LIFE CYCLE COSTING ANALYSES

FOR PIPELINE DESIGN

AND

SUPPORTING SOFTWARE

By

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AQUA Hydraulic Utilities software and updates can be downloaded from the following websites:

http://www.wrc.org or http://www.sinotechcc.co.za

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EXECUTIVE SUMMARY

The geographically mismatch of the water demand centres and the water resources necessitate the transport of water over long distances and high elevation differences. On average water is transported about 350 km in South Africa (Basson, Van Niekerk & Van Rooyen, 1997). High energy costs and the increasing demand require that the water transfer infrastructure should function optimally. Since the 1930's various researchers contributed to the identification and development of factors and relationships to quantify the energy loss in pipelines, which led by 1958 to the development of pressures, head losses and discharge relationships (Chadwick and Morfett, 1999) for the design and evaluation of pipes and pipe systems.

There are various factors that influence the hydraulic capacity and pipeline designers need to take all of these into consideration during the design. For instance the estimation of roughness parameter for a pipeline has a significant effect on the hydraulic capacity and operational costs. An underestimation of this parameter can be catastrophic when the required demand cannot be met.

Life Cycle Costing Analyses of pipeline systems

In the current economic setting more than ever, cost estimation is one of the most important aspects of the design engineer. The Life Cycle Cost (LCC) of an asset is defined as the present value of the total cost of that asset over its operating life, including initial capital cost, operating and maintenance cost, energy cost and the cost or benefit of the eventual disposal of the asset (New South Wales DPWS Report, 2001). Life Cycle Costing Analysis techniques take into account the total costs that the project will impose upon the client during the whole of its life.

The objectives of life cycle costing are: to enable investment options to be more effectively evaluated, to consider the impact of all costs rather than only the initial capital costs, to perform a sensitivity analysis and to assist the effective management of the completed project.

This report is a simple guide to Life Cycle Costing Analysis, limited to the design/analyses of bulk pipelines and emanated from research funded by the Water Research Commission (WRC) entitled "*Review of factors that influence the energy loss in pipelines and procedures to evaluate the hydraulic performance for different internal conditions*".

During this study existing software was adapted that could assist designers in evaluating a pipeline system over its full life cycle. In other words the factors affecting the operational efficiency and functionality of a pipeline can now be analysed over the full life cycle of the pipeline. One of the governing issues during the planning and implementation stages of a pipeline, or a distribution network, is the selection of the most appropriate pipe material for the specific operational and field conditions. During the planning stage it becomes tedious to analyse all the different alternatives and to compare them on a sound and equal basis.

To assist the planner/designer in the evaluation process existing software that performs life cycle costing was adapted for this purpose and is called ***AQUA Hydraulic Utilities*** (see **Figures i** and **ii**). The program determines the life-cycle cost by calculating the Nett Present Value (NPV) and the Internal Rate of Return (IRR) for the different pipeline system alternatives.

A Step-by-step guide utilizing two examples, a gravity system and a pumping system, was also developed that demonstrates the calculations as performed in ***AQUA Hydraulic Utilities***. In this guide the different life cycle cost elements are introduced to the design engineer and it is indicated how these cost elements will effect the final decision.

Websites for downloading software and updates:
http://www.wrc.org or http://www.sinotechcc.co.za

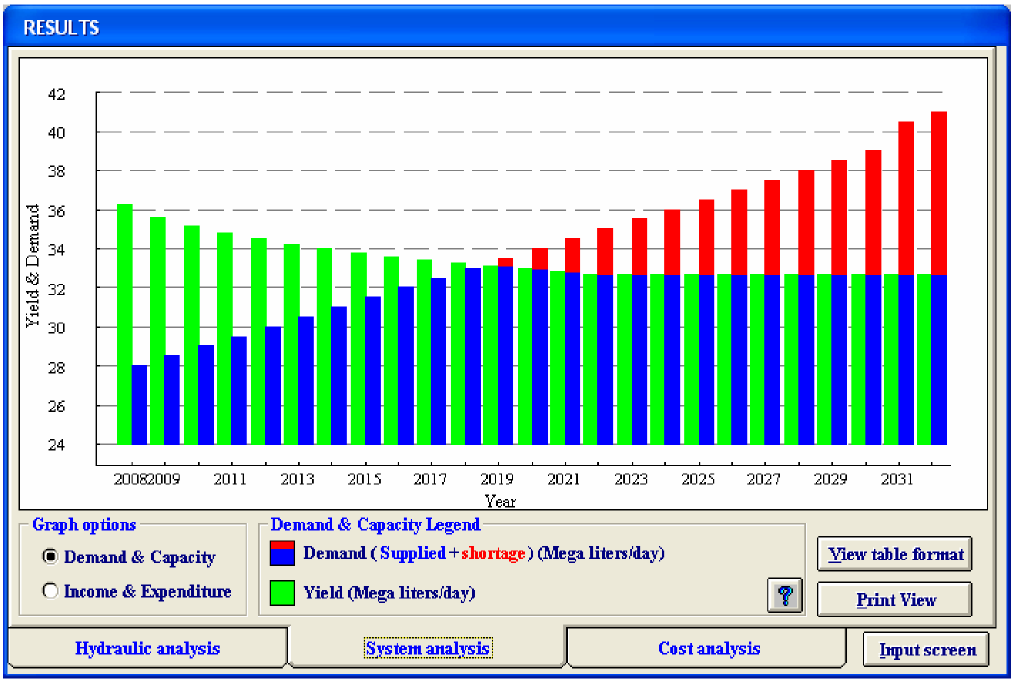

Figure i: System analysis - Demand and capacity results screen

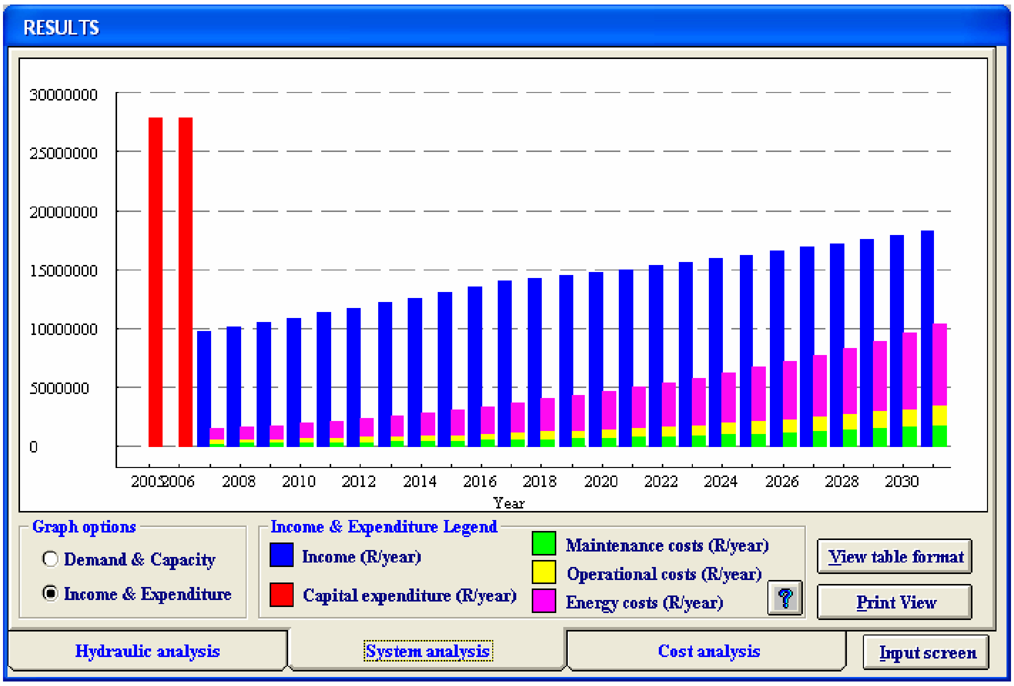

Figure ii: System analysis - Income and expenditure

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The Steering Committee and Project Team responsible for this study consisted of the following persons:

Mr JN Bhagwan	:	Water Research Commission – Chairman
Mr PJ le Roux	:	GMKS/SASTT
Ms MS Woest	:	Eskom Enterprises, TSI
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This study was made possible with the co-operation of many individuals and institutions. The authors therefore wish to record their sincere thanks to them.

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GLOSSARY OF TERMS

Capital Costs	-	Expenditures that typically result in the construction of a fixed asset that has a useful life of over one year.
Cost Breakdown Structure (CBS)	-	The CBS is a schematic tree shaped structure, in which all the costs and eventual benefits of the system are represented and the interdependence and timing is reflected. In other words it organizes the various components of life cycle costs and indicate their inter dependability (Veefkind, M, 2002).
Discount rate	-	The interest rate used to discount future cash flow to their present values. This represents the rate of return that could have been obtained by investing in a project with risks comparable to the project being considered.
Interest	-	The charge or cost of borrowing money, measured in terms of a percentage per annum of the principal amount.

Internal Rate of Return (IRR)	-	The discount rate at which the Nett Present Value of income and expenditure on a project are equal, thus the nett cash flow is equal to zero.
Life Cycle Costing (LCC)	-	A method in which costs are identified with an asset throughout its entire life cycle. This includes planning, design, acquisition and support costs and other costs directly attributed to owning the asset (New South Wales DPWS Report, 2001).
Net Present Value (NPV)	-	The present value of the future net revenues of an investment less the investment's current and future cost. An investment is profitable if the NPV of the net revenues it generates in the future exceeds its costs, in other words if the NPV is positive. (Income = + and Expenses = -)
Operating Costs	-	Costs that are directly related to rendering of services. The operation cost has a fixed and a variable component. The variable component is proportional to the goods delivered. The collection of revenues and other ongoing activities to keep it operational.
Payback period	-	The time required for an investment to generate enough net income or savings to cover the initial capital layout of the investment.
Escalation rate	-	The rate at which prices/costs increase (inflation)

1 INTRODUCTION

One of the governing issues during the planning and implementation stages of a pipeline, or a distribution network, is the selection of the most appropriate pipe material for the specific operational and field conditions. The governing parameters that influence the life cycle cost of a pipeline are:

- the cost of capital
- realisation of the demand
- diameter required to provide the hydraulic capacity (different wall roughness of the different pipe materials)
- system pressures
- external installation conditions and loadings
- water quality and potential reaction with the pipe material or internal coating
- cathodic protection of the system (stray currents etc.)
- maintenance requirements and upgrading costs including the escalation of different maintenance cost components
- operational costs and the escalation of operational cost
- the ease of replacement (minimising the time of the interrupted supply)

During the planning stages it becomes tedious to analyse all the different alternatives and to compare them on a sound and equal basis. Regardless of the type or system that will be implemented (number of pumps, pipe material, phasing of the construction etc.) the realisation of the demand up to the design capacity of the pipeline can be taken as a constant and hence discarded for a specified capacity. To assist the planner/designer in the evaluation process software that performs life cycle costing was developed called ***AQUA Hydraulic Utilities***. The program determines the life-cycle cost by calculating the Nett Present Value (NPV) and the Internal Rate of Return (IRR) for the different alternatives.

1.1 What is Life Cycle Costing Analysis?

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.

LCCA has its roots in the 1960s, when scientists concerned about the rapid depletion of fossil fuels developed it as an approach to understand the impacts of energy consumption (Svoboda, 1995). Since then it has been applied successfully in various fields for the financial evaluation of products and projects.

LCCA is a key analytical tool used by engineers in the development, production and through-life support of material systems. The technique is based on the common sense 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 pipeline. A complete life cycle cost analysis should include all of the costs and benefits that result from the construction of a pipeline, both the direct and indirect financial impacts.

The aim of this chapter is to demonstrate how LCCA can assist to obtain a quick and easy method of determining what the real "best alternative" is for a given pipeline systems (gravity or pumping).

Although other components like the end storage (reservoirs) play an important role in the components sizing and operation, this aspect was not included in this investigation. It is accepted that the pumping capacity is sufficient to be able to provide the demand in the available pumping hours and that the end reservoir has the capacity to supply the demand pattern that may occur.

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 unbiased assumptions, which produce fair comparisons of alternate designs (NCSPA, 2002). Engineering/economical assumptions such as project design life; pipe roughness, deterioration rate, discount rate, escalation rate and inflation should be made.

1.2 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). Although there are a number of commercially available models that may be used for LCCA, it was decided to include a model specifically for the evaluation of pipelines.

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.

It was decided that the LCCA model used in the ***AQUA Hydraulic Analysis*** package should be clear and user friendly, allowing the user to understand the calculation procedures that are used. A LCCA cost breakdown structure (CBS) was used that supports and highlights the LCCA process. The CBS allows the control and facilitates decision making according to a set criteria.

2 COST COMPONENTS INCLUDED IN LIFE CYCLE COSTING ANALYSIS

2.1 Time stream of costs and income

Development professionals should respond to owners needs and demands in a financially sound way. The designer today requires a methodology to analyse the initial project capital cost, energy consumption, and operational and maintenance cost. The life cycle approach is concerned with the time stream of costs and income that flows throughout the life of a project, **Figure 1**.

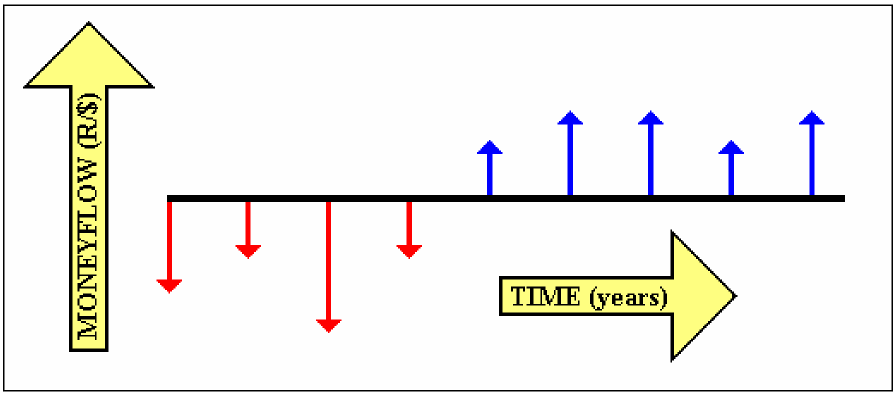

Figure 1: Cash flow diagram (Veefkind, 2002)

The cash flow diagram is obtained from the systems CBS (Veefkind, 2002). The cash flow stream will be different for each of the alternatives that will be analysed. LCCA is usually performed to enable the comparison of alternative systems and/or to evaluate an investment decision. To enable the comparing of alternatives the time cash stream (costs and income) as shown in **Figure 1**, are discounted back to present worth values in a base year.

The Life Cycle Costing Analysis (LCCA) requires the determination of the capital, operating, maintenance and energy costs applicable throughout the life cycle of the pipeline and pump station. These components of the life cycle are discussed in more detail in the paragraphs below.

It is impossible to accurately predict all the costs involved during the life cycle of a pipeline, and hence a sensitivity analysis is required especially on the major cost components.

2.2 Capital cost

Capital cost for a pipeline has two main components:

- Material cost
- Construction cost

When the capital cost is determined it is important to include all the costs that are associated with the production, construction and testing of the pipeline. It is important to include all the major costs and identify the grey areas where uncertainty exists, for example estimating the rock excavations without a detailed soil analysis.

Usually the major costs for a pipeline include:

- Pipeline material cost
- Excavation cost
- Laying of pipeline
- Valve chambers
- Mechanical equipment such as valves
- Testing

2.3 Operational cost

During the design life of the pipeline, there will be associated operating costs. An example of this is for instance when the pipeline requires cathodic protection. On a monthly basis there will be electricity costs attributed with the energy used. Administrative and financial personal will be required to keep the pipeline operational. The operational costs are usually small compared to the capital, maintenance and energy costs but should nevertheless be included in the life cycle cost of the pipeline.

2.4 Maintenance cost

Once the pipeline has been completed it should be maintained. Typical maintenance cost for a pipeline will be 0,4% of the capital cost of the pipeline and 2,5 to 4% on the electrical and mechanical capital cost. In South Africa this is usually one of those budgets hardly spent and insufficient. Maintenance is often only done when a problem arises or when there is nothing else to do. By keeping the pipeline properly maintained its life is increased.

2.5 Energy cost

The water sources in South Africa are in most cases not close to the end users. Water frequently has to be pumped over great distances and high elevations. When attempting to optimise a pipeline design, energy costs thus plays a predominant role.

Although it can also be seen as an operating cost, it was identified as a separate component since its escalation rate can be different and it can be a major cost component. This energy cost is only applicable to pumping systems.

2.6 Residual value

In most cases pipelines are buried under ground and thus are usually disposed of/taken out of service by leaving them where they are. When a new pipeline is installed on the same route as an existing pipeline it is commonly installed parallel to the existing one. This allows for the construction of the new pipeline while the old pipeline is still operational. The older one is hardly ever taken apart or removed from the ground. The resilient value of a pipeline system is thus in most cases negligible.

3 INTEREST RATES USED IN THE LCCA

In order to be able to evaluate any system all the relevant costs that have an influence should be calculated. The following equation as defined by the Hydraulic Institute (2002), reflects components that will influence the monetary value in a specific year:

$$C_j = C_{cj} + C_{mj} + C_{oj} + C_{ej} + C_{ij} \qquad \text{. . . (1)}$$

Where: C_j	=	Monetary value (positive or negative) for a specific year
C_{cj}	=	Capital cost for a specific year
C_{mj}	=	Maintenance cost for a specific year
C_{oj}	=	Operational cost for a specific year
C_{ej}	=	Energy cost for a specific year
C_{ij}	=	Income from water sales for a specific year
j	=	Specific life cycle year

C_{cj} - Capital cost

This is the initial cost of the system. Smaller pipes can be used resulting in lower initial cost, but resulting in higher pump heads and thus higher energy costs. The initial cost includes the plan, design and construct of the water supply system.

C_{mj} - Maintenance cost

To sustain an optimum working system, regular and efficient servicing of the system is required. The maintenance cost component usually escalates as the system ages.

C_{oj} - Operational cost

In order to operate the pipeline system various personnel provide an input into its daily operating thereof. In other words to keep the pipeline system operational requires man hours with several other expenses such as transport, electricity etc. Manpower entities and consumables are needed to run and operate the system.

C_{ej} - Energy cost

Energy consumption can be one of the larger cost components in pumping systems and may dominate the expenses of the LCCA. The energy cost is derived from the pumping hours and energy charge rates. Smaller diameters will result in higher pumping heads and thus higher power consumption, pushing up the energy cost.

C_{ij} - Income

The supplied water is sold at a certain tariff to consumers. Annually the tariff might increase and thus the annual income increases. The yield from the system can however reduce due to the deterioration of the pipe.

The estimated or calculated costs for the various components constitute the expenditures/income for each year in the life cycle of the system. In order to compare alternatives these costs for each year should be brought back to present values.

4 METHODS OF COMPARING ALTERNATIVES

To be able to compare alternatives over the life cycle it is required to compare the Time-Value of Money (Grant, Ireson, Leavenworth, 1990). The nett present value (NPV) and the internal rate of return (IRR) methods are normally used to provide an economical/financial ranking of different alternatives.

4.1 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 nett 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 (Equation 6.2) with which the future values are discounted back to present day values is shown below:

$$P = \frac{F}{(1+i)^n} \qquad \text{. . . (2)}$$

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

4.2 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 (IIEC, 2002). 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 nett 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

5 SENSITIVITY ANALYSIS

Sensitivity analysis is a test of the outcome of an appraisal based on alternative values of one or more variable parameters about which there is uncertainty; for example, a change in the design period or the discount rate.

Before finally selecting an investment project, it is sometimes desirable to test its economic feasibility based on alternative values of key parameters uncertain in the future, e.g., expected life of the building, energy price escalation rate, and discount rate. It is also important to know the value or range of values of parameters that affect the LCC analysis. This can be done by recomputing the LCC for minimum and maximum values of the parameters in question, (Rakhra, 1980). This informs the decision-maker of the consequences associated with uncertainties in the data.

As described by Rakhra (1980), the LCC analysis requires the following steps:

- Specify the objectives and constraints of the analysis.
- Identify options to achieve the objectives.
- Specify various assumptions regarding discount rate, inflation rate, economic life, etc.
- Identify and estimate relevant costs.
- Convert all costs into constant monetary values and to a common base (present value).
- Compare the total life cycle costs for each option and select the one with the minimum total costs.
- Analyse the results for sensitivity to the initial assumptions.

6 COST COMPONENTS APPLICABLE TO PIPELINE SYSTEMS

6.1 Introduction

Pipeline systems can either be gravity system 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.

To perform a LCCA the applicable component's costs needs to be identified and as accurately as possible quantified. The costs components of the two systems are described in the paragraphs below:

6.2 Cost components for a gravity system

The cost components of a gravity system consist of:

Capital cost

- 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 cost

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

Operational cost

- 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 costs and running the telemetry system are also included under operational cost.

6.3 Cost components for a pumping system

A pumping system has all of the above costs as described for a gravity system. Only the additional costs are described below:

Capital cost

- Construction of pump station building with pumps, valves, pipe work, motors, switchboards and electrical supply.

Energy cost

- The energy cost is taken as a separate cost although sometimes included under operating cost. The energy cost is the energy input at the pumps and is dependent on the energy tariff structure, number of pumping hours during the year, efficiency of pumps, pumping head and volume of water pumped. This cost escalates during the life span of the system and can be a very important cost component when comparing alternatives.

7 ROUGHNESS PARAMETER CALCULATION/CALIBRATION

During the design or rehabilitation of a pipeline system an extremely important design component is the roughness parameter. Designers use different friction loss formulae to calculate the losses in a system for a specific demand. The assumed roughness parameter also differs and has a significant influence on the actual demand. The increase in the roughness parameter over the design life period of the pipeline also plays an important role.

The calculations to perform a calibration and sensitivity analysis of these parameters were included in the ***AQUA Hydraulic Utilities*** program. With this software program the effect of the different friction formulae can be calculated and compared. The program also allows the back-calculation of the roughness parameters based on measured losses between different points on the system and the flow rate.

In the next section the principles that have been discussed have been incorporated in a computer utility program called ***AQUA Hydraulic Utilities***.

8 AQUA HYDRAULIC UTILITIES

The software was developed to provide a quick and easy way to perform life cycle analysis on pipelines.

8.1 Installing the Program

To install AQUA Hydraulic Utilities program:

Insert distribution CD in the CD-drive and follow the automatic instructions the user is instructed from here on by the installation program

or:

The user can also install AQUA Hydraulic Utilities through windows program manager.

The installation program creates the directory specified by the user and then copies the necessary files to this directory. The following files should be in the selected directory:

User Directory\AQUAHU.exe
\Readme.txt
\AQUAHU.hlp
\St6unst.log
\Projects\Example 1 (Gravity system).ahu
\Projects\Example 2 (Pumping system).ahu
\Documents\Step-by-step guide for LCCA of pipelines.pdf

AQUA Hydraulic Utilities runs on any personal computer, but requires Windows N.T., Windows 2000 or Windows 95/98/ME/XP, as it is a 32-bit application. The program takes up approximately 12 MB of hard disk space, requires 64 Mb of RAM and a pointing device (mouse) is a helpful tool.

8.2 Screens

The program's help file provides the user with explanations on all the required input data to perform the life cycle costing analysis and the roughness parameter analysis. In the paragraphs below a number of program screen images are presented. It is recommended that the "Step-by-step guide for LCA of pipelines" be read in conjunction with the software's help functions to obtain a better understanding of the use of the program.

8.2.1 Input screens

The program has two pipeline system options, gravity or pumping.

Figure 2: System type selection

Once the system type selection was made all the relevant system data should be entered. This is done on one screen that has three or four "tabs" at the bottom of the screen, see **Figures 3** to **6**.

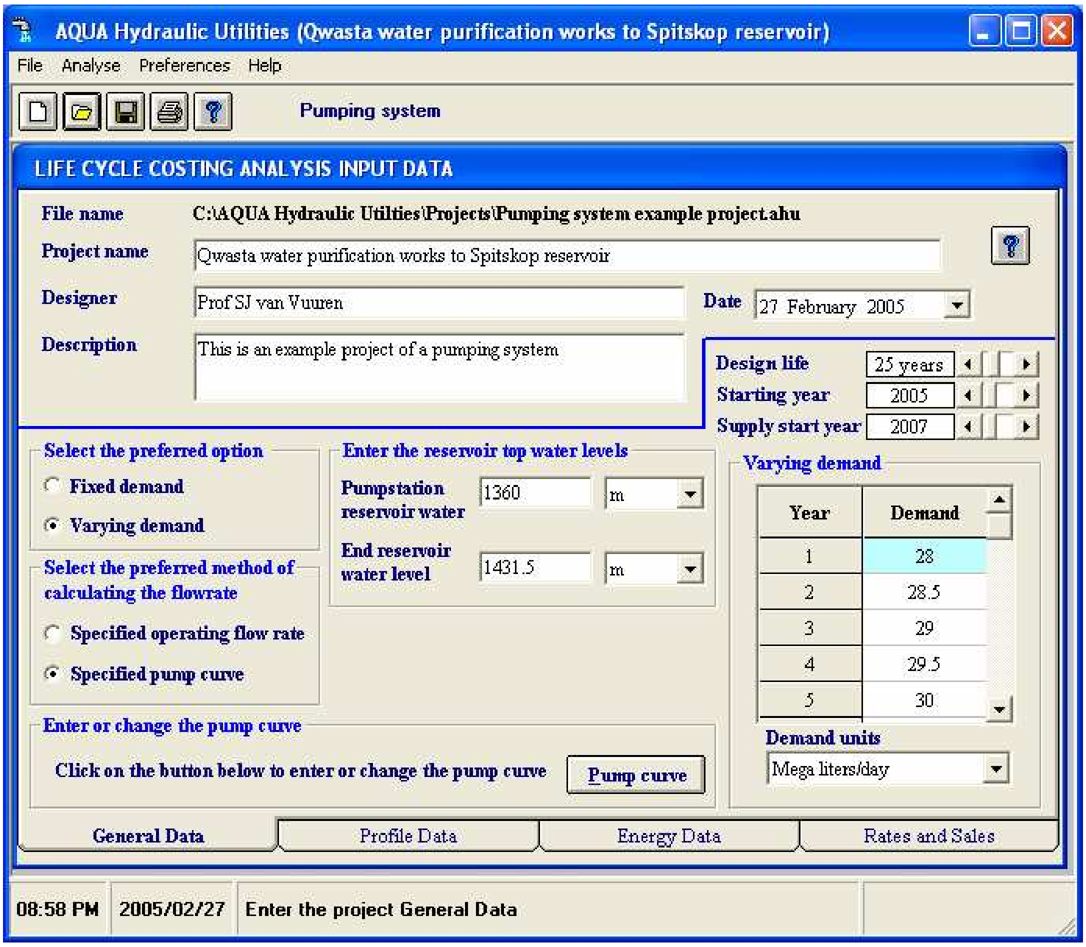

Figure 3: General data

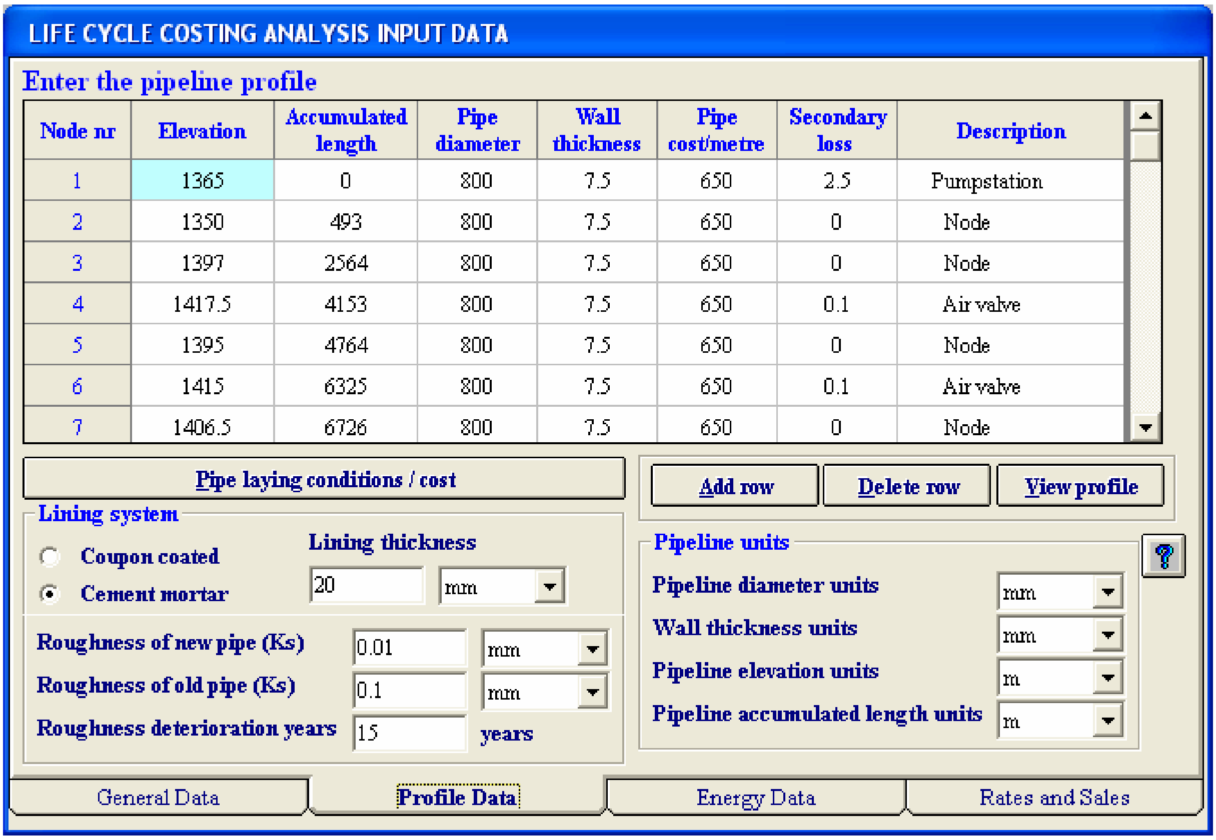

Figure 4: Profile data

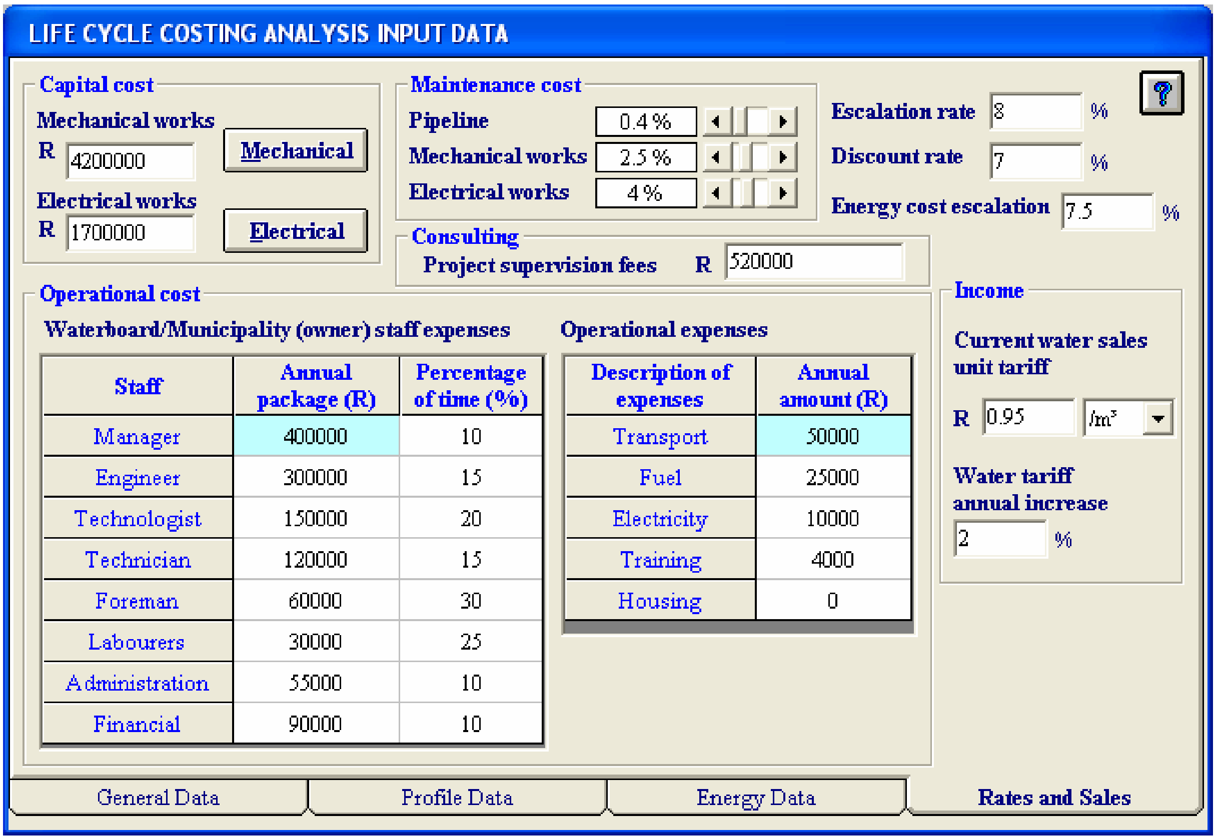

Figure 5: Rates and Sales data

In the case of a pumping system a fourth tab, energy data, is shown.

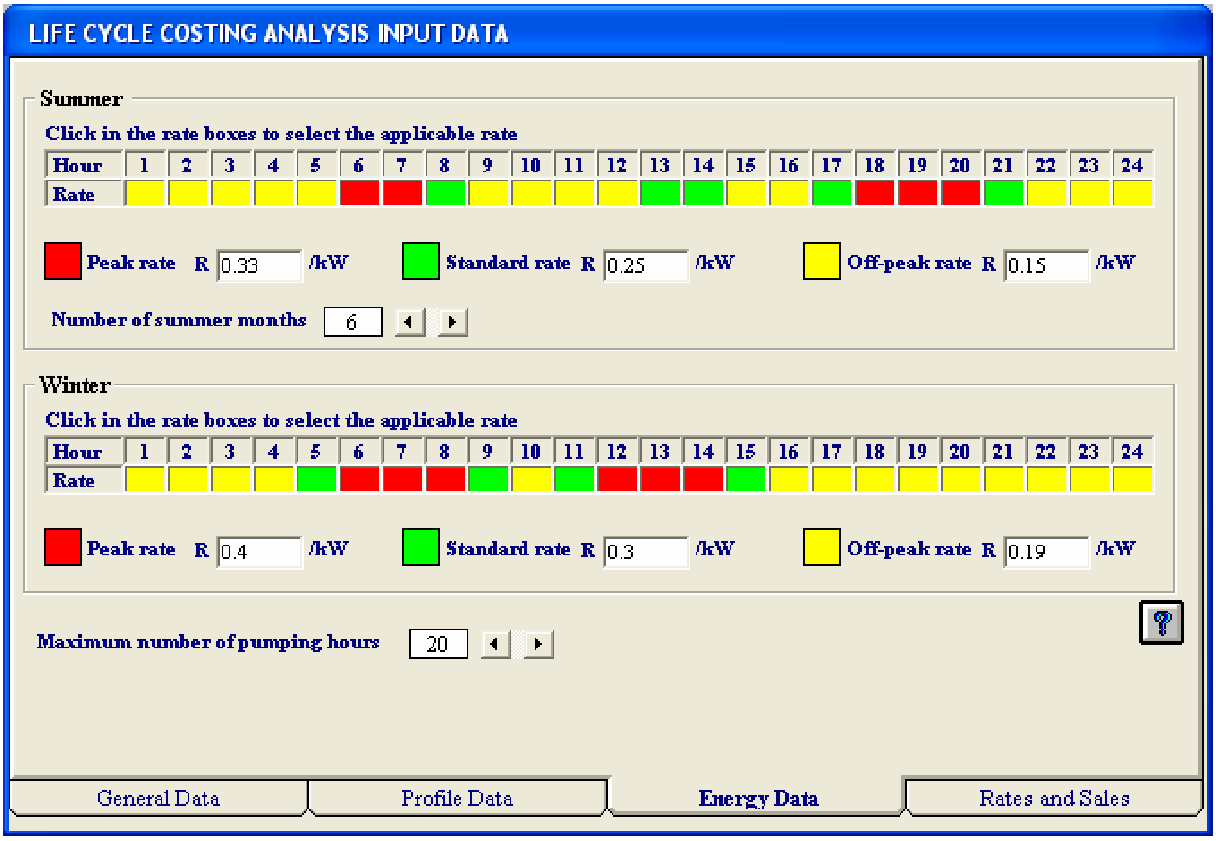

Figure 6: Energy data

On the profile data screen tab the user also has the option to view the entered pipeline profile see **Figure 7**.

Figure 7: Viewing the pipeline profile

The additional feature that allows the user to perform a calibration of the roughness parameter is activated on this screen. Up to five scenarios can be analysed where different measured pressures can be entered and the roughness parameter back calculated for a specific flow rate, see **Figure 8**. This can then also be plotted on the pipeline profile graph (**Figure 9**).

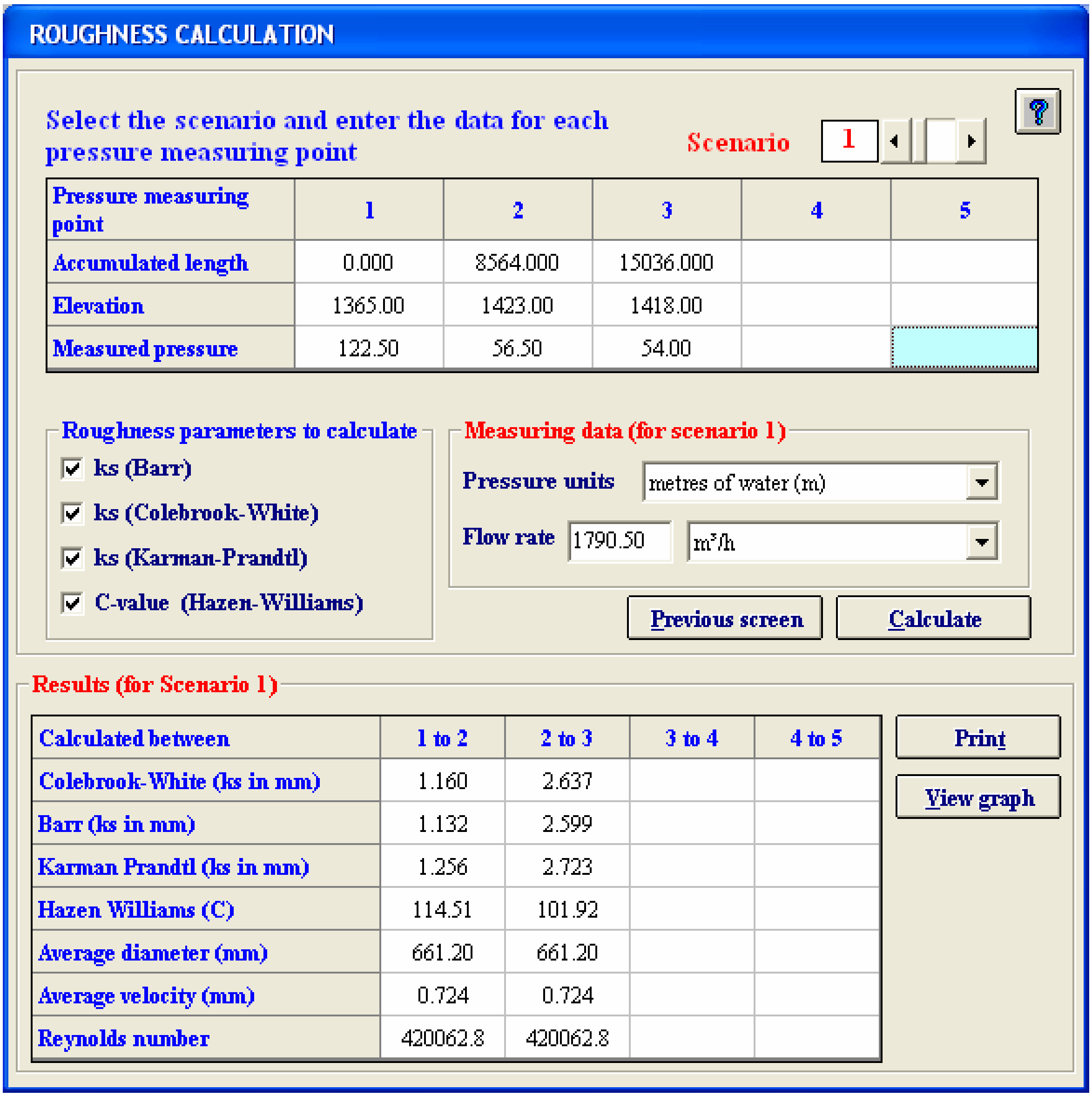

Figure 8: Calculation of roughness parameter

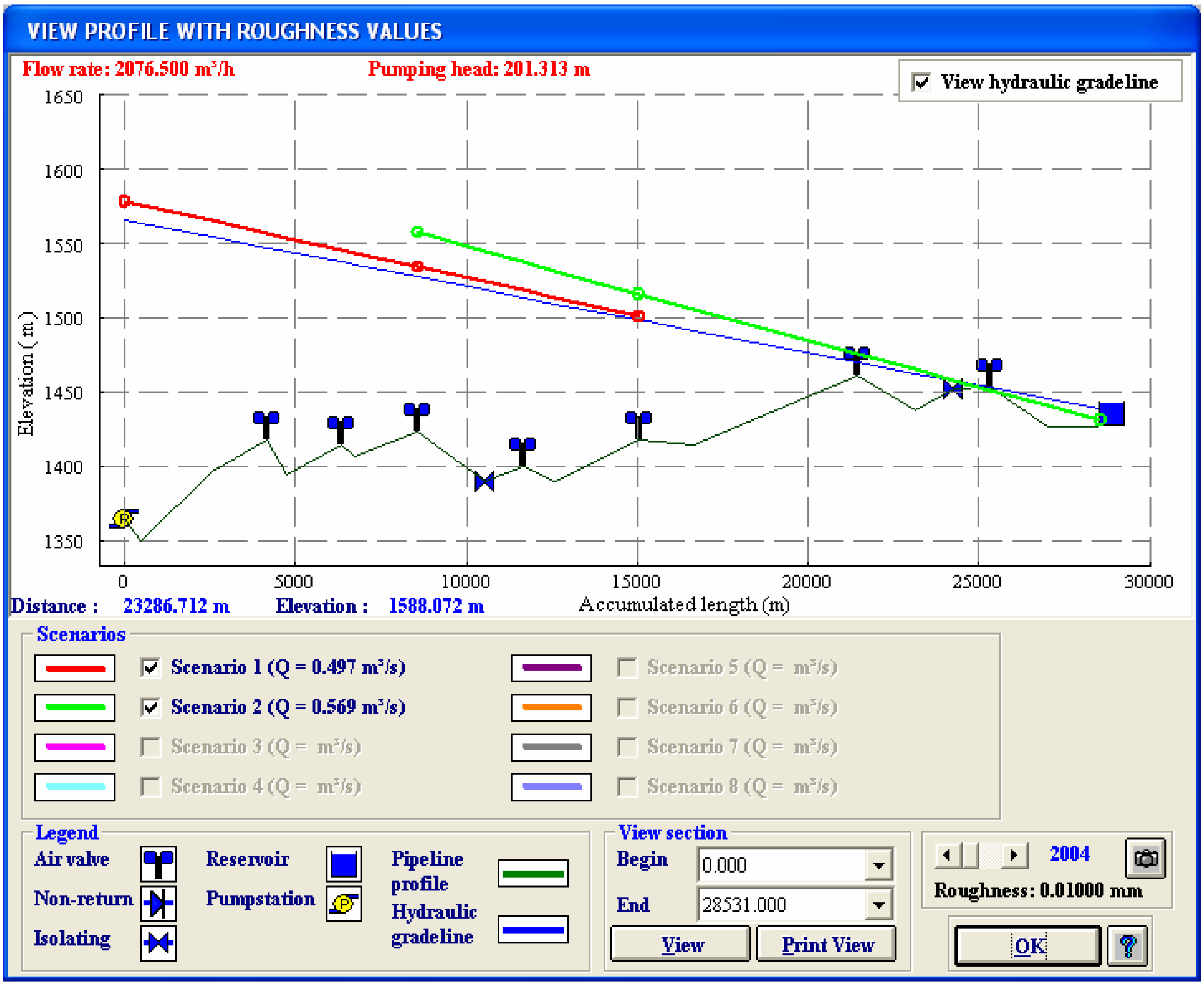

Figure 9: Plotting of scenario hydraulic gradelines on pipeline profile

Once all the input data are entered as shown the Life Cycle Costing Analysis can be performed.

8.2.2 Analysis Screen

The program will check that all the entered data are correct and then show the Analysis screen (**Figure 10**).

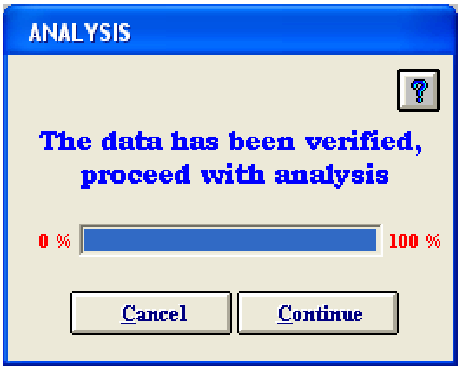

Figure 10: Analysis screen

Once the analysis was successfully executed the user can click on the *Continue* button. The program will draw all the graphical plots and show all the calculated tables as indicated in the next paragraph.

8.2.3 Results Screens

The Results screen consists of a number of tabs with the determined results.

- Hydraulic analysis
- System analysis
- Cost analysis

With these results the user can determine the "total cost" of the designed system.

The first result shown is the hydraulic analysis of the system over the design life period thereof, see **Figure 11**. The hydraulic gradeline for the system is plotted on the pipeline profile for the entered or calculated flow rate.

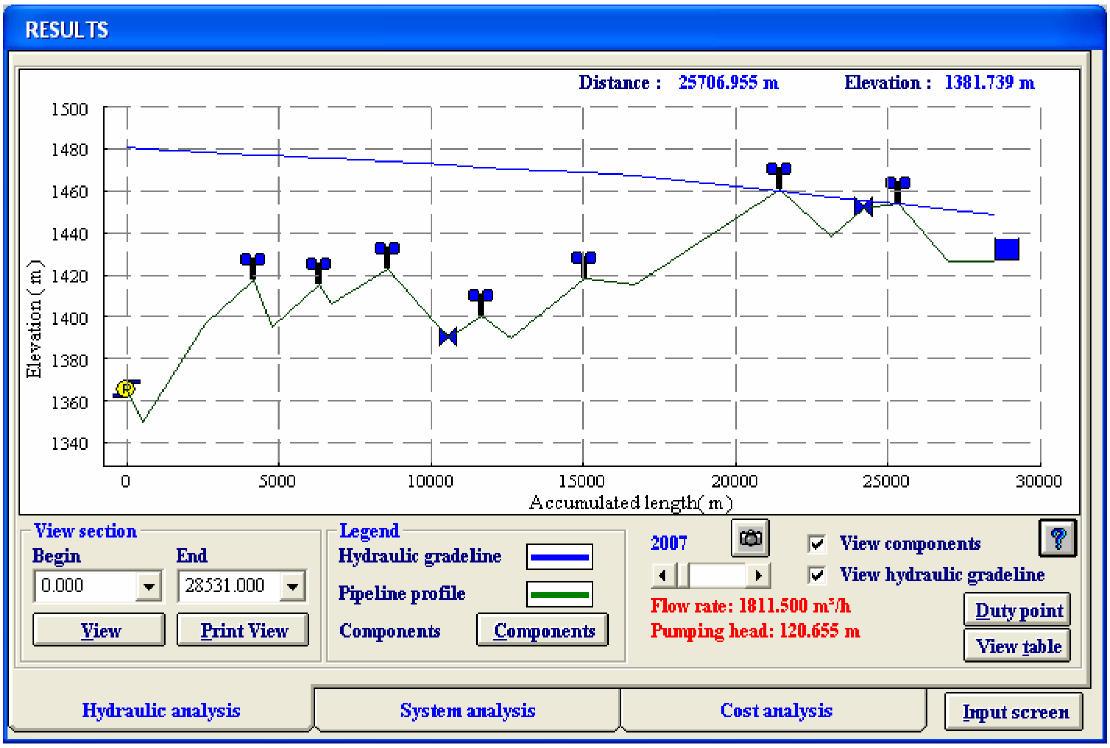

Figure 11: Hydraulic analysis results screen

The system analysis results, is one of the tabs showing the calculated demands and yields (**Figure 12**) as well as the income & expenditure (**Figure 13**) through the design life period. These calculated values are shown on graphs and in table format.

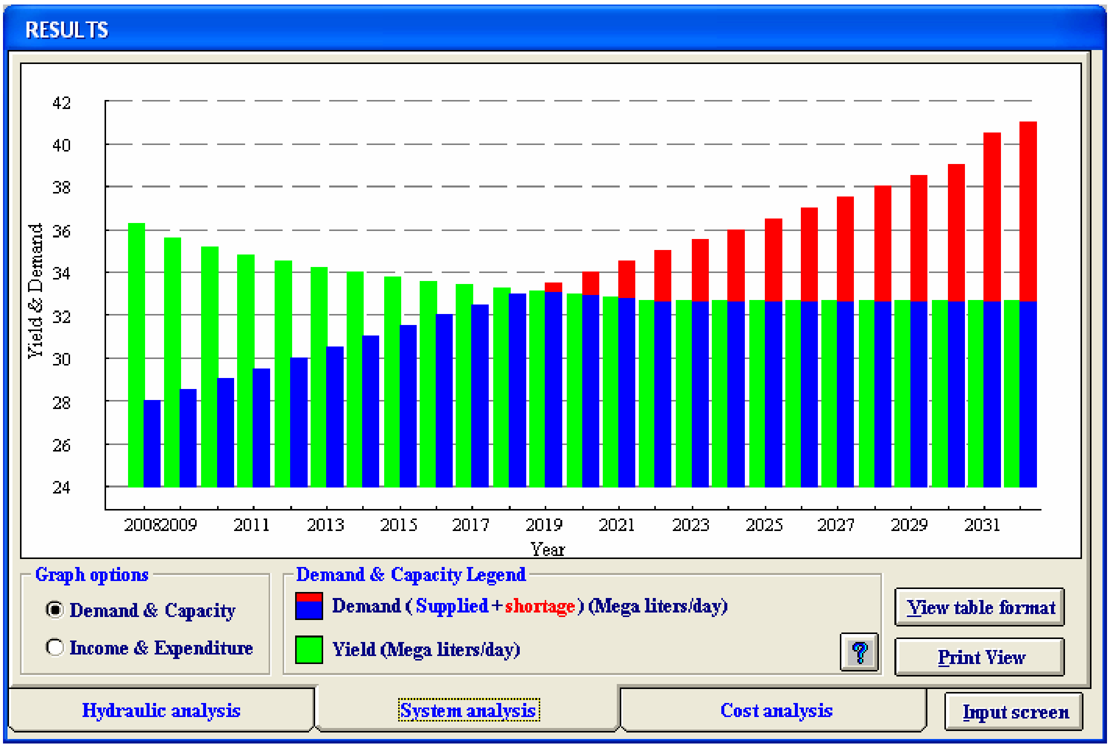

Figure 12: System analysis - Demand and capacity results screen

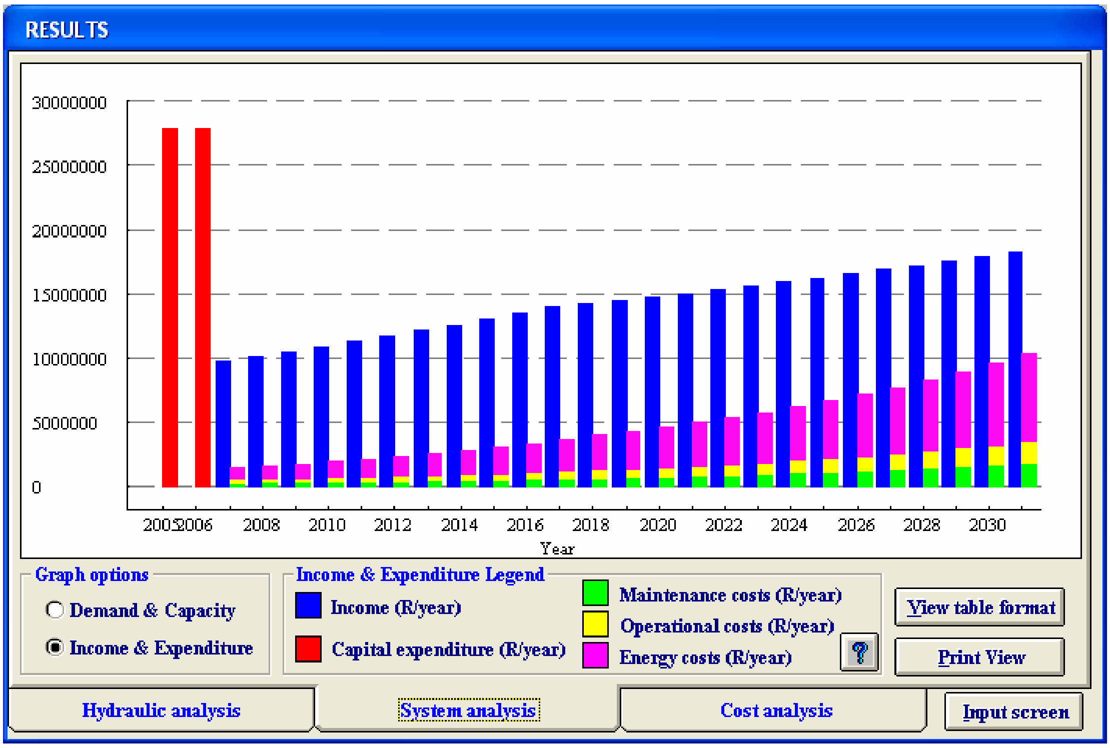

Figure 12: System analysis - Income and expenditure

The cost analysis is one of the tabs showing the calculated capital cost as well as the other associated expenditures throughout the life cycle such as energy, maintenance and operational costs. This summarizes the costs of the project and this can now be compared with other alternatives, see **Figure 13**. The nett present value of the income as well as the expenditure is shown. The internal rate of return is calculated and a graph thereof can be viewed by clicking on the *View IRR* button.

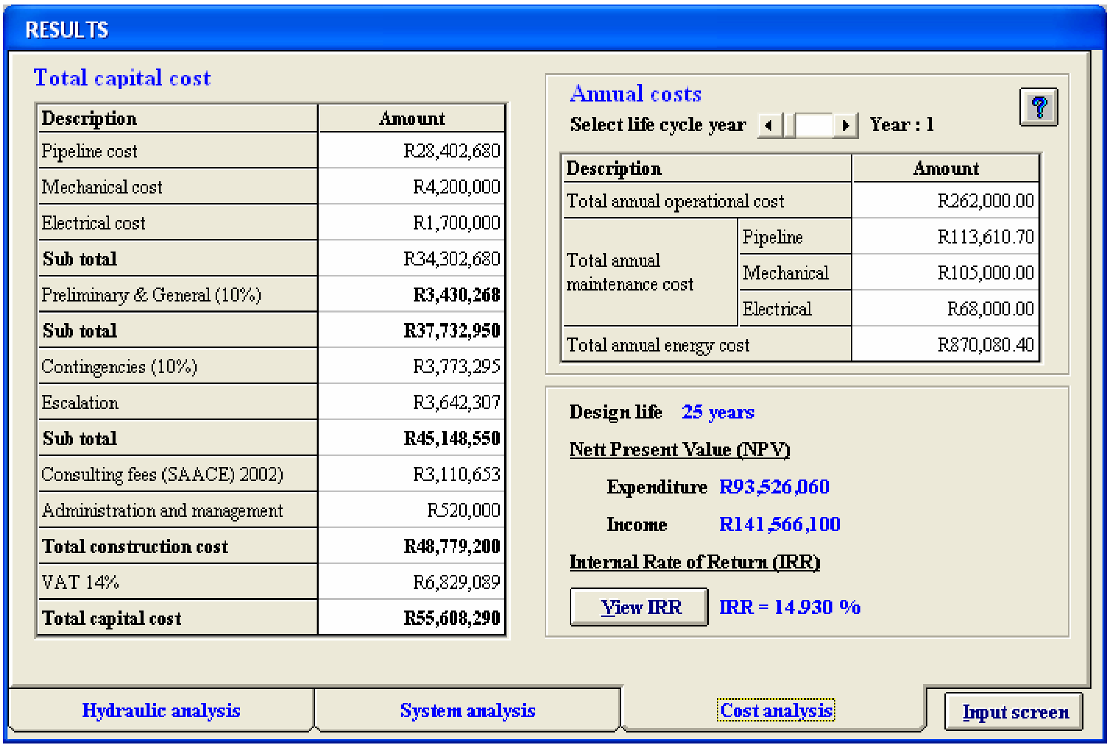

Figure 14: Cost analysis results screen

8.2.4 Other Screens

There are a number of other screens that will assist the user in performing the life cycle costing analysis. These are the option of importing data from a spreadsheet type application (**Figure 16**), setting user preferences (**Figure 15**), printing input data and result (**Figure 17**) etcetera.

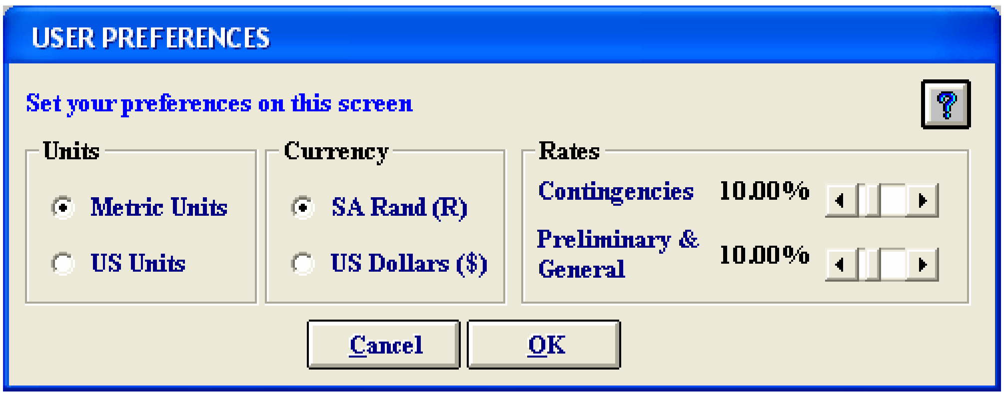

Figure 15: Setting the user preferences

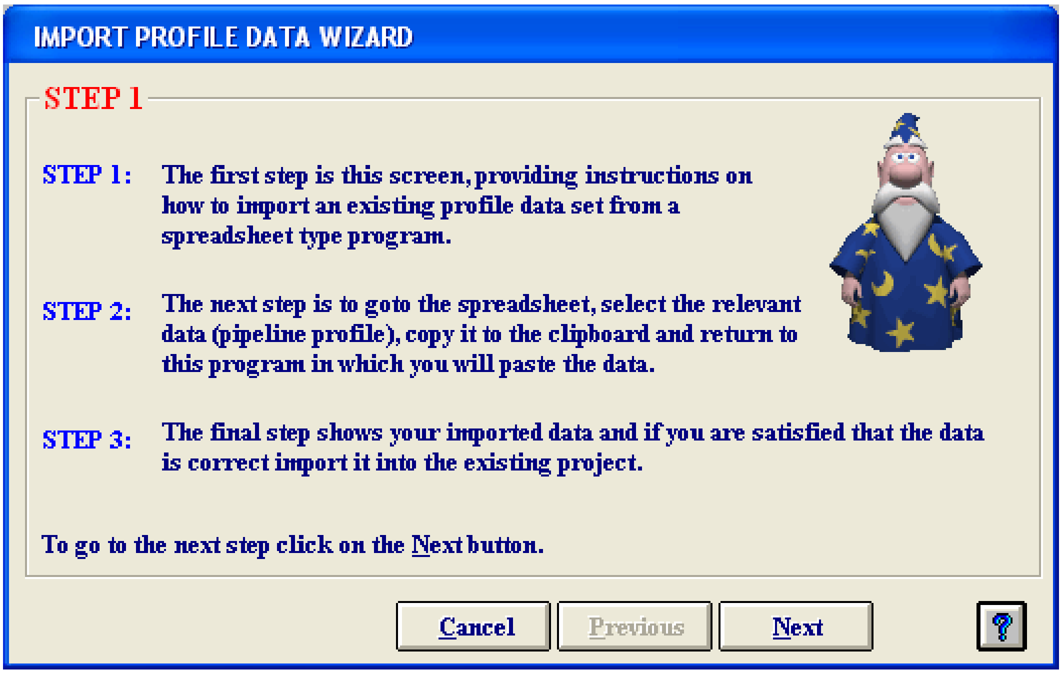

Figure 16: Import profile data wizard

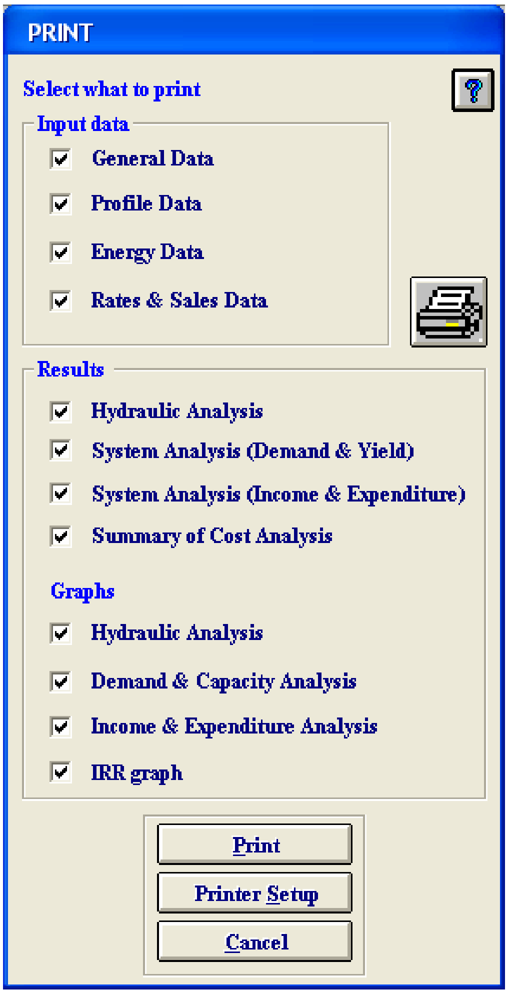

Figure 17: Printing the analysis

9 CONCLUSION

The ***AQUA Hydraulic Utilities*** program provides the engineer or designer with a tool to ensure that the design is the most economical solution for the complete design life of the system.

The program requires the user to enter the demands, design life, pipeline profile, pipeline characteristics, laying details, rates and costs. The program will determine the initial capital requirements, the annual maintenance and operational costs and in the case of a pumping system, the energy costs. The program provides a graphical representation of these costs, as well as the hydraulic capacity of the ageing system. Tables with all the calculated results are also shown with the capability to export these to other Windows applications.

The Help Section of the developed software also contains a *Step-by-step hand calculation* of the Life Cycle Costing Analysis procedure detailing all the calculations needed to evaluate a system over its entire design life.

The web sites for downloading the software and where updates will be posted are:
http://www.wrc.org
http://www.sinotechcc.co.za

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