Agar
MicBio	Fstrep	Faecal streptococci	count	Agar

Group	Abbreviation	Description	Unit	Equipment
MicBio	HTP	Standard total plate count	count	colony counter
MicBio	SalmonellaSpp	Salmonella species	count	Solus/Biolog
MicBio	ShigellaSpp	Shigella species	count	Agar
MicBio	Tcoli	Total coliforms	count	Colitag
MicBio	VibrioSpp	Vibrio species	count	Autoclave
Pest	2,4 D	2,4-D and the corresponding amine	µg/L	GC-MS/LC-MS
Pest	Acetochlor	Acetochlor	µg/L	GC-MS/LC-MS
Pest	Alachlor	Alachlor	µg/L	GC-MS/LC-MS
Pest	Aldicarb	Aldicarb	µg/L	GC-MS/LC-MS
Pest	Aldrin	Aldrin	µg/L	GC-MS/LC-MS
Pest	alphaHCH	alpha hexachlorocyclohexane	µg/L	GC-MS/LC-MS
Pest	AtrSim	Triazine and triazinone group (primarily atrazine, simazine and metribuzine)	µg/L	GC-MS/LC-MS
Pest	betaHCH	beta hexachlorocyclohexane	µg/L	GC-MS/LC-MS
Pest	Br2Et	Ethylene dibromide	µg/L	GC-MS/LC-MS
Pest	Br4_5_DPE	Tetrabromodiphenyl ether and pentabromodiphenyl ether	µg/L	GC-MS/LC-MS
Pest	Br6_7_DPE	Hexabromodiphenyl ether and heptabromodiphenyl ether	µg/L	GC-MS/LC-MS
Pest	Bromacil	Bromacil	µg/L	GC-MS/LC-MS
Pest	Bromoxynil	Bromoxynil	µg/L	GC-MS/LC-MS
Pest	Buprofenzin	Buprofenzin	µg/L	GC-MS/LC-MS
Pest	Carbaryl	Carbaryl	µg/L	GC-MS/LC-MS
Pest	Carbendazim	Carbendazim	µg/L	GC-MS/LC-MS
Pest	Carbofuran	Carbofuran	µg/L	GC-MS/LC-MS
Pest	Chlordane	Chlordane	µg/L	GC-MS/LC-MS
Pest	Chlordecone	Chlordecone	µg/L	GC-MS/LC-MS
Pest	Cl2Benz	Hexachlorobenzene	µg/L	GC-MS/LC-MS
Pest	Cl6Benz	Pentachlorobenzene	µg/L	GC-MS/LC-MS
Pest	Cyproconazole	Cyproconazole	µg/L	GC-MS/LC-MS
Pest	DDD	DDD	µg/L	GC-MS/LC-MS

Group	Abbreviation	Description	Unit	Equipment
Pest	DDE	DDE	µg/L	GC-MS/LC-MS
Pest	DDT	DDT	µg/L	GC-MS/LC-MS
Pest	Dieldrin	Dieldrin	µg/L	GC-MS/LC-MS
Pest	Dieldrin	Dieldrin	µg/L	GC-MS/LC-MS
Pest	Diuron	Diuron	µg/L	GC-MS/LC-MS
Pest	Endosulfan	Endosulfan	µg/L	GC-MS/LC-MS
Pest	Endrin	Endrin	µg/L	GC-MS/LC-MS
Pest	EPTC	EPTC	µg/L	GC-MS/LC-MS
Pest	Fipronil	Fipronil	µg/L	GC-MS/LC-MS
Pest	Fosthiazate	Fosthiazate	µg/L	GC-MS/LC-MS
Pest	gammaHCH	Lindane	µg/L	GC-MS/LC-MS
Pest	Heptachlor	Heptachlor	µg/L	GC-MS/LC-MS
Pest	Hexabromobiphenyl	Hexabromobiphenyl	µg/L	GC-MS/LC-MS
Pest	Hexabromocyclododecane	Hexabromocyclododecane	µg/L	GC-MS/LC-MS
Pest	Hexazinone	Hexazinone	µg/L	GC-MS/LC-MS
Pest	Imidacloprid	Imidacloprid	µg/L	GC-MS/LC-MS
Pest	Iprodione	Iprodione	µg/L	GC-MS/LC-MS
Pest	MCPA	MCPA	µg/L	GC-MS/LC-MS
Pest	Metolachlor	Metolachlor	µg/L	GC-MS/LC-MS
Pest	Mirex	Mirex	µg/L	GC-MS/LC-MS
Pest	Parathion	Parathion	µg/L	GC-MS/LC-MS
Pest	Propoxur	Propoxur	µg/L	GC-MS/LC-MS
Pest	Sulcotrione	Sulcotrione	µg/L	GC-MS/LC-MS
Pest	Sulfosulfuron	Sulfosulfuron	µg/L	GC-MS/LC-MS
Pest	Tembotrione	Tembotrione	µg/L	GC-MS/LC-MS
Pest	Terbutylazine	Terbutylazine	µg/L	GC-MS/LC-MS
Pest	Thiamethoxam	Thiamethoxam	µg/L	GC-MS/LC-MS
Pest	Toxaphene	Toxaphene	µg/L	GC-MS/LC-MS
Pest	Triadimefon	Triadimefon	µg/L	GC-MS/LC-MS

Group	Abbreviation	Description	Unit	Equipment
Pest	Triadimenol	Triadimenol	µg/L	GC-MS/LC-MS
Pest	TribenuronMet	Tribenuron-methyl	µg/L	GC-MS/LC-MS
Pest	Trichlorfon	Trichlorfon	µg/L	GC-MS/LC-MS
Pest	Trifluralin	Trifluralin	µg/L	GC-MS/LC-MS
Pest	Triticonazole	Triticonazole	µg/L	GC-MS/LC-MS
Ppol	Acenapth	Acenapthylene	µg/L	GC-MS
Ppol	Anth	Anthracene	µg/L	GC-MS
Ppol	Arochlor 1260	Arochlor 1260	µg/L	GC-MS
Ppol	Arochlor1254	Arochlor 1254	µg/L	GC-MS
Ppol	Benz(a)anth	Benzo(a) anthracene	µg/L	GC-MS
Ppol	Benz(a)pyr	Benzo(a)pyrene	µg/L	GC-MS
Ppol	Benz(b)fluor	Benzo(b) fluoranthene	µg/L	GC-MS
Ppol	Benz(ghi)pery	Benzo(g,h,i) perylene	µg/L	GC-MS
Ppol	Benz(k)fluor	Benzo(k) fluoranthene	µg/L	GC-MS
Ppol	Chrys	Chrysene	µg/L	GC-MS
Ppol	Dibenz(ah)anth	Dibenz(a,h) anthracene	µg/L	GC-MS
Ppol	Fluor	Fluorene	µg/L	GC-MS
Ppol	Fluoranth	Fluoranthrene	µg/L	GC-MS
Ppol	Indeno[123cd]pyr	Indeno[1,2,3-cd] pyrene	µg/L	GC-MS
Ppol	Napth	Napthalene	µg/L	GC-MS
Ppol	PCB	Polychlorinated biphenyls (PCBs)	µg/L	GCxGC TOFMS
Ppol	Phenanth	Phenanthrene	µg/L	GC-MS
Ppol	Pyr	Pyrene	µg/L	GC-MS
Ppol		Polychlorinated Biphenyls (PCBs)	µg/L	GC-MS
Sed	CEC	Cation-exchange capacity	mmol/g	ICP/ICP-MS
Sed	Min	Mineral composition	name	Not used currently
Sed	PSize	Particle size	µm	Sieves/FlowCam
TrInorg	AlDiss	Aluminium (total & soluble)	mg/L	ICP/ICP-MS
TrInorg	As(V)	Arsenic (V)	mg/L	IC/ICP/MS

Group	Abbreviation	Description	Unit	Equipment
TrInorg	AsTot	Arsenic (total & soluble)	mg/L	ICP/ICP-MS
TrInorg	Bdiss	Boron	mg/L	ICP/ICP-MS
TrInorg	BeDiss	Beryllium	mg/L	ICP/ICP-MS
TrInorg	Br	Bromide	mg/L	HPLC
TrInorg	CdTot	Cadmium	mg/L	ICP/ICP-MS
TrInorg	CNTot	Cyanide (total)	mg/L	HPLC
TrInorg	CoDiss	Cobalt	mg/L	ICP/ICP-MS
TrInorg	Cr(VI)	Chromium (VI)	mg/L	ICP/ICP-MS
TrInorg	CrTot	Chromium(III + VI)	mg/L	ICP/ICP-MS
TrInorg	CuASol	Copper	mg/L	ICP/ICP-MS
TrInorg	FeTot	Iron	mg/L	ICP/ICP-MS
TrInorg	HgTot	Mercury (total)	mg/L	ICP/ICP-MS
TrInorg	HOCl	Free available chlorine	mg/L	Chlorine meter
TrInorg	I	Iodine	mg/L	HPLC
TrInorg	LiDiss	Lithium	mg/L	ICP/ICP-MS
TrInorg	MnDiss	Manganese	mg/L	ICP/ICP-MS
TrInorg	NiDiss	Nickel	mg/L	ICP/ICP-MS
TrInorg	PbTot	Lead (total & soluble)	mg/L	ICP/ICP-MS
TrInorg	SbDiss	Antimony	mg/L	ICP/ICP-MS
TrInorg	Se(IV)	Selenium(IV)	mg/L	IC/ICP/MS
TrInorg	SeTot	Selenium	mg/L	ICP/ICP-MS
TrInorg	SrTot	Strontium	mg/L	ICP/ICP-MS
TrInorg	UTot	Uranium	mg/L	ICP/ICP-MS
TrInorg	VTot	Vanadium	mg/L	ICP/ICP-MS
TrInorg	ZnDiss	Zinc	mg/L	ICP/ICP-MS

Table E.3 Estimated outsourcing costs per group of constituents per sample

Group key	Description	Cost/sample
Bio	Biological parameters involved in the direct estimation of biological effect	R 22 350
ChEmC	Chemicals of emerging concern: chemicals where significant hazard has been demonstrated in laboratory work but the effect at user level is not fully understood (including EDCs)	R 5 000
DrWater	Constituents typically associated with drinking water treatment including THMs	R 7 000
GenChem	General chemistry: constituents that determine the hazard of other variables and that may have hazard potential in own right	R 6 050
Iso	Isotope analyses specifically O and N	R 100
MicBio	Micro biota that are considered to entail a significant hazard	R 9 650
Pest	Pesticides that are commonly used in South Africa and that entail a significant hazard and/or significant mobility	R 10 000
Ppol	Priority pollutants: constituents considered to have a high hazard potential including those regulated under the Stockholm convention	R 6 000
Sed	Measures involved in sediment characterisation and its impact on other hazards	R 3 000
SOG	Soap, oils and grease: indicators of potential pollution and possible decrease in dissolved oxygen	R 1 000
TrInorg	Trace inorganics: those inorganics that are seldom present above a few milligrams per litre but that entail a significant hazard	R 4 000
Dating	Isotope ratios used to date groundwater	R 1 725

Note: (1) In current (2016) rand value.

Table E.4 Total outsourcing cost for surface water quality monitoring

Constituent group	Frequency of total suite being applied per sample	Number of samples per year									Annual cost
		Vaal	Orange	Inkomati-Usuthu	Pongola-Mzimkhulu	Berg-Olifants	Breede-Gouritz	Limpopo	Mzimvubu-Tsitsikamma	Olifants	
GenChem	1.00	3 480	2 088	3 246	3 108	2 328	3 588	3 042	2 868	1680	R 153 839 400
TrInorg	1.00	3 480	2 088	3 246	3 108	2 328	3 588	3 042	2 868	1680	R 101 712 000
MicBio	0.25	3 408	2 088	3 192	3 108	2 328	3 588	3 036	2 868	1680	R 61 026 600
Sed	0.33	2 928	1 920	2 424	2 460	1 920	2 964	2 820	2 460	1248	R 20 932 560
DrWat.	1.00	1 104	552	1 710	1 392	864	1 320	1 050	1 092	612	R 67 872 000
Ppol	0.50	3 480	2 088	3 246	3 108	2 328	3 588	3 042	2 868	1680	R 76 284 000
Pest	0.75	3 480	2 088	3 246	3 108	2 328	3 588	3 042	2 868	1680	R 190 710 000
ChEmC	0.75	3 480	2 088	3 246	3 108	2 328	3 588	3 042	2 868	1680	R 95 355 000
Bio	0.10	3 288	2 040	3 120	3 000	2 232	3 408	2 892	2 676	1620	R 54 256 860
SOG	0.10	480	168	768	648	408	624	216	408	432	R 415 200
Total		28 608	17 208	27 444	26 148	19 392	29 844	25 224	23 844	13992	R 822 403 620

Note: (1) Annual costs, in current (2016) rand value.

(2) Based on current assumptions of the network configuration.

Table E.5 Total outsourcing cost for groundwater quality monitoring

Constituent Group	Frequency of total suite being applied per sample	Annual costs for baseline sites	Annual costs for trend sites	Total annual cost per constituent group
Total samples per year		9 828	6 086	
GenChem	1.00	R 59 459 400	R 36 820 300	R 96 279 700
TrInorg	1.00	R 39 312 000	R 24 344 000	R 63 656 000
MicBio	0.00	R 0	R 0	R 0
Sed	0.00	R 0	R 0	R 0
DrWater	0.00	R 0	R 0	R 0
Ppol	0.25	R 14 742 000	R 9 129 000	R 23 871 000
Pest	0.25	R 24 570 000	R 15 215 000	R 39 785 000
ChEmC	0.25	R 12 285 000	R 7 607 500	R 19 892 500
Bio	0.00	R 0	R 0	R 0
SOG	0.00	R 0	R 0	R 0
Dating	0.10	R 1 695 330	R 1 049 835	R 2 745 165
Iso	1.00	R 982 800	R 608 600	R 1 591 400
Total		**R 153 046 530**	**R 94 774 235**	**R 247 820 765**

Note: (1) Annual costs, in current (2016) rand value.

(2) Based on current assumptions of the network configuration.

Table E.6 Sampling costs for water quality monitoring

Site types	Equivalent trips per year									Total trips and costs
	Vaal	Orange	Inkomati-Usuthu	Pongola-Mzimkhulu	Berg-Olifants	Breede-Gouritz	Limpopo	Mzimvubu-Tsitsikamma	Olifants	
Reservoir/ Barrage/ Lake	14	9	18	13	7	14	14	16	4	108
River (W-Comp)	9	7	19	18	12	15	21	13	4	118
River (GenFFU)	94	62	61	67	57	87	77	66	42	613
River (Hum,LS,Rec Only)	20	7	32	27	17	26	9	17	18	173
River (Baseline)	5	2	3	5	4	8	6	8	3	43
Spring/Eyes	3	0	2	0	0	0	0	0	0	6
Total surface water	**145**	**87**	**135**	**130**	**97**	**150**	**127**	**120**	**70**	**1060**
Cost per equiv. trip										R 35 000
Surface water sampling (R million)	R 5.07	R 3.04	R 4.73	R 4.53	R 3.39	R 5.23	R 4.43	R 4.18	R 2.45	R 37.08
Groundwater (Baseline)	52	81	19	30	14	20	65	37	94	410
Groundwater (Trend)	72	51	9	15	15	14	34	25	19	254
Total Groundwater	123	132	28	44	29	34	99	61	113	663
Cost per equiv. trip										R 35 000
Groundwater sampling (R million)	R 4.31	R 4.63	R 0.97	R 1.55	R 1.01	R 1.18	R 3.47	R 2.14	R 3.94	R 23.21
Total (R million)	R 9.39	R 7.68	R 5.71	R 6.09	R 4.40	R 6.41	R 7.90	R 6.32	R 6.39	R 60.29

Note: (1) Annual costs, in current (2016) rand value.

APPENDIX F

Scheduling and cash flow projection tools

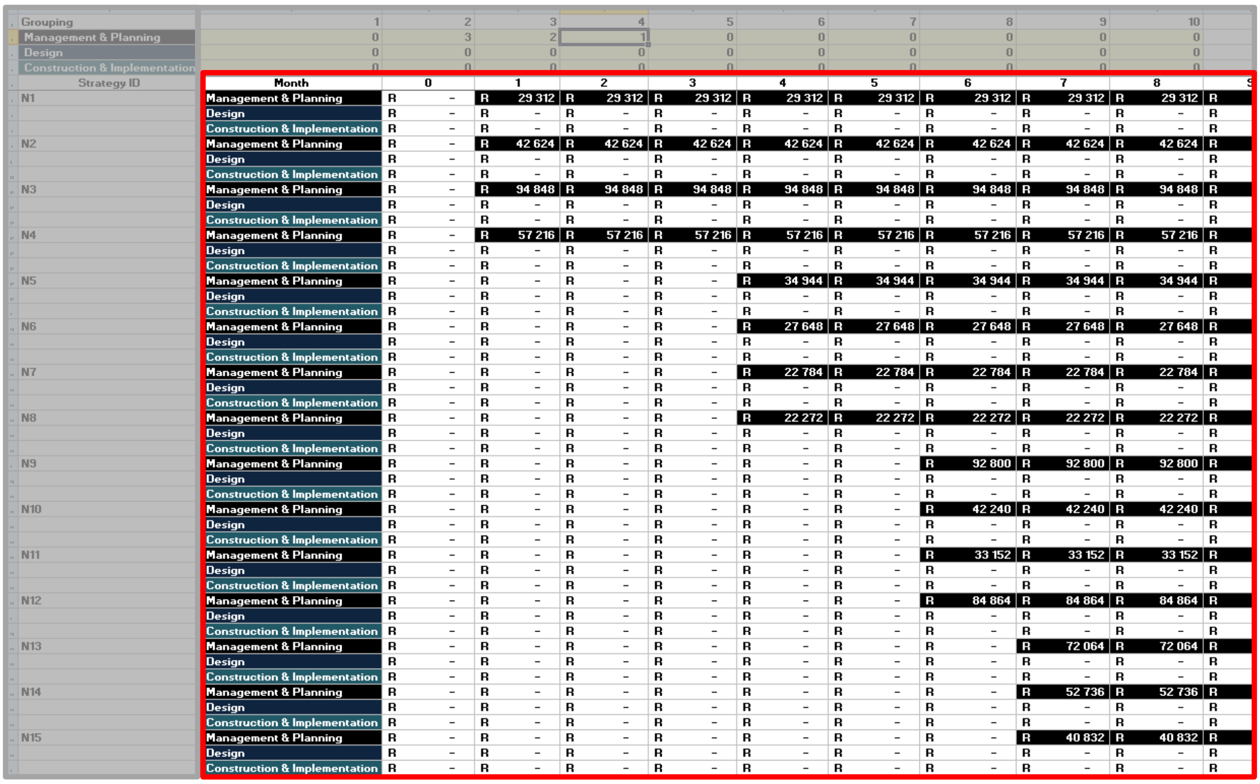
Grouping	1	2	3	4	5	6	7
Management & Planning	0	0	0	0	0	0	0
Design	0	0	0	0	0	0	0
Construction & Implementation	0	0	0	0	0	0	0

Strategy ID	Month	0	1	2	3	4	5	6
N1	Management & Planning	R –	R 29 312	R 29 312	R 29 312	R 29 312	R 29 312	R 2
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N2	Management & Planning	R –	R 42 624	R 42 624	R 42 624	R 42 624	R 42 624	R 4
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N3	Management & Planning	R –	R 94 848	R 94 848	R 94 848	R 94 848	R 94 848	R 9
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N4	Management & Planning	R –	R 57 216	R 57 216	R 57 216	R 57 216	R 57 216	R 5
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N5	Management & Planning	R –	R 34 944	R 34 944	R 34 944	R 34 944	R 34 944	R 3
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N6	Management & Planning	R –	R 27 648	R 27 648	R 27 648	R 27 648	R 27 648	R 2
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N7	Management & Planning	R –	R 22 784	R 22 784	R 22 784	R 22 784	R 22 784	R 2
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N8	Management & Planning	R –	R 22 272	R 22 272	R 22 272	R 22 272	R 22 272	R 2
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N9	Management & Planning	R –	R 92 800	R 92 800	R 92 800	R 92 800	R 92 800	R 9
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N10	Management & Planning	R –	R 42 240	R 42 240	R 42 240	R 42 240	R 42 240	R 4
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N11	Management & Planning	R –	R 33 152	R 33 152	R 33 152	R 33 152	R 33 152	R 3
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N12	Management & Planning	R –	R 84 864	R 84 864	R 84 864	R 84 864	R 84 864	R 8
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N13	Management & Planning	R –	R 72 064	R 72 064	R 72 064	R 72 064	R 72 064	R 7
	Design	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R
N14	Management & Planning	R	R 52 736	R 52 736	R 52 736	R 52 736	R 52 736	R 5

Figure F.1 Defining time shifts for station groupings

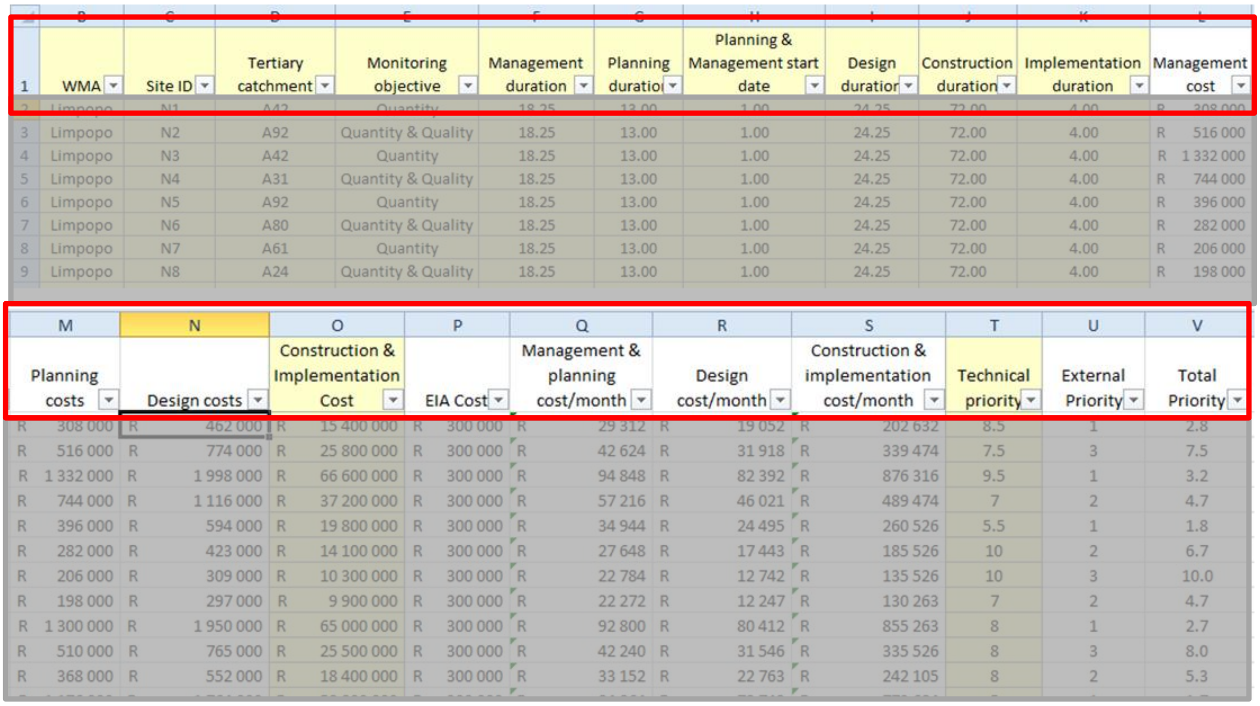
	B	C	D	E	F	G	H	I	J	K
1	WMA	Site ID	Tertiary catchment	Monitoring objective	Management duration	Planning duratio	Planning & Management start date	Design duratior	Construction duration	Implementation duration
2	Limpopo	N1	A42	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
3	Limpopo	N2	A92	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
4	Limpopo	N3	A42	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
5	Limpopo	N4	A31	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
6	Limpopo	N5	A92	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
7	Limpopo	N6	A80	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
8	Limpopo	N7	A61	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
9	Limpopo	N8	A24	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
10	Limpopo	N9	A31	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
11	Limpopo	N10	A80	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
12	Limpopo	N11	A23	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
13	Limpopo	N12	A71	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
14	Limpopo	N13	A62	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
15	Limpopo	N14	A62	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
16	Limpopo	N15	A24	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
17	Limpopo	N16	A50	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
18	Limpopo	N17	A71	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
19	Limpopo	N18	A23	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
20	Limpopo	N19	A31	Quantity	18.25	13.00	1.00	24.25	72.00	4.00
21	Limpopo	N20	A71	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00
22										
23										
24										
25										
26										
27										

Figure F.1 Defining start dates for individual stations



Strategy ID	Month	0	1	2	3	4	5	6	7	8	
N1	Management & Planning	R –	R 29 312	R 29 312	R 29 312	R 29 312	R 29 312	R 29 312	R 29 312	R 29 312	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N2	Management & Planning	R –	R 42 624	R 42 624	R 42 624	R 42 624	R 42 624	R 42 624	R 42 624	R 42 624	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N3	Management & Planning	R –	R 94 848	R 94 848	R 94 848	R 94 848	R 94 848	R 94 848	R 94 848	R 94 848	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N4	Management & Planning	R –	R 57 216	R 57 216	R 57 216	R 57 216	R 57 216	R 57 216	R 57 216	R 57 216	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N5	Management & Planning	R –	R –	R –	R –	R 34 944	R 34 944	R 34 944	R 34 944	R 34 944	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N6	Management & Planning	R –	R –	R –	R –	R 27 648	R 27 648	R 27 648	R 27 648	R 27 648	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N7	Management & Planning	R –	R –	R –	R –	R 22 784	R 22 784	R 22 784	R 22 784	R 22 784	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N8	Management & Planning	R –	R –	R –	R –	R 22 272	R 22 272	R 22 272	R 22 272	R 22 272	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N9	Management & Planning	R –	R –	R –	R –	R –	R –	R 92 800	R 92 800	R 92 800	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N10	Management & Planning	R –	R –	R –	R –	R –	R –	R 42 240	R 42 240	R 42 240	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N11	Management & Planning	R –	R –	R –	R –	R –	R –	R 33 152	R 33 152	R 33 152	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N12	Management & Planning	R –	R –	R –	R –	R –	R –	R 84 864	R 84 864	R 84 864	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N13	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R 72 064	R 72 064	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N14	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R 52 736	R 52 736	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
N15	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R 40 832	R 40 832	R
	Design	R –	R –	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R –	R –	R

Figure F.3 Example of Gantt chart output



WMA	Site ID	Tertiary catchment	Monitoring objective	Management duration	Planning duration	Planning & Management start date	Design duration	Construction duration	Implementation duration	Management cost
Limpopo	N1	A42	Quantity	18.25	13.00	1.00	24.25	72.00	4.00	R 308 000
Limpopo	N2	A92	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00	R 516 000
Limpopo	N3	A42	Quantity	18.25	13.00	1.00	24.25	72.00	4.00	R 1 332 000
Limpopo	N4	A31	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00	R 744 000
Limpopo	N5	A92	Quantity	18.25	13.00	1.00	24.25	72.00	4.00	R 396 000
Limpopo	N6	A80	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00	R 282 000
Limpopo	N7	A61	Quantity	18.25	13.00	1.00	24.25	72.00	4.00	R 206 000
Limpopo	N8	A24	Quantity & Quality	18.25	13.00	1.00	24.25	72.00	4.00	R 198 000

Planning costs	Design costs	Construction & Implementation Cost	EIA Cost	Management & planning cost/month	Design cost/month	Construction & implementation cost/month	Technical priority	External Priority	Total Priority
R 308 000	R 462 000	R 15 400 000	R 300 000	R 29 312	R 19 052	R 202 632	8.5	1	2.8
R 516 000	R 774 000	R 25 800 000	R 300 000	R 42 624	R 31 918	R 339 474	7.5	3	7.5
R 1 332 000	R 1 998 000	R 66 600 000	R 300 000	R 94 848	R 82 392	R 876 316	9.5	1	3.2
R 744 000	R 1 116 000	R 37 200 000	R 300 000	R 57 216	R 46 021	R 489 474	7	2	4.7
R 396 000	R 594 000	R 19 800 000	R 300 000	R 34 944	R 24 495	R 260 526	5.5	1	1.8
R 282 000	R 423 000	R 14 100 000	R 300 000	R 27 648	R 17 443	R 185 526	10	2	6.7
R 206 000	R 309 000	R 10 300 000	R 300 000	R 22 784	R 12 742	R 135 526	10	3	10.0
R 198 000	R 297 000	R 9 900 000	R 300 000	R 22 272	R 12 247	R 130 263	7	2	4.7
R 1 300 000	R 1 950 000	R 65 000 000	R 300 000	R 92 800	R 80 412	R 855 263	8	1	2.7
R 510 000	R 765 000	R 25 500 000	R 300 000	R 42 240	R 31 546	R 335 526	8	3	8.0
R 368 000	R 552 000	R 18 400 000	R 300 000	R 33 152	R 22 763	R 242 105	8	2	5.3

Figure F.4 Input data for individual stations

Grouping	1	2	3	4	5	6	7	8	
Management & Planning	0	3	2	1	0	0	0	0	
Design	0	0	0	0	0	0	0	0	
Construction & Implementation	0	0	0	0	0	0	0	0	
Strategy ID	Month	0	1	2	3	4	5	6	
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N9	Management & Planning	R –	R –	R –	R –	R –	R –	R 92 800	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N10	Management & Planning	R –	R –	R –	R –	R –	R –	R 42 240	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N11	Management & Planning	R –	R –	R –	R –	R –	R –	R 33 152	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N12	Management & Planning	R –	R –	R –	R –	R –	R –	R 84 864	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N13	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N14	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N15	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N16	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N17	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N18	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N19	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
N20	Management & Planning	R –	R –	R –	R –	R –	R –	R –	R
	Design	R –	R –	R –	R –	R –	R –	R –	R
	Construction & Implementation	R –	R –	R –	R –	R –	R –	R –	R
Monthly Total		R –	R 224 000	R 224 000	R 224 000	R 331 648	R 331 648	R 584 704	R
		R –	R 224 000	R 448 000	R 672 000	R 1 003 648	R 1 335 296	R 1 920 000	R

Figure F.5 Data copied to develop a national timeline

	A	B	C	D	E	F	G	H	I	J	K
1											
2			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	Limpopo	Surface Water	R 981 632	R 981 632	R 981 632	R 981 632	R 981 632	R 981 632	R 981 632	R 981 632	R 981 6
4		Groundwater	R 49 082	R 49 082	R 49 082	R 49 082	R 49 082	R 49 082	R 49 082	R 49 082	R 49 0
5		Water quality	R 72 641	R 72 641	R 72 641	R 72 641	R 72 641	R 72 641	R 72 641	R 72 641	R 72 6
6		***WMA total***	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 354*	*R 1 103 3*
7	Olifants	Surface Water	R 713 728	R 713 728	R 713 728	R 713 728	R 713 728	R 713 728	R 713 728	R 713 728	R 713 7
8		Groundwater	R 35 686	R 35 686	R 35 686	R 35 686	R 35 686	R 35 686	R 35 686	R 35 686	R 35 6
9		Water quality	R 52 816	R 52 816	R 52 816	R 52 816	R 52 816	R 52 816	R 52 816	R 52 816	R 52 8
10		***WMA total***	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 230*	*R 802 2*
11	Inkomati-Usuthu	Surface Water	R 337 719	R 337 719	R 337 719	R 337 719	R 337 719	R 337 719	R 337 719	R 337 719	R 337 7
12		Groundwater	R 16 886	R 16 886	R 16 886	R 16 886	R 16 886	R 16 886	R 16 886	R 16 886	R 16 8
13		Water quality	R 24 991	R 24 991	R 24 991	R 24 991	R 24 991	R 24 991	R 24 991	R 24 991	R 24 9
14		***WMA total***	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 596*	*R 379 5*
15	Pongola-uMzimkhulu	Surface Water	R 412 544	R 412 544	R 412 544	R 412 544	R 412 544	R 412 544	R 412 544	R 412 544	R 412 5
16		Groundwater	R 20 627	R 20 627	R 20 627	R 20 627	R 20 627	R 20 627	R 20 627	R 20 627	R 20 6
17		Water quality	R 30 528	R 30 528	R 30 528	R 30 528	R 30 528	R 30 528	R 30 528	R 30 528	R 30 5
18		***WMA total***	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 699*	*R 463 6*
19	Vaal	Surface Water	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 616	R 1 167 6
20		Groundwater	R 58 381	R 58 381	R 58 381	R 58 381	R 58 381	R 58 381	R 58 381	R 58 381	R 58 3
21		Water quality	R 86 404	R 86 404	R 86 404	R 86 404	R 86 404	R 86 404	R 86 404	R 86 404	R 86 4
22		***WMA total***	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 400*	*R 1 312 4*
23	Orange	Surface Water	R 849 803	R 849 803	R 849 803	R 849 803	R 849 803	R 849 803	R 849 803	R 849 803	R 849 8
24		Groundwater	R 42 490	R 42 490	R 42 490	R 42 490	R 42 490	R 42 490	R 42 490	R 42 490	R 42 4
25		Water quality	R 62 885	R 62 885	R 62 885	R 62 885	R 62 885	R 62 885	R 62 885	R 62 885	R 62 8

Figure F.6 Data input data for the national timeline

Start year	Limpopo	Olifants	Inkomati-Usuthu	Pongola-uMzimkhulu	Vaal
	1	2	3	4	5
	0	1	2	3	4
Limpopo					
Olifants					
Inkomati-Usuthu					
Pongola-uMzimkhulu					
Vaal					
Orange					
Mzimvubu-Tsitsikamma					
Breede-Gouritz					
Berg-Olifants					

Figure F.6 **Changes in start year per WMA**