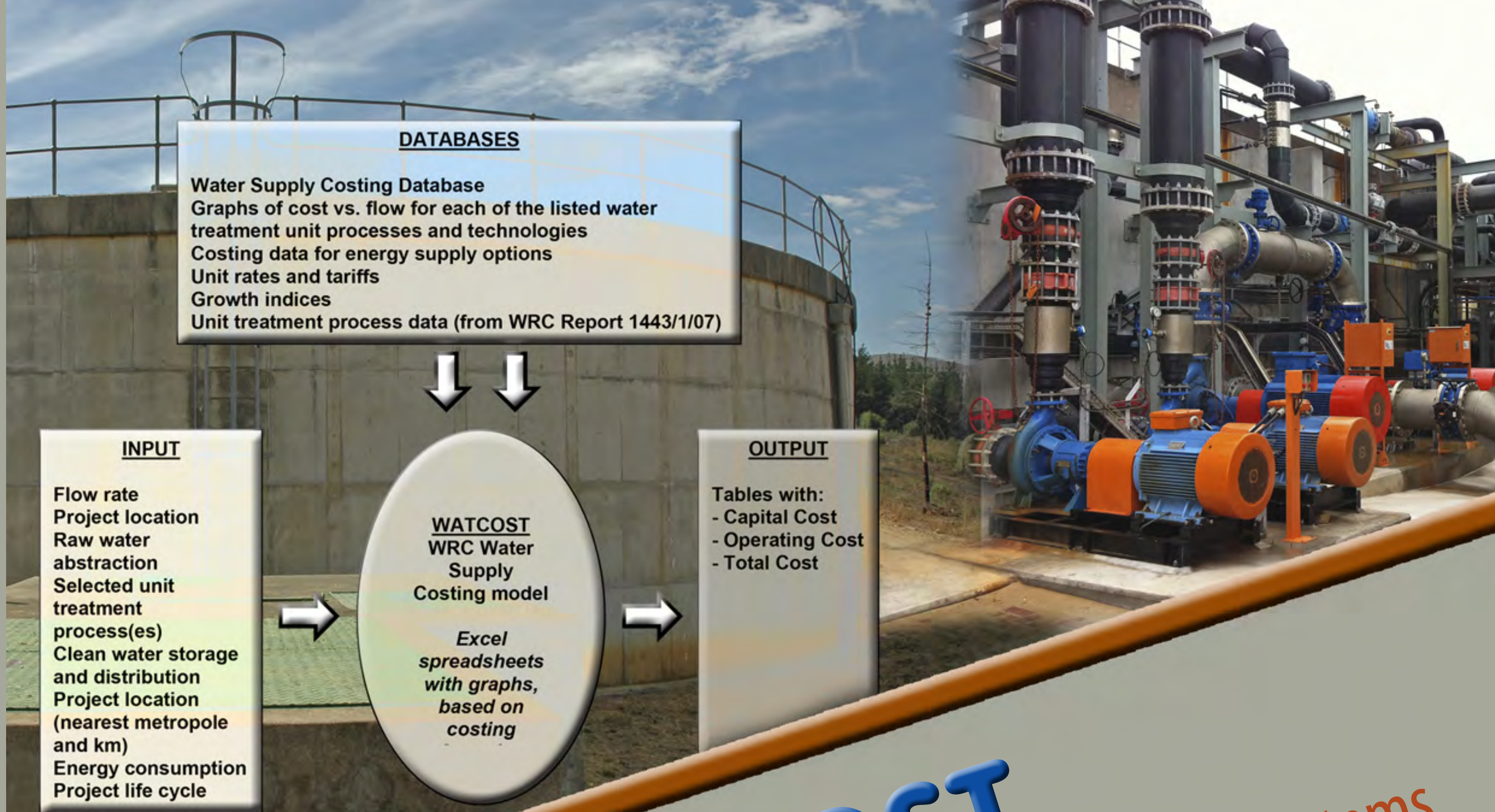

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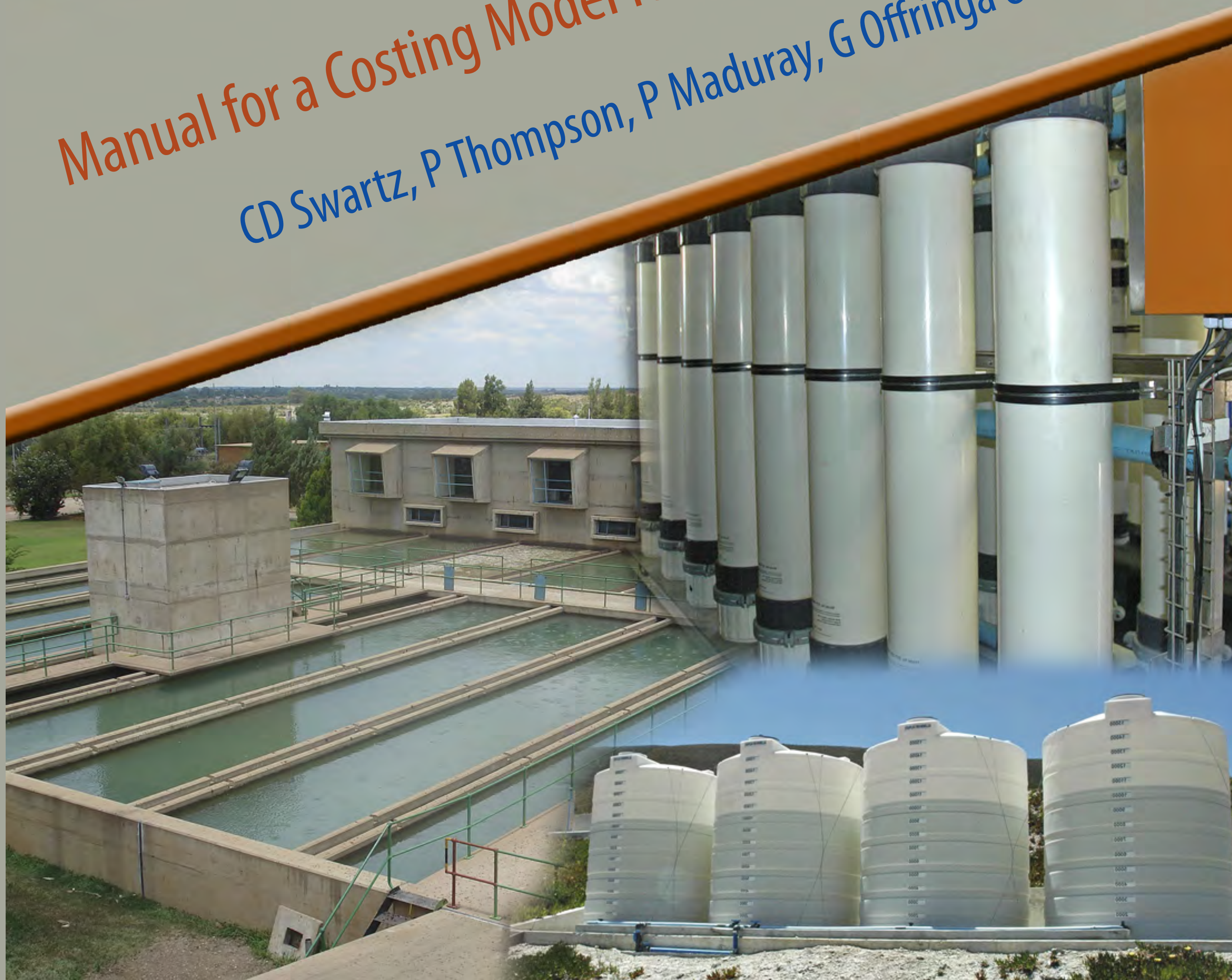

WATER RESEARCH COMMISSION
TT 552/13

WATCOST

Manual for a Costing Model for Drinking Water Supply Systems

Report to the
Water Research Commission

by

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The publication of this report emanates from a project entitled *Development of a costing model to determine the cost-efficiency and energy efficiency of water treatment technologies and supply options* (WRC Project No. K5/1992//3).

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ABOUT THE MANUAL

This Water Research Commission project developed a user-friendly costing model for estimating costs of drinking water supply systems. This model allows economic comparison between different water treatment and supply options being considered for a water supply scheme(s). It further also allows costing reports to be created for existing water treatment systems, which assists with budgeting and asset management processes.

The aim of this manual is two-fold: firstly, it can be used as a reference document for information on costing data for water supply projects, with actual costing figures that can be obtained from the tables and graphs in the document. Secondly, the manual is also an aid to using the WATCOST Model to obtain costing data for water supply projects, either in total or for specific components in the drinking water supply cycle.

The WATCOST Costing Model is available electronically from the WRC website (www.wrc.org.za) Knowledge Hub, and is referred to in this manual.

The electronic copy of the model on the WRC website Knowledge Hub contains the following:

- User Instructions
- Input Component (where the user will enter required information)
- Software that will do the cost calculations – the Model Component
- Output Component (that will provide the tables and graphic costing results)
- Database of costing information (not accessible to the user, only for doing cost calculations)

The Costing Model can be used to:

- Estimate first-order capital and operating costs of water supply systems
- Estimate costs for upgrading existing systems
- Determine the approximate value of existing water treatment systems.

The manual is intended for use by decision-makers, consultants, engineers, planners, water supply authorities, and the Department of Water Affairs to estimate costs of new water supply systems, costs for upgrading or refurbishing existing systems, and also to determine approximate value of existing water supply and water treatment assets. The Manual only provides first order estimates that can be used for planning purposes, for budgeting and to compare alternatives on a financial basis. It should be expressly emphasised here that the manual or model is not sufficiently accurate to use the costing data for tender purposes or for detailed costing.

ACKNOWLEDGEMENTS

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The Steering Committee (Reference Group) responsible for this project consisted of the following persons:

Dr J Burgess	Water Research Commission (Research Manager)
Ms M Krüger	Midvaal Water
Mr C van der Walt	CSV Consulting Engineers
Mr B Theunissen	Aurecon
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Mr Ben van der Merwe	Consultant
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Mr E Schmollgrüber	Wettech SA
Mr R Brown	Drakenstein Municipality
Prof C Buckley	University of KwaZulu-Natal
Mr A Ottermann	Pula Strategic Resource Management

The financing of the project by the Water Research Commission and the contribution of the members of the Steering Committee is acknowledged gratefully.

The project was only possible with the co-operation of a number of individuals and institutions. The authors therefore wish to record their sincere thanks to the following:

- Engineers from consulting engineering companies for their valuable information and costing data
- Planning and operational personnel of the various water boards in the country for operational costing data
- Dr Johan Snyman, economic consultant in Stellenbosch, for valuable insight into forecasting methods and price indices.

GLOSSARY OF TERMS

Non-Construction Capital Cost

Non-construction capital cost is an allowance for the following elements associated with the constructed facilities:

- Facilities planning
- Engineering design
- Permitting
- Services during construction
- Administration

Land Cost

The market value of the land required to implement the water supply alternative.

Land Acquisition Cost

The estimated cost of acquiring the required land, exclusive of the land cost.

Total Capital Cost

Total capital cost is the sum of construction cost, non-construction capital cost, land cost, and land acquisition cost.

Operation and Maintenance Cost (O&M Cost)

The estimated annual cost of operating and maintaining the water supply facility when operated at average day capacity.

Equivalent Annual Cost

Total annual life cycle cost of the water supply alternative based on service life and time value of money criteria established herein. Equivalent Annual Cost accounts for:

- Total Capital Cost
- Operations and Maintenance (O&M) costs (with the facility operating at average day capacity)
- Time value of money (annual interest rate)
- Facilities service life

Unit Production Cost

Equivalent Annual Cost divided by total annual water production.

Criteria

Cost estimating and economic criteria are guidelines for estimating costs associated with water supply options.

Peak Flow Ratio

Construction and capital cost of water supply facilities will be based on maximum installed capacity designed to accommodate peak or maximum daily flow (MDF) requirements. Operation and maintenance (O&M) costs and total annual water production are based on the average daily flow (ADF) produced. The peak flow ratio (MDF/ADF) for an individual water supply system depends on the demand characteristics of the service area. For public supply systems the required peak flow ratio is generally at least 1.25 for large systems and can be greater than 2.0 for small systems. However, the total system peaking requirement may or may not apply to individual components of an integrated water supply system.

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CHAPTER 1. INTRODUCTION

1.1. The Need for Costing Information on Drinking Water Treatment Projects

While considerable information is available on technical aspects (design, operation, and maintenance) of water treatment technologies, there is a lack of information about costs, in particular life-cycle costs, which are used in the comparison and selection of these technologies. This includes both capital and operating costs (operation, maintenance, and management). In this regard, the escalating cost of energy is becoming a factor deserving of increasing recognition. Both municipalities and consultants have scant comparative costing information for drinking water treatment system options on which to base their decisions for new water treatment schemes, resulting in incomplete planning and inadequate budgeting for these systems. Further, little information is available to answer the question, “When is it more economical to install a number of smaller, decentralised plants, instead of providing a larger, centralised water treatment plant with its associated larger distribution network?” Of great value would be the development of a costing model, which could determine the costs of different water treatment systems, technologies and options to be considered for implementation in a water supply scheme.

The project was a logical follow-up to the WRC project on "The Selection of Small Water Systems for Potable Water Supply to Small Communities" (WRC Report 1443/1/07), where all the existing and emerging technologies were evaluated (desk and field study) and technology information sheets drawn up for the different technologies. The sheets contain information on technology description, purpose of the technology, flow diagrams, performance limitations, operating requirements and maintenance requirements, whereby these technologies can be compared with the view of selecting the most appropriate (best) technology for a particular application. While some qualitative costing is presented in the sheets, there was a significant lack of available costing information, which demonstrated the need for further research to obtain accurate costing information for small-scale water treatment systems.

This project thus developed a user-friendly costing model for establishing and predicting the cost-efficiency of a range of small-scale water treatment technologies that are used in water supply schemes, as well as providing decision support for the selection of decentralised versus centralised water supply. This allows economic comparison between different water treatment and supply options being considered for water supply schemes. It also allows costing reports for existing water treatment systems to be created, which assists with budgeting and asset management.

The WATCOST Model is aligned with the Department of Water Affairs (DWA) Costing Model, so that the two can be integrated. An additional document was drawn up for unit costs of municipal services (CoGTA (2010) “An Industry Guide to Infrastructure Service Delivery Levels and Unit Costs”). Costing data for water services in the Industry Guide is an extension of the costing data contained in the DWA Benchmark Document (2009), which is the document describing the unit costs derived from the DWA Costing Model.

According to the Industry Guide (CoGTA, 2010) cost benchmarks are often required for different purposes and at different levels of detail. They serve primarily as a reference or check for evaluation of conceptual project plans and project proposals. They can also be useful references for regional and national budgeting and strategic planning. However, **such figures should not be used for detailed cost calculations in feasibility studies or business plans, and definitely not for tendering purposes. For such purposes, site specific design information and material costs should be gathered and prepared**.

1.2. Scope and Layout of the Manual

The aim of this manual is two-fold: firstly, it can be used as a reference document for information on costing data for water supply projects, with actual costing figures that can be obtained from the tables and graphs in the document. Secondly, the manual is also an aid when using the WATCOST Model to obtain costing data for water supply projects, either in total or for specific components in the drinking water supply cycle.

The manual provides a description of the cost components of water supply systems, and looks at the concept of life-cycle costing (Chapter 2). The chapter also explores cost estimation, and focuses on the criteria that make up or determine the costs of water supply projects. Guidelines are provided on how costs may be compared. An overview of some existing costing models concludes this chapter.

Chapter 3 discusses the procedure that was followed in developing the WATCOST model, firstly looking at the requirements of a costing model according to the specific aims and objectives of this research project. It then describes the characteristics of WATCOST, and how these will provide a practical and user-friendly costing model for water supply projects.

In Chapter 4, the structure of the WATCOST model is given in the form of flow diagrams, and this is followed by a description of the methodology that was followed by the project team to develop the model and to obtain costing data (Chapter 5).

In order to orientate the reader to the water treatment processes for which costing data is included in the manual, Chapter 6 provides a description of the water treatment unit processes and process configurations. The description includes the conventional water treatment processes as well as membrane treatment processes of which a growing number of plants are being constructed at present.

Costing information is provided in Chapter 7, which includes description of the cost factors for both capital and operating costs. Chapter 8 provides guidelines on how the WATCOST model may be used, utilising the spreadsheets in the downloadable model. Costing estimation guidelines are given for four applications, namely costing of new projects, costing for upgrading and extension of existing projects, costing of refurbishments, and costing to determine the value of existing water supply systems.

Chapter 9 concludes by providing cost comparison criteria and information for the comparison of the costs of centralized water supply systems versus decentralized water supply systems.

1.3. Products of the Costing Model Project

The WATCOST Costing Model is electronically from the WRC website (www.wrc.org.za) Knowledge Hub.

The electronic copy of the model contains the following:

- User instructions
- Input component (where the user will enter required information)
- Software that will do the cost calculations – the model component
- Output component (that will provide the tables and graphic costing results)
- Database of costing information (not accessible to the user, only for doing cost calculations)

The costing model can be used to:

- Estimate first-order capital and operating costs of water supply systems
- Estimate costs for upgrading existing systems
- Determine the approximate value of existing water treatment systems.

1.4. Who the Manual is Intended for

The manual is intended for use by decision-makers, consultants, engineers, planners, water supply authorities and the Department of Water Affairs to estimate costs of new water supply systems, costs for upgrading or refurbishing existing systems, and also to determine approximate value of existing water supply and water treatment assets. The Manual only provides first order estimates that can be used for planning purposes, for budgeting and to compare alternatives on a financial basis**. It should be expressly emphasised here that the manual or model is not sufficiently accurate to use the costing data for tender purposes or for detailed costing.**

CHAPTER 2. OVERVIEW OF COST ESTIMATION AND THE USE OF COSTING MODELS

2.1. Cost Components of Water Supply Systems

Costing of components in water supply systems includes (broadly) the following aspects:

a. Capital costs of components/plant/distribution system
b. Life-cycle costs of components
c. Labour
d. Management implications
e. Energy
f. Chemicals
g. Water quality
h. Operation
i. Maintenance

2.2. Life Cycle Costing

Van Vuuren and Van Dijk (2006) provide a summary of Life Cycle Costing (LCC) as background to their development of a Life Cycle Costing Model (LCCM). According to the authors, Life Cycle Costing Analysis (LCCA) is the identification and analysis of all costs incurred in acquiring, operating, supporting and disposing of a material system or equipment. It is used to identify the budget implications of capital investment decisions and the cost impact of various design and support options.

Life Cycle Costing Analysis started in the 1960s, when it was developed as an approach to understand the impacts of energy consumption. Since then it has been applied successfully in various fields for the financial evaluation of products and projects, including in water supply projects. As such, it is a key analytical tool used by engineers in the development, production and support of material systems.

The technique is based on the concept that "time is money". ***By placing a time value on money, future expenditures are brought back to a present base year where a direct comparison between alternatives can be made.***

Life cycle costs should include the direct costs and indirect costs as well as benefits associated with the material or process. A complete life cycle cost analysis should include <u>all of the costs and benefits</u> that result from the construction of infrastructure or equipment. This includes both the direct and indirect financial impacts.

The optimisation of the system can be obtained by comparing the Life Cycle Cost (LCC) of the alternative systems and it is of value to reflect the capital and operational cost benefit of an investment. As is the case with most evaluation techniques, the real challenge lies in making <u>unbiased assumptions</u>, which produce fair comparisons of alternate designs (NCSPA, 2002). Engineering and economic assumptions such as project design life, discount rate, escalation rate and inflation should be made.

2.2.1. Life Cycle Costing Analysis Model

A Life Cycle Costing Analysis (LCCA) model is in essence an accounting structure containing terms and factors which enable an estimation of the various cost components representing a pipeline system (New South Wales DPWS Report, 2001).

According to the New South Wales DPWS Report (2001), the LCCA model developed enables the user to:

- Represent the financial characteristics of the pipeline system being analysed including the maintenance and operational requirements as well as limitations and constraints in the system.
- Easily understand the LCCA process and allowing a user friendly interaction with it.
- Analyse a system comprehensively enough to highlight the important aspects of the system.

2.3. Cost Estimating

Kawamura and McGivney (2008) provide a comprehensive insight to cost estimating in water supply projects in a manual that provides a framework, with spreadsheets and graphs for performing costing for water supply projects. As a starting point, they state that accurate cost estimating is very important and has been the mainstay of human development for at least 8000 years. Sustainable growth has been possible because the developers could afford it, and, among other things, they were good at estimating.

2.3.1. Structure of the Manual

The Kawamura and McGivney manual is an outline for preparing good cost estimates for water treatment plants. It includes basic water treatment plant design philosophy and process schematics, predesign cost estimating methods and procedures, process parameters and their cost curves, and total plant costs. This in turn includes tables and equation functions, as well as capital, and operations and maintenance (O&M) costs for each type of water treatment plant (conventional as well as more advanced treatment processes).

The methodology used is derived from best practices of cost estimating and the personal experience of the authors. They used studies and public documents provided by governments, and their own historical data.

2.4. Costing Criteria

Wycoff (2009) proposed cost estimating and economic criteria to be used in the development of regional planning level water supply facilities cost estimates for the 2010 District Water Supply Plan (DWSP). The definitions and criteria are consistent with those employed in 2005 and previous DWSPs but incorporate certain modifications and updates as appropriate for application in 2010, and can be used for the development of comparable planning level LCC estimates for all water supply alternatives.

2.4.1. Definitions

Construction Capital Cost

Construction cost is the total amount expected to be paid to a qualified contractor to build the required facilities at peak design capacity.

Non-Construction Capital Cost

Non-construction capital cost is an allowance for the following elements associated with the constructed facilities:

- Facilities planning
- Engineering design
- Permitting
- Services during construction
- Administration

Land Cost

The market value of the land required to implement the water supply alternative.

Land Acquisition Cost

The estimated cost of acquiring the required land, exclusive of the land cost.

Total Capital Cost

Total capital cost is the sum of construction cost, non-construction capital cost, land cost, and land acquisition cost.

Operation and Maintenance (O&M) Cost

The estimated annual cost of operating and maintaining the water supply facility when operated at average day capacity.

<u>Equivalent Annual Cost</u>

Total annual life cycle cost of the water supply alternative based on service life and time value of money criteria established herein. Equivalent Annual Cost accounts for:

- Total Capital Cost
- Operations and Maintenance (O&M) costs (with the facility operating at average day capacity)
- Time value of money (annual interest rate)
- Facilities service life

<u>Unit Production Cost</u>

Equivalent Annual Cost divided by total annual water production.

2.5. Methods of Comparing Alternatives

Van Vuuren and Van Dijk (2006) states that in order to compare project alternatives over the life cycle of a project, it is required to compare the Time-Value of Money. The net present value (NPV) and the internal rate of return (IRR) methods are normally used to provide an economical/financial ranking of different alternatives. These concepts are described below.

2.5.1. Net Present Value (NPV)

The NPV method discounts all future costs to the base year at a given interest rate (discount rate) reflecting the cost of capital. The discount rate is thus used to convert all future income and future expenditure to a base year for comparison purposes. If the total discounted income is greater than the total discounted expenditure then it indicates that this is eventually a viable project. It must however be highlighted that the choice/selection of the discount rate may have a significant influence on the net present values. It is therefore recommended to always undertake a sensitivity analysis to identify the possible risks of changing cost of capital. The NPV is a very easy method to use. The formula with which the future values are discounted back to present day values is shown below:

$$P = \frac{F}{(1+i)^n} \qquad [2.1]$$

where: *F* = the future value
P = the present value
i = Interest rate (discount rate)
n = Number of years the amount should be brought forward

2.5.2. Internal Rate of Return (IRR)

The internal rate of return (IRR) of an investment is the discount rate, which causes the present value of its net cash inflows to equal zero. Another way of defining IRR is as follows: the IRR of a cash flow is defined as the discount rate which would result in that cash flow having a NPV of zero. If a project has an IRR, which is greater than the alternative options for investing the capital, then it should be considered an attractive project. The determination of the IRR for a project, generally involves trial and error or a numerical technique. The following steps can be followed to determine the IRR of a project:

- Select at random a trial discount rate
- Define the costs as negatives (-) and the income as positives (+)
- Apply the NPV to each of these future costs and incomes using the selected discount rate
- If the net present value is positive, then the actual internal rate of return is higher and if the net worth is negative, then the actual internal rate of return is lower than that selected
- Adjust the selected discount rate and recalculate the NPV until the NPV income and NPV expenditure are equal

2.6. Forecasting escalation

The following three methods can be used to forecast escalation for future years:

- Consult economic specialists at the period in time under consideration
- Consider major events affecting the construction industry (e.g. World Cup)
- Consider trends

(For services sector: use average inflation (interest) rate (CPI) or use indices (see Appendix A).

2.7. Costing models

2.7.1. International models

2.7.1.1 The ASPENTECH family of cost estimating programs (www.aspentech.com)

AspenTech offers 16 families of products and more than 200 individual tools in all. These tools were originally developed for the petroleum industry. The Economic Evaluation Family provides model- and operations-based cost estimating tools for facility design, facility operation and supply chain management. Each product runs on AspenTech's Icarus cost engine, which includes volumetric models that perform calculations and deploy sets of cost indices that are updated yearly.

Aspen Capital Cost Estimator is one of three products in AspenTech's Economic Evaluation Family. Formerly known as KBase, Capital Cost Estimator is used for the front-end engineering design phase. The ability to conduct trending estimates lets project managers keep an eye on costs during basic engineering tasks, while model and analysis tools help firms develop strategies for executing projects that involve numerous subcontractors. In addition, Aspen Capital Cost Estimator lets project managers track cost estimate and construction schedule changes based on criteria such as design standards, construction technique, shift and work week length and the use of remote fabrication shops.

The other tools in the Economic Evaluation Family are **Aspen Icarus Process Evaluator**, which is intended for use in the conceptual design phase, allowing modellers to run the costs associated with 30 or more design options, and **Aspen InPlant Cost Estimator**, which is used for estimating "small" operations costs, such as new construction within existing plants, of less than $10 million.

The Aspen cost estimating programs operate on the principle of estimating the cost of each sub-part or module of a process plant. Modules are then connected to form a process train, thereby providing the total cost of a full plant. Thus, in cost estimating a water treatment facility, the costs is estimated separately for an in-line (coagulant)mixer, a flocculation channel, a settler, etc., until all the modules of the plant are costed. “Connection modules”, such as pipes and valves are then costed separately and all costs integrated and added to give a total cost. Separate parts of the distribution system need to be costed in the same way to obtain a total cost of a supply scheme. The program is mainly aimed at petroleum and chemical engineering cost estimating and is not really suitable to (especially South African) water treatment plant cost estimating.

2.7.1.2 e-STM8 Construction estimating software (Builder’s Pal) and other construction software (www.downloadatoz.com/business_directory/estm8-construction-estimating-software/)

e-STM8 Construction estimating software facilitates the preparation of detailed, profitable bids while managing job costs and subcontractor bids. e-STM8 offers basic and advanced estimating features which allow the accurate construction of an estimate. The software enables one to set default labour rates, plant rental cost and material purchase prices. e-STM8 is most suitable for contract tendering where an un-priced bill of quantities is provided by the employer and contractors are required to price and submit their tenders. The quantity take-offs are assumed to have been made earlier by the employer. An idea of how the program output is portrayed, may be found at www.downloadatoz.com/business_directory/estm8-construction-estimating-software/screenshot.html

The program could be adapted for use as a water treatment plant cost estimating tool, but has not specifically been designed for such an application in mind. Other construction software programs in the same category and performing approximately the same functions include "Clear Estimates" http://www.constructionsoftwarereview.com/directory/clear-estimates/clear-estimates,"Spectrum" www.dexterchaney.com "Sage Master Builder" http://www.sagecre.com/products/master_builder and "Success Estimator" www.uscost.com/successestimator.asp

2.7.2. The DWA Cost Benchmark: Typical Unit Costs for Water Services Development Projects: A Guide for Local Authorities (Basic Services only), *Department of Water Affairs*, August 2009:

2.7.2.1 Background

The cost of water supply services infrastructure can vary significantly, with changing site conditions and the changing global economic climate. Experience has also shown that cost estimates for water services development projects seldom use the same costing factors, planning norms and design criteria. This complicates the task of project managers, strategic planners and therefore also cost estimators.

The Department of Water Affairs (DWA) has therefore undertaken a costing exercise to determine cost benchmarks for typical water services development projects (DWA, 2009). The costs were derived from the department's rural water supply projects completed since 1994 and from as-build project costs sourced from numerous implementing agents and consultants involved with basic water service delivery.

Actions are underway to extend the cost information in order to improve accuracy and site-specific variance. The assistance of all stakeholders and especially that of local authorities will be sought for this purpose.

While the accuracy of cost information is expected to improve with accumulation of more cost information, the publication of presently available cost benchmarks by DWA (DWA, 2009) serve to provide guidance to local authorities and water services institutions in their decision-making.

It is important to note that the costing information in the DWA cost benchmarks is provided only at component, scheme, regional, and national level, and that the cost sensitivity to site-specific conditions decreases in the same sequence.

The purpose of the DWA cost benchmarks is stated as to provide typical unit costs of water services projects and individual infrastructure components, as benchmarks for decision-making at local authority, provincial and national level.

The costs in this publication are dated **August 2009 using accumulated cost data over the last five years and escalating these to the common date of August 2009**. When used in future years, the costs should be escalated by the published production price index (PPI) for civil engineering. This can be obtained from Statistics South Africa, tel. +27 (0)12 310 8600.

Cost benchmarks are required for different purposes and at different levels of detail. They serve primarily as a reference or check for evaluation of conceptual project plans and project proposals. They can also be useful references for regional and national budgeting and strategic planning.

The following summary levels are included in this document:

- National: average unit costs considering national characteristics and needs
- Provincial: typical unit costs reflecting the characteristics of the province
- Scheme level: typical unit costs for different scheme types
- Component level: typical unit costs of individual infrastructure components

It is again important to have cognizance of the fact that these cost benchmarks should not be used for detailed cost calculation in feasibility studies or business plans. For this purpose site-specific design information and material costs should be gathered. ***A computer based costing model has been developed by DWA to assist with conceptual planning and costing at pre-feasibility level and will in particular assist planners and consultants to evaluate alternative projects for a specific need or circumstance.***

2.7.2.2 Process to Develop Benchmarks

Unit costs (benchmarks) were calculated for each infrastructure component and project element using information from the following sources and investigations:

The primary source of cost information is the DWA Cost Model, developed by Directorate WS (MP&IS). It established representative cost functions for each infrastructure component based on cost information supplied by numerous engineering consulting firms and a wide spectrum of materials suppliers and industry role players. This Cost Model, and the databases of information that were obtained by the DWA for developing this model, will be extremely valuable for the current project to establish base data for the WRC water supply costing model.

The unit costs presented in the DWA Cost Model are based on historical as-build construction costs and typical material prices, sourced from consulting engineering firms and manufacturers. The majority of the information was collated under a DWA study to develop a Cost Model for rural water supply schemes, which was updated by recently completed projects and other cost information.

Specific reference is made to input from:

- DWA Directorate Water Services Macro Planning & Information Support
- DWA Directorate Water Services Project Development and Support
- CMIP Project Implementation Programme
- Consulting Engineering Firms implementing DWA projects
- Selected Equipment and Materials Manufacturers
- Reviewers and other individuals who provided input.

CHAPTER 3. DEVELOPMENT OF THE WATCOST MODEL

3.1. Requirements of the Model

This project aimed to develop a user-friendly costing model for estimating costs of drinking water supply systems. This allows economic comparison between different water treatment and supply options being considered for water supply schemes. It will further also allow costing reports to be done for existing water treatment systems, which will assist with budgeting and asset management processes.

Costing criteria and costing components that are applicable to local conditions and small water treatment systems in South Africa should be established. These components include, inter alia, the following:

- Capital costs of components/plant
- Life-cycle costs of components
- Labour implications
- Management implications
- Energy
- Chemicals
- Water quality

The following aspects involved in cost determination should be considered:

- Economy of scale
- Modular systems
- Minimum requirements for O&M of the plants
- Reliability
- Treatment system security
- Mode of operation (continuous /number of hours per day)
- Escalation
- Monitoring and control requirements

3.2. Characteristics of the Model

In developing the model framework, a number of additional requirements for the model were set. The WATCOST model therefore has the following features:

- It focuses on the water treatment component of the water supply system, but includes estimates for the following:
    - Raw water abstraction facilities
    - Raw water transport
    - Clean water storage (reservoirs)
    - Distribution networks (various levels of service)
- The model produces outputs for capital costs, operating costs (which includes maintenance costs), total costs, in costs per annum and per kilolitre of water produced.
- Costs are based on life-cycle costing.
- Data used for calculating costs should be current; from local information; and should be based on local indices where applicable.
- The databases are structured to enable easy, annual updating.
- The model is spreadsheet based (Microsoft Excel).
- The model is user friendly, unambiguous and easy to operate, requiring minimal data inputs from the user (drop down menus are used).

- The databases contain a suite of proposed treatment process configurations, so that the user can compare costs of different treatment options for a given raw water quality range and flows.
- The model is not a decision support tool, but has been designed in such a way that a decision-making functionality can be added seamlessly at a later stage.
- The unit process characteristics are based on the suite of technologies in the WRC Research Reports entitled *The Selection of Small Water Treatment Systems for Potable Water Supply to Small Communities*, Volume 1 by Swartz *et al.* (2007) and Volume 2 by Delcarme *et al.* (2007), the WRC handbook *Water Purification Works Design* (Van Duuren, 1997) and the WRC report *Package water treatment plant selection* (Voortman and Reddy, 1997).
- The model includes for variations in costs for undertaking water supply projects in different geographic areas.
- The model allows for cost escalation by updating unit costs and tariffs on an annual basis.
- It includes the costs of soft issues such as training, monitoring and control, compliance and management.
- Costing of energy requirements is a secondary focus, and the model allows for costing of some alternative energy supply options.
- Operational costs allows for human resource costs of personnel as required by the DWA according to their plant classification system.
- The costs include the establishment and maintenance of security systems for protecting all the components of the water supply systems, i.e. catchments, water sources (surface water, ground water, alternative water sources), abstraction facilities and raw water supply pipelines, water treatment plants, clean water reservoirs, distribution networks and consumer points.
- The model caters for small-scale systems (community-scale plants, which include package plants), to large treatment plants, but excludes home treatment devices. Depending on the characteristics of the costing data that will be obtained for different treatment plant sizes, small and large plants could either be handled separately (i.e. different costing formulae and graphs), or on the same set of graphs. Therefore, economy of scale was taken into account in developing the model.
- The model was designed in such a way that it can be modified at any time by the project team, and later by a designated administrator.

The main categories of the costing data used in the WATCOST Model include:

- Capital
- Replacement
- Refurbishment
- Operation
- Maintenance
- Financing and insurance costs (not addressed in this project).

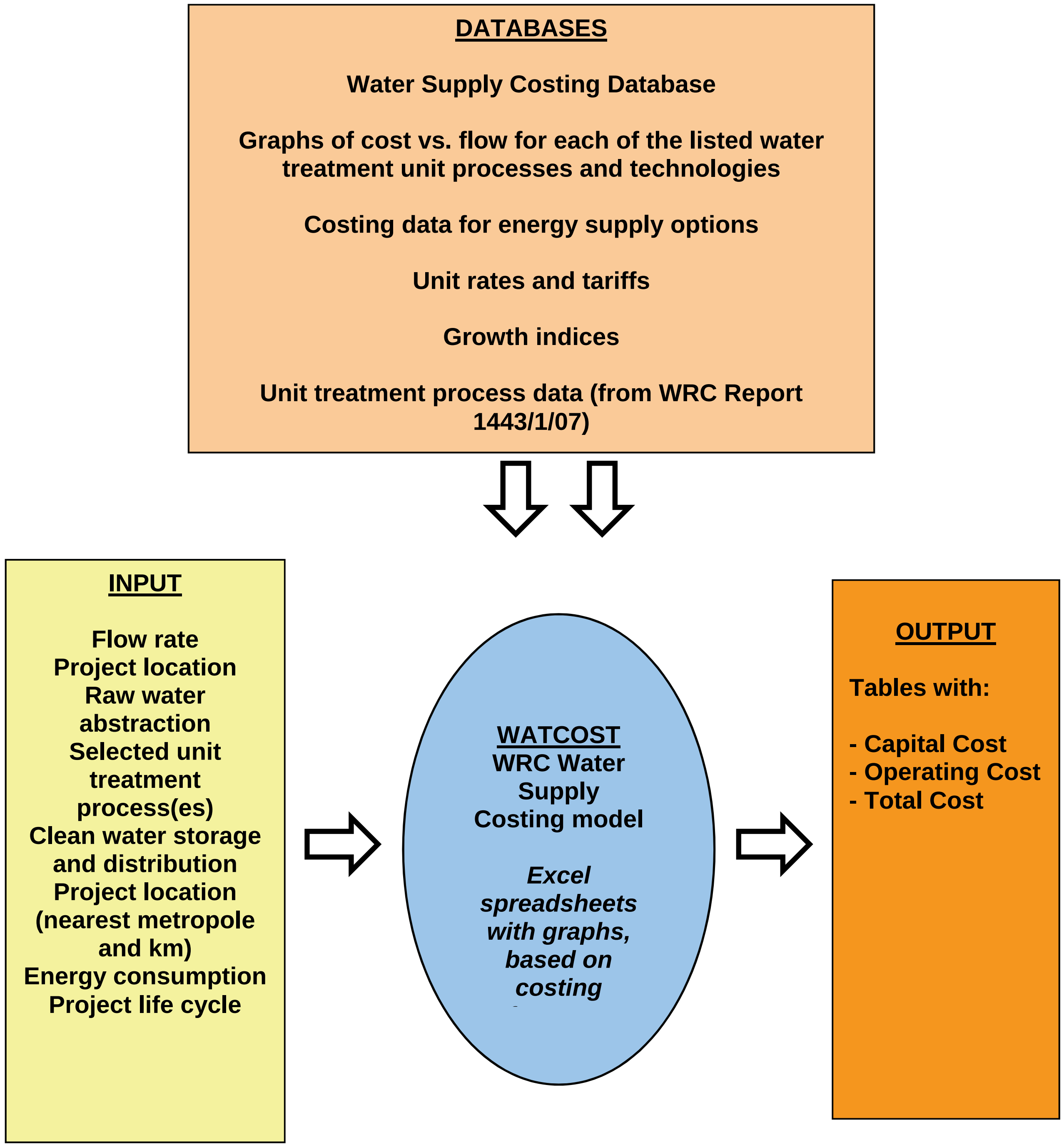
CHAPTER 4. STRUCTURE OF THE MODEL

In this chapter, an overview is provided of the structure of the WATCOST Costing Model. It shows the overall layout of the four main components of the model, namely: input, model, output, and databases. This is followed by a flow diagram indicating the potential uses of the model.

The spreadsheets that were developed for the input into the model and the output that is generated are then provided, which are explained by means of a description of the WATCOST Model operating procedure (how data are entered, which calculations are performed, and how the output is presented).

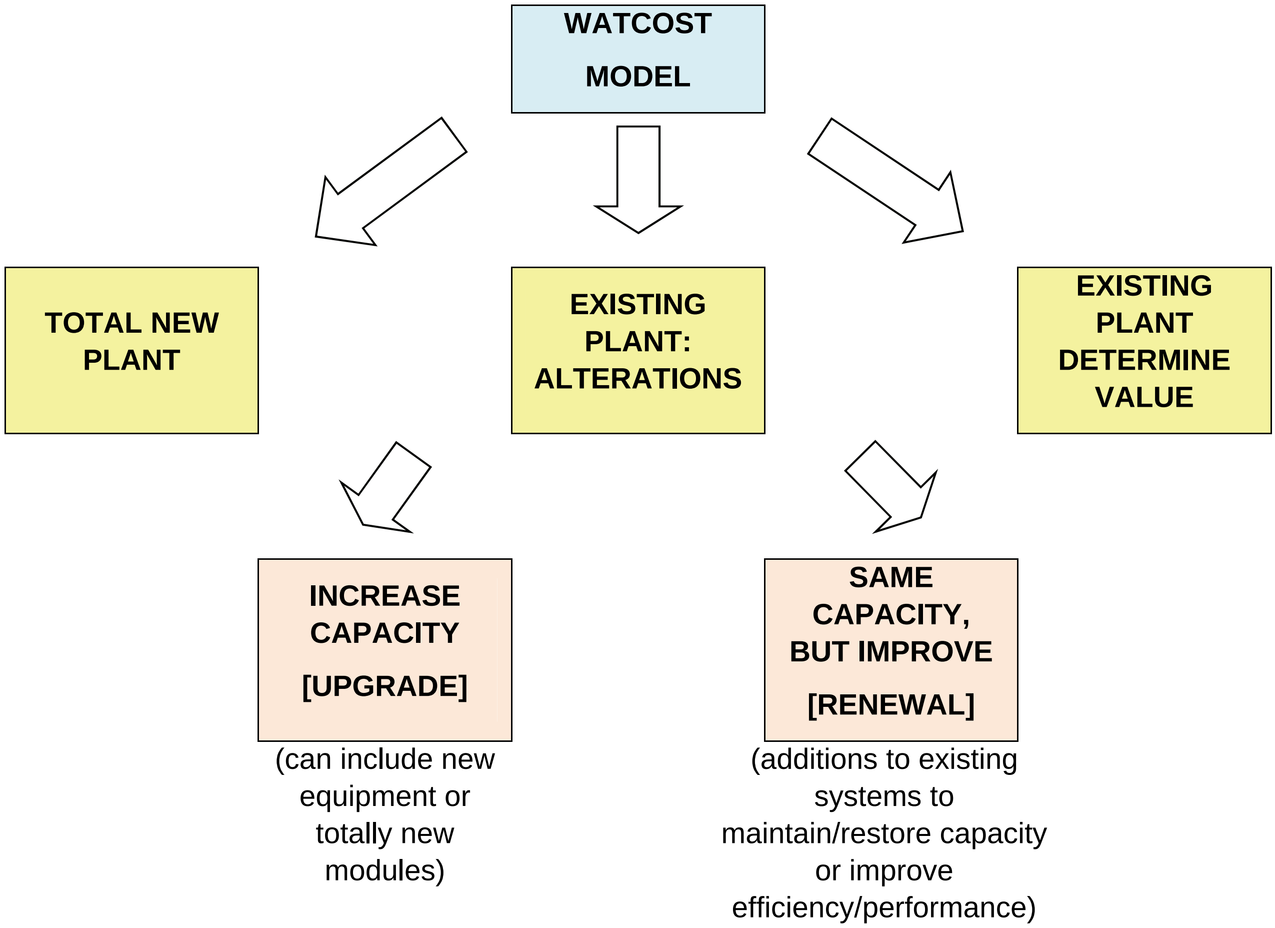
The structure of the databases and compilation thereof is also presented.

4.1. Layout of the WATCOST Costing Model



4.2. Application of WATCOST

The model can be applied for the following purposes:



WATCOST INPUT SPREADSHEET

1.	**Project Type**		
1.1	New treatment plant or water supply system?		☐
1.2	Existing treatment plant or water supply system?		☐
	1.2.1 Upgrade?		☐
	1.2.2 Refurbishment?		☐
2.	**Project Details**		
2.1	Flow rate (ML/d) [product water delivery capacity] [Estimated quantity of water to be produced at the end of the design period of the project or current phase of the project, in ML/d] (1)		
2.2	Project Location		
2.3	Nearest metropole	Drop-down list of South African metropoles	
2.4	Distance to nearest metropole (km)		
2.5	Electricity tariff at project location		
2.6	Estimated electricity use by the project (in kWh/d)		
2.7	Type of raw water abstraction	From drop-down menu: intake tower; raw water pumps; borehole pumps	
2.8	Supply of abstracted raw water to the treatment plant		
	2.8.1 Distance of raw water source from the treatment plant		☐
	2.8.2 Terrain (topography)	From drop-down menu: flat; mild slopes; steep slopes	
3.	**Treatment**		

Select one or more unit processes from the list below:

Pre-sedimentation	☐	Rapid sand filtration	☐
Aeration	☐	Pressure sand filtration	☐
Prechlorination	☐	Slow sand filtration	☐
Pre-ozonation	☐	Intermediate chlorination	☐
Pre-lime dosing	☐	Ultrafiltration/microfiltration	☐
Pre soda-ash dosing	☐	Reverse osmosis	☐
Horizontal flow sedimentation	☐	Post-chlorination	☐
Clariflocculator	☐	Ozonation	☐
Sludge blanket settling	☐	Chloramination	☐
Dissolved air flotation (DAF)	☐	Sludge treatment	☐
Post-lime dosing	☐	Additional dosing systems (M&E only)	☐
Post carbon dioxide dosing	☐	(e.g. $KMnO_4$, PAC, CO_2)	

(1) Redundancy is not provided for in the costing model, e.g. no additional filters are provided for redundancy purpose in the cost estimations

WATCOST INPUT SPREADSHEET

4.	**Clean Water Storage**	
4.1	Number of reservoirs	
4.2	Reservoir capacities:	
	4.2.1 Reservoir 1 capacity	
	4.2.2 Reservoir 2 capacity	
	4.2.3 Reservoir 3 capacity	
	4.2.4 Reservoir 4 capacity	
5.	**Distribution Networks**	
5.1	Estimated number of persons served in the community	
5.2	Service level:	Drop-down menu: house connections; yard connections; street taps
5.3	Excavation material (type):	Drop-down menu: soft soil; moderate soil hardness; hard soil
6.	**Project Life Cycle**	
Design period, in years		

Select:
Costing for one option?
Costing for different alternatives (up to 5 alternatives)?

WATCOST MODEL PROCEDURE

1. Process Configurations

The user of the model must decide on the process configuration to be used for the specific application, and then select the unit treatment processes that will best meet the requirements (taking into consideration the quality of the raw water source(s), availability of resources for operation and maintenance of the treatment system, ease of operation, robustness, and expected unit process performance).

(For consideration of criteria other than cost, the user will be referred to WRC Report 1443/1/07).

The selection of applicable process configuration options is based on the knowledge base of applicable treatment processes for given raw water qualities.

2. Cost calculations for unit treatment processes

The model then calculates costs for the required flow rate for each unit treatment process (and each technology option that it may comprise) based on the formulae and graphs derived from and contained in the costing data database of the model (see the **DATABASE** component below for more details on how the costing data is obtained and organized).

3. Cost calculations for raw water abstraction and pumping

The model calculates an estimated cost for raw water abstraction, based on the hourly flow rate in the input data, and the type of abstraction scheme selected in the drop-down menu. The user may also provide the size of the pumps should the raw water abstraction scheme already provide for later phases of the water supply project.

4. Cost calculations for raw water transport

Based on the hourly flow rate provided in the input component, or selected pipe size if the raw water conveyance pipe already provide for later phases of the project, the topography of the route and the distance in km of the abstraction point from the treatment plant, a cost is calculated for the raw water transport to the plant.

A link will be provided to van Vuuren and van Dijk (2007), WRC Report TT278/06 *Life Cycle Costing Analyses for Pipeline Design, with supporting software*.

5. Cost calculations for clean water storage

The required storage capacity for clean water and the daily flow as provided in the input component allows the calculation of reservoir size(s), based on standard free board and inlet/outlet arrangements.

6. Cost calculations for clean water distribution

Only a rough cost estimate is provided, and it requires a more detailed design by the user to do a more accurate cost calculation. The rough cost estimate will be based on the number of connection points and km of distribution network piping.

A link will be provided to van Vuuren and van Dijk (2007), WRC Report TT278/06 *Life Cycle Costing Analyses for Pipeline Design, with supporting software*.

7. Cost calculations for maintenance

Maintenance costs are calculated as a percentage of the total cost for the water supply system, and depend on the water supply system, i.e. different maintenance percentages for different water supply systems.

8. Cost calculations for planning, design and construction supervision

Based on the type of water supply system and the total cost for construction, equipment, infrastructure and maintenance, a cost is calculated for the planning, design and construction supervision of the project. This is based on proposed percentages by professional bodies such as the Engineering Council of South Africa (ECSA).

WATCOST MODEL PROCEDURE	
9.	**Cost calculations for operational management**
	Costs are calculated for all activities related to operational management of the water supply system, and the water treatment plant in particular, over the project life time (i.e. life cycle costs). This is based on the DWA classification of the treatment plant, which in turn is based on the capacity of the treatment plant (in ML/d) and the process configuration.
10.	**Cost calculations for other items**
	Any further cost items that become apparent during the development of the model are added to the total costs, and are based on either the total calculated cost or on some other item(s) related to the characteristics and capacity of the treatment plant.
11.	**Allowance for project location**
	Adjustments are made to certain cost items for water supply projects that are situated in remote locations and that will, for example, result in increased delivery costs, technical back-up and skills shortages.
12.	**Project life cycle** (normally design period, in years)
	The project design period or life cycle in years determines the amortisation costs, which are based on the current interest rate. Interest rates are one of the indices links in the model.

WATCOST OUTPUT SPREADSHEET 1

1. Table with Capital Cost

The table with Capital Cost contains the following elements:

Element	Applicable range [1]		Design quantity [2]	Design unit [3]	No. of items	Cost per item	Cost per element
	Min	Max					
RAW WATER							
Raw water intake tower	This is site-specific and should be costed accordingly						
Raw water pumps [4]							
Borehole systems [5]							
Raw water conveyance (piping cost) [4]							
TREATMENT							
Unit Process 1							
Unit Process 2							
Unit Process 3							
Unit Process 4							
Unit Process 5							
Unit Process 6							
Unit Process 7							
CLEAN WATER STORAGE							
Reservoir 1							
Reservoir 2							
DISTRIBUTION							
Distribution network (total amount)							
Sub Total Capital Cost							
Total correction amount for raw water (includes Project size, Location, Topography, etc.) [6]							
Total correction amount for treatment (includes Project size, Location, Topography, etc.) [6]							
Total correction amount for clean water storage (includes Project size, Location, Topography, etc.) [6]							
Total correction amount for distribution (includes Project size, Location, Topography, etc.) [6]							
TOTAL CONSTRUCTION COST							
Add P&Gs (include local labour, SMMEs, Health and Safety, etc.) (5-10% of Total Construction Cost) [7]							
Add Professional Fees (Planning, Design, Engineering, Legislative (includes Environmental aspects)							
TOTAL CAPITAL COST							

(1) The applicable range indicates the minimum and maximum flow rates for which costing data were available during the development of the current version of the model.
(2) Design unit flow rate or dosage rate according the internationally accepted norms
(3) Metric units (SI)
(4) Calculated in model of Van Vuuren and Van Dijk (2006)
(5) From cost tables in DWA Costing Benchmark (2009)
(6) Correction amount = correction factor <u>from tables below</u> × Sub Total Capital Cost
(7) Also include 1% for training

CORRECTION FACTORS FOR CONSTRUCTION COST

(from DWA Costing Benchmark, 2009)

Table 4.1: Project water distribution costs based on the number of people served

Community size description	Number of persons	Hard soil excavation	Moderate soil hardness	Soft soil excavation
Very small	1000	1549842	1259247	968652
Small	5000	7749212	6296235	4843258
Medium	20000	30996849	25184940	19373031
Large	50000	77492123	62962350	48432577

Table 4.2: Project size correction factors

Size description	Size values	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Small	< 1500 people	20%			5%
Medium	1500-5000 people	0%			0%
Large	> 5000 people	-10%			-3%

Table 4.3: Project location correction factors

Distance from metros	Distances	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Near	< 50 km	-2%	0%	0%	0%
Medium	50-100 km	0%	5%	3%	10%
Far	100-200 km	1%			
Very far	> 200 km		10%	8%	15%

Table 4.4: Topography correction factors

Topography description	Slope	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Flat	< 1% slope		0%	0%	2%
Sloped	1-5% slope		2%	2%	0%
Steep	> 5% slope		5%	5%	5%

Table 4.5: Site access correction factors

Access description	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
None existing	5%	5%	5%	
Track existing	12%	2%	2%	
Gravel Road existing	0%	0%	0%	
Paved road existing	0%	0%	0%	

Table 4.6: Clearing correction factors

Vegetation description	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Savannah	0%			
Bush	1%			
Trees	2%			

Table 4.7: Availability of contractor correction factors

Availability	Description	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
High	Under quoting	-2%	-2%	-10%	-5%
Medium	Competitive	0%	0%	0%	0%
Low	Low availability	5%	5%	15%	10%

Table 4.8: Security correction factors

Size description	Size values	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Rudimentary	Little vandalism	0%	0%	0%	
Standard	Some vandalism	0%	3%	1%	
Sophisticated	High vandalism	1%	5%	3%	

Table 4.9: Geology correction factors

Size description	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Soft				0%
Intermediate				30%
Hard rock				60%

Table 4.10: Land acquisition and servitudes correction factors

Land description	RAW WATER	TREATMENT	CLEAN WATER STORAGE	DISTRIBUTION
Public area		0%		0%
Agricultural land		1%		1%
Built-up area		3%		2%

WATCOST OUTPUT SPREADSHEET 2

2. Table with Operating and Maintenance Cost

The table with Operating Cost contains the following elements:

Element	Unit	Unit cost	No. of units per day	Cost per day	Cost per year	Cost per kilolitre	Unit
RAW WATER							
Operation – labour costs							
Pumping costs – energy							
Total operating costs for raw water							
Maintenance cost for raw water (* %)							
TREATMENT							
Operation costs –labour							
Energy costs – electricity or alternative							
Chemicals							
Monitoring and quality control							
Other treatment plant operating costs							
Total operating costs for treatment							
Maintenance costs for treatment (* %)							
CLEAN WATER STORAGE							
Operation costs –labour							
Energy costs – electricity or alternative							
Total operating costs for clean water storage							
Maintenance costs for clean water storage (* %)							
DISTRIBUTION							
Operation costs – labour							
Total operating costs for distribution							
Maintenance costs for network (* %)							
Sub Total Project Operating and Maintenance Cost							
Additional overhead items (as may be added during development of the model)							
TOTAL OPERATING AND MAINTENANCE COST							

WATCOST OUTPUT SPREADSHEET 3

3. Table with Total Cost

The table with Total Cost contains the following elements:

CAPITAL COSTS	
Capital cost element (from WATCOST Output Spreadsheet 1)	**Total cost**
Sub Total Capital Cost	
Total correction amount for raw water (includes Project size, Location, Topography, etc.)	
Total correction amount for treatment (includes Project size, Location, Topography, etc.)	
Total correction amount for clean water storage (includes Project size, Location, Topography, etc.)	
Total correction amount for distribution (includes Project size, Location, Topography, etc.)	
TOTAL CONSTRUCTION COST	
Add P&Gs (include local labour, SMMEs, Health and Safety, etc.) (5-10% of Total Construction Cost)	
Add Professional Fees (Planning, Design, Engineering, Legislative (includes Environmental aspects))	
TOTAL CAPITAL COST	
Total capital cost amortized over x years at y percent interest	

OPERATING AND MAINTENANCE COSTS (from WATCOST Output Spreadsheet 2)						
Element	**Unit**	**Unit cost**	**No of units per day**	**Cost per month**	**Cost per year**	**Cost per kilolitre**
O&M for raw water abstraction and pumping						
O&M for treatment plant						
O&M for clean water storage and pumping						
O&M for distribution network						
O&M overhead costs						
Total operating and maintenance costs						

TOTAL PROJECT COSTS			
Total capital, operating and maintenance costs			
Other items (that may become apparent during development of the model)			
TOTAL PROJECT COST			

DATABASES / INFORMATION SOURCES

1. Costing Data

Costing data are obtained for current water supply projects or projects that were completed in the past ten years. The costs are broken down as far as is possible to produce costs per unit treatment process for a wide range of treatment capacities, from small-scale treatment plants (community scale – for a number of households) to large water treatment plants (for the large cities or water boards).

The costs are plotted for treatment cost versus unit treatment process capacity. Lines are fitted and formulae established (for acceptable line fits), which are then used in calculating costs in the model for the flow rate that was entered in the input by the user.

Attempts were made that graphs should have as many data points as possible (depending on availability of data), but at least five; however, this was not possible in all cases. Correlation (R^2) values are indicated clearly on the graphs to give an indication on the accuracy of local cost estimation of that particular unit treatment process. Data covers a wide range of treatment plant sizes (capacities) as far as possible, and data-points are not being centred around one size (capacity).

2. Unit Costs and Rates, Tariffs and Indices

A range of unit costs, tariffs and indices are entered into the information bases database, and are hyperlinked to the real-time original indices. Examples are current electricity tariffs, remuneration packages for treatment plant personnel and maintenance personnel, and kilometre tariffs.

CHAPTER 5. METHODOLOGY FOR DEVELOPING THE MODEL AND OBTAINING COSTING DATA

5.1. Approach

The WATCOST Model has been aligned with the DWA Costing Model, so that the two could be integrated. More recently, an additional document was also drawn up for unit costs of municipal services (CoGTA (2010) “An Industry Guide to Infrastructure Service Delivery Levels and Unit Costs”). Costing data for water services in the Industry Guide are an extension of the costing data contained in the DWA Benchmark Document, 2009, which is the document describing the unit costs derived from the DWA Costing Model.

According to the Industry Guide (CoGTA, 2010) cost benchmarks are often required for different purposes and at different levels of detail. They serve primarily as a reference or check for evaluation of conceptual project plans and project proposals. They can also be useful references for regional and national budgeting and strategic planning. However, **such figures should not be used for detailed cost calculations in feasibility studies or business plans, and definitely not for tendering purposes. For such purposes, site specific design information and material costs should be gathered and prepared**.

There is a clear distinction between supply cost (i.e. the cost of obtaining materials from supplier) and service installed cost. A construction margin (previously termed “profit” in the Industry Guide 2007 document), which accounts for contractor overheads, material wastage, cost of moving materials around on site and contractor profit is therefore added to the supplier cost to provide the service installed unit cost.

The construction margin is a function of various factors, including amongst others:

- The nature and complexity of the project;
- The project location and proximity to services;
- Number of contractors bidding for work; and
- The prevailing economic climate (i.e. in recessionary economic conditions, competition for available work is high, which forces margins lower).

A number of factors influence the actual capital costs of municipal infrastructure projects. For water treatment works, some of the cost influencing factors is:

- *Project size*: A reduction in the cost is anticipated for larger projects in view of the economy of scale.
- *Location*: Extensive distances from economic centres and expertise can have a significant cost implication, especially if operation and maintenance of advanced treatment processes are involved.
- *Topography*: This mainly influences the cost of access roads, but may in particular affect the cost of delivering package treatment plants
- *Specialist contractors*: As treatment works require specialized expertise, the availability of such contractors is critical.

5.2. Costing categories and sources of water supply costing data used in the WATCOST Model

The costing categories and main features of each are described below.

5.2.1. Capital Costs

Drinking water supply components:

- **Raw water abstraction and transport**
- **Water treatment works**

The following ratios are generally used for the civil works and M&E of a water treatment works:

Civil	Electrical	Mechanical
Civil **60%**	**Electrical** **12-15%** consisting of **Electric Electronic** **80% 20%**	**Mechanical** **25-28%**
Also include a factor of +25% for Waterworks		

- **Reservoirs**

The following is an excerpt from the Industry Guide (2010) on the costing factors associated with storage reservoirs:

> "Reservoirs are used to store treated bulk water from purification/treatment plants (bulk storage) or as distribution reservoirs to gravity feed water reticulation pipe networks in communities (e.g. reticulation reservoirs). In some instances, reservoirs may be used for hydraulic purposes to reduce pipeline costs or pipe pressure (pipe class). They can also be used to optimize level of supply, pipe sizes and pump station operating rules (schedules).
>
> "Reticulation reservoirs are normally placed on the highest available / accessible sites to allow effective gravity feed and adequate line pressure in the water reticulation. The exact location of the reservoirs will depend on the hydraulic pressures required. Construction can be at, above or below ground level. Various materials including polyethylene, bricks, steel, concrete and reinforcing mesh with supporting (tarpaulin) can be used in construction.
>
> "Depending on the population size and water requirements, reservoir sizes may vary from small (10 kL) to large (>10 000 kL). Reservoirs will be designed based on the accepted design criteria of the industry, the scheme requirements and of those specifications as determined by the individual municipality."

The expected lifespan and the availability of funds may play a role in selection of affordable construction materials. For instance, concrete structures are very costly to construct but last longer (have a longer life expectancy). Polyethylene and steel structures may on the other hand be preferred due to ease of construction, practicality and project economy. Various materials are used in construction, as shown in Table 5.1.

Table 5.1: Expected life-span of various reservoir construction materials

Material	Cost effective usage based on capacity of reservoirs
Polyethylene reservoirs	• Sizes less than 50 kL • Lifespan 10-15 years
Steel reservoirs	• Sizes between 50 to 500 kL • Lifespan 20-25 years
Brick reservoirs	• Sizes between 50 to 500 kL • Lifespan 20-30 years
Concrete reservoirs	• Sizes exceeding 500 kL • Lifespan exceeding 50 years

(DWA Cost Benchmark, 2009)

The WATCOST costing data were obtained from tender prices from new treatment plants or plant extensions over the past 15 years, and comprise the capital cost components above. The sections below indicate how these cost indices escalate with time.

5.2.2. Labour Rates

Labour rates are determined per region/province (Figure 5.1). The rate of increase in labour cost between August 2007 and July 2008 is significant (approximately 12.75% year on year). This rate of increase slowed in the latter half of 2008 and in 2009.

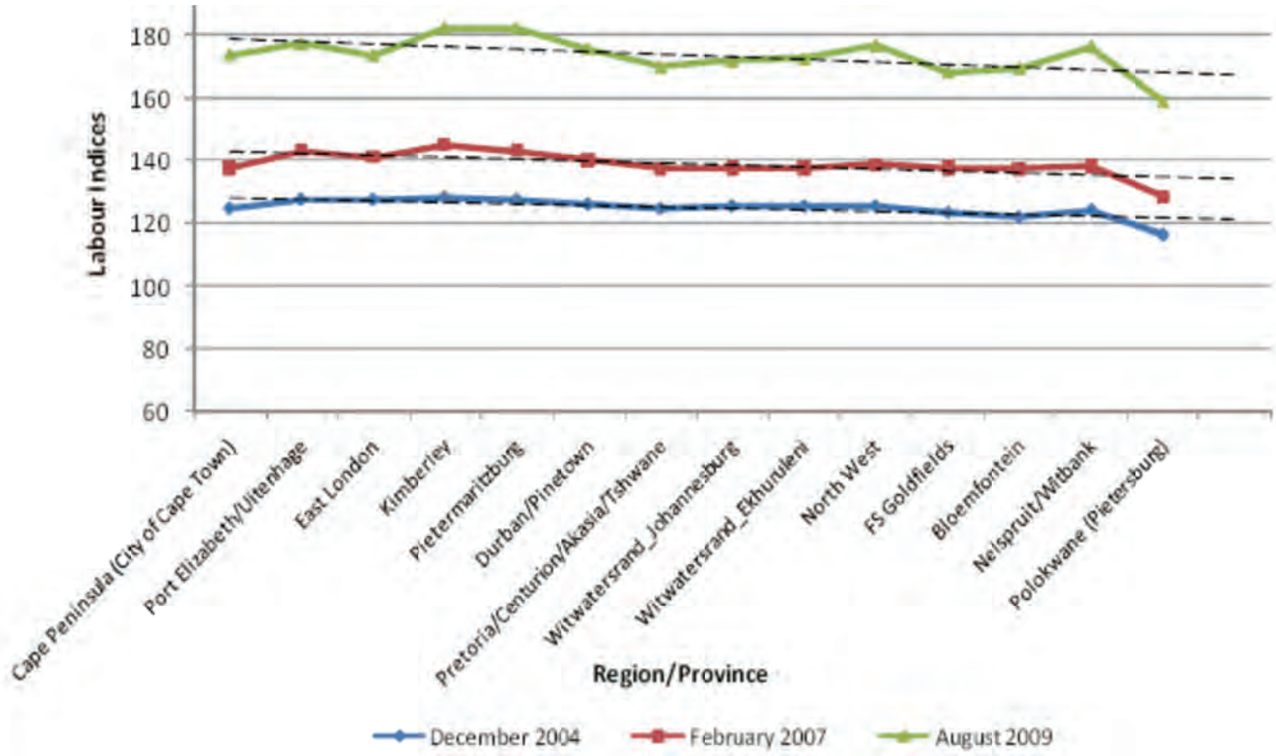


Figure 5.1: New labour cost indices per region / province. **Data obtained from SAFCEC (www.safcec.org.za; September 2009)**

Compared to the weighted average labour index (174.11) in August 2009, cost of labour in Limpopo is significantly less than the average (159.1). On the opposite end of the spectrum, labour is more costly in Pietermaritzburg (182.4) and Kimberley (182.5). Labour costs impacts significantly on unit costs 2007/08 when compared to 2005.

5.2.3. Plant and Material Rates

The general approach and guideline design followed was:

- Gauteng is used as base province and factors incorporated to reflect regional costs based on Gauteng value of 1.0.
- All rates and prices exclude VAT at 14% and professional fees at ESCA rates.
- All rates and prices obtained from suppliers are 'bin' rates and transport costs were calculated and incorporated as regional averages.
- Most rates and prices were obtained for one major centre in each province only.
- From the averages calculated, it is noted that there is a prominent trend and need for provincial adjustment and premiums.
- The rate of increase of materials and plant increased between 2007 and 2009.
- However due to the strengthening of the rand, the rate of increase of the fuel price increase has been fairly steady between 2004 and 2009 – refer to Figure 5.2.
- A more detailed breakdown of the escalation factors and indices is provided in Appendix A.

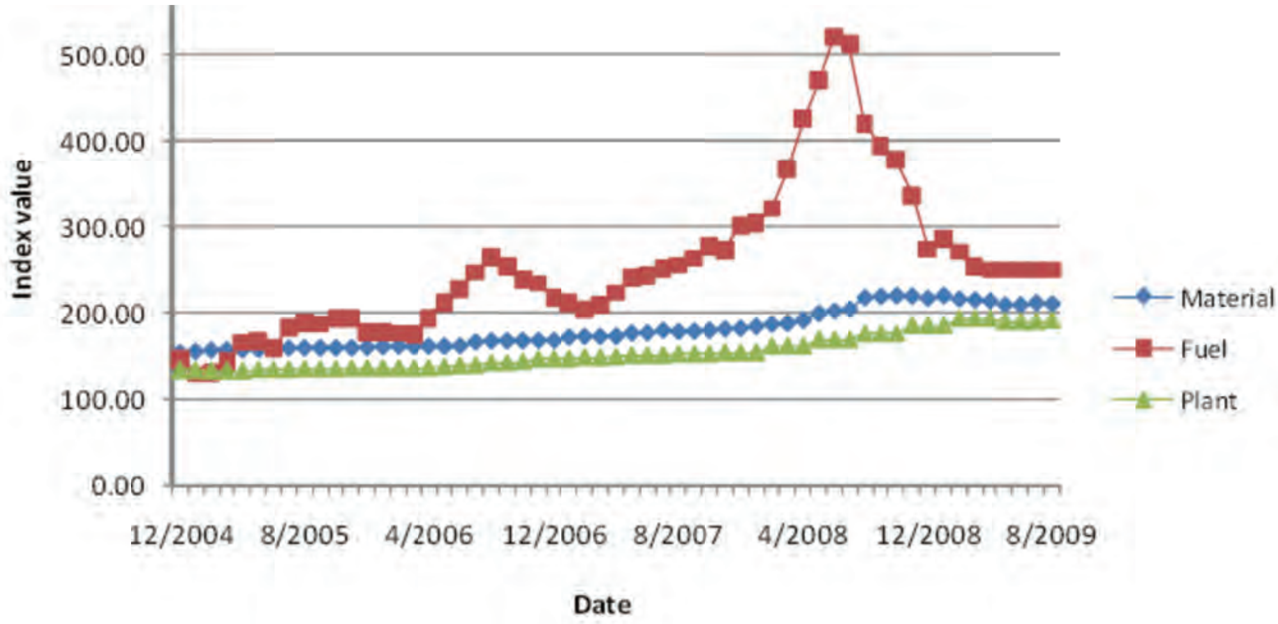


Figure 5.2: New materials, fuel and plant indices per region / province. **Data obtained from SAFCEC (www.safcec.org.za; September 2009)**

5.2.4. Management Cost Factors

Often the estimated capital costs of the works reflect the costs of the materials and the costs of constructing the various components of the particular infrastructure scheme. This would imply that various cost escalating factors such as topography, soil conditions, remoteness, availability of contractors and security have been accounted for.

However, the actual final cost of a project, (e.g. water supply scheme) may be almost double the estimated capital cost in view of additional expenses incurred in terms of:

- Institutional and social development;
- Professional fees in terms of feasibility studies (example: ground water studies, environmental impact assessments), design and construction supervision;
- Contingencies for unforeseen expenses; and
- VAT at 14%

5.2.5. Cost Influencing Factors

The factors affecting the costs of water supply projects, and which should be allowed for when estimating capital costs of systems, are shown in Table 5.2.

How to use the Cost Influencing Factors

- The Cost Influencing Factors can be used to refine costs to specified site conditions.
- The Factors Affecting Costs are the main cost influencing factors.
- They may not be applicable to every infrastructure type, and therefore are only listed where applicable.
- The escalation (percentages) must be added to 1 (100%) before multiplying it with the published unit cost.

If more than one factor is chosen for a specific infrastructure component, the calculation is made as follows:

Adjusted Unit Cost = Unit Cost x (1 + [factor1+factor2+factor3+factor4]) [5.1]

The figures listed are generic escalations for key of the aspects influencing the costs of the respective infrastructure component. Note that the figures give a lower limit, average (mostly=0; no escalation) and a higher limit. Subject to the extent of the specific factor, it may be better to use a figure in-between these limit values.

Table 5.2: Cost influencing factors of water supply projects (from DWA Cost Benchmark, 2009)

Factors affecting costs		Surface water	Groundwater	Pump stations		Water treatment	Bulk pipeline	Reservoir	Reticulation
				Surface	Borehole				
Project size definitions	Small	< 10 mil m^3	1-3 boreholes	< 50 kW	1-3 boreholes		contract		<1500 pp
	Medium	10-40 mil m^3	3-10 boreholes	50-150 kW	3-10 boreholes		contract		1500-5000 pp
	Large	> 40 mil m^3	> 10 boreholes	> 50kW	> 10 boreholes		contract		>5000 pp
Project size	Small	+10%	+30%	+5%	0		+5%		+5%
	Medium	0	0	0	-5%		0		0
	Large	-10%	-15%	+3%	-8%		-3%		-3%
Remoteness Location Distance from economic centre	Near (<50 km)	-2%	0	0	0	0	0	0	0
	Distant (50-100 km)	0	+8%	+5%	+5%	+5%	+10%	+3%	+10%
	Remote (>100 km)	+1%							
	Remote (>200 km)		+12%	+10%	+10%	+10%	+15%	+8%	+15%
Topography	Flat (<1% slope)			0	0	0	0	0	+2%
	Sloped (1-5% slope)			+2%	+2%	+2%	0	+2%	0
	Steep (>5% slope)			+5%	+5%	+5%	+5%	+5%	+5%
Access	Non-existing	+5%	+50%	+5%	+10%	+5%		+5%	
	Track existing	+12%	0	+2%	0	+2%		+2%	
	Gravel road existing	0	0	0	0	0		0	
	Paved road existing	0	0	0	0	0		0	
Clearing	Savannah	0					0		
	Bush	+1%					+2%		
	Trees	+2%					+5%		

Table 5.2: Cost influencing factors of water supply projects (from DWA Cost Benchmark, 2009) ***(Continued)***

Factors affecting costs		Surface water	Groundwater	Pump stations		Water treatment	Bulk pipeline	Reservoir	Reticulation
				Surface	Borehole				
Project size definitions	Small	< 10 mil m^3	1-3 boreholes	< 50 kW	1-3 boreholes		contract		<1500 pp
	Medium	10-40 mil m^3	3-10 boreholes	50-150 kW	3-10 boreholes		contract		1500-5000 pp
	Large	> 40 mil m^3	> 10 boreholes	> 50kW	> 10 boreholes		contract		>5000 pp
Availability of contractor	High (under-quoting)	-2%	-10%	-5%	-5%	-2%	-10%	-10%	-5%
	Medium (competitive)	0	0	0	0	0	0	0	0
	Low (low availability)	+5%	+10%	+15%	+10%	+5%	+15%	+15%	+10%
Security	Rudimentary (little vandalism)	0		0	0	0		0	
	Standard (some vandalism)	0		+3%	0	+3%		+1%	
	Sophisticated (high vandalism)	+1%		+10%	+15%	+5%		+3%	
Geology	Soft						0		0
	Intermediate						+30%		+30%
	Hard rock						+60%		+60%
Land acquisition and servitudes	Public area			0		0	0	0	
	Agricultural land			+1%		+1%	+1%	+1%	
	Built-up area			+2%		+3%	+4%	+2%	

5.2.6. Preliminary and General items (P&Gs) for Contractors Establishment

Preliminary and General (P&G) cost items are based on a percentage of the total capital cost of the project excluding VAT, contingencies, disbursements, professional fees, relocations and land acquisition.

The purpose of preliminaries is to describe the works as a whole, and to specify general conditions and requirements for their execution, including such things as sub-contracting, approvals, testing and completion. Preliminaries relate to the cost-significant items required by the method and particular circumstances under which the work is to be carried out, and those costs concerned with the whole of the works rather than just Work Sections. These costs may either be once-off, fixed costs, such as the cost of bringing to site and erecting site accommodation (and subsequent removal) or time-related, such as the heating, lighting and maintenance cost for that accommodation.

Experience has shown that, in general, higher P&Gs are expected in rural areas than in urban or home-based contracts. Contractors who are home-based, or are already established (project phase 2 or 3) or projects expanded also have the benefit of offering low P&Gs as a distinct advantage over contractors who need to establish site from zero or from another area/region.

Table 5.3 is an indication of the typical P&Gs as related to various infrastructure schemes and project value. Typical P&Gs are shown in Table 5.4.

Table 5.3: Typical P&G changes per infrastructure type (from Industry Guide 2007)

COMPONENT	P&G (%) FOR PROJECT SIZE RANGE				
	CAPITAL COST RANGE (IN R x 1000)				
	0-200	200-600	600-1 500	1 500-5 000	>5000
Reticulation	30	25	22	20	18
Reservoirs	30	25	22	20	18
Bulk pipelines	25	22	20	18	15
Pump stations	25	22	20	20	18
Treatment works	30	25	22	20	18
Dams and weirs	30	25	22	20	18
Boreholes	10	5	3	2	2
Power supply	25	18	15	10	5

Table 5.4: Typical P&Gs (from Industry Guide 2007)

CAPITAL COST	<R600 000	R600 000 to R2 million	R2 million to R10 million	R10 million to R500 million
PRELIMINARY AND GENERAL				
Dam	30%	→		14%
GW development	18%	→		5%
Pump station	20%	→		12%
Treatment works	25%	→		15%
Bulk pipeline plus reticulation	15%	→		5%
Power supply	25%	→		15%

5.2.7. Professional Fees

5.2.7.1 Engineering

The focus of this section is mainly in terms of Professional Fees as these relate to feasibility studies, design, tender preparation, construction supervision and project management. The Engineering Council of South Africa (ECSA) issued a guideline in Board Notice 2 of 2009: "Guideline Scope of Services and Tariff of Fees for Persons Registered in terms of the Engineering Profession Act, 2000, (Act No.46 of 2000)". The commencement date of these Rules was 1 January 2009 and any amount mentioned in or fee calculated in terms of this Schedule is exclusive of VAT.

Table 5.5 shows primary and secondary fees for professional services.

Table 5.5: Primary and secondary fees for professional engineering services

Cost of the Works		Basis of Fee Calculation	
For projects up to R 440 00 where the cost of the works:		A Lump Sum or on Time Basis	
Exceeds	**But does not exceed**	**Primary Fee**	**Secondary Fee**
R440 000	R1 110 000	R55 000	12.5% on the balance over R440 000
R1 110 000	R5 500 000	R137 500	10.0% on the balance over R1 110 000
R5 500 000	R11 000 000	R577 500	9.0% on the balance over R5 500 000
R11 000 000	R27 500 000	R1 072 500	8.0% on the balance over R11 000 000
R27 500 000	R55 000 000	R2 392 500	6.0% on the balance over R27 500 000
R55 000 000	R330 000 000	R4 042 500	5.5% on the balance over R55 000 000
R330 000 000		R19 167 000	5.0% on the balance over R330 000 000

The following insight is provided as to the determining of professional fees:

5.2.7.2 Fees for normal services: civil and structural engineering services pertaining to engineering projects.

i. The basic fee for *normal services* in the disciplines of civil and structural engineering, pertaining to Engineering Projects, is determined from the table below. The fee is the sum of the primary fee and the secondary fee applicable to the specific *cost of the works* in respect of which the *services* were rendered on the project excluding the report stage which shall be reimbursed on a time basis.

ii. The following *additional fee* shall be applicable to the value of the reinforced concrete and structural steel portions of the works, inclusive of the costs of concrete, reinforcing, formwork, structural steel work and any pro-rata preliminary and general amount: where structures of identical design are repeated on the same project, the combined costs shall be cumulated for the determination of the cost of the reinforced concrete and structural steel works. In cases where structures require individual design, a separate additional fee shall be calculated for each structure based on the cost of the reinforced concrete and/or structural steel work for that particular structure. The additional fee is the sum of the primary fee and the secondary fee applicable to the specific cost of the works in respect of which the services were rendered on the project.

iii. To calculate the fee for railway track work in terms of this item, 50% of the cost of the permanent way materials is excluded from the cost of the works, but the full cost of ballast and equipment specially designed by the consultant is included in the cost of the works.

Typical professional fees can be found in Table 5.6.

Table 5.6: Typical professional fees

CAPITAL COST	<R600 000	R600 000 to R2 million	R2 million to R10 million	R10 million to R500 million
Planning Fees	13%	11%	7%	5%
Design Fees	12.5%	10%	7.5%	7.5%
Contract Management	4%	3%	2%	2%
Construction Supervision	10%	9%	7%	4%
Training and Capacity Building Fees	10%	7%	4%	2%

5.2.7.3 Other professional service fees

A holistic approach to project funding must take into account other required professional technical services such as geotechnical experts, land surveyors, and/or environmental specialists, amongst others. The scale of fees for each professional is governed by the respective statutory body:

- The South African Council for the Quantity Surveying Profession;
- The South African Council for the Architectural Profession;
- South African Council for Professional and Technical Surveyors; and
- Engineering Council of South Africa.

Although the composition of the professional team of service providers is project specific, a guide to this cost is based on project experience. This is summarised in Table 5.7.

Table 5.7: Allowable professional service fees of the professional team (from "Guideline for costing basic household sanitation", April 2007)

Infrastructure project type	Allowable professional service fee (as % of total project construction value)					Groundwater Protocol *
	Geotechnical Engineer	Quantity Surveyor	Land Surveyor	Architect	Environ-mentalist	
Water						
	1%				0.5%	
	1%	0.5%	0.5%		1%	
Sanitation						
	1%				0.5%	
	1%	0.5%	0.5%		1%	
Roads	0.5%		1%		0.5%	
Stormwater					0.5%	
Building projects (multi-purpose halls/ sports facilities)	0.5%	1%		2%	0.5%	R40 000 (*)
Expert Inputs						

* It is assumed that a Groundwater Protocol study is undertaken for a group of communities within a ward as part of one study, with costs shared between projects

5.2.8. Operating costs

Operating costs include the following:

- Human Resources
- Chemicals
- Energy
- Safety
- Raw Water Cost
- Waste Disposal
- Monitoring (including Blue Drop costs) and Training Costs

5.2.8.1 Water quality monitoring costs

The DWA (2006) provides a simple spreadsheet model to assist Water Services Authorities to cost out and budget for the minimum requirements necessary for effective Drinking Water Quality Management. At that stage of development (2006), the model included the costing of:

- Staff training
- Preparation of an operator's manual
- Operational monitoring, including sampling equipment
- Compliance monitoring

There are two modes of using this spreadsheet: basic and advanced.

BASIC: This is the default mode and requires the user to simply complete the red cells in the *Classification of water works* sheet and the *Summary of costs* sheet, by either clicking on the drop down menus to select an option, or by completing a cell.

ADVANCED: This mode allows the user to customise the support spreadsheets to the Summary of costs sheet. For example, the user can adjust the labour rates per hour and change the frequency of the compliance monitoring per determinand.

Before a user can use the ADVANCED mode, the user must unhide and unprotect the following worksheets:

- Staff Training Costs
- Operator's manual costs
- Operational monitoring costs
- Compliance monitoring costs

The *Staff training costs* spreadsheet is based on the class of the water works and the class of the Operator and Supervisor required to be trained. The user can adjust the costs of the training courses for both the Operator and the Supervisor. Annual refresher training is based on 50% of the cost of the initial training.

The *Operator's manual costs* spreadsheet is based on the class of the water works and the number of hours taken to prepare the Operator's manual as well as review the manual annually. The user can adjust the number of hours taken as well as the labour rate per hour.

The *Operational monitoring costs* spreadsheet is based on the cost of the once-off sampling equipment required for operational monitoring, the consumables required, and the labour and transport required for sampling. The user can adjust the cost of the sampling equipment and consumables.

The *Compliance monitoring costs* spreadsheet is based on the population served, the analytical costs per determinand, the sampling frequency per determinand, the labour required for sampling analyses as well as transport. The user can adjust the population served, analytical cost and frequency per determinand, and the labour and transport rate.

The first version of the operational costing database spreadsheet is shown in Table 5.8.

The operational costing data were processed by performing correlations and fitting curves to the data. The graphs that were thus drawn up are presented below, under the following headings:

- Human resources
- Chemicals
- Energy
- Safety
- Raw water cost
- Waste disposal
- Refurbishment costs

Table 5.8: Spreadsheet for costing of water quality monitoring at water treatment plants (from Manus and Hodgson, 2006)

GUIDE TO COSTING OF MINIMUM REQUIREMENTS FOR DRINKING WATER QUALITY MANAGEMENT			
(Please complete ALL cells shaded in red)			
1. STAFF TRAINING ON DRINKING WATER QUALITY MANAGEMENT			
Based on staff requirements according to the regulations for the Registration of Waterworks and Process Controllers			
Number of Operators	**3**	**Class of Works**	D
Cost of training	**Initial training**	**Refresher training**	
	R 34 500.00	R 17 250.00	
2. OPERATORS' MANUAL			
Based on number of hours to prepare an Operators' Manual			
	Class of Works		
	D		
Cost of preparation	**Initial preparation**	**Annual review**	
3. OPERATIONAL WATER QUALITY MONITORING			
Based on sampling equipment, consumables, labour and transport			
			Costs
Once-off; sample taps	No of sample sites/taps required	**5**	R 5 000.00
Once-off: sampling equipment	Other sampling and onsite measuring equipment		R 36 540.00
Annual: sampling consumables	Sampling consumables per year		R 5 059.90
Annual: Labour	Estimated number of hours for operational monitoring per month	**20**	R 18 000.00
Annual: Transport	Estimated distance travelled per month	**250**	R 9 000.00
4. COMPLIANCE MONITORING			
Based on analysis in an accredited laboratory, labour for sampling, transport and sample courier			
			Costs
	Population served	**52 00**	
Annual: Analytical costs	Number of reticulation sample points	**3**	R 32 204.00
Annual: Labour	Estimated number of hours for compliance sampling per month	**16**	R 38 400.00
Annual: Transport	Estimated distance travelled per month	**180**	R 6 480.00
Annual: Sample Courier	Estimated costs for courier of samples per month	**R 500.00**	R 6 000.00
5. COSTS			
		Initial Costs (first year)	**Annual Costs**
	Staff training	R 34 500.00	R 17 250.00
	Operators' Manual	R 24 000.00	R 4 800.00
	Operational monitoring	R 103 599.90	R 62 059.90
	Compliance monitoring	R 83 084.00	R 83 084.00
	TOTAL	**R 245 183.90**	**R 167 193.90**
	14% VAT	**R 34 325. 77**	**R 23 407.14**
	GRAND TOTAL	**R 279 509.67**	**R 190 601.04**
	Costs per person per year	**R 4.78**	**R 3.26**
	Costs per person per month	**R 0.40**	**R 0.27**

5.2.9. Maintenance Costs

Typical maintenance costs for water supply projects appear in Table 5.9.

Table 5.9: Typical maintenance costs for water supply projects (from DWA Cost Benchmark, 2009)

COMPONENT	Annual maintenance cost as % of Replacement Value		
	low	high	recommended
Boreholes	7.00%	10.00%	7.00%
Diesel	8.00%	10.00%	8.00%
Electric	4.00%	6.00%	4.00%
Solar	4.00%	6.00%	4.00%
Wind	6.00%	8.00%	6.00%
Hand	8.00%	15.00%	8.00%
Dams	0.10%	0.25%	0.25%
Building	0.25%	0.50%	0.50%
Roads and bridges	0.50%	0.75%	0.75%
Line reservoirs	0.25%	2.00%	1.00%
Service reservoirs	0.25%	2.00%	1.00%
WTW – civil	0.25%	1.00%	0.50%
WTW – mechanical and electrical	4.00%	7.00%	4.00%
Pump station – civil	0.25%	1.00%	0.50%
Pump station – mechanical and electrical	1.50%	4.00%	4.00%
Bulk pipelines	0.10%	0.50%	0.50%
Reticulation	1.00%	3.00%	2.00%

5.2.10. Refurbishment Costs

Refurbishment costs include all expenditure required to renew infrastructure, processes, or equipment, with the aim of restoring plant capacity, improving performance, or allowing for changes in raw water quality. It excludes any new treatment processes or equipment.

Refurbishment costs are incurred to renew civil structures or improve the structural integrity, repair of mechanical and electrical equipment or general modifications to existing systems that will have the effect of prolonging the life of the assets and/or improving the performance of the treatment plant or water supply system component.

It is not possible to provide actual costing data for refurbishment activities for the user of the WATCOST model, as the scope and extent of the work vary extensively. Examples of refurbishment costs can be found in the COGTA Industry Guide. These costs will be improved and adjusted on a continuous basis.

5.2.11. Financing and Insurance Costs (not addressed in this project).

The costs for financing of water supply projects and insurance of infrastructure and equipment do not form part of the scope and are therefore not addressed in this project.

CHAPTER 6. COSTING DATA FOR WATER TREATMENT PROCESSES

This chapter provides the costing data that were gathered in graphical format. The graphs may then be used to determine the capital or operating costs of different unit processes. When using the WATCOST model, the costs are directly calculated using the equations of the best-fit lines for the costing data obtained in the project.

6.1. WATCOST Costing Database

Following a workshop with the Umgeni Water Planning Section in Pietermaritzburg during 2010 to obtain an insight into the costing procedures employed by the water board, as well as a workshop in Durbanville, a series of Excel spreadsheets were proposed by the project team and drawn up by Umgeni Water. These spreadsheets will be used for capturing all costing data obtained during the second phase of the project.

Costing data were obtained for current water supply projects or projects that were completed in the past ten years. The costs are broken down as far as possible to produce costs per unit treatment process for a wide range of treatment capacities, from small-scale treatment plants (community scale – for a number of households) to large water treatment plants (for the large cities or water boards).

Umgeni Water obtained the bulk of their data contribution by work sessions with consulting engineers to discuss tenders that were submitted for water supply projects within the jurisdictional area of the water board. The costing sheets were obtained and then processed by the engineers working on this research project, after which they were entered into the Water Supply Costing Model Database.

The database was furthered developed as the entering of costing data proceeded, by adding relevant sections and columns as required.

Personal interviews with consulting engineers provided to be the best source of costing data for water supply projects that were in progress at the time of writing or in the planning stages, or have been executed during the past ten years.

The following firms supplied information during contacts and visits:

Aurecon	Aveng (previously Keyplan)	KV3, Bellville
BKS	Umhlatuzi Water	Bergstan
KV3, Pretoria	Eskom	Water and Wastewater Eng
Stemele Bosch Africa	Bigen Africa	Midvaal Water
Goba and Associates	Aurecon Pretoria (Africon)	Sedibeng Water
SSI	Element, Cape Town	Amatola Water
WPCP	Arcus Gibb, Cape Town	City of Cape Town
Peter Swan	MBB Consulting Engineers, Stellenbosch	Uhambiso Consult
Süd-Chemie		UWP Consulting Engineers
Bateman	Tutuka	PDNA Central Karoo
Aqua Engineering	Degremont	Jeffares and Green
Tuiniqua Consulting Engineers	Overberg Water	Umgeni Water

The spreadsheet that was used to provisionally group and store all the costing data was further improved and extended. The following are some of the features that were included in the costing database:

- The WATCOST model links up with the pipeline costing program developed by the University of Pretoria (Prof Fanie van Vuuren / Dr Marco van Dijk). Both these researchers attended project meetings which were held in Pretoria.
- In establishing unit tariffs for remuneration, the local and regional government structures were handled on the following basis:
  - Metros
  - District Municipalities (DMs)
  - Local Municipalities (LMs)

- The WATCOST model is not able to do detailed costing for pipe networks (distribution systems), but provision was made for a factor for topography in the overall distribution network cost estimation.
- In adding a factor for maintenance, the same percentage was used for each of the water supply system components (raw water abstraction and transport; treatment; storage; distribution).
- The maintenance factors were broken up into: civil; M&E; instrumentation. These percentages are known and were obtained from the Umgeni Water Planning Department.
- Correction factors were added at the end of the table in the rows for TOTALS; i.e. it used an overall factor for all four components.
- In establishing water consumption figures, a figure of 75 L/capita/day was used, rather than the RDP value of 30 L/capita/day.
- Reference was made to the available guidelines documents for MFMA and PFMA, as well as to the Guidelines for Councillors and the asset management budgeting guidelines document, which both provide a good overview of the budgeting process in municipalities.
- DWA Classifications of A, B, C, D etc. were used for the model.
- Functionality was included in the model to compare costs of different water supply options (this also relates to the issue of centralisation versus decentralisation). **It must just be clearly stated that accuracies are limited to around 20-30%, and that the outputs are only for budgeting purposes and should not be used for design or tendering purposes.**

6.2. Capital Costs

The following graphs were compiled from the costing data that were obtained and entered into the WATCOST database. Note that all outlier points are shown in red. The occurrence of outliers can be ascribed to different costing bases that were used, e.g. with M&E or without M&E, including or excluding cost of supportive functions such as training, environmental aspects.

Please note that costs should not be estimated for plant capacities lower than the lowest data point or higher than the highest data point on the graphs, as such estimates would be unreliable.

6.2.1. Pre-treatment processes

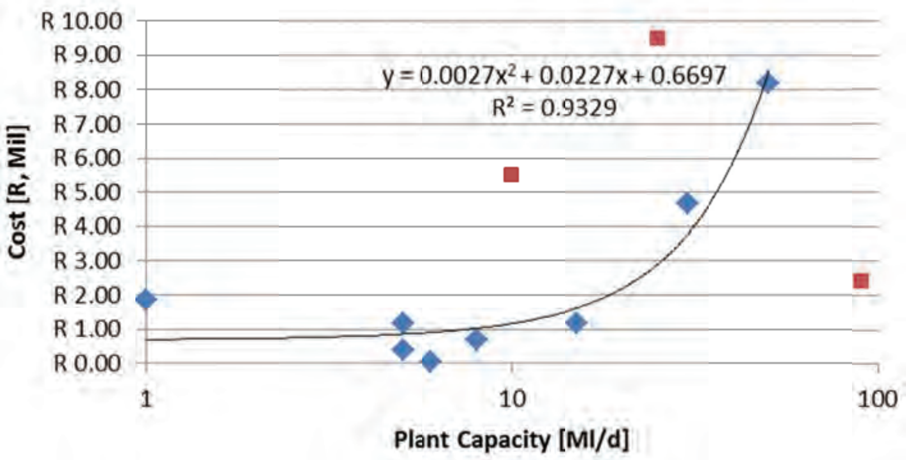


Figure 6.1: Capital cost curve for inlet distribution works of less than 50 ML/d

6.2.2. Chemical treatment

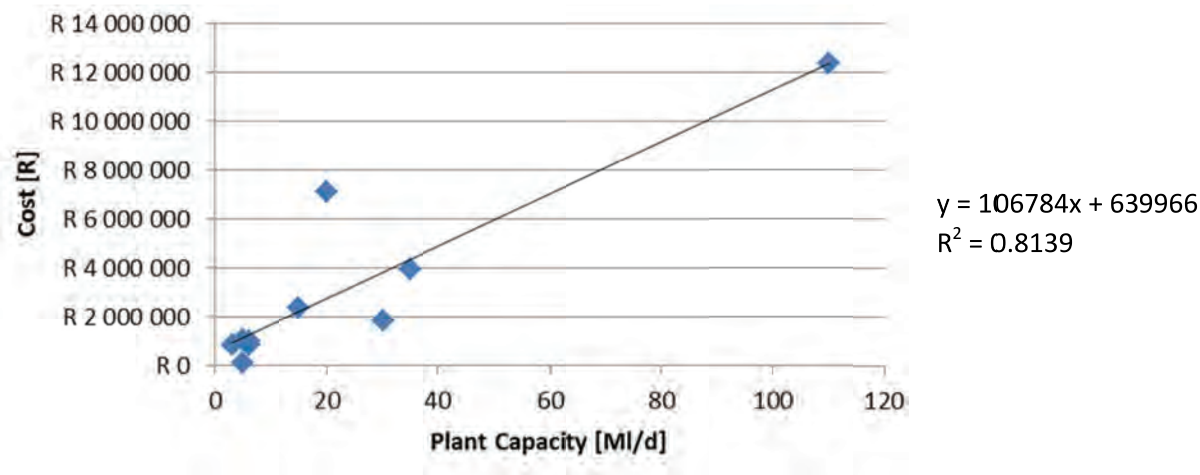


Figure 6.2: Capital cost curve for flocculation – all capacities

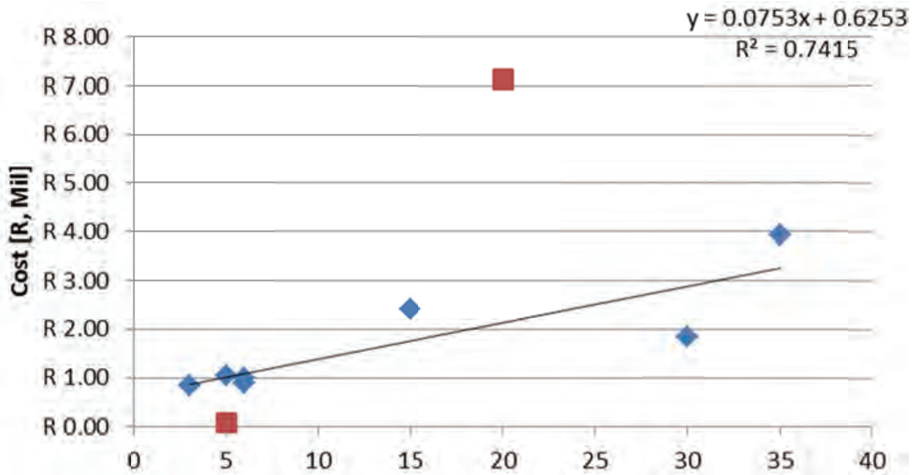


Figure 6.3: Capital cost curve for flocculation from 1 ML/d to 35 ML/d

6.2.3. Phase separation

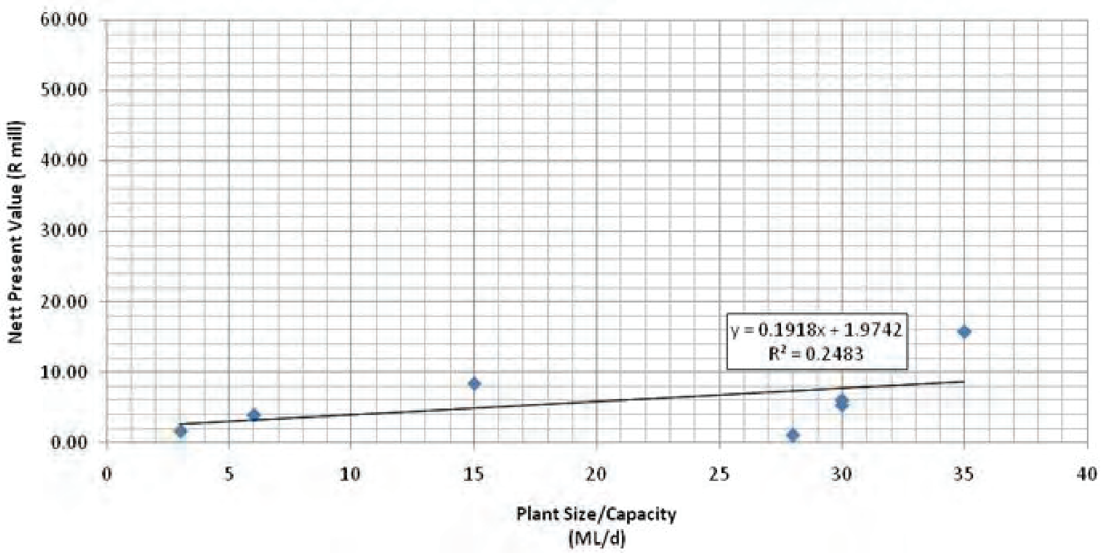


Figure 6.4: Capital cost curve for phase separation (horizontal flow sedimentation)

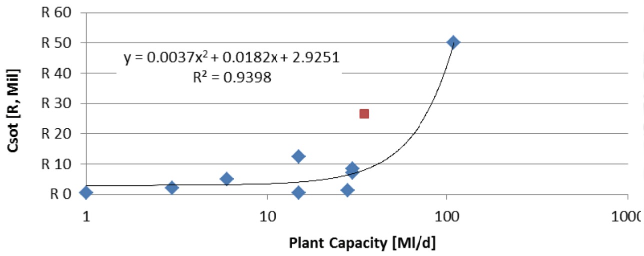


Figure 6.5: Capital cost curve for primary sedimentation

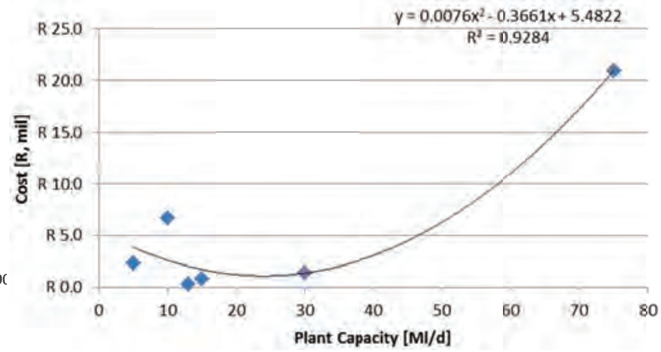


Figure 6.6: Capital cost curve for clarification

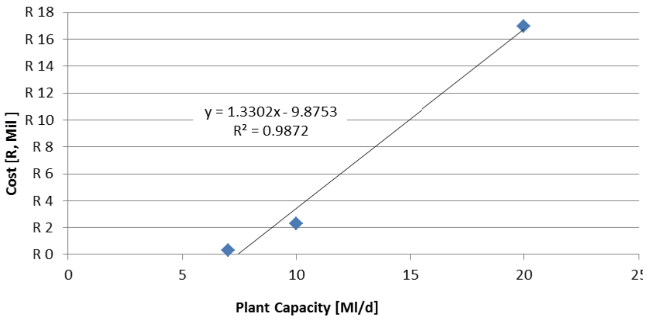


Figure 6.7: Capital cost curve for pulsator clarifiers

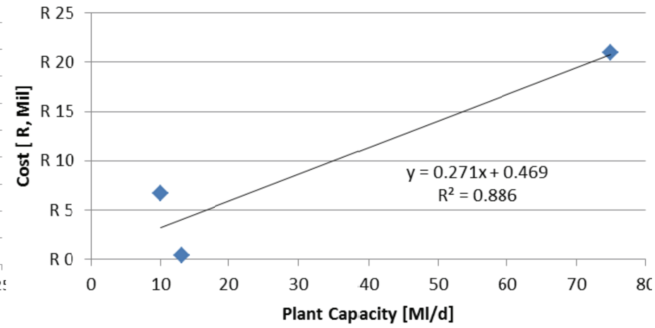


Figure 6.8: Capital cost curve for clariflocculation

6.2.4. Filtration

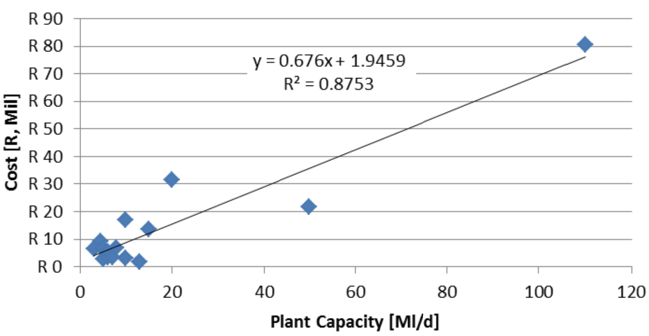


Figure 6.9: Capital cost curve for rapid gravity filters – all capacities

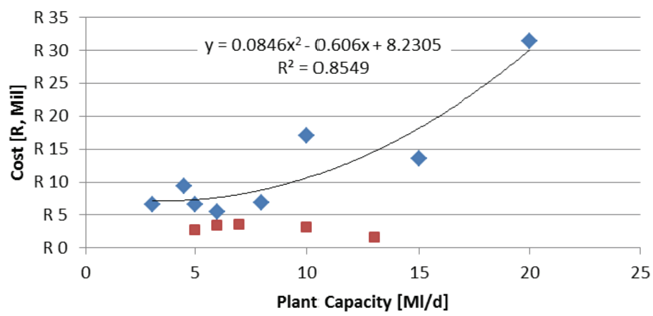
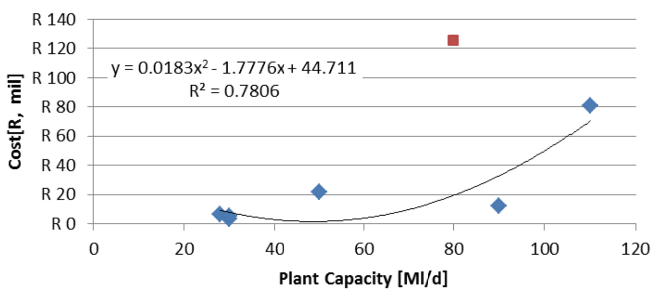


Figure 6.10: Capital cost curve for rapid gravity filters – 1 ML/d to 20 ML/d



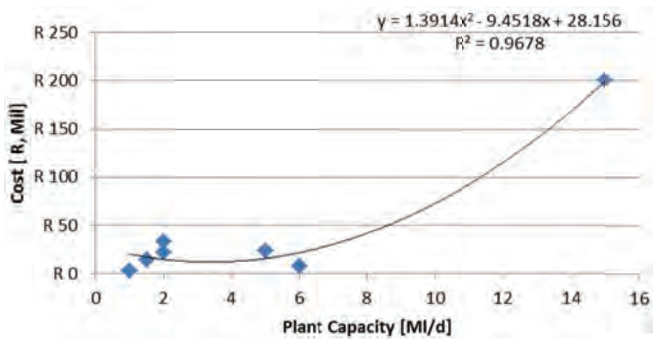


Figure 6.11: Capital cost curve for rapid gravity filters – 30 ML/d to 110 ML/d

Figure 6.12: Capital cost curve for reverse osmosis

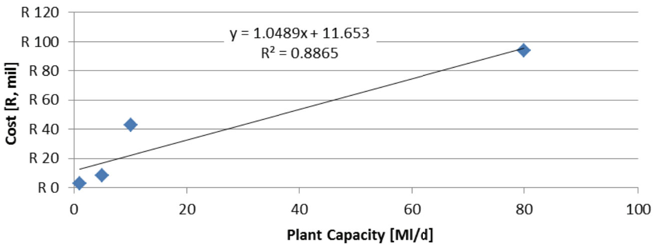


Figure 6.13: Capital cost curve for ultrafiltration

6.2.5. Disinfection

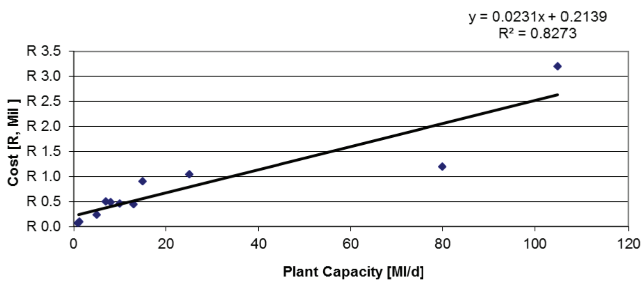


Figure 6.14: Capital cost curve for chlorination – all capacities

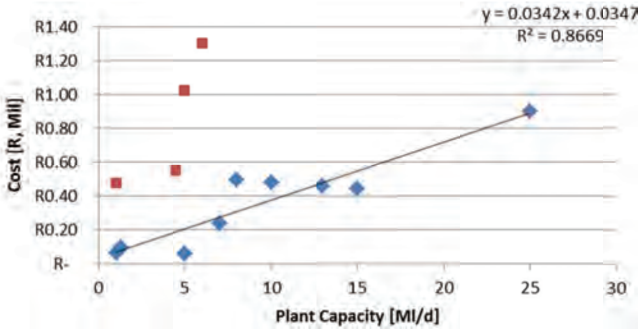
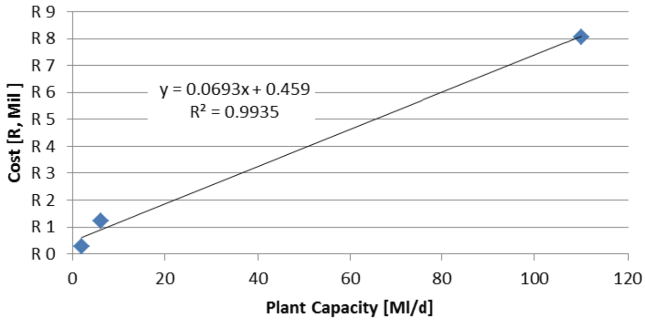


Figure 6.15: Capital cost curve for chlorination – 1 ML/d to 25 ML/d



Not recommended for use – insufficient data

Figure 6.16: Capital cost curve for chloramination

6.2.6. Reservoirs

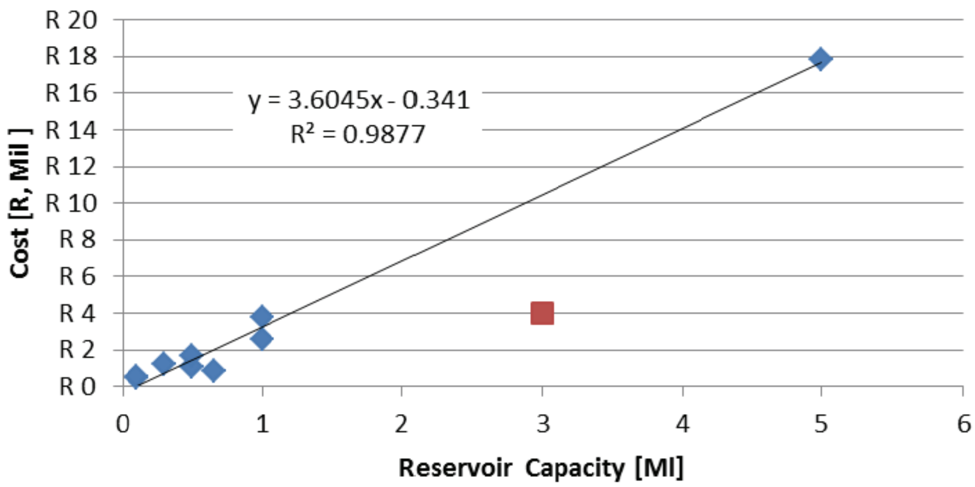


Figure 6.17: Capital cost curve for reservoirs

6.2.7. Preliminary and General

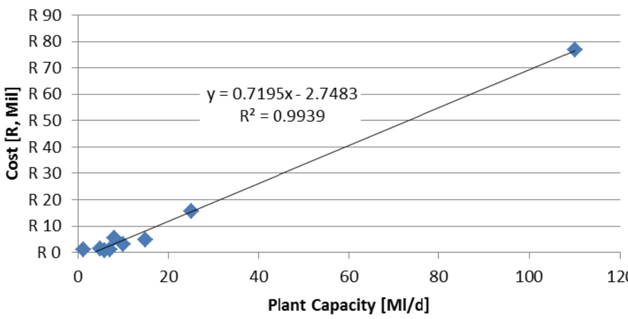


Figure 6.18: Capital cost curve for P&G – all capacities

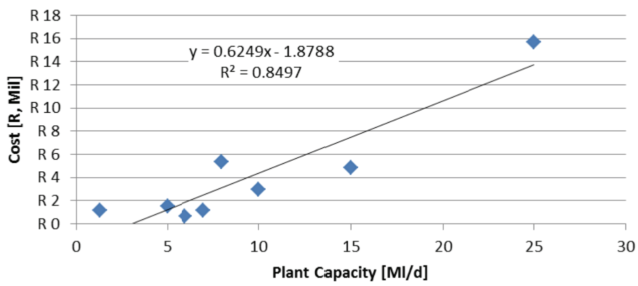


Figure 6.19: Capital cost curve for P&G – up to 25 ML/d

6.2.8. Package Plants

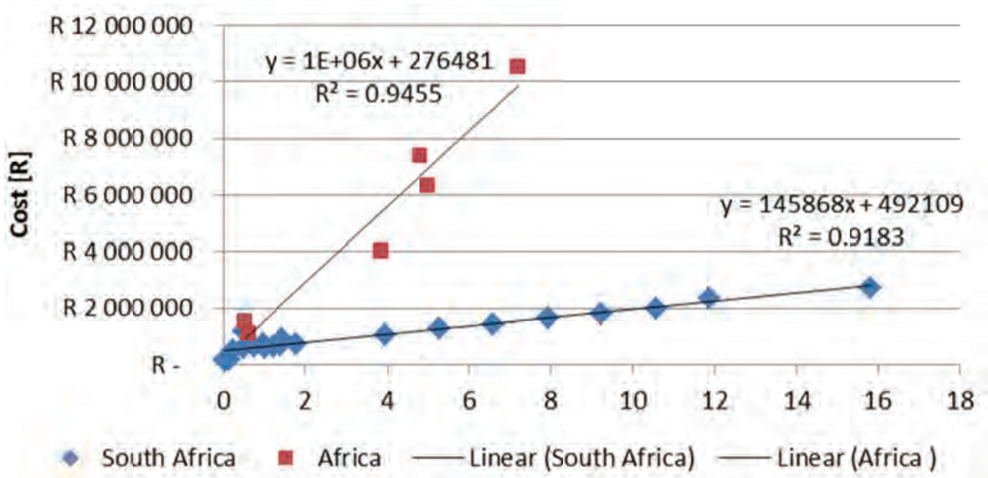


Figure 6.20: Capital cost curves for package plants

6.3. Operating Costs

6.3.1. Human resources (HR)

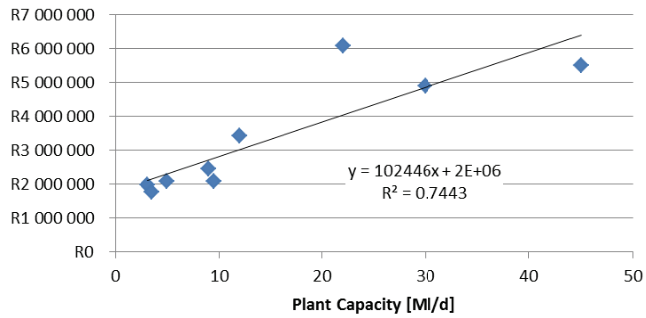


Figure 6.21: Operating cost curve for HR – 3 ML/d to 45 ML/d

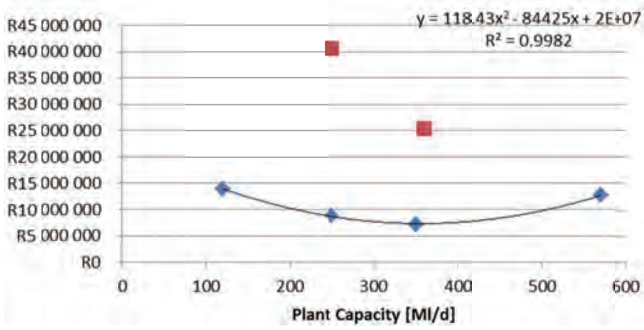


Figure 6.22: Operating cost curve for HR – 120 ML/d to 570 ML/d

6.3.2. Chemicals

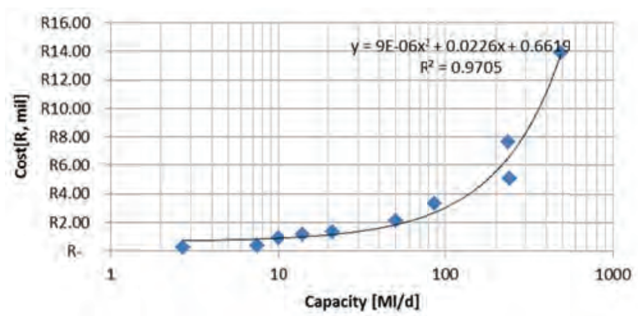


Figure 6.23: Operating cost curve for chemical costs – all capacities

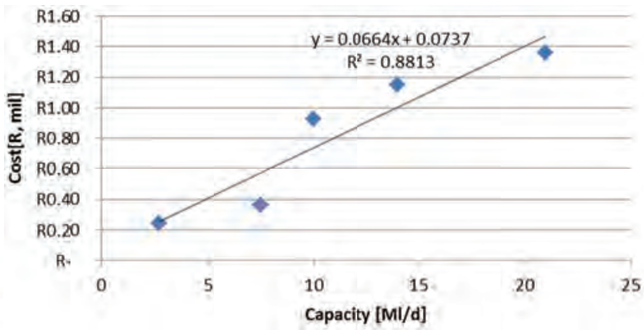


Figure 6.24: Operating cost curve for chemical costs – up to 25 ML/d

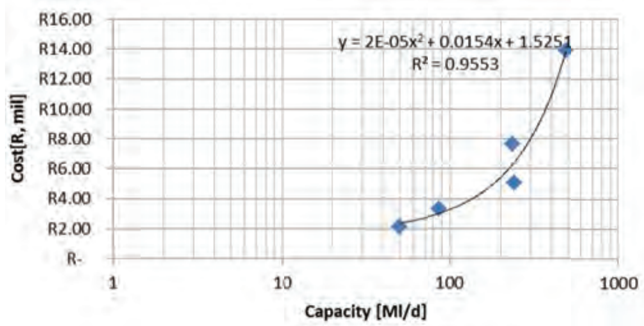


Figure 6.25: Operating cost curve for chemical costs – 50 ML/d to 500 ML/d

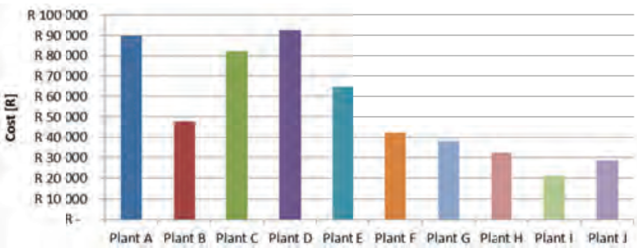


Figure 6.26: Bar charts for chemical costs per megalitre

6.3.3. Electricity

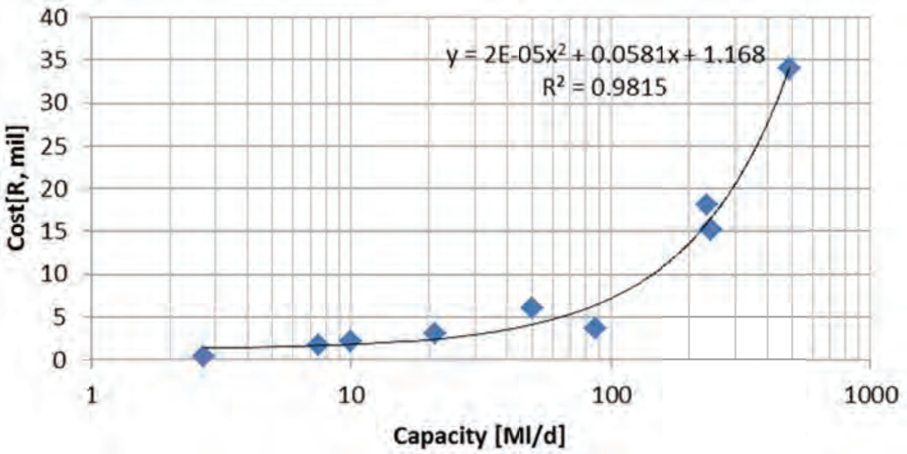


Figure 6.27: Operating cost curve for energy

6.3.4. Safety

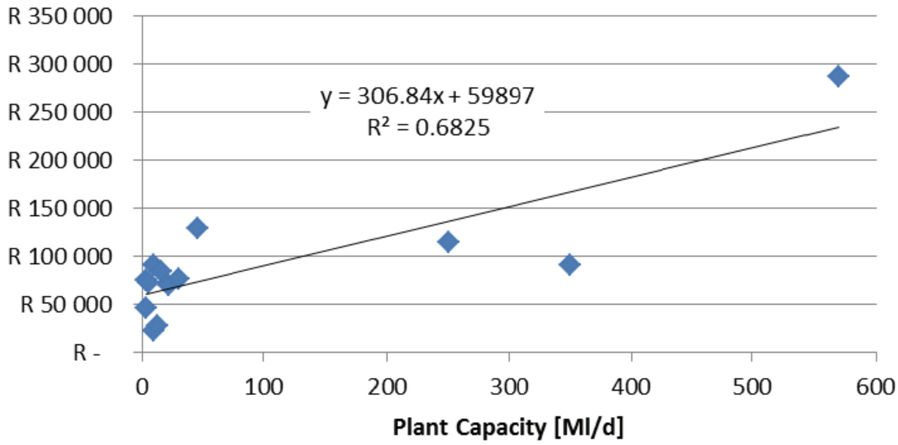


Figure 6.28: Operating cost curve for safety

6.3.5. Maintenance

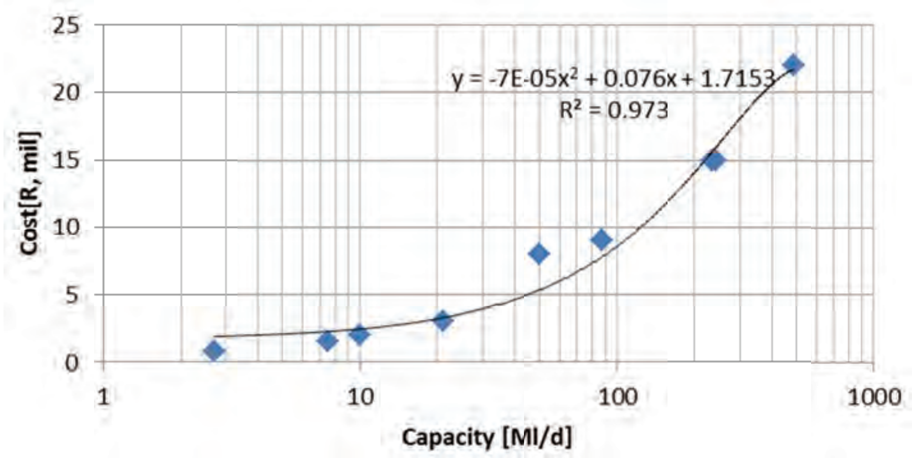


Figure 6.29: Operating cost curve for maintenance costs – all capacities

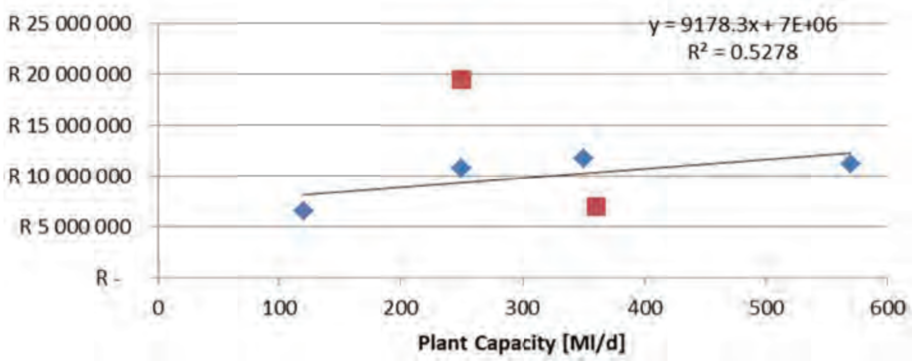


Figure 6.30: Operating cost curve for maintenance – 120 ML/d to 570 ML/d

The cost of waste handling can be a significant contributor to the overall cost of a treatment works. Insufficient local data was collected to represent the costs graphically. The WATCOST user should obtain site-specific costs for waste handling when doing cost estimations.

6.4. Pipeline Systems

Pipeline systems can either be gravity fed or pumping systems. Each one of these systems has its own unique design aspects, such as pipeline pressure class selection, pump station design, electrical and mechanical components, etc.

The cost components of a gravity system consist of:

Capital

- Design and supervision cost i.e. cost for the design of the pipeline system and the cost for supervising its construction.
- Pipeline cost, the cost of the pipeline itself with lining system, external protection, delivered to site and installed in the pipe trench.
- Excavation cost, preparing of bedding and blanket in trench, compaction, and material cost.
- Mechanical and electrical works cost, such as valves, special fittings, telemetry system, cathodic protection, flow meters, etc.
- The cost of the valve and meter chambers

Maintenance

- Maintaining the pipeline, fixing leaks and bursts.
- Inspection of the pipeline
- Replacing or renovating valves and other devices on the pipeline

Operational

- To keep the system operational the running costs need to be identified, such as the costs to have operators, managers and administrative personnel available and working on the system.
- Other costs, such as electricity and telemetry are also included under operational cost.

CHAPTER 7. USING WATCOST TO ESTIMATE COSTS

7.1. Cost Estimating Guidelines for the WATCOST User

Specific guidelines for the user on how the inputs should be made, acceptable inputs and limitations of the program, how more than one (up to five) treatment configurations may be compared, and how to interpret the output, is provided in the downloadable model, and is also contained in the manual.

7.2. Costing of New Projects

For estimating the costs of new water supply systems, certain assumptions will need to be made with respect to the project life-cycle, operational criteria (dosages, number of hours per day that the plant will operate, personnel to be employed, etc.).

The input page will require project specific information, such as the required plant inflow rate to produce sufficient quantities of clean water to meet the peak demands of the users. The user will also have to decide beforehand which process(es) he/she would like the cost estimates to be done for, and information on the topography, distance from the nearest metropole, etc.

When the required information has been entered, the model program will perform calculations to estimate both the capital and operating costs for the specific intended water supply configuration selected, and provide the output to the user in a one to two page output table. The output will also contain an amortization of the capital costs over the specified project life, and calculate the amortised and operating costs as a unit cost (Rand per kilolitre of water supplied to the consumer).

7.3. Costing to Determine Value of Existing Water Supply Systems

The WATCOST Model may also be used to obtain an order of magnitude of the value of existing water supply system components, for instance water treatment unit processes, reservoirs and pipelines. This is in particular valuable to water supply authorities for populating and regular updating of their asset registers, which then assists with determining devaluation and remaining lifetime of the assets.

The procedure for using the model for this purpose is the same as for estimating the costs of new processes and systems, where in this instance all the input data are already known (or may be readily determined), and the model then enabled to calculate the net present value of the assets.

CHAPTER 8. COST COMPARISONS – DECENTRALIZED *VERSUS* CENTRALIZED WATER SUPPLY

Swartz *et al.* (2009) reported that experience has shown that direct application of technologies developed in the West often does not function properly or is not sustainable when applied in developing countries, due to socio/cultural or political factors. Involvement of local companies, authorities and communities is imperative in trying to ensure successful application over the longer term. Local inputs in development of the technologies are also very important.

A lot of attention is also currently being paid to solutions in which the users can directly implement the treatment systems themselves, e.g. Point of Use (POU) treatment systems. In many cases, these decentralised systems should be the preferred option as compared to centrally managed solutions (centralisation), which often suffer from deterioration and poor maintenance. Therefore, help from industrialized countries (e.g. Europe) should focus on creating the local capacity to create solutions instead of introducing ready-to-use equipment.

Considering the large changes required to improve the situation, transition management is an important step. For example, POU treatment could serve as a temporary solution until central systems function reliably. Solutions for developing countries should not be necessarily "low-tech". Modern technology is often more efficient, more reliable, and therefore more suitable. In order to select drinking water investments, not only cost criteria should be handled, but the whole sustainability and feasibility of solutions should be considered (technical, economical, and political). In order to prevent that only the rich part of the population profits from improved water supply, commonalities in interest between poorest and other parts of population should be created. This could lead to justification of new concepts, e.g. the concept of free water for the poor.

In many developing and transition countries, the operation of centralized systems in some cases is less reliable than in the industrialized countries and the resources are often less well managed. Once again, this may be ascribed to a number of reasons, of which lack of funding, lack of management and technical capacity, and political interference are some of the more important factors. Monitoring water quality is therefore even more crucial, in water sources, in the treatment process, and in the treated water (final product). In order to enable this, cost-effective on-line monitoring technologies for a range of parameters should become available, thereby reducing the risk associated with non-availability of plant managers and process controllers. Where funding remains a problem, attention should be given to alternative financing methods.

Table 8.1 provides costs for water supply to various community sizes (levels of supply). These values can be shown graphically to compare the capital and operating costs for different options of a number of smaller systems versus one larger centralised system.

Table 8.1: Decentralised versus centralised project costing data

WATCOST
DECENTRALISED VS. CENTRALISED PROJECT COSTING DATA
(from DWA Cost Benchmarks, August 2009)
2009 data

Component	Sub-component	Capital Cost Per Scheme (Rand)			
		Very Small (1000 people)	**Small (5000 people)**	**Medium (20000 people)**	**Large (50000 people)**
Groundwater: Borehole Establishment	Good prospects Hard Rock	R 104 500	R 205 200	R 809 400	R 2 017 800
	Abrasive Rock	R 150 100	R 296 400	R 1 174 200	R 2 929 800
	Uncons Rock	R 195 700	R 387 600	R 1 539 000	R 3 841 800
	Leached Karst	R 362 900	R 722 000	R 2 876 600	R 7 185 800
	Average prospects Hard Rock	R 147 250	R 391 400	R 1 438 300	R 3 590 050
	Abrasive Rock	R 208 050	R 558 600	R 2 046 300	R 5 110 050
	Uncons Rock	R 268 850	R 725 800	R 2 654 300	R 6 630 050
	Leached Karst	R 512 050	R 1 379 400	R 5 086 300	R 12 710 050
	Poor prospects Hard Rock	R 275 500	R 904 400	R 3 621 400	R 9 055 400
	Abrasive Rock	R 381 900	R 1 254 000	R 5 035 000	R 12 597 000
	Uncons Rock	R 488 300	R 1 603 600	R 6 448 600	R 16 138 600
	Leached Karst	R 959 500	R 3 169 200	R 12 726 200	R 31 840 200
Groundwater: Borehole Equipment	Diesel	R 170 955	R 512 865	R 1 709 550	R 4 273 875
	Electricity	R 208 945	R 626 835	R 2 089 450	R 5 223 625
	Hand Pump	R 57 900	R 173 700	R 579 000	R 1 447 500
	Solar	R 265 930	R 797 790	R 2 659 300	R 6 648 250
	Wind	R 154 400	R 463 200	R 1 544 000	R 3 860 000
	Plant size	**30 kL/d**	**320 kL/d**	**600 kL/d**	**1 600 kL/d**
Surface Water Treatment Plant	Package Plant	R 409 239	R 1 498 566	R 2 550 330	R 6 306 630
	Conventional Treatment Plant	R 587 309	R 2 006 756	R 3 137 562	R 6 634 487
	Advanced Treatment Plant	R 1 403 670		R 3 657 450	R 7 611 450
	Motor size	**2 kW**	**8 kW**	**33 kW**	**82 kW**
Pump Stations Diesel Driven Low Speed Low Head	Mechanical Pump	R 6 960	R 23 123	R 65 041	R 128 841
	Energy Source	R 19 735	R 29 197	R 64 680	R 135 645
	Pump Pipework	R 6 335	R 21 527	R 61 739	R 123 878
	Diesel Pumps Total	R 33 031	R 73 848	R 191 460	R 388 363

Table 8.1: Decentralised versus *centralised project costing data (continued)*

Component	Sub-component	Capital Cost Per Scheme (Rand)			
	Motor size	**1 kW**	**4 kW**	**17 kW**	**42 kW**
Pump Stations Electrical Driven Low Speed Low Head	Mechanical Pump	R 4 330	R 12 405	R 30 713	R 55 922
	Pump Switchgear	R 10 612	R 13 888	R 26 171	R 50 738
	Energy Source	R 13 507	R 17 074	R 30 097	R 58 349
	Pump Pipework	R 3 846	R 13 068	R 37 478	R 75 199
	Electrical Pumps Total	R 32 295	R 56 435	R 124 460	R 240 208
	Motor size	**3 kW**	**14 kW**	**54 kW**	**136 kW**
Pump Stations Diesel Driven High Speed High Head	Mechanical Pump	R 10 189	R 33 894	R 95 211	R 188 604
	Energy Source	R 21 312	R 37 082	R 96 220	R 214 494
	Pump Pipework	R 9 341	R 31 739	R 91 026	R 182 641
	Diesel Pumps Total	R 40 842	R 102 641	R 282 457	R 585 740
	Motor size	**1 kW**	**7 kW**	**28 kW**	**130 kW**
Pump Stations Electrical Driven High Speed High Head	Mechanical Pump	R 19 604	R 50 261	R 113 094	R 276 244
	Pump Switchgear	R 11 158	R 16 618	R 37 090	R 135 426
	Energy Source	R 14 101	R 20 047	R 42 653	R 199 736
	Pump Pipework	R 5 670	R 19 267	R 55 257	R 176 304
	Electrical Pumps Total	R 50 534	R 106 193	R 248 094	R 787 709
	Pipeline length	**5 km**	**8 km**	**17 km**	**32 km**
Bulk Pipeline FC/Concrete	Soft Soil Excavation	R 198 868	R 436 342	R 2 511 737	R 6 958 624
	Moderate Soil Hardness	R 258 529	R 567 245	R 3 265 258	R 9 046 212
	Hard Soil Excavation	R 318 189	R 698 148	R 4 018 779	R 11 133 799
	Average	R 258 529	R 258 529	R 3 265 258	R 9 046 212
	Pipeline length	**5 km**	**8 km**	**17 km**	**32 km**
Bulk Pipeline uPVC/HDPE	Soft Soil Excavation	R 377 779	R 670 359	R 2 309 034	R 5 727 916
	Moderate Soil Hardness	R 491 113	R 871 466	R 3 001 744	R 7 446 291
	Hard Soil Excavation	R 604 446	R 1 072 574	R 3 694 454	R 9 164 665
	Average	R 491 113	R 871 466	R 3 001 744	R 7 446 291
	Pipeline length	**5 km**	**8 km**	**17 km**	**32 km**
Bulk Pipeline Steel	Soft Soil Excavation	R 768 891	R 1 468 084	R 5 449 618	R 12 735 657
	Moderate Soil Hardness	R 999 558	R 1 908 509	R 7 084 503	R 16 556 354
	Hard Soil Excavation	R 1 230 225	R 2 348 934	R 8 719 388	R 20 377 051
	Average	R 999 558	R 1 908 509	R 7 084 503	R 16 556 354

Table 8.1: Decentralised versus *centralised project costing data (continued)*

Component	Sub-component	Capital Cost Per Scheme (Rand)			
	Pipeline length	**5 km**	**8 km**	**17 km**	**32 km**
Bulk Pipeline GRP	Soft Soil Excavation	R 615 113	R 1 174 467	R 4 359 694	R 10 188 526
	Moderate Soil Hardness	R 799 646	R 1 526 807	R 5 667 602	R 13 245 083
	Hard Soil Excavation	R 984 180	R 1 879 147	R 6 975 511	R 16 301 641
	Average	R 799 646	R 1 526 807	R 5 667 602	R 13 245 083
	Capacity	**60 kL**	**300 kL**	**1300 kL**	**3200 kL**
Reservoir Ground Reservoir	Brick	R 162 213	R 626 930	R 2 148 572	R 4 578 924
	Concrete	R 172 609	R 595 075	R 1 837 758	R 3 673 890
	Steel	R 151 549	R 645 100	R 2 414 164	R 5 430 661
	PE	R 107 165	R 467 525	R 1 969 025	R 4 821 875
	Capacity	**60 kL**	**300 kL**	**1300 kL**	**3200 kL**
Reservoir Elevated Reservoir	Concrete	R 485 055	R 853 723	R 2 236 229	R 5 001 241
	Steel	R 194 024	R 341 491	R 894 494	R 2 000 499
	PE	R 124 961	R 464 644	R 1 738 457	R 4 286 082
	Capacity	**60 kL**	**300 kL**	**1300 kL**	**3200 kL**
Water Reticulation House Connection	Hard Soil Excavation	R 1 549 842	R 7 749 212	R 30 996 849	R 77 492 123
	Moderate Soil Hardness	R 1 259 247	R 6 296 235	R 25 184 940	R 62 962 350
	Soft Soil Excavation	R 988 652	R 4 843 258	R 19 373 031	R 48 432 577
	Project Capital Cost	**< R 600 000**	**R 0.6 m-R 2.0 m**	**R 2.0 m-R 10 m**	**R 10 m-R 500 m**
Professional Fees	Planning Fees	13%	11%	7%	5%
	Design Fees	12.5%	10%	7.5%	7.5%
	Contract Management	4%	3%	2%	2%
	Construction Supervision	10%	9%	7%	4%
	Training and Capacity Building	10%	7%	4%	2%
	Project Capital Cost	**< R 600 000**	**R 0.6 m-R 2.0 m**	**R 2.0 m-R 10 m**	**R 10 m-R 500 m**
P&Gs (Preliminary and General)	Dam	30%	24%	19%	14%
	Groundwater Development	18%	14%	9%	5%
	Pump Station	20%	18%	15%	12%
	Treatment Works	25%	21%	18%	15%
	Bulk Pipelines and Reticulation	15%	11%	8%	5%
	Power Supply	25%	21%	18%	15%

Table 8.1: Decentralised versus *centralised project costing data (continued)*

GENERAL ASSUMPTIONS	
Unit costs represent typical and not site-specific conditions. Population size categorised as follows (representing cost sensitivity and economy of scale): 0-1 000 people 1 000-5 000 people 5 000-20 000 people 20 000-50 000 people More than 50 000 people Housing density categorised into: Low population/housing density (5-15 persons/ha) Moderate population/housing density (15-40 people/ha) Higher population/housing density (40-70 people/ha) Average house occupancy: 5 people per household Service levels and water consumption: Street taps (25 L per person per day) Yards taps supply (80 L per person per day) House connections (250 L per person per day)	Soil hardness and excavation characteristics: Soft soil (no ripping or blasting) Moderate soil hardness (10% ripping; no blasting) Hard soil (15% ripping; 5% blasting) Topography and pumping requirements: Low speed / low head (1450 rpm; average of 90 m head) High speed / high head (2900 rpm; average of 150 m head) No provision has been made for: Special structures such as river and road crossings Extreme soil condition (e.g. hard rock) or topography New access roads, land acquisition, servitudes Unit costs exclude provision for professional fees, P&Gs, taxes and VAT

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APPENDIX A: UNIT COSTS AND RATES, TARIFFS AND COST INDICES

A 1. Unit costs, unit rates and tariffs

A 1.1 Electricity Unit Costs

The National Energy Regulator (NERSA) last year (on 24 February 2010) granted a three year price determination – the second Multi-Year Price Determination (MYPD 2) – that covers the Eskom financial period from 2010/2011 to 2012/2013 as follows:

Standard average prices and percentage price increases	2010/11	2011/12	2012/13
Standard average price (c/kWh)	41.57	52.30	65.85
Price increases (%)	24.8	25.8	25.9

In addition to determining the average Eskom price increase, NERSA also approves the structure of the tariffs, the rates and the increases applied to the rates to recover the total revenue allowed. The latter is submitted by Eskom to NERSA each year for approval.

On 28 February 2011 NERSA made known the tariff determination for 2011/12.

The average price increase per tariff category is as follows:

Tariffs	Increase (%)
Local authority rates	25.34
Non-local authority urban tariffs	26.95
Non-local authority rural tariffs	25.8
Residential tariffs	14.3

The reasons for the increases per tariff category and those applied to individual tariff rates not being the same as the Eskom average increase are as explained in the downloadable file named 'ESKOM Priceincrease2011'.

Electricity tariffs of Cape Town and Durban (as examples)

a. <u>City of Cape Town</u>

Schedule of electricity tariffs effective from 1 July 2011 (note: all figures exclude VAT):

Domestic Tariffs

Domestic customers are defined as juristic or natural persons purchasing electricity in private residential establishments where electricity is used primarily for residential use including, but not limited to, houses, blocks of flats, town house complexes, bed and breakfast establishments, second dwellings and bona fide residential establishments registered by the Welfare Department.

Where electricity received does not exceed 450 kWh per month (on average, including any free portion received), consumers will receive a free basic allocation of up to 50 kWh. Should electricity received exceed 450 kWh per month (on average, including any free portion), then the free electricity portion will no longer be made available to the household.

The average receipt of 450 kWh per month is an average measured over a period of twelve consecutive months, and includes any Free Basic Electricity that may have been received.

Where Free Basic Electricity is received, this forms part of the LifeLine Block 1 allocation of energy, so only a maximum of 100kWh of the 150kWh is paid for by these consumers, the other 50kWh is paid for by the City.

Qualifying domestic consumers on prepayment meters will not receive the free basic allocation in months in which no electricity is purchased unless this is specifically claimed at a vending outlet in each such month. Qualifying consumers on credit meters will be credited with as much of the free basic allocation as is used during the metering period.

Domestic (>450 kWh received per month)		
Energy Charge (c/kWh)	Block 1 (<= 600kWh)	107.43
	Block 2 (> 600kWh)	118.06
Lifeline (<450 kWh average received)		
Energy Charge (c/kWh) (Any FBE received forms part of the Block 1 receipt)	Block 1 (0-150 kWh)	61.60
	Block 2 (150.1-350 kWh)	81.04
	Block 3 (350.1-600 kWh)	107.43
	Block 4 (> 600 kWh)	118.06

Commercial Tariffs

Commercial/Industrial consumers are defined as those consumers that are not defined as Domestic consumers and include, but are not limited to, halls, places of worship, schools, sports clubs, restaurants, theatres, consulting room establishments, and all other commercial and industrial premises.

Residential establishments such as hotels, hostels, guest houses, boarding houses and retirement homes or where the supply to a residential premise exceeds 100A will also be regarded as Commercial customers.

Commercial customers with an installed capacity of 500 kVA or less may elect to take their supply at either of the Small Power Tariffs or the Large Power Low Voltage Tariff. Customers with installed capacity exceeding 500 kVA and up to 1 MVA must take their supply at either the Large Power Low Voltage or the Large Power Medium Voltage tariff. Customers with installed capacity of above 1 MVA must take their supply at the Large Power Medium Voltage or the Time of Use tariff.

It should be noted that when a tariff is selected the customer needs to take cognisance of other provisos in the relevant other policies and documentation that may impact on that selection.

The Demand Charges on all the relevant tariffs is only applicable on weekdays between 06:00 and 22:00 provided suitable metering is installed at the customers' premises.

Small Power	
Small Power 1 (>1000 kWh average per month)	
Service Charge (Rand per day)	17.21
Energy Charge (c/kWh)	93.15
Small Power 2 (<1000kWh average per month)	
Energy Charge (c/kWh)	144.60
Large Power	
Low Voltage	
Service Charge (Rand per day)	28.67
Energy Charge (c/kWh)	48.84
Demand Charge (R/kVA)	145.32
Medium Voltage	
Service Charge (Rand per day)	28.67
Energy Charge (c/kWh)	45.40
Demand Charge (R/kVA)	135.16

Time of Use

Service Charge (Rand per day)		4680.00
Energy Charge - High Demand (c/kWh)	Peak	230.14
	Standard	60.86
	Off Peak	33.13
Energy Charge - Low Demand (c/kWh)	Peak	65.34
	Standard	40.54
	Off Peak	28.75
Demand Charge (R/kVA)		73.00

Notes to the TOU Tariff:

High Demand season is from June to August, Low Demand season is from September to May.

Hours of Operation:

Peak	Weekdays 07:00 to 10:00, 18:00 to 20:00
Standard	Weekdays 06:00 to 07:00, 10:00 to 18:00, 20:00 to 22:00
Off Peak	All other times

Off Peak

This tariff is only available for use in conjunction with the Small Power User tariff. It will be applicable during the Off Peak periods from 22:00 to 06:00 on weekdays and from 22:00 on Friday to 06:00 the following Monday. The minimum charge is applicable if the Rand value of the energy consumed during the off peak periods is less than the amount of the Minimum Charge. This tariff may be discontinued as of 1 July 2012.

Minimum Charge (Rand per day)	53.51
Energy Charge (c/kWh)	48.84

Lighting Tariffs

Street Lighting and Traffic Signals

Energy Charge (R/100W/ burning hour)	0.1022

Private Lights

Energy Charge (R/100W/ burning hour)	0.1115

Other Tariffs

Wheeling Tariff

Energy Surcharge (c/kWh)	Firm	12.68
	Non-firm	7.78

The Tariffs were approved by the Council of the City of Cape Town on 8 June 2011.

Monthly service or minimum charges are calculated using the applicable daily charge multiplied by the number of days in the billing period.

In terms of the new Electricity Supply By-law as promulgated on 16 March 2010, new or transferred electricity supplies can only be registered in the name of the owner of the property (that is, the ratepayer). The owner can appoint a proxy (such as a managing agent) to act on his/her behalf. For Domestic supplies, the business partner's name in the City's billing system will be that of the owner, and the account can be sent "care of" the address of the proxy. For all other tariff categories the business partner's name in the billing system will also be that of the owner, but the account can be sent "care of" the proxy's name and address.

b. City of Durban

Electricity tariffs translate to a nominal increase of 26.71% to municipalities effective 01 July 2011. In line with the National Energy Regulator of South Africa (NERSA) allowing Eskom an average tariff increase of 25.8% effective 01 April 2011, the eThekwini Electricity has implemented an average tariff increase of 19.8%. A summary of the increases pertaining to the specific tariffs is highlighted in the tables below:

NOTE: A full breakdown of the schedule of connection fees and charges is available at *http://www.durban.gov.za/durban/services/electricity/tariffs*

Final tariff increases

Description	Tariff	Increase	Amount
Residential customers	Scale 3, 4, 8, 9	18.5% Energy charge	93.71 c/kWh
Residential customers Free Basic Electricity (Scale 12)	Free Basic Electricity customers will continue to receive 65 units free per month. Energy purchased thereafter will be subject to a 9.5% increase	9.5% Energy charge	71.54 c/kWh
Business and general	Scale 10, 11	20.85% Energy charge	113.09 c/kWh
	Scale 1	20.85% Energy charge Service charge	 101.86 c/kWh 142.01 R/month
Commercial TOU	CTOU	20.85%	
Residential TOU	RTOU*	18.5%	
Industrial TOU	Customers' increase will vary, depending on their individual load profiles.	20.85% ± 1%	

* The implementation of this tariff is dependent on the successful implementation of the smart metering technology

Obsolete and discontinued tariffs

The LV3-Part, Scale 2 and Scale 5/6/7 are no longer available to new customers. They will attract higher than average increases. Customers are urged to study their load profiles and investigate the possibility of migrating to alternate tariffs.

Description	Tariff	Increase
Business and general	Scale 2 (002/021)	22.5%
Low voltage 3 part	LV3-Part	22.5%
Business and general	Scale 5/6/7	22.5%
Industrial Time of Use		**Amount**
Peak	High demand season June-August	183.91 c/kWh
Standard		52.64 c/kWh
Off peak		31.11 c/kWh
Peak	Low demand season September-May	55.94 c/kWh
Standard		36.82 c/kWh
Off peak		27.46 c/kWh
Network demand charge (based on actual demand)		57 R/kVA
Network access charge (based on notified max. demand)		17.10 R/kVA
Service charge		2046.00 R/month
Voltage surcharge	**Voltage**	**Surcharge (%)**
To be raised on the sum of Energy,	275 kV	0
	132 kV	2.25

Network demand charge, and Network access charge.	33 kV	3
	11 kV	10.5
	6.6 kV	12.75
	400 V	22.5

A 1.2 Services Unit Costs

The starting point in dealing with financial arrangements is cost, both capital and on-going operating and maintenance costs. As mentioned, these costs need to be calculated for particular circumstances and may differ from area to area within a municipality. Infrastructure cost can vary significantly and for this reason this report has the functionality as a **Guideline** (as opposed to a Specification or Standard). The main factors that impacts on unit costs are:

Topography

Physical features, such as terrain (slope) – ranging from flat to mountainous and/or combinations thereof and existing physical features, e.g. natural, infrastructure.

Geology and Geotechnical considerations

Soil characteristics such as soil types – cohesive & non-cohesive, soil conditions – soft to hard, rock, and where applicable borrow pit/s & spoil/dump/disposal site/s and local / *in situ* materials.

Hydrology

Drainage characteristics, i.e. sub-surface & surface in terms of drainage and stormwater requirements and where applicable water sources and access.

Context / Locality of the project

Aspects such as accessibility to site – rural (remoteness) or urban (built environment); working space; security; availability and accessibility of local resources; climate – rain, dust (dry, wind), season (hot, cold).

Environment

Environmental considerations: erosion control and rehabilitation measures; borrow pit/s and spoil / dump / disposal site/s; ecologically sensitive areas/s, traditional site/s, historical zones; protection of water, soils and vegetation.

Labour

Availability of local people (unskilled to skilled), local sub-contractors, and small emerging contractors.

Other aspects

Aspects such as distance to travel to site, transportation requirements, accredited or non-accredited training requirements (including for EPWP); task/ production rates for LIC work items and published wage schedules; wage rate (unskilled/semi-skilled) varies anywhere between government gazettes and the Industry's minimum wage rates respectively – also varies per province and whether in rural or urban context.

It therefore needs to be recognized and accepted that, in the case of both capital costs and monthly charges, there exist great variation in amounts at a National level, between different provinces and municipalities, and even within municipal boundaries – terrain changes (flat vs. undulating), geotechnical variances (soft material *vs*. rock excavations), and hydrology.

A 2. Indices

In the updated version of the *Industry Guide to Infrastructure Service Delivery Levels and Unit Costs* (CoGTA, 2010) unit costs were determined by using the following three different approaches:

i. The Contract Price Adjustment Factor (CPAF) and SAFCEC indices:

This was applied to the Civil Engineering components of the unit costing. The price increase varied between 20 and 22% depending on the category of work.

ii. The JBCC Calculation and Indices:

This was applied to the Building components of the unit costing. The lump sum contract approach was used that resulted in a price increase of 21.47%

iii. The SEIFSA indices combined with SAFCEC indices:

This was applied to the Electrical Engineering components for the Street lights and Highmast lights. The SEIFSA does not incorporate the fuel price increase hence the practice is to combine it with SAFCEC fuel indices. The price increase was calculated at 19.84%

Contract Price Adjustment Factor

In accordance with Clause 49(2), the value of each certificate issued in terms of Clause 52(1) shall be increased or decreased by the amount obtained by multiplying "Ac", defined in Clause 2 of this Schedule, by the Contract Price Adjustment Factor, rounded off to the fourth decimal place, determined according to the formula:

$$(1 - x) \left[\frac{a\,Lt}{Lo} + \frac{b\,Pt}{Po} + \frac{c\,Mt}{Mo} + \frac{d\,Ft}{Fo} - 1 \right] \qquad [A1]$$

where:

"x" is the proportion of "Ac" which is not subject to adjustment. Unless otherwise stated in the Appendix this proportion shall be 0,15.

"a", "b", "c" and "d" are the co-efficients determined by the Engineer and specified in the Appendix, which are deemed, irrespective of the actual constituents of the work, to represent the proportionate value of labour, plant, materials (other than "special materials" specified, in terms of Clause 49(3), in the Appendix) and fuel respectively. The arithmetical sum of "a", "b", "c" and "d" shall be unity.

"L" is the "Labour Index" and shall be the actual Wage Rate index for all workers in the civil engineering industry (weighted average for all areas) as published in the Statistical News Release (P0142.2) of the Central Statistical Service.

"P" is the "Plant Index" and shall be the "Civil Engineering Plant Index" as published in the Statistical News Release (PO 142.2) of the Central Statistical Service.

"M" is the "Materials Index" and shall be the "Price Index of Civil Engineering Materials", as published in the Statistical News Release (PO 142.2) of the Central Statistical Service.

"F" is the "Fuel Index" and shall be the weighted average of the fuel indices for "Diesel, before deduction of refund" and "Diesel, after deduction of refund" as published in the Statistical News Release (PO 142.2) of the Central Statistical Service for the "Coast" or "Witwatersrand". The weighting ratio and the use of the "Coast" and "Witwatersrand" indices shall be as specified by the Engineer in the Appendix. Unless otherwise specified by the Engineer in the Appendix, the weighting ratio shall be 1 to 1.

The suffix "o" denotes the basic indices applicable to the base month, which shall be the month prior to the month in which the closing date for the tender falls.

The suffix "t" denotes the current indices applicable to the month in which the last day of the period falls to which the relevant payment certificate relates.

If any index relevant to any particular certificate is not known at the time when the certificate is prepared, the Engineer shall estimate the value of such index. Any correction which may be necessary when the correct indices become known shall be made by the Engineer in subsequent payment certificates.

<u>Methodology for Calculation of Future Unit Costs using SAFCEC Indices Future Cost Calculations:</u>

The updating of cost to amend the unit cost figures to accommodate price increase can be done for any interim month. It is suggested that this be done by using the tables that have been set up for the base month of August 2009 which is the month for which the unit cost have last been updated. The steps to be followed are as detailed below:

Step 1:

Go to the SAFCEC Website for the CPAF Indices (Old Index) and select the month for which the price increase is to be determined [http://safcec.org.za]

Step 2:

Select the Labour index for the appropriate area and capture this in the yellow block marked (i).

Step 3:

Select the other Indices for Plant (ii), Material (iii) and Fuel (iv) and capture the figures in the blocks marked green (ii), blue (iii) and red (iv), respectively.

Step 4:

The escalation factor is calculated using the SAFCEC CPAF. Read the percentage escalation for the particular contract type in the respective block in Table 1b.

Step 5:

The escalation amount is calculated by multiplying the escalation factor by the service unit cost in the Industry Guideline 2009 document (which was calculated for August 2009).

Step 6:

Add the escalation amount (in step 5) to the Industry Guide 2009/2010 unit cost to derive the new unit cost.

		Average Annual Interest rates(%)																			Rate (i) from Yr of Constr. To Current year (2012)	No of Periods (n)
		1994	**1995**	1996	**1997**	1998	**1999**	2000	**2001**	2002	**2003**	2004	**2005**	2006	**2007**	2008	**2009**	2010	**2011**	2012		
year of construction	1994	16.25%	**18.00%**	19.80%	**19.25%**	22.66%	**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*14.61%*	*18*
	1995		**18.00%**	19.80%	**19.25%**	22.66%	**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*14.52%*	*17*
	1996			19.80%	**19.25%**	22.66%	**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*14.31%*	*16*
	1997				**19.25%**	22.66%	**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*13.97%*	*15*
	1998					22.66%	**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*13.62%*	*14*
	1999						**18.69%**	14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*12.97%*	*13*
	2000							14.50%	**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*12.53%*	*12*
	2001								**13.42%**	15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*12.37%*	*11*
	2002									15.50%	**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*12.27%*	*10*
	2003										**13.40%**	11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*11.95%*	*9*
	2004											11.00%	**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*11.79%*	*8*
	2005												**10.50%**	15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*11.89%*	*7*
	2006													15.67%	**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*12.08%*	*6*
	2007														**13.75%**	15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*11.49%*	*5*
	2008															15.17%	**12.50%**	9.50%	**9.00%**	9.00%	*11.03%*	*4*
	2009																**12.50%**	9.50%	**9.00%**	9.00%	*10.00%*	*3*
	2010																	9.50%	**9.00%**	9.00%	*9.17%*	*2*
	2011																		**9.00%**	9.00%	*9.00%*	*1*
	2012																			9.00%	*9.00%*	*0*

APPENDIX B: CHARACTERISTICS OF TYPICAL RAW WATER SOURCES

The paragraphs below provide the essential background information on the characterisation of the different main raw water types, in order to obtain a purified drinking water complying with the requirements of the new SANS 241:2011.

B 1. Turbid water

Suspended solids that occur in raw water give it a turbid or murky appearance. These solids (usually measured as turbidity) and the appearance they cause are undesirable for aesthetic reasons. The objective of treating turbid raw water is therefore to reduce turbidity levels (clarification) so that the water appears clear, acceptable aesthetically and good enough to ensure effective disinfection.

The reduction of turbidity (or treatment of turbid raw water) always involves fine filtration preceded by a variety of combination of other unit processes. Therefore, the reduction of turbidity in medium to very high turbidity raw water can be divided into two main stages:

Stage 1: Reduction of turbidity (to < 10 NTU) to protect the fine filter from frequent clogging and ensure effective operation.

Stage 2: Further reduction of turbidity to levels by fine filtration to less than 1 NTU, to produce a water that is aesthetically acceptable and which also ensure effective disinfection.

B 2. Coloured Water

Coloured water is defined as any natural water containing organic matter which gives rise to a yellow to brown colour. It therefore refers to organically coloured surface water, and excludes any coloured water arising from industrial activities.

Colour, as is the case with taste, odour and turbidity, forms a primary aesthetic quality parameter when water is supplied from any raw water source for human consumption. From a health perspective, the organic substances in the water result in reduced disinfection efficiency, and can also lead to the formation of undesired disinfection by-products.

Organic compounds in water also serve as nutrient source for microorganisms which can lead to bacterial growth in water purification plants and distribution systems. This results in deterioration of the water quality and slime formation in tanks and pipes, and also leads to biological corrosion.

B 3. Brackish Water

For raw waters with high salinity, such as seawater or brackish water, treatment processes must remove most of the dissolved salts (desalinate) in order to make the water potable (i.e. lower the TDS to less than 1000 mg/L or EC to less than 150 mS/m)). This can unfortunately not be achieved be most of the fine filtration technologies, so that there are no affordable treatment devices for application in rural communities.

B 4. Hard and Soft Water

Hardness in water is caused by the presence of any polyvalent metal cation. The principle cations are: calcium, magnesium, strontium, iron and manganese, with calcium and magnesium being the most prevalent. The associated anions are normally bicarbonate, sulphate, chloride, nitrate, and silicate.

Public acceptance of hardness varies from community to community, consumer sensitivity related to what the consumer is accustomed to. Hard (150-300 mg/L $CaCO_3$) and very hard water (>300 mg/L $CaCO_3$) results in high soap consumption and the scaling of pipelines, boilers, geysers and kettles.

B 5. Microbiologically Contaminated Water

Most waters, natural or treated but without disinfection, would usually have some extent of contamination that does not render the water potable. This contamination can be reduced to some extent by filtration processes, especially slow sand filtration, but not completely. Disinfection by chlorination is widely used to treat contamination. The disinfection applied must also be able to adequately protect the water throughout its pathways to the furthest consumer. Hence, addition of disinfectants is also necessary even for waters that are uncontaminated in order to protect the water from contamination during the distribution.

Water to be disinfected must always be clear enough in terms turbidity levels (WHO guideline is < 1 NTU) in order to prevent disinfectants from reacting with or being consumed by turbidity particles to form disinfectant by-products. Where chlorination is applied, care must be taken not to overdose and impair the taste of the final water.

B 6. Eutrophic Water

The deterioration of surface water quality due the pollution from point source discharges (waste water treatment works and industrial effluent) and diffuse surface runoff (modern agriculture, industrialization and urbanization) has thus been recognized as a major global water resource concern. One of the primary effects of pollution is nutrient enrichment of receiving waters commonly referred to as eutrophication. This results in the stimulation of an array of symptomatic changes, amongst which increased production of algae, cyanobacteria and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water uses.

The taste and odour problems in drinking water can either directly or indirectly be linked to cyanobacteria which can produce compounds such as geosmin in spring, summer and autumn months in South Africa. It causes the drinking water to have an earthy-muddy-musty taste and odour. Although not toxic to the consumers it tends to generate suspicion with regard to the quality and health effects of the drinking water, which leads to customer complaints and encourages consumers to seek alternative sources of drinking water.

Effective methods to remove intact algal cells before releasing metabolites are coagulations, sedimentation, flotation and filtration.

B 7. Nitrate-containing water

High concentrations of nitrates in raw water can be reduced by a number of technologies. These include membrane desalination, ion exchange and biological nitrate removal (also called biodenitrification), none of which can be readily or affordably applied on household scale in rural applications.

All nitrate removal technologies are expensive and require well-trained operators and specialised maintenance. Ion-exchange and reverse osmosis may have a lower efficiency if compared with biological denitrification, but they seem to be more suitable for medium and small applications. Better economics, larger automation possibilities, lower level in feed and process parameters control and no need for extensive post-treatment (in the case of reverse osmosis) are advantages of these processes.

B 8. Fluoride-containing water

High concentration of fluoride in raw water can be reduced by a number of technologies. These include membrane desalination (reverse osmosis, see section on brackish water), flocculation and adsorption. Adsorption defluoridation is more suited towards local application. In involves the downward flow of raw water through a column packed with a strong adsorbent, typically activated alumina but activated charcoal or ion exchange resins are also used (the latter when the fluoride concentration is less than 10 mg/L).

APPENDIX C: OVERVIEW OF WATER TREATMENT PROCESSES

In this appendix, an overview is provided of the most important water treatment processes used in municipal drinking water supply. The aim of the overview is to provide the user of WATCOST with process information that will facilitate easier use of the model, especially where it is the intention to compare different treatment alternatives for a specific application.

C 1. Process configurations

The Process Configurations database contains a comprehensive number of possible process configurations that are commonly used in the production of treated water for drinking purposes. These will include, inter alia, the following treatment process configurations:

- Conventional treatment (turbidity or colour removal)

  (Chemical treatment – phase separation – filtration – disinfection)
- Conventional treatment with pretreatment

  (Pretreatment – chemical treatment – phase separation – filtration – disinfection)
- Conventional treatment with post-treatment

  (Chemical treatment – phase separation – filtration – disinfection – post treatment)
- Chlorination only
- Iron and / or manganese removal

  (pH adjustment – oxidation – chemical treatment (optional) – phase separation (depending on Fe levels) – filtration – chlorination)
- Nitrate removal
- Fluoride removal
- Desalination
- Conventional treatment with algae removal
- Conventional treatment with taste and odour removal
- Conventional treatment with advanced oxidation

C 2. Unit treatment processes

C 2.1 Pre-treatment

Pretreatment processes are required in instances when the quality of the raw water is very poor due to events such as high rainfall, algal blooms or discharges from wastewater treatment plants. These processes are then applied upstream of the normal treatment processes applied at the treatment plant, and could be either temporary or permanent. The processes used could be any of the unit treatment process employed in drinking water treatment, such as settling (plain sedimentation for removing high suspended solids loadings), activated carbon (for taste and odour problems) or oxidation processes.

C 2.2 Chemical treatment

The purpose of flocculation and coagulation is to remove colloidal as well as suspended matter from water. This is achieved by adding a chemical, which break-up into ions, which are negatively and positively charged. These ions attract dirt particles, which are also charged. The particles collide with each other, aggregate, and grow heavier until they begin to sink.

There are three steps in this process: Flash mixing, Floc formation, and Floc conditioning.

C 2.3 Phase Separation

a. <u>Sedimentation</u>

Types of sedimentation designs and processes

The various designs of sedimentation units that can be applied in small water treatment systems are identified by the flow pattern, configuration and operation methods as follows:

- Horizontal flow sedimentation tanks
- Radial flow sedimentation
- Up-flow sedimentation tanks
- Batch sedimentation

The flow in the first three is continuous, while batch sedimentation systems involve intermittent filling, settling and emptying of the tank. Descriptions of each of the above types are provided in the following paragraphs.

Horizontal flow sedimentation tanks:

Conventional sedimentation process made of a rectangular shaped tank, with inlet and outlet structures and a sloping floor, in which water flows slows in the horizontal direction providing quiescent conditions for suspended solids/flocs to settle at the bottom by gravity.

Upflow sedimentation tanks (including sludge blanket clarifiers)

- Basins with a circular, square or rectangular surface area with conical bottoms in which water flows upwards and settleable solids are returned by the force of gravity.

Batch sedimentation:

Water can be clarified by filling a large container consisting of a tank / reservoir or other large basin with chemically pre-conditioned water. Water is normally entered at an offset angle to create a stirring motion inside the tank so that chemical distribution can be improved. Chemicals are either introduced as part of a pre-conditioning process using a chemical feeder (e.g. dosing pump) or manually added into the reservoir, while water is being entered.

Once the tank is full the water inlet is stopped and the water is left in the container allowing the flocs to settle. After settling has taken place the clear water is pumped from the upper area of the settler. The bottom water that contains the settled sludge is then drained to waste at the end of the cycle.

This system operates on a batch concept, whereby a batch of water with sufficient flocculation chemicals is left for a set time, e.g. 4 hours, to settle.

b. <u>Dissolved Air Flotation</u>

An alternative to the combination of sedimentation and flocculation, especially for the removal of colour causing particles and algae is a process called dissolved air flotation. Dissolved Air Flotation (DAF) is a solid-liquid separation unit process that transfers solids to the liquid surface through attachment of fine air bubbles to solid particles.

The phenomenon of DAF consists of three processes, namely bubble generation, attachment of solids to the bubbles, and solids separation. The DAF system is actually a water tank with scrapers at the water surface level. Water flows at horizontal level where the air bubbles are formed upon the release of pressure. The air bubbles, together with flocs, float to the water surface and are removed by scrapers.

C 2.4 Filtration

The process of filtration usually forms the main treatment stage in most water treatment plants. Although there are different configurations, types of filter media and applications of filtration, the process is characterised by similar operation and maintenance aspects.

The purpose of the filters is remove the remaining turbidity in the clarified water which is required to meet the strict standards set for drinking water quality.

Three types of filters are generally used:

- Rapid gravity sand filters
- Slow sand filters
- Dual media pressure filters

Rapid gravity sand filters are preceded by flocculation and sedimentation process. The filtration rate applied is usually 5 m/h. The filters are cleaned by a backwash process. In this process the flow to the filters is reversed by passing upward through the sand. The process is aided by also passing air through nozzles in the sand. Mud, sludge carried over from the clarifier, and other impurities are removed from the sand.

The operator should monitor the following: sand depth; mud balling; cracks in the sand and filter runs. The level of sand should not be below 600 mm. The operator must also be aware of the effects of damaged nozzles and have these repaired or replaced.

Slow sand filters are used because of low maintenance, simplicity of operation and minimum supervision required. Fairly large areas are required for slow sand filter due to the slow rate of filtration (5 m/day). In this system however, the bacteriological quality of the water is enhanced by dirt layer, which forms at the surface of the sand. Again the depth of sand, turbidity and filter runs must be monitored. The level of sand should not be below 300 mm.

As the filter begins to block, the filter runs decrease and the turbidity increases. The filter is cleaned by draining the filter and allowing it to dry. The dry crust, which is a few millimetres thick, is then scraped off.

Dual media pressure filters were generally used to filter water in swimming pools but are being increasingly used in the drinking water industry. In this type of filter water is pumped under pressure through a layer of sand as well as a layer of anthracite (dual media). The filter is cleaned by backwashing the media. It is sometimes necessary to physically wash the sand as cracks may occur in the media. The turbidity and filter runs must be monitored and recorded in this process.

C 2.5 Disinfection

The previous processes dealt mainly with clarity of the water i.e. reducing turbidity. The disinfection process is used to remove bacteria and ensure that the bacteriological quality complies with the required standards. Although the water may appear clear, many bacteria and pathogens remain in the water. It is therefore essential to disinfect the water prevent the spread of waterborne diseases.

The most common form of disinfection is the use of chlorine or chlorine compounds. Chlorine is also used to eliminate taste and odours in water. Some microorganisms such as *Giardia* and *Cryptosporidium* are resistant to the effects of chlorine. Other forms of disinfection are also available: ozonation and ultra-violet light. Due to the high cost of installation and maintenance and the fact that there is no residual present, these methods have not been popular.

The operator should ensure that the water is properly disinfected at the plant and in the distribution system. The chlorine levels in the water should be measured and recorded at least once a day.

Disinfection methods of water treatment kill most of the harmful bacteria, viruses, cysts and worms found in water that can cause acute illness. Disinfection methods include chlorination, pasteurisation, ultraviolet light or UV water treatment and ozonation.

The most common, oldest and least expensive method used to disinfect water is chlorination. A chemical feed pump continuously dispenses chlorine gas into the water supply. Chlorine, is a strong oxidizing agent, kills most bacteria and some viruses. In the proper concentrations and under adequate exposure time, chlorine is an excellent disinfectant. However, it is a dangerous and potentially fatal chemical if used improperly.

Care must be taken to ensure that only clean, clear water is used. Chlorine reacts with certain metals and organic matter in the water. It is also essential to ensure that the turbidity is sufficiently reduced as high turbidities have an adverse effect on disinfection.

The major problem with this water treatment system is the potential formation of hazardous, chlorinated, organic chemicals (trihalomethanes) when the chlorine reacts with organic molecules in the water supply. Using an activated carbon filter after chlorination will remove excess chlorine and limited amounts of chlorinated chemicals formed. Chlorination may also oxidize and remove some colour and odour-causing substances including some iron and hydrogen sulphide.

The chemical feed pump requires frequent maintenance. The chemical reservoir must be kept filled and the pump checked at regular intervals for worn parts. Chlorine gas is also hazardous and may be problematic at small plants with unskilled labour.

Chlorine compounds

Chlorine dioxide disinfection
Chlorine dioxide (ClO_2) is used principally as a primary disinfectant for surface waters with odour and taste problems. It is an effective biocide at concentrations as low as 0.1 mg/L and over a wide pH range. It penetrates the bacterial cell wall and reacts with vital amino acids in the cytoplasm of the cell to kill the organisms. The by-product of this reaction is chlorite.

Chlorine dioxide disinfects according to the same principle as chlorine, however, as opposed to chlorine, chlorine dioxide has no harmful effects on human health.

Calcium hypochlorite
Hypochlorite is mixed with water applied in the same way as chlorine dioxide. Calcium hypochlorite is supplied in a powder or granular form with a chlorine concentration of between 60% and 70%. It is generally easier to handle. A disadvantage in this method is the fact that blockages occur in the pumps and piping.

Sodium hypochlorite
Sodium hypochlorite is applied in the same way as chlorine dioxide. It is supplied in a liquid form with a chlorine concentration of 12-15%. It is generally much easier to handle. A disadvantage of this method is the fact that sodium hypochlorite loses its concentration with time.

Salt chlorinator (on-site chlorine generation)
The generation of chlorine or chlorine compounds on-site is achieved by the electrolysis of a salt solution. In this process bulk common salt is supplied to a salt saturator where a 20-30% solution is produced. The solution is diluted to 3% and fed to the electrolysis cell. The process involves the application of an electrical current to a salt solution in a specially designed electrolysis cell. In the electrolysis process the salt is converted to chlorine gas or sodium hypochlorite. This is used to disinfect the water.

The main advantage is the elimination of transport, handling and costs of gas chlorine or chlorine compounds. Only a small electric current is required for the process.

Ozone disinfection
Ozone is a very strong oxidation medium, with a remarkably short life span. It consists of oxygen molecules with an extra O-atom, to form O_3. When ozone comes into contact with odour, bacteria or viruses the extra O-atom breaks them down directly, by means of oxidation. The third O-atom of the ozone molecules is then lost and only oxygen will remain.

Disinfectants can be used in various industries. Ozone is used in the pharmaceutical industry, for drinking water preparation, for treatment of process water, for preparation of ultra-pure water and for surface disinfection. The main disadvantage is cost of installation and the fact that there is no residual to eradicate secondary contamination.

Ultra violet light
Ultraviolet (UV) irradiation is effective against the chlorine resistant protozoa *Giardia* and *Cryptosporidium*. No negative by-products are formed. Ultraviolet irradiation disrupts the genetic nature (DNA) of microorganisms.

The required dose may be affected by the amount of UV light absorbed by impurities, suspended matter and dissolved organic compounds in the water. Therefore the higher the turbidity, the higher the UV dosage required. There is no easy method of measuring fluence (dosage).

UV light does not produce any residual making it ineffective against secondary contamination or the growth of other microorganisms. It is therefore advisable to follow UV with a chemical based disinfect to produce a residual.

Iodine
Iodine has been used to disinfect water for nearly a century. It has advantages over chlorine in convenience and probably efficacy; many travellers find the taste less offensive as well. It appears safe for short and intermediate length use (3-6 months), but questions remain about its safety in long-term usage. **It should not be used by persons with allergy to iodine, persons with active thyroid disease, or pregnant women.**

Note that Iodine and other halogens appear to be relatively ineffective at killing cyclospora, a troublesome diarrhoea-causing bacterium seen in Nepal only in the late spring and summer months. At these times it may be reasonable to pre-filter water to remove the large cyclospora (about the size of *Giardia* cysts), and then treating with iodine.

Bromine
Bromine is not generally used in the disinfection of drinking water in the country. Studies in the United States have indicated that during the ozonation of water containing bromine especially along coastal regions, the by-products of bromine were carcinogenic to laboratory animals.

C 2.6 Stabilisation

Before delivering water to the distribution systems it must be chemically stable. Stable water is neither corrosive nor deposit-forming in pipes and fixtures

Stabilisation is achieved by adding chemicals to water to produce *calcium carbonate precipitation potential* (CCPP) of 4 mg/L. The calculation of the CCPP is complex and can only be done by qualified chemists.

The two chemicals most commonly used for stabilisation are slaked lime ($Ca(OH)_2$) and carbon dioxide (CO_2).

- **Lime** is used to stabilise soft water (low calcium content), and water with low pH.
- **CO_2** is used to stabilise water with high pH and also to add alkalinity to water

Other chemicals include soda-ash (sodium carbonate, Na_2CO_3) and sodium hydroxide (caustic soda, NaOH).

APPENDIX D: EXTRACTS FROM THE DWA COSTING BENCHMARK

Typical Unit Costs for Water Services Development Projects: A Guide for Local Authorities *(Basic Services only)*

Department of Water Affairs, August 2009

Compiled by **PULA** strategic resource management (Pty) Ltd (Mr Arno Otterman)

Scheme Type Unit Costs

Typical Groundwater & Surface Water Scheme Costs

Capital Cost per Household(excluding fees, P&G + VAT)

Water Service	Water Supply

Capital Cost Groundwater Scheme per Household

Sum of CapCostPerHH			Scheme Size			
ComponentDescription	Element	Material	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Groundwater	Borehole Equipment	Electricity	R 1 045	R 627	R 522	R 522
		Hand Pump	R 290	R 174	R 145	R 145
	Borehole Establishment	Unconsolidated Rock	R 1 344	R 726	R 664	R 663
Water Treatment Works	Conventional	(blank)	R 2 937	R 1 003	R 784	R 663
Pump Stations	Energy Source	Electric	R 68	R 17	R 8	R 6
	Mechanical pump	Electric	R 22	R 12	R 8	R 6
	Pump pipework	Electric	R 19	R 13	R 9	R 8
	Pump switchgear	Electric	R 53	R 14	R 7	R 5
	Pumphouse building	Concrete	R 1 097	R 219	R 55	R 22
Bulk Pipeline	uPVC / HDPE	Moderate soil hardness (10% rpping)	R 2 456	R 871	R 750	R 745
Reservoir	Ground Reservoir	Concrete	R 2 120	R 1 380	R 1 348	R 877
Water Reticulation	Street tap	Moderate soil hardness (10% rpping)	R 1 220	R 1 220	R 1 220	R 1 220
	House connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
	Yard connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
Grand Total			R 12 669	R 6 277	R 5 519	R 4 881

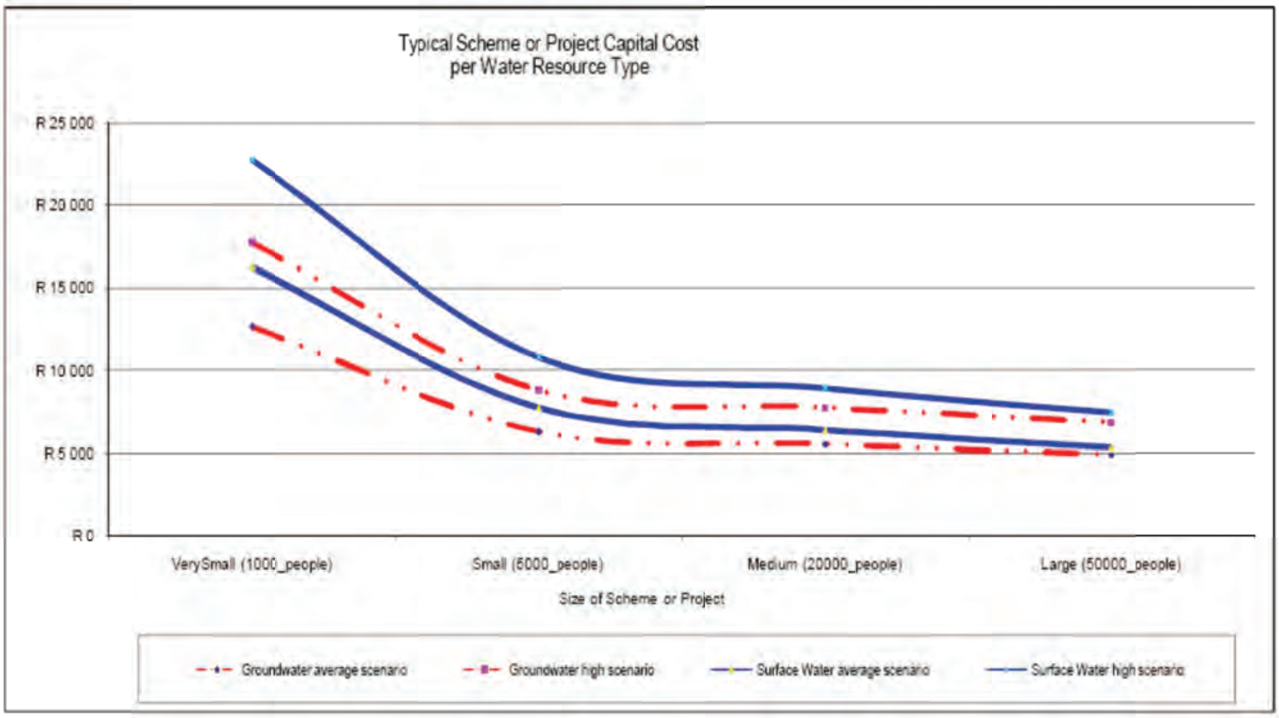
Water Service	Water Supply

Capital Cost Surface Water Scheme per Household

Sum of CapCostPerHH			Scheme Size			
ComponentDescription	Element	Material	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Surface Water	DamWall	Earthfill	R 5 215	R 2 424	R 1 792	R 1 473
	Spillway	Earthfill	R 1 059	R 541	R 375	R 290
Water Treatment Works	Conventional	(blank)	R 2 937	R 1 003	R 784	R 663
Pump Stations	Energy Source	Electric	R 68	R 17	R 8	R 6
	Mechanical pump	Electric	R 22	R 12	R 8	R 6
	Pump pipework	Electric	R 19	R 13	R 9	R 8
	Pump switchgear	Electric	R 53	R 14	R 7	R 5
	Pumphouse building	Concrete	R 1 097	R 219	R 55	R 22
Bulk Pipeline	uPVC / HDPE	Moderate soil hardness (10% rpping)	R 2 456	R 871	R 750	R 745
Reservoir	Ground Reservoir	Concrete	R 2 120	R 1 380	R 1 348	R 877
Water Reticulation	Street tap	Moderate soil hardness (10% rpping)	R 1 220	R 1 220	R 1 220	R 1 220
	House connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
	Yard connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
Grand Total			R 16 264	R 7 715	R 6 356	R 5 314

Summary of Scheme-Type Costs per Household

Scheme Type	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Groundwater	R 12 669	R 6 277	R 5 519	R 4 881
Groundwater	R 17 736	R 8 787	R 7 726	R 6 834
Surface Water	R 16 264	R 7 715	R 6 356	R 5 314
Surface Water	R 22 770	R 10 801	R 8 898	R 7 439


Typical Scheme or Project Capital Cost
per Water Resource Type
R 25 000
R 20 000
R 15 000
R 10 000
R 5 000
R 0
VerySmall (1000_people)
Small (5000_people)
Medium (20000_people)
Large (50000_people)
Size of Scheme or Project
Groundwater average scenario
Groundwater high scenario
Surface Water average scenario
Surface Water high scenario

Scheme Type Unit Costs

Typical Groundwater & Surface Water Scheme Costs

Capital Cost per Person served (excluding fees, P&G + VAT)

Water Service	Water Supply

Capital Cost Groundwater Scheme per Person

Sum of CapCostPerPerson			Scheme Size			
ComponentDescription	Element	Material	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Groundwater	Borehole Establishment	Unconsolidated Rock	R 269	R 145	R 133	R 133
	Borehole Equipment	Electricity	R 209	R 125	R 104	R 104
		Hand Pump	R 58	R 35	R 29	R 29
Water Treatment Works	Conventional	(blank)	R 587	R 201	R 157	R 133
Pump Stations	Energy Source	Electric	R 14	R 3	R 2	R 1
	Mechanical pump	Electric	R 4	R 2	R 2	R 1
	Pump pipework	Electric	R 4	R 3	R 2	R 2
	Pump switchgear	Electric	R 11	R 3	R 1	R 1
	Pumphouse building	Concrete	R 219	R 44	R 11	R 4
Bulk Pipeline	uPVC / HDPE	Moderate soil hardness (10% rpping)	R 491	R 174	R 150	R 149
Reservoir	Ground Reservoir	Concrete	R 424	R 276	R 270	R 175
Water Reticulation	Street tap	Moderate soil hardness (10% rpping)	R 244	R 244	R 244	R 244
	House connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
	Yard connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
Grand Total			R 2 534	R 1 255	R 1 104	R 976

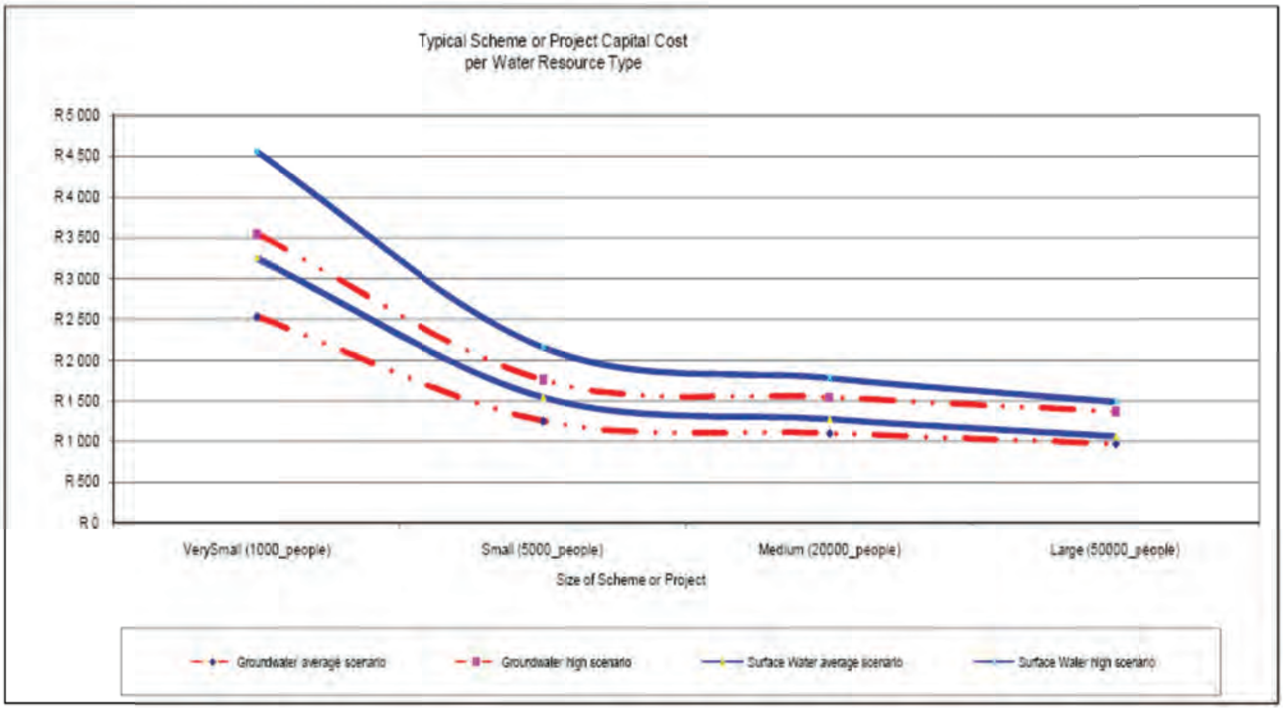
Water Service	Water Supply

Capital Cost Surface Water Scheme per Person

Sum of CapCostPerPerson			Scheme Size			
ComponentDescription	Element	Material	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Surface Water	DamWall	Earthfill	R 1 043	R 485	R 358	R 295
	Spillway	Earthfill	R 212	R 108	R 75	R 58
Water Treatment Works	Conventional	(blank)	R 587	R 201	R 157	R 133
Pump Stations	Energy Source	Electric	R 14	R 3	R 2	R 1
	Mechanical pump	Electric	R 4	R 2	R 2	R 1
	Pump pipework	Electric	R 4	R 3	R 2	R 2
	Pump switchgear	Electric	R 11	R 3	R 1	R 1
	Pumphouse building	Concrete	R 219	R 44	R 11	R 4
Bulk Pipeline	uPVC / HDPE	Moderate soil hardness (10% rpping)	R 491	R 174	R 150	R 149
Reservoir	Ground Reservoir	Concrete	R 424	R 276	R 270	R 175
Water Reticulation	Street tap	Moderate soil hardness (10% rpping)	R 244	R 244	R 244	R 244
	House connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
	Yard connection	Moderate soil hardness (10% rpping)	R 0	R 0	R 0	R 0
Grand Total			R 3 253	R 1 543	R 1 271	R 1 063

Summary of Scheme-Type Costs

Scheme Type	VerySmall (1000_people)	Small (5000_people)	Medium (20000_people)	Large (50000_people)
Groundwater	R 2 534	R 1 255	R 1 104	R 976
Groundwater	R 3 547	R 1 757	R 1 545	R 1 367
Surface Water	R 3 253	R 1 543	R 1 271	R 1 063
Surface Water	R 4 554	R 2 160	R 1 780	R 1 488



Typical Scheme or Project Capital Cost
per Water Resource Type
R 5 000
R 4 500
R 4 000
R 3 500
R 3 000
R 2 500
R 2 000
R 1 500
R 1 000
R 500
R 0
VerySmall (1000_people)
Small (5000_people)
Medium (20000_people)
Large (50000_people)
Size of Scheme or Project
Groundwater average scenario
Groundwater high scenario
Surface Water average scenario
Surface Water high scenario

Water Treatment Works

Types of Treatment Processes

Capital Cost (excl. fees, P&G + VAT)

ComponentDescription	Water Treatment Works

Average of CapCos	Scheme Size	Capacity	Capacity Unit			
	VerySmall (1000_people)	Small (5000_people)		Medium (20000_people)	Large (50000_people)	
	30	320	160	600	1600	**CAPITAL COST**
Element	kl/day	kl/day	kl/day	kl/day	kl/day	**per Scheme Size**
Package Plant	R 409 239	R 1 498 566		R 2 550 330	R 6 308 630	
Conventiona	R 587 309	R 2 006 756		R 3 137 562	R 6 634 487	
Advanced Treatment	R 1 403 670		R 1 917 690	R 3 657 450	R 7 611 450	

ComponentDescriptior	Water Treatment Works

Average of CapCostPerPerson	Scheme Size	Capacity	Capacity Unit			
	VerySmall (1000_people)	Small (5000_people)		Medium (20000_people)	Large (50000_people)	
	30	320	160	600	1600	**CAPITAL COST**
Element	kl/day	kl/day	kl/day	kl/day	kl/day	**per Person served**
Package Plant	R 409	R 150		R 128	R 126	
Conventiona	R 587	R 201		R 157	R 133	
Advanced Treatment	R 1 404		R 384	R 183	R 152	

ComponentDescriptior	Water Treatment Works

Average of CapCostPerHH	Scheme Size	Capacity	Capacity Unit			
	VerySmall (1000_people)	Small (5000_people)		Medium (20000_people)	Large (50000_people)	
	30	320	160	600	1600	**CAPITAL COST**
Element	kl/day	kl/day	kl/day	kl/day	kl/day	**per Household**
Package Plant	R 2 046	R 749		R 638	R 631	
Conventiona	R 2 937	R 1 003		R 784	R 663	
Advanced Treatment	R 7 018		R 1 918	R 914	R 761	

ComponentDescriptior	Water Treatment Works					
	1000	5000		20000	50000	
Average of MaintCostPerHH	Scheme Size	Capacity	Capacity Unit			
	VerySmall (1000_people)	Small (5000_people)		Medium (20000_people)	Large (50000_people)	
	30	320	160	600	1600	**MAINTENANCE:**
Element	kl/day	kl/day	kl/day	kl/day	kl/day	**Cost per annum**
Package Plant	R 184	R 67		R 57	R 57	**per Household**
Conventiona	R 206	R 70		R 55	R 46	
Advanced Treatment	R 702		R 192	R 91	R 76	

ComponentDescriptior	Water Treatment Works					
Average of OperCostPerHH	Scheme Size	Capacity	Capacity Unit			
	VerySmall (1000_people)	Small (5000_people)		Medium (20000_people)	Large (50000_people)	
	30	320	160	600	1600	**OPERATION :**
Element	kl/day	kl/day	kl/day	kl/day	kl/day	**Cost per annum**
Package Plant	R 383	R 156		R 113	R 81	**per Household**
Conventiona	R 347	R 141		R 102	R 73	
Advanced Treatment	R 998		R 762	R 548	R 481	

TYPICAL PROFESSIONAL FEES

CAPITAL COST	< R 600 000	R 600 000 to R 2 mil	R 2 mil to R 10 mil	R 10 mil to R 500 mil
Planning Fees	13%	11%	7%	5%
Design Fees	12,5%	10%	7,5%	7,5%
Contract Management	4%	3%	2%	2%
Construction Supervision	10%	9%	7%	4%
Training & Capacity Building Fees	10%	7%	4%	2%

TYPICAL P&G'S

CAPITAL COST	< R600 000	R 600 000 to R2 mil	R2 mil to R10 mil	R10 mil to R500 mil
PRELIMANARY + GENERAL				
Dam	30%			14%
GW development	18%	→	→	5%
Pump Station	20%	→	→	12%
Treatment Works	25%	→	→	15%
Bulk Pipelines + Reticulation	15%	→	→	5%
Power Supply	25%	→	→	15%

OTHER COSTS & TAXES

Land Acquisition:	grazing	R 3 000	per hectare		
	cultivated land	R 7 000	per hectare		
Relocation cost:	Site specific	R 25 000	up to	R 95 000	per dwelling
Establishment of access to site (Rand per km):	Track	R 25 000	to	R 100 000	per km
	Gravel road	R 100 000	to	R 300 000	per km
	Paved road	R 300 000	to	R 600 000	per km
Scheme transfer cost to local authorities:		8%	to	15%	of capital for small projects
		5%	to	8%	of capital for large schemes
Allowance for O&M start-up:		7%	to	10%	of capital
Allowance for Security in crime areas:		2%	to	4%	of capital
Cost escalation due to remoteness from economic centers :		10%	to	15%	of capital
VAT		14%	of total cost		

Factors Affecting Costs		Surface water	Ground - water	Pump stations: Surface	Pump stations: Bore hole	Water treatment	Bulk pipeline	Reser-voir	Reticulation
Project size definitions	Small	<10 mil. m^3	1-3 boreholes	<50kW	1-3 boreholes		contract		<1500 People
	Medium	10-40 mil. m^3	3-10 boreholes	50-150kW	3-10 boreholes		contract		1500-5000 People
	Large	>40 mil. m^3	>10 boreholes	>150kW	>10 boreholes		contract		>5000 People
Project size	Small	+10%	+30%	+5%	0		+5%		+5%
	Medium	0	0	0	-5%		0		0
	Large	-10%	-15%	+3%	-8%		-3%		-3%
Remoteness Location Distance from economic centre	Near (<50km)	-2%	0	0	0	0	0	0	0
	Distant (50-100km)	0	+8%	+5%	+5%	+5%	+10%	+3%	+10%
	Remote (>100km)	+1%							
	Remote (>200km)		+12%	+10%	+10%	+10%	+15%	+8%	+15%
Topography	Flat (<1% slope)			0	0	0	0	0	+2%
	Sloped (1-5% slope)			+2%	+2%	+2%	0	+2%	0
	Steep (>5% slope)			+5%	+5%	+5%	+5%	+5%	+5%
Access	None existing	+5%	+50%	+5%	+10%	+5%		+5%	
	Track existing	+12%	0	+2%	0	+2%		+2%	
	Gravel road existing	0	0	0	0	0		0	
	Paved road existing	0	0	0	0	0		0	
Clearing	Savannah (Sparse)	0					0		
	Bush	+1%					+2%		
	Trees	+2%					+5%		
Availability of contractor	High (Under quoting)	-2%	-10%	-5%	-5%	-2%	-10%	-10%	-5%
	Medium (Competitive)	0	0	0	0	0	0	0	0
	Low (Low availability)	+5%	+10%	+15%	+10%	+5%	+15%	+15%	+10%
Security	Rudimentary (Little vandalism)	0		0	0	0		0	
	Standard (Some vandalism)	0		+3%	0	+3%		+1%	
	Sophisticated (high vandalism)	+1%		+10%	+15%	+5%		+3%	
Geology	Soft						0		0
	Intermediate						30%		30%
	Hard rock						60%		60%
Land acquisition & servitudes	Public area			0		0	0	0	
	Agricultural land			+1%		+1%	+1%	+1%	
	Build-up area			+2%		+3%	+4%	+2%	

How to Use Cost Influencing Factors

The Unit Costs listed in previous chapters of this document, represent the average circumstances and not all site specific situations.

The above Cost Influencing Factors can be used to refine costs to specified site conditions. The Factors Affecting Costs are the main cost influencing factors. They may not be applicable to each and every infrastructure type and therefore are only listed where applicable.

The figures listed are generic escalations for key of the aspects influencing the costs of the respective infrastructure component. Note that the figures give a lower limit, average (mostly=0; no escalation) and a higher limit. Subject to the extent of the specific factor, it may be better to use figure in-between these figures.

The escalation (percentages) must be added to 1 (100%) before multiplying it with the published unit cost. If more than one factor is chosen for a specific infrastructure component, the calculation is made as follows:

Adjusted Unit Cost = Unit Cost x (1 + [factor1+factor2+factor3+factor4])

Life Expectancy

COMPONENT	Life Expectancy (years)		
	WRC 897/1/01	DWAF	Recommended
buildings	50-100	30	70
line reservoirs	20	30	50
service reservoirs	50-80	50	50
WTW -civil	60-70	30-50	60
WTW -mechanical & electrical	15-25	15 small, 30 large	25
pump station -civil	60-70	30-50	60
pump station -mechanical & electrical	25	15 small, 30 large	25
bulk pipelines	65-95	30-50	50
reticulation		30-50	30
telemetry	10		10

Maintenance

COMPONENT	Annual maintenance cost as % of Replacement Value		
	low	high	recommended
boreholes	7.00%	10.00%	7.00%
diesel	8.00%	10.00%	8.00%
electric	4.00%	6.00%	4.00%
solar	4.00%	6.00%	4.00%
wind	6.00%	8.00%	6.00%
hand	8.00%	15.00%	8.00%
dams	0.10%	0.25%	0.25%
buildings	0.25%	0.50%	0.50%
roads & bridges	0.50%	0.75%	0.75%
line reservoirs	0.25%	2.00%	1.00%
service reservoirs	0.25%	2.00%	1.00%
WTW -civil	0.25%	1.00%	0.50%
WTW -mechanical & electrical	4.00%	7.00%	4.00%
pump station -civil	0.25%	1.00%	0.50%
pump station -mechanical & electrical	1.50%	4.00%	4.00%
bulk pipelines	0.10%	0.50%	0.50%
reticulation	1.00%	3.00%	2.00%

The following listing contains selected assumptions and constant values selected for the calculation of unit cost (from DWA Benchmark, 2009).

Component	Description of Selected Assumptions and Constants Used	Value	Units
Groundwater	Assume that handpumps can be installed on all production bh		
Groundwater	No of BH per 1500 people in poor GW Prospects	6	number of boreholes
Groundwater	No of BH per 2500 people in good GW Prospects	3	number of boreholes
Groundwater	No of BH per 2000 people in average GW Prospects	2	number of boreholes
Surface water	River Slope	1.5%	%
Surface water	Freeboard height	1.5	m
Surface water	Capacity-Yield ratio (e.g. 3xMAR)	2%	%
Surface water	Land acquisition (typically 5% of wall cost) & relocation of people (can vary from 20% to >100% of wall cost)	5%	% of damwall cost
Surface water	Basin clearing & access road (% of capital wall cost)	8%	% of damwall cost
Pumpstations	Typical area per pump set	6.00	m^2
Pumpstations	Typical building cost per square meter floor area : cage	800	R/m^2
Pumpstations	Typical building cost per square meter floor area : prefab	1500	R/m^2
Pumpstations	Typical building cost per square meter floor area : brick	2800	R/m^2
Pumpstations	Typical building cost per square meter floor area : concrete	3500	R/m^2
Pumpstations	Pump Hour Electrical	12	hr/day
Pumpstations	Pump Hour Diesel	8	hr/day
Pumpstations	Pump Hour Solar	6	hr/day
Pumpstations	Specified "low" pump head	90	m
Pumpstations	Specified "high" pump head	150	m
Pumpstations	Electric Motor Efficiency	90%	eff
Pumpstations	Diesel Motor Efficiency	70%	eff
Pumpstations	Solar Motor Efficiency	80%	eff
Pumpstations	No of Pump Sets with Standby (perPS)	2	No
Pumpstations	No of Pump Stations (repetitive booster)	1	number of pump stations
Bulk Pipeline	Cost escalation for Excavation with 10% ripping	1.3	% escalation
Bulk Pipeline	Cost Escalation for Excavation with 15% ripping & 5% blasting	1.6	%escalation
Reticulation	Specified service level mix		
Reticulation	Percentage Below RDP	0%	%
Reticulation	Percentage Street tap	100%	%
Reticulation	Percentage Yard Tanks	0%	%
Reticulation	Percentage Kitch Con	0%	%
Reticulation	Percentage House Con	0%	%
Reticulation	Average Water Use per Service Level		
Reticulation	Avg Use Street tap	25	L/c/d
Reticulation	Avg Use Yard Tanks	80	L/c/d
Reticulation	Avg Use Kitch Con	120	L/c/d
Reticulation	Avg Use House Con	250	L/c/d
Reticulation	Typical Bulk Water Supply Losses		
Reticulation	Bulk Losses Street tap	12%	%
Reticulation	Bulk Losses Yard Tanks	10%	%
Reticulation	Bulk Losses Kitch Con	8%	%
Reticulation	Bulk Losses House Con	7%	%
Reticulation	Typical Reticulation Water Supply Losses		
Reticulation	Reticulation Losses Street tap	15%	%
Reticulation	Reticulation Losses Yard Tanks	12%	%
Reticulation	Reticulation Losses Kitch Con	10%	%
Reticulation	Reticulation Losses House Con	10%	%