DECISION SUPPORT SYSTEM FOR THE DEVELOPMENT OF RURAL WATER SUPPLY SCHEMES

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WRC Report No. 837/1/01

Water Research Commission

DECISION SUPPORT SYSTEM FOR THE DEVELOPMENT OF RURAL WATER SUPPLY SCHEMES

Report to the
WATER RESEARCH COMMISSION

by

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WRC Project No 837/1/01
ISBN 1 86845 709 5

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ACKNOWLEDGMENTS

A special thanks must go to the WRC Research Manager for this project Mr Kevin Pietersen as well as to his predecessor, Mr Tony Reynders who regrettably passed away between the conception and implementation phases of the project. Dr George Green of the WRC must also be thanked for his positive contributions and support.

Many of the contents of the component files of the RWS-DSS have been adapted from previous work contained in WRC Report No. 677/1/98. The contributions of the authors of this report, Karim Sami and Ricky Murray, are acknowledged.

The Project Steering Committee have made positive contributions throughout and thanks therefore go to:

Mr B Taylor, CSIR
Mr WE Bertram, DWAF, Directorate of Geohydrology
Mr C Siebert, Development Bank of Southern Africa
Mr P Ravenscroft, Maluti Water
Dr M Shand, Ninham Shand
Mr CJ Haupt, Water Systems Management
Prof JM. van Bever-Donker, Dept. of Earth Sciences, University of the Western Cape
Dr A Shaker, National Community Water Supply and Sanitation Training Institute
Mrs B. Pretorius, DWAF, Directorate of Water Services

The Rural Water Supply Decision Support System is being actively supported by the Department of Water Affairs and Forestry (DWAF). Particular thanks go to the Regional Director for the Eastern Cape, Mr Trevor Balzer (DWAF, King Williams Town), and his staff Ms Tandeka Mbassa, Ms Lerato Mokoena, Mr Rogers Jack, Ms Therese Kollman, Mr Uli Glatz (seconded to DWAF, KWT, from Ninham Shand) and Mr Greg Forsyth (seconded from the CSIR), as well as Ms Kerry Harris (ISD, DWAF, Pretoria), Mr Ernst Bertram (DWAF, Pretoria) and Mr Mike Smart (DWAF, Cape Town).

We are also grateful for the positive feedback, interactions and data we have been provided with from industry. Particular thanks go to Mr Giert Nel (WSA), Mr Ross Henderson (Stewart Scott), Mr Johann Rademeyer (Hippo Drilling), Mr Peter Drake (API Pumps), Mr Rob Bell (Monopumps & Borehole Water Association of South Africa), Mr Victor Horne (previously of KwaZulu/Natal Joint Services Board), Mr Ian Geldert and Mr Colin Murphy (Main Industries), Mr Jamie De Jaeger (Mvula Trust), Mr Phillip Ravenscroft (Maluti Water), Ms Julia Cain (Mattcom), Mr Malcolm White (Rural Development Services Network) and Mr Jeff Jolly (Groundwater Consulting Services).

Placement masters hydrogeology student Mr Arjen Naafs, from the Netherlands, must be thanked for the contributions he made to field and computer testing of the groundwater methods.

Emphatic thanks must also be extended to university colleagues who, throughout the project period, have consistently offered support, encouragement and feedback and who include Mrs Glynn Armstrong, Mr Evan Dollar, Ms Nikki Motteux, Dr Winston Leukes, Mrs Juanita McLean and Ms Deidre Watkins.

EXECUTIVE SUMMARY

The report represents the final documentation of WRC project K5/837, 'Guidelines for the Development of Rural Water Supply Schemes - Further Development of a Decision Support System' which was a continuation of a previous project that concluded with WRC Report 677/1/98 by Sami and Murray. The original project ('Guidelines for the Evaluation and Development of Water Resources for Rural Development with an Emphasis on Groundwater') was designed to integrate many of the perceived issues related to the development of rural water supply schemes and to develop some new approaches to assessing groundwater resources and their potential for exploitation within relatively small scale rural water supply schemes. The project reported on here was designed to establish a computer based Decision Support System (DSS) and to populate it with the information and approaches outlined in the earlier report. The primary objectives of the project were :

- ❑ To setup and develop the Delphi shell DSS for application to any subject requiring interactive decision-making computer support.
- ❑ To create and develop the Rural Water Supply DSS for use within a Windows application.
- ❑ To promote the use of the RWS-DSS for planning and evaluating future rural water supply projects.

Supporting objectives were :

- ❑ To fill in more detail related to some issues than was possible during the first project.
- ❑ To test the applicability of the DSS using established and new rural water supply schemes.
- ❑ To test the usefulness of the DSS as a training tool for enhancing the awareness of various practitioners in he field of the many issues influencing the success or failure of rural water supply schemes.
- ❑ To hold workshops to present the DSS to established practitioners and obtain feedback on its advantages and disadvantages.

The project was designed to begin in January 1997 and to be led by the authors of the first report. However, the start was delayed due to a change in project personnel, a situation that also contributed to a slower start than was originally envisaged as this meant that the new project leader had to spend time becoming familiar with the approach adopted in the first project, as well as the contents of the report. During the course of the project, the approaches used by the Department of Water Affairs and Forestry (and others) in the design and implementation of rural water supply schemes were also being radically revised, in keeping with the social and political changes that were occurring in post- Apartheid South Africa. This meant that many of the institutional issues related to rural water supply only started to be properly defined during the project. The difficulties of developing the content of the DSS under such dynamically changing conditions needs to be stressed. A further point is that, on reflection it was not a very good idea to develop the generic DSS computer code at the same time as establishing the content of the specific Rural Water Supply DSS. Corrections to the code and associated procedures for entering the RWS information meant that old ground had to be re-covered quite frequently, slowing down the rate at which further information could be added, or existing information content tested. Despite all these problems, the project has succeeded in developing a satisfactory DSS shell, transferring the information contained within the original report (WRC Report No. 677/1/98) to the DSS, adding more up-to-date information and approaches, as well as addressing some of the objectives related to testing and training. There do, however, remain a number of issues associated with further technology transfer and the assessment of the system for solving practical problems that the project has been unable to address. The project team, in cooperation with the WRC and the Project Steering Committee are making every effort to deal with these problems as part of the post-project technology transfer actions.

The report is divided into five sections so that readers with different levels of interest can easily find the relevant parts. The first section (A: Project Context) reports on the background to the project, lists the original objectives and potential benefits, as well as providing a non-technical summary to the project as a whole. It also contains the details of any tests of the developed system that have been carried out, technology transfer actions that have taken place, as well as the main conclusions and recommendations for future work.

The second section (B: User Guide: Rural Water Supply Decision Support System - RWS-DSS) represents a guide to the use of the rural water supply DSS that has been developed. This section provides an overview of the DSS and a guide to its use, rather than being a complete reproduction of the content of the DSS itself, much of which was already covered by the earlier report (WRC Report No. 677/1/98). The objective of this section is to provide a hard copy framework that should assist the potential user in the application of RWS-DSS and which highlights some of the issues that users should be aware of. Section B is designed in the format of a supplementary manual to accompany the guidelines contained in WRC Report No. 677/1/98. Wherever that report has been updated by additional material more detail is provided within this text. Sections B4 to B11 are written to guide the RWS-DSS software user through the various components and sub-components contained within the computer program and to lead the user to the more detailed step-by-step guidelines built directly into the RWS-DSS computer program itself. The respective sections are presented in the recommended order suggested for application in a decision support environment for rural water supply and the user is encouraged to adopt the approach presented in this step-by-step sequence.

The third section (C: DSS Shell System) explains the approach used in the design of the generic DSS Shell (written in Delphi code) and is designed as a manual for those users who might be in a position to further develop the RWS-DSS system, or who might wish to apply the shell to a different problem. It provides the full technical details about how to establish the text files that populate the DSS Shell with information, numerical inputs, calculations and flow control, etc. for a specific DSS.

The fourth section (D: RWS-DSS Structure and Contents) lists (in a structured way) all the components of RWS-DSS and includes cross references to the text input files that deal with those components. This section can be used to obtain an overview of the content of the system, as well as directing a future developer (i.e. someone who may wish to update the system) to the relevant text input files. The content of this section can be used with a utility program (DSSViewer) to access the detail of the system design interactively.

The fifth section (E: Glossary of Terms) provides a glossary of the terms used within the report and has been included to ensure that there is as little confusion or misunderstanding as possible, given that different disciplines (and even different individuals within the same discipline) often use different terminology for the same thing.

The RWS-DSS computer program has been based on rural water supply project planning and implementation in the context of the South African Reconstruction and Development Programme. The computer program is generic in content but designed to encourage the user to consider all factors affecting rural water supply provision, bring together information and implement technically and economically appropriate rural water supply systems which are socially acceptable. The initial target user group can be broadly defined as personnel or institutions working on projects implemented by the Department of Water Affairs and Forestry (DWAF) within South Africa. However, it is likely that the system could also be of value to rural water supply developers in other parts of Southern Africa where the issues and problems are broadly similar.

The main recommendation is that the system should now be put to use, thoroughly tested and modified where necessary to ensure that it realises its potential for the solution of real problems. This means that it has to move away from the research environment of a University and into the practical environment of a government department or private consultant. One of the post-project tasks of the project team, with the cooperation of the WRC, is to find suitable custodian organisations for the system who have the resources to fulfill this role.

ABBREVIATIONS and ACRONYMS used in RWS-DSS

a	Annum
ADWD	Average Daily Water Demand
Al	Aluminium
As	Arsenic
avge	Average
BOD	Biological Oxygen Demand
C	Centigrade
Ca	Calcium
Cd	Cadmium
Cl	Chloride
CCWR	Computing Centre for Water Research
CDT	Constant Discharge Test
cm^2	Square centimetres
CSIR	Centre for Scientific & Industrial Research
d	Day
dd/mm/yy	Day/month/year
DFID	Department for International Development (previously the British Overseas Development Administration).
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DSS	Decision Support System
D-to-B	Distance-to-Boundary method
DD-to-B	Drawdown-ro-Boundary method
DWAF	Department of Water Affairs & Forestry
EC	Electrical conductivity
E.coli	Faecal coliform
EIA	Environmental Impact Assessment
EM	Electromagnetic
F	Fluoride
FDM	Frequency Domain Method
Fe	Iron
GF/C	Fine filter paper
GPS	Global Positioning System
GWD	Garden Irrigation Water Demand
Hg	Mercury
hr/d	Hours per day
HWD	Household Water Demand
IWD	Institutional Water Demand
IWQS	Institute for Water Quality Studies
IWR	Institutue for Water Research
K	Potassium
km	Kilometres
km^2	Square kilometres
Late-T	Late-Time method
l/c/d	Litres per capita per day
l/d	Litres per day

l/hr	Litres per hour
l/min	Litres per minute
l/s	Litres per second
m/a	Metres per annum
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbc	Metres below borehole collar height
mbgl	Metres below ground level
m^3/a	Cubic metres per annum
m^3/d	Cubic metres per day
m^3/hr	Cubic metres per hour
m^3/mth	Cubic metres per month
MDWD	Maximum Daily Water Demand
Mg	Magnesium
mg/l	Milligrammes per litre
ML	Millilitres
mm	Millimetres
mm/a	Millimetres per annum
mMSL	Metres above mean sea level
Mn	Manganese
mS/m	Millisiemens per metre
NGDB	National Groundwater Data Base
N	Nitrate
Na	Sodium
NGM	National Groundwater Maps
NGO	Non Governmental Organisation
NH4 as N	Ammonia
No.	Number
N/S/E/W	North/South/East/West
Ortho	Orthographic
P	Phosphorous
pH	Measure of acidity or alkalinity
PHWD	Peak Hourly Water Demand
RWS	Rural Water Supply
Q	Discharge/Sustainable yield
s	Available drawdown
S	Storativity
Sf	Fracture Storativity
Si	Silica
Sm	Matrix Storativity
SO4	Sulphur
sp. grav.	Specific gravity
SWD	Stock Water Demand
t	Elapsed time
T	Transmissivity
TA	Training Agent
TAL	Total alkalinity

TDM	Time Domain Method
TDS	Total Dissolved Solids
Tf	Fracture Transmissivity
TLC	Transitional Local Council
Tm	Matrix Transmissivity
Tmax	Higher transmissive zone in an aquifer
Tmin	Lower transmissive zone in an aquifer
TOC	Total dissolved Organic Carbon
Topo	*Topographic*
UWL	Unaccounted for Water Losses
VES	Vertical Electrical Sounding
VLF	Very Low Frequency
WASP	Water Aquifer Separation Principle
WB	Water Board
WR90	Surface Water Resources of South Africa 1990 (WR90).
WRC	Water Research Commission
Zn	Zinc

SECTION A
PROJECT CONTEXT

This section of the report provides a summary of the motivation for the project and the processes that were followed in the development of the software and the information content of the Rural Water Supply DSS. Also included are some details of the testing that has been carried out to date, as well as recommendations for future testing and implementation. The references provided within this section are applicable to the whole report.

The computer hardware requirements of the RWS-DSS are provided at the front of this report for clarity and so that potential users can check them against what they have available.

Operating System:	Windows 95 or higher
Processor:	Pentium P100 or greater.
Memory:	32 Megabytes or greater (less memory is possible, but will slow down the rate at which those components that involve large data inputs will be displayed on the screen).
Hard Drive:	Minimum of 5 Megabytes of free space (this requirement will ultimately depend upon how many specific schemes will be handled at one time).
Monitor:	SCGA colour monitor (while usable on monochrome monitors, certain features will be hard to see unless colour is available).
Screen Mode:	800 x 600 pixels, with 256 colours as a minimum. 16 bit (65 000 colours) or greater is recommended.

The computing skills required for use of the program are minimal and anyone familiar with the basic use of Windows 95 should have no problems. Installation of the software is through a simple install program. For those users who wish to modify the RWS-DSS content, familiarisation with Section C of this report is necessary, together with a reasonable degree of confidence in the creation, editing and saving of text files.

1. INTRODUCTION

1.1 THE NEED FOR A RURAL WATER SUPPLY DECISION SUPPORT SYSTEM

The need for a Rural Water Supply - Decision Support System (RWS-DSS) computer program, as a tool for development, has become increasingly clear in the South African context:

- There is a shortage of trained staff within official agencies responsible for implementing the Reconstruction and Development Programme (RDP).
- There is also a gap in practically applicable technical methods available for rural water supply development planning, design and implementation.
- Previously, commercial consultants, commanding high fees and often holding a monopoly on water services design and provision, were given carte blanche to design their own water supply delivery process. However, this situation has improved in recent years as the problem has been addressed by the relatively new Directorate of Water Services of DWAF.
- Emphasis on the delivery of water supply hardware has often been at the expense of ensuring that the systems installed will be sustainable after the construction engineers leave site, i.e. impatient and ill-advised consultants and inappropriate hardware.
- "Implementing agencies" have managed planning and construction but have not necessarily facilitated local solutions to local problems, i.e. inappropriate respect for and engagement of the poor.
- Recent studies have been showing the many complex and inter-related reasons for WHY there is a continuing low success rate of projects implementing rural water services provision.
- There remains a need to improve methodologies which address HOW to make rural water supply systems succeed.

1.2 TERMS OF REFERENCE

The terms of reference for Water Research Commission Project Number K5/837 were the further development of a decision support system computer program based on the principles described in WRC Report No. 677/1/98, "Guidelines for the evaluation and development of water resources for rural development with an emphasis on groundwater"(Sami and Murray, 1998). As far as possible the Rural Water Supply - Decision Support System computer program was to provide a tool to accompany these guidelines. But, by definition, the further development of a decision support system for rural water supply implied a broader context than the original document in that equal emphasis was required for all factors being considered.

1.3 PROJECT AIMS

The primary aims of this project can be summarised as the development and preliminary testing of a Rural Water Supply Decision Support System (RWS-DSS) computer program designed specifically to address all aspects of rural water supply project planning, implementation and management.

The primary project objectives were:

- ***To setup and develop the Delphi shell Decision Support System (DSS) for application to any subject requiring interactive decision-making computer support.***

- ***To create and develop the Rural Water Supply - Decision Support System (RWS-DSS), not previously setup, directly for use in a Windows application.***

- ***To promote the use of the RWS-DSS for planning and evaluating future rural water supply projects.***

Supporting objectives were:

- ***To fill in more detail related to some issues than was possible during the first project.***

- ***To test the applicability of the DSS using established and new rural water supply schemes.***

- ***To test the usefulness of the DSS as a training tool and for enhancing the awareness of various practitioners in the field of the many issues influencing the success or failure of rural water supply schemes.***

- ***To hold workshops to present the DSS to established practitioners and obtain feedback on its advantages and disadvantages.***

Because the originally approved project staff elected not to undertake the project and were replaced by new staff, because of experience gained during the evolution of the program and also because of directives given by the Project Steering Committee some of the objectives of the RWS-DSS were re-interpreted with a view to meeting the needs of DWAF and are outlined as follows:

- Development of a standardized decision-making tool for evaluating options for practical application to rural water services provision.

- Emphasis on small-scale, locally managed water resource development where funds and available skills may presently be the main limiting factors to project success.

- Integration of all factors affecting the sustainability of rural water supply schemes into one user-friendly computer program.

- Provision of generic, yet specific, step-by-step guidelines for ease of working through the rural water supply development process.

- Training to encourage understanding and efficacy in implementation of all of the different aspects of the work.
- To encourage improvements in cost recovery.
- To bring together information providing a facility to keep a record of work done in a format that is accessible to computer programs already being used by DWAF.
- To provide a customised reporting system.
- To incorporate all DWAF directives as they have been developed (where applicable).
- To incorporate all guidelines as far as possible directly within the RWS-DSS computer program.

2. PROJECT PRODUCTS

The work undertaken during the project has resulted in the development of two interlinked computer products for use in practical applications as reported in more detail below. These are:

- A generic Decision Support System (DSS) Shell computer package, written in Delphi computer language, to provide an environment in which to create and develop any decision support system including the Rural Water Supply Decision Support System. The technical details of the DSS Shell are provided in Section C of this report.
- A specific Rural Water Supply - Decision Support System (RWS-DSS) coded for use within the DSS Shell package and designed for user friendly practical applications. The contents of the RWS-DSS and guidelines for its use are included in Sections B and D of this report.

There has also been a masters research project (Naafs, 1999) associated with testing the groundwater component of the RWS-DSS system. Field testing was conducted on rural water supply borehole test pumping programmes in areas of the Eastern Cape and data manipulation and analysis was accomplished through application of the relevant sections in the RWS-DSS computer program. In this way the RWS-DSS computer program, and indirectly the DSS computer program, were fairly rigorously tested by the use of real-time data.

3. TARGET GROUPS AND PROJECT BENEFITS

The original target user group was broadly defined as planners, funders and trainers working in the rural water supply sector. Since a Water Research Commission Project Steering Committee directive, provided at the annual meeting of February 1999, the RWS-DSS has been more specifically designed and customised to meet the requirements of the Department of Water Affairs and Forestry (DWAF) as key stakeholders in the rural water supply sector.

The RWS-DSS may be found to be most useful as a means to offer support for takeover at the local government or District Council level where capacity building is required. At regional and local level the RWS-DSS may also assist with increasing the capacity of both field personnel and local Water Committees in the identification of training needs and transference of skills to local people. Field practitioners may be specialists in one particular field of expertise and the program may assist them to better understand and address other factors of equal relevance to the rural water supply development process. For example, engineers and technical staff, who are neither groundwater specialists nor hydrologists, may find the methodologies and explanations presented for the quantification of water supply yield helpful. However, the system cannot be considered as a substitute for the use of properly qualified specialists to quantify and evaluate the more technical aspects of rural water supply design and implementation. It merely puts all the technical deatils in the correct context. Overall, it is hoped that use of the RWS-DSS program will help facilitate informed decisions and/or evaluation of the most feasible and sustainable rural water supply options available to any community for development.

Interest in the RWS-DSS project has been expressed by international organizations, such as the Southern African Development Corporation (SADC) and the British Geological Survey (BGS), who are currently implementing rural water supply projects in other southern African countries. The RWS-DSS package may also prove to be useful to these organizations.

The computer skills required to use the system are relatively straightforward and anyone who is familiar with a Windows operating system environment and the use of a mouse to click and select various options. While it is anticipated that there will be potential users who are unfamiliar with even simple computer use, the training required is probably less than is required for many other commercially available and widely used software packages (such as spreadsheets, word processors and text file editors).

4. BACKGROUND TO PROGRAM DEVELOPMENT

As noted in section A.2 above, the project has involved the parallel development of two products.

4.1 GENERIC DSS SHELL PROGRAM

The first is a generic DSS Shell that can be used to set up a DSS for almost any topic and the full details of this program are provided in Section C. This program makes use of straightforward text input files to define the contents of a specific DSS. The text input files provide the system with all the necessary information that is required in terms of :

- Flow control from one aspect of the DSS to another (achieved in several different ways that are flexible enough to allow the user to move in the sequence that the DSS designer expects, or to take short cuts and move to other components as required).

- Text type information that explains various details of the decision system, directs users to external sources of information, explains technical terms or provides directives for the input of quantitative data.
- Inputting text and quantitative information either interactively or as reads from an external data file.

- Performing calculations on data and generating new information.
- Saving all input information to a file for later re-use and revision.
- Generating reports of the details of an application of the DSS.

All of these are achieved by the use of a defined set of keywords and symbols (explained in full detail in Section C) that allow a designer to establish a DSS without any specialised knowledge of computer languages. It would clearly take some time for a designer to be trained and become experienced in the use of the system to establish a DSS, but the skills required are little more than a sound understanding of a Windows based text editor and some reasonable knowledge of the structure of folders or directories and files in a Windows environment.

4.2 SPECIFIC RWS-DSS

The coding of the text files for the rural water supply DSS took place in parallel with the development of the DSS Shell, which on reflection was not the best approach to be used, but was the only practical approach given the relatively short duration (2 years) of the project. The main problems were related to the fact that changes in the Shell programming concepts frequently meant that the RWS-DSS text files had to be revised, slowing down the further addition of new DSS components and thorough testing of existing components.

The details of the content are not included in this report as most of the issues and specialist techniques are documented elsewhere and particularly in Sami and Murray (1998). To include them in this report would be a duplication of the computer based system and would result in a report that would be extremely long and almost impossible to read. Section B provides a guide to the structure of the DSS, as well as acting as a 'road map' and user manual for the use of the RWS-DSS. Section D lists the various components that are included and provides references to the text files that deal with the components (this list is included for the benefit of future design modification, rather tahn the normal user of the system). It is evident that the system is very comprehensive in its coverage of the issues involved, although not all are covered with the same level of detail.

It will become apparent to users that there are occasionally several options that can be followed to achieve a result in the DSS components. Some of these may involve going through quite detailed data entry procedures, while alternatives may be to go straight to the final stage of the procedure and enter a result that has been obtained from an external source. This approach has been adopted for the sake of flexibility, but does make some parts of the system appear relatively complex to users who are not specialists in those areas. This point serves to illustrate that the range of potential users is quite wide, but that not all categories of users will work with different components of the system at the same level of detail.

There are some aspects of the system that are known to have limitations and have been developed to a lower level of completeness than others. For example, while the surface water resource estimation procedures that are included have been based on approaches widely used within South Africa, there are more up-to-date approaches that could be added at a later stage. The groundwater evaluation methods, on the other hand, have been given a great deal more attention. This serves to illustrate that the system needs to be continuously upgraded as new information and methodologies become available if it is to perform optimally. This also means that the future custodians of the RWS-DSS should assume the responsibility to carry out such upgrades.

5. PILOT TESTING AND FEEDBACK

The DSS programming functions have been routinely tested by IWR staff at all stages of the development. Teething problems in the Delphi code were detected as new RWS-DSS text code components were developed and tested on an ongoing basis as part of the construction process.

Field testing and application of the groundwater components was undertaken by a hydrogeology student from the Netherlands who visited the IWR to conduct research for his masters thesis during a 3 month period in 1998 (Naafs, 1999). A summary of the results of this study were as follows: The calculated yield recommendations compare favourably to those obtained from a comparable program customised for use in a QuattroPro spreadsheet environment by Mr Karim Sami who contemporaneously developed that product during the present RWS-DSS project period. But, the borehole testing analysis section contained in the RWS-DSS was found to be easier and quicker to use the than Mr Sami's recent product. The resulting thesis was submitted to the Free University of Amsterdam in November 1999 and has resulted in the award of an MSc degree.

Two short lecture courses were presented to a selection of Rhodes University students following geography, geology and environmental science honours courses. The hydrogeology component was taught to third year students during the 1998 academic year and the broad framework of rural water supply in the context of the RWS-DSS was taught to honours level students during the 1999 academic year. As a practical exercise students were required to use and test the RWS-DSS system, while it was in the process of development, and to complete a questionnaire specifically constructed for this purpose.

Certain relevant sections have also been examined by representatives from industrial suppliers as well as Non-Governmental organisations working in the rural water supply development sector.

The outcomes of the various testing procedures were as follows:

- Some problems were detected and the text files and program were updated.
- The ease of data entry and manipulation was demonstrated.
- It was concluded that the DSS provides a logical framework for the user.
- The potential use of the RWS-DSS product as a holistic training tool has been demonstrated.
- The graphing function can be used to process data more quickly and easily than customised software.

- The present component section content has been shown to be more than comprehensive and, if anything, too large (i.e. too comprehensive in some parts for practical application).

- It has been demonstrated that there is certainly a need for further refinement of the content after experience has been gained through real applications.

- It has emerged that some consultants, participating in the field testing exercise, were reticent about providing their yield recommendations for comparison against RWS-DSS results.

A copy of the RWS-DSS program was sent to staff members at the University of Zululand, Department of Hydrology for review and testing as a student teaching aid in July 1999 after suggestions that it may be appropriate for a second semester course. There has been no feedback yet but it is known to have been used for an honours hydrology and water resource management course.

There are still a number of questions about the value of the RWS-DSS that need to be answered:

- How and where can the DSS be of most use ?

- How can the DSS be introduced at the regional level ?

- Can the DSS offer support at local government or district council level where capacity building is required ?

- Can the DSS assist field personnel who may be specialists in one particular field of expertise to understand and address other factors of equal relevance ?

- Is the DSS sufficiently user-friendly ?

- Can the system increase the capacity of field personnel and local water committees in the identification of training needs and the transfer of skills to local people ?

- Is the DSS useful for the supervision of personnel employed by DWAF to implement the rural water supply project process ?

- Can the DSS be used to increase regional office accessibility to individual project data?

- Can the DSS be used for integrated planning ?

- Can the DSS help to avoid previous problems typically encountered in the design and implementation of rural water supply projects.

6. TECHNOLOGY TRANSFER BY PRODUCT DEMONSTRATION AND DISSEMINATION

At the February1999 WRC Steering Committe meeting for this project a directive was given that, because the ideas and concepts contained in the RWS-DSS are designed to assist DWAF, the program must be reviewed and tested by DWAF personnel at the regional and local levels, i.e. collaboration and the active participation of DWAF personnel in testing was required.

Since then, meetings have been held with various personnel at the DWAF, Eastern Cape offices. The general response to the product has been very positive, a real need has been expressed for the RWS-DSS as a tool for development and, in principle, DWAF have agreed to support the use of the system. Changes to the content of the DSS are not simply to be invited, but actively encouraged and it is anticipated that as testing proceeds the specific user group will become more clear.

A proposal to carry out a case-study using information from three rural water supply projects within the Eastern Cape (Xhora, Herschell and Sipaqheni) has been accepted by the DWAF, Eastern Cape Management Committee and the details of how this project is to proceed were still being discussed while this report was being finalised.

7. CONCLUSIONS AND RECOMMENDATIONS

Despite some of the difficulties that were faced by the development team, the primary objectives of the project have been met. The third objective of promoting the RWS-DSS for use in the planning and evaluation of future rural water supply projects is the area which has been addressed less successfully than the other two objectives and which needs the most further attention. It is possible that in trying to develop a comprehensive system that covers a very wide range of the issues associated with the design of rural water supply schemes, the RWS-DSS has become too complex. However, not all of the components of the system (particularly the very technical ones) need to be visited by every possible user and therefore, while being quite complex, the system may still be practically useful. The answer to such questions will really only emerge as the RWS-DSS becomes used for practical purposes and therefore most of the recommendations for future work revolve around the implementation of the software.

One of the functions of the DSS Shell is to be able to provide a relatively easy way of designing a reporting system that allows all the input information on a specific scheme to be summarised for record purposes. Detailed reporting facilities have not been included within RWS-DSS (i.e. the relevant text input files for the DSS Shell have not been created yet) because there was little clarity about the format of the reports required by different organisations.

The following sub-sections provide further detail about several specific proposals for future actions.

7.1 INVOLVEMENT OF A SPECIALIST ENGINEER AS EXTERNAL ADVISER FOR TECHNOLOGY TRANSFER

The addition of an external observer to provide a fresh view and to act as an objective critic would benefit the technology transfer and further editing of the system. Ideally, this would be someone with engineering skills because this may be perceived to have been the weak spot amongst the team of people who have previously been involved in the project development; persons with skills in hydrology, hydrogeology, geology, rural development, water & catchment management and geography. An external adviser would also need to have an on-the-ground approach to problem solving, in-depth experience of all aspects of rural water supply project planning, implementation, operation and maintenance and the required computer skills. It is further suggested that the proposed candidate might first be involved as an external adviser in the Eastern Cape and then seconded to assist with technology transfer in other parts of the country.

7.2 COMPONENT SECTIONS THAT MIGHT BE ADDED TO THE RWS-DSS

The following have already been identified as possible additions to the range of components of the present DSS.

- A methodology for the quantification of yield from infiltration galleries possibly to be based on current research project being funded by the WRC (Mouton, P, Pers. Comm).

- Community capacity building needs assessment as distinct from a training needs assesment as defined by the Institutional and Social Development Package for Water Supply Projects (ISD - DWAF, 1999).

As the research and development of the current project has progressed the need has been highlighted for associated subject areas that were not covered in the original report (Sami and Murray, 1998). In future these might be addressed by additional component sections contained within the RWS-DSS or it may be more appropriate to develop them within linked, but separate, decision support systems. Examples include:

- Design installations and estimation.

- Rural community sanitation.

- Geohydrological risk as required by DWAF.

7.3 THE FUTURE OF THE RWS-DSS AND ITS DISTRIBUTION

The contributions that the Institute for Water Research can make to the further development of the system are very limited (mostly to training in, and support of the DSS Shell program), as the senior author of this report will no longer be available to contin ue with developments. It is therefore necessary to establish one or more organisations that are able to act as custodians of the RWS-DSS and to continue with promoting its testing, implementation and refinement. When the current round of testing for DWAF purposes has been completed, potential wider RWS-DSS product dissemination might include:

- Catchment Management Agencies in support of their objectives.

- Significant gaps in a recently developed GIS based computer program for rural water supply throughout South Africa by DWAF (Marais, 1999), suggests that there might be a role to consider for the RWS-DSS.

- Other universities such as the University of the Western Cape, the University of the North, the University of Fort Hare and the University of Transkei, might be encouraged to adopt the system for teaching and training purposes.

- Non-Governmental organizations.

- Marketing of the RWS-DSS product in countries where the Southern African Development Community (SADC) is operating in areas where the Development Bank of South Africa (DBSA) are currently funding projects.

- Interest shown in the product by practitioners working internationally, who requested more information after it was featured in the international magazine World Water & Environmental Engineering (June,1998; Volume 21, issue 6), might also be followed up.

- Collaboration and possible exchange of products/lessons learned with the British Geological Survey currently developing decision support systems for application in other central African countries who contacted the IWR.

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SECTION B
USER GUIDE: RURAL WATER SUPPLY DECISION SUPPORT SYSTEM (RWS-DSS)

The Rural Water Supply Decision Support System computer program is designed to assist the user in the selection of appropriate rural water supply schemes in accordance with the Department of Water Affairs and Forestry's community water supply policy for South Africa. Installation instructions are simple and provided with the CD that contains the software.

The system helps in the identification of key issues to be considered when planning rural water supply schemes and systematically guides the user through various methodologies tp quantify the available water sources and assess other critical parameters in order to select a sustainable water supply option.

These considerations include: the registration, assessment and prioritising of need which defines the objectives of a scheme; technical issues such as water demand and determination of required design system capacity; water resource selection, protection and treatment (if required); water resource management strategy encompassing data and information capture, capacity building training as well as operation and maintenance; economic issues around costs and benefits.

Information, analytical techniques and local data, when incorporated into the RWS-DSS, allow the user to plan a technically appropriate water supply system that is sustainable and acceptable to the community to be served.

The user is encouraged to work progressively through each section using a step-by-step approach.

1. RWS-DSS PROGRAM SCOPE AND OBJECTIVES

The RWS-DSS program has been based on rural water supply project planning for the South African Reconstruction and Development Water Supply Programme. The requirements and criteria of other funding agencies may differ from those considered in these guidelines.

The South African Department of Water Affairs and Forestry has identified the provision of sustainable water and sanitation services to all as being a top priority (DWAF,1994). The main policy principles relating to water supply are:

- ❑ Development should be demand driven and community based. This suggests that a water supply scheme should meet a community's demands and that communities must accept responsibility for their own development.

- ❑ Water has economic value. In other words a cost must be attached to water so that cost recovery is sufficient to meet long term water demands.

- ❑ The user pays. This principle suggests that communities will have to pay for water according to the level of service provision they receive.

The supply of water to rural areas is complex; socially, technically and financially it is complicated. The RWS-DSS computer program aims to make this complexity accessible. Information required and analytical techniques incorporated into the RWS-DSS, when supplemented by specific local data, have been designed to assist the user to compare and evaluate all available rural water supply sources and systems and select a workable development option based on informed decisions.

The decision support system computer program for rural water supply is **not** a specialised application for, for example, technical engineering design, construction or operation and maintenance specifically. The RWS-DSS is generic in content and designed to encourage the user to consider all factors affecting rural water supply provision, bring together information and plan technically and economically appropriate rural water supply systems which are socially acceptable. It is believed that this has not previously been attempted, and these first guidelines may not be complete, but it is hoped that use of the program may initiate discussion and feedback for upgrading where required.

2. USE OF THE RWS-DSS SYSTEM

The Rural Water Supply Decision Support System is designed to encourage the user to work systematically through the major factors considered to be of importance in the Rural Water Supply planning process. The step-by-step approach is considered to be standard practise in successful Rural Water Supply system design and operation.

The RWS-DSS aims for simplicity, flexibility and accessibility for the user:

- ❑ *Simplicity*: Each of the component sections and sub-sections contain a definition of objectives, an explanation of the principles and how to apply methodologies. Technical sections have more detailed step-by-step guidelines for use by the more inexperienced user if required.

- *Accessibility*: Implies simple data and information entry, manipulation and computer calculation (where applicable). All entered input is stored and becomes available for later retrieval and use anywhere in the system, i.e. sections can be highly interactive.

- *Flexibility*: EITHER individual components can be processed independently, OR the user can work through all sections consecutively. Hence, entry of information can be as simple or as detailed as needed and an over-ride facility can be selected where required.

WRC Report Number 677/1/98 (Sami and Murray, 1998) provides the basic guidelines for the methodologies contained in the RWS-DSS components. The present text is designed to supplement the WRC guidelines for computer applications. Where the methods contained in the above WRC Report have not been used, more specific guidelines are contained herein and the user is referred to other sources of information for more background (if required).

RWS-DSS system design guidance for user orientation through inter-related sections is facilitated by Bitmaps/Flow charts which appear behind every screen or component of the system (listed in Section D of this report). This is designed to help the user to navigate through the system. Similarly, 'Help' sections are built into the RWS-DSS component sections in the form of either 'More on' text or 'step-by-step' guidelines. The Glossary of Terms and abbreviations/acronyms is also provided to assist the less experienced user.

Technical sections are constructed in the format: text, text option, numeric input, computer calculation, result, continue or quit and exit. Where information has been asked for in another section it is always possible to cross-refer to the original input box.

To familiarize themselves with the system users are encouraged to go through each section looking at all of the factors for consideration and how these might inter-relate to other sections. When processing, if a preceding section has been omitted the user is encouraged to return to the relevant section and enter the data before proceeding through the system; for example, it is necessary to enter certain parameters into the water demand section for computer calculation in some of the <***Detailed Survey***> and <***Budget***> components.

At all stages of development step-by-step guidelines are provided within the RWS-DSS computer package. While the user is cautioned that some sections may require input from specialists these guidelines can be used by non-specialists to monitor work from an informed viewpoint. For example, social consultants and trainers can be guided by the contents of the more technical sections and geohydrologists or engineers can follow the steps required for successful community involvement. It may also be possible for funders to use the information entered either to assess funding applications or to evaluate reports detailing how funds have been used.

4. THE RWS-DSS MAIN MENU

The headings of the six main components of the RWS-DSS are provided below and diagramatically in Figure B.1, while the planning framework for technical tasks is given in Table B.1.

A. WATER SUPPLY PROJECT CONTEXT
B. FEASIBILITY STUDIES
C. DETAILED SURVEY
E. TRAINING
F. BUDGET
G. BUSINESS PLAN

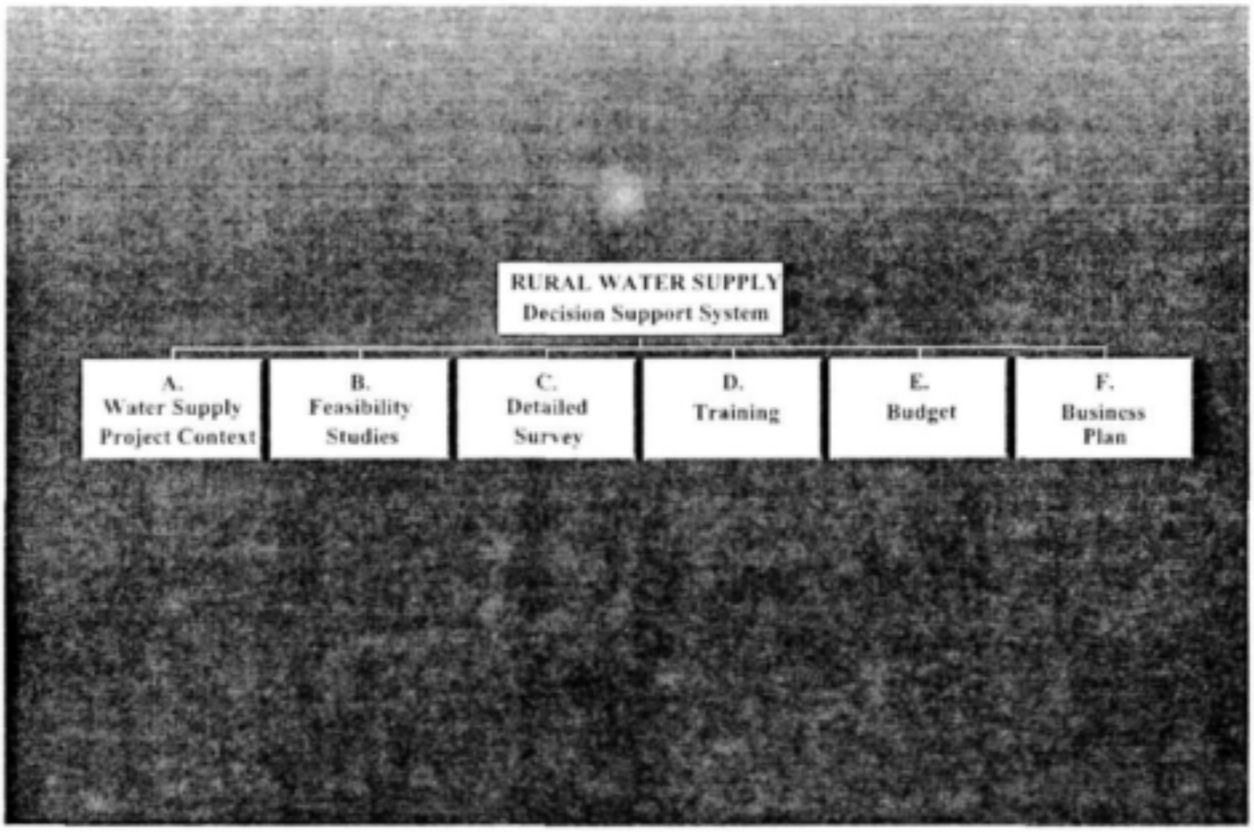


Figure B.1 RWS-DSS Main Menu Bitmap/Flowchart

Table B.1 RWS-DSS Planning framework for the required technical tasks

	KEY WORDS: POTENTIAL; ACCESSIBILITY; EXPLOITABILITY
PHASE 1:	**Desk study data review and field reconnaisance**
	- Survey of water use and verification of registered needs:
	- Evaluation of water demand and system capacity:
	- Walkover survey of topography, geology and soils:
	- Hydrocensus: - Available surface water sources - Available groundwater sources - Water quality sampling: - Field testing kit for titration, pH, temp, EC and TDS - Snatch samples (composite sampling) from: Surface sources; Boreholes; Springs; Shallow wells
	- Water source selection
	- Identification of existing sources of contamination and activities which could lead to contamination of identified water sources:
	- Biological survey:
	Report back to the Community Water Committee
PHASE 2:	**Social survey:**
	- Infrastructure feasibility
	- Cost effectiveness and economic feasibility
	- Social appropriateness
	Report back to the Community Water Committee
PHASE 3:	**Detailed field survey collection programme:**
	- Data collection:
	- Test drilling programme
	- Geophysical survey
	- Deep borehole drilling
	- Test pumping
	- Water quality sampling (Purging and sampling carried out according to DWAF standards):
PHASE 4:	**Detailed survey data analyses and evaluation:**
	- Aquifer characteristics
	- Groundwater flow dynamics
	- Water resource quantification
	- Hydrogeological risk analyses

Further details of the component structure and content is provided in Section D. These include, for example, the registration, assessment and prioritisation of needs which define the objectives of a scheme; technical issues such as required design system capacity, water resource selection and need for it's protection; water resource management strategy encompassing data and information capture and community training (pre-project mobilisation, during project implementation and post project monitoring, operation and maintenance); economic issues and associated costs and benefits. The contents of some of the above components are more comprehensive than others.

A recommended planning framework for the more technical aspects of the required work, as contained in the RWS-DSS computer package, is provided in Table B.1. Flow charts for user orientation through the main menu (Figure B.1) and each of the components appear behind every screen in the RWS-DSS. These can be accessed by the user, at any time.

4. WATER SUPPLY PROJECT CONTEXT COMPONENT (A)

Guidelines are contained in Sami and Murray (1998), Chapters 2 to 4, as restructured (where applicable) according to the DWAF (1999) ISD package. Table B.2 provides the objectives of the Water Supply Project Context component and the steps required when using component A. Figure B.2 provides the corresponding flow chart to assist in user orientation.

Table B.2 RWS-DSS Water supply project context objectives and required steps

Objectives	
1	A description of the specific provincial location of the community
2	Pre-feasibility study registration of needs (based on Mvula Trust application for funding Part 1)
3	Details of the responsible Water Committee including formation, representation and membership
4	Project agent details and record of rate of success associated with their previous involvement in RWS projects
5	Post feasibility study community statement relating to the preferred option (based on Mvula Trust application for funding Part 2)
Steps	
1	Liaison between community, project agent and potential funders, i.e. situational assessment from local knowledge based on site interviews and interaction.
2	Community based organisation application for funding

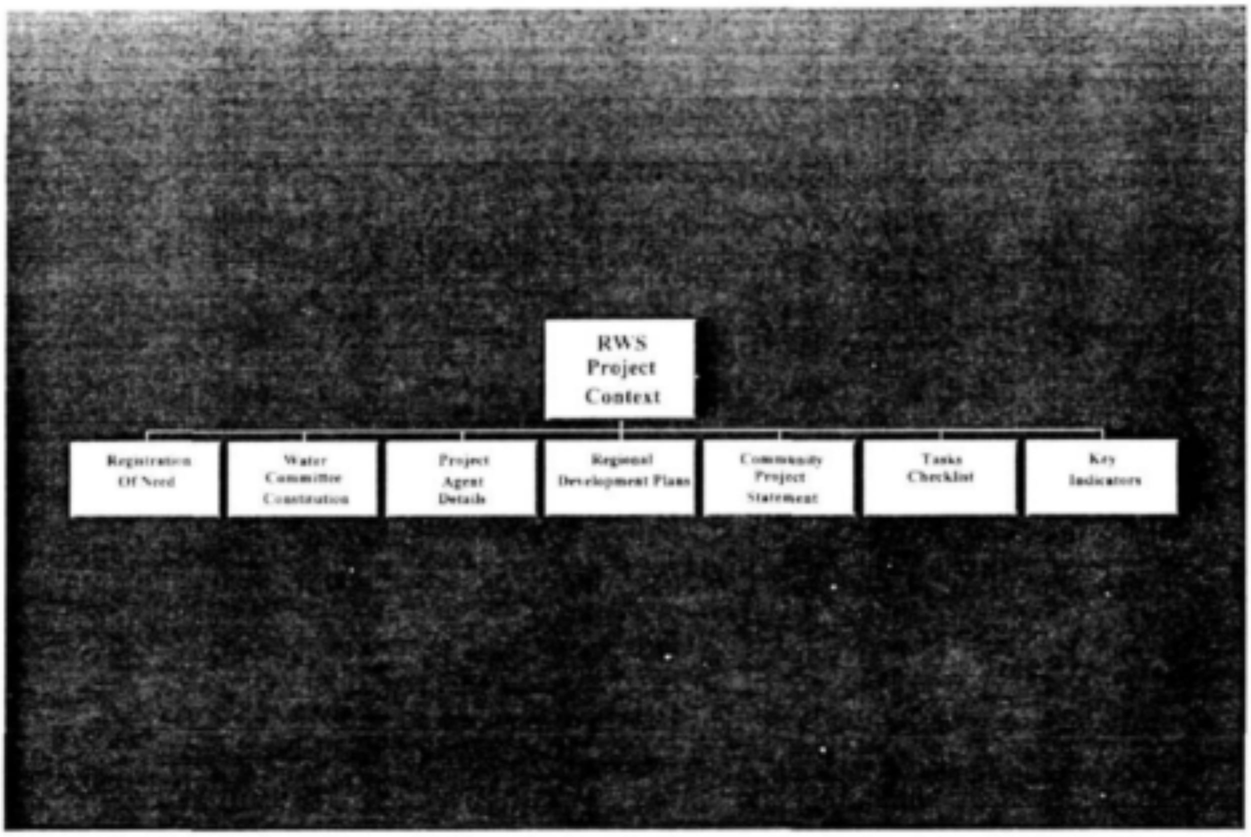


Figure B.2 Water Supply Project Context Bitmap/Flowchart

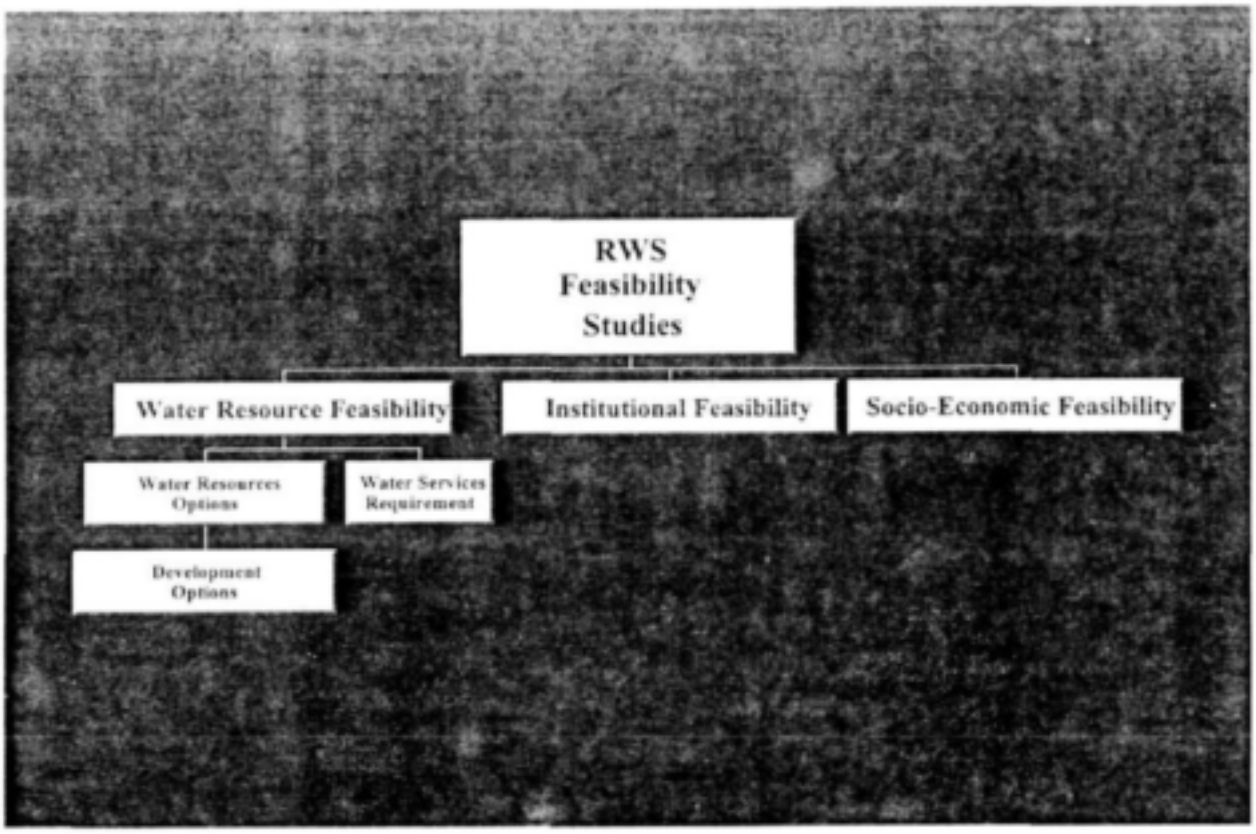
Additionally, a series of forms are provided for the purpose of assessment, and keeping a record of work progress in terms of the degree to which the required tasks for the project preparation process have been achieved. The ISD's Key indicators are also included to assist in this process.

5. FEASIBILITY STUDIES COMPONENT (B)

Guidelines are contained in Sami and Murray (1998), Chapters 2 to 6, as restructured (where applicable) according to the DWAF (1999) ISD package. Table B.3 provides the objectives of the Feasibility Studies component for Component B. Figure B.3 provides the corresponding flow chart to assist in user orientation.

Table B.3 RWS-DSS Feasibility studies objectives

Objectives:	
1	Assessment of all technical considerations for the planned water supply
2	Assessment of institutional capacity
3	Assessment of community preference and capacity in relation to project cost and ability to pay



Fgure B.3 RWS-DSS Feasibility Studies Bitmap/Flowchart

Sub-components to be processed include <***Water Resource Feasibility***>, <***Institutional Feasibility***> and <***Socio-economic Feasibility***>. Factors that require consideration are outlined in a 'Help' facility. The emphasis of the component is the <***Water Resource Feasibility***> component. This appears to be where there are gaps in the recent work undertaken by DWAF's ISD whereas the other components have been the subject of significant reconsideration and restructuring. The user is referred to recent DWAF publications if supplemental information is required.

Some of the sections contained in the Feasibility Studies component will need input from specialists to complete. Social consultants should seek help for technical sections while geohydrologists and engineers should seek help wiith the community sub-components.

5.1 WATER RESOURCE FEASIBILITY (Component B.1)

Basic guidelines contained in Sami and Murray (1998), Chapters 5 and 6, are supplemented (wherever required) by additional sub-component sections explained below. Table B.4 provides the objectives of the Water Resource Feasibility component.

Table B.4 RWS-DSS Water resource feasibility objectives

Objectives	
1	Verification of community's water supply problems and registered water demand needs
2	Assessment of feasible water sources and technical intervention options
Steps	Provided in Tables B.5 to B.8

A further objective may prove to be the contribution of information towards the DWAF - GIS environment mapping of all existing and recently installed South African water supply installations. The user is encouraged to complete the required input components and notify DWAF as and when new rural water supply projects have been commissioned.

Sub-components Components to be processed include <***Water Services Requirement***>, <***Water Resources Options***> and <***Development Options***>. Factors that require consideration are outlined in a 'Help' facility. The user is encouraged to process the suggested water services requirement and water resources options components before making use of the development option selection facility.

5.1.1 Water Services Requirement (Component B.1.1)

Guidelines for <***Water Demand***> are contained in Sami and Murray (1998), Chapter 5. Other sub-component Components have been developed from information required by various Non-Governmental Organizations. Table B.5 provides the objectives of the Water Services Requirement sub-component and the steps required. Figure B.4 provides the corresponding flow chart to assist in user orientation.

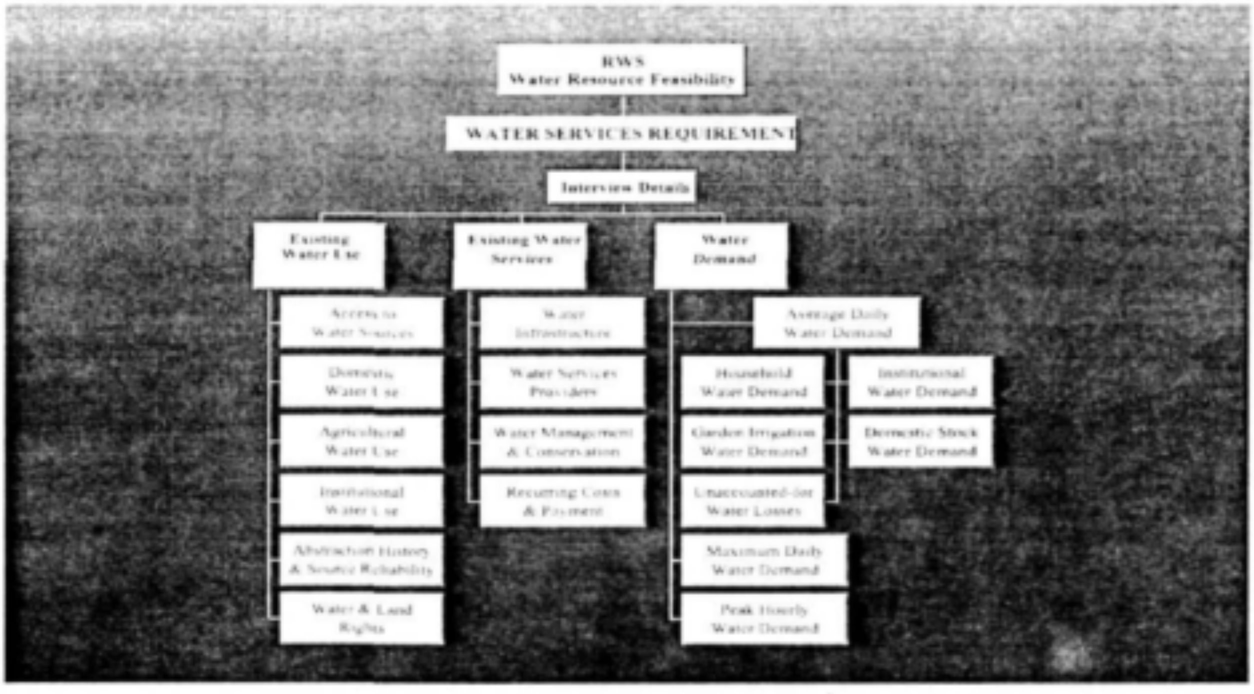


Figure B.4 RWS-DSS Water Services Requirement Bitmap/Flowchart

Table B.5 RWS-DSS Water Services Requirement objectives and required steps

Objectives	
1	Appraisal of existing water use
1.1	To assess the community's existing access to water sources
1.2	To evaluate the present quantity and existing quality of the water used by the community
	To assess the community perceptions of existing accessible water sources
2	To make an inventory of existing water supply infrastructure
2.1	To assess the condition, technical efficiency and strengths and weaknesses of existing water supply systems
2.2	To investigate the availability of Water Services Providers in the immediate area and management practices
2.3	To assess current water management and conservation strategies
2.4	To determine the recurring costs of existing water services and success of cost recovery measures (if applicable)
3	Assessment of present and future design water demands
3.1	Calculation of Average Daily Water Demand for schemes with a maximum design capacity of 1 000 m^3 per day. Includes: - Estimation of existing population characteristics and likely growth rates. - Estimation of household, agricultural, institutional, garden irrigation, stock and industrial water use as well as water losses.
3.2	Calculation of Maximum Daily Water Demand and Peak Hourly Water Demand (fluctuating community water requirements) to design the system capacity of different infrastructural components.
Steps	
1	Surveys/interviews
2	Collation, review and analysis of information
3	Reporting of results

Sub-components to be processed include <***Interview Details***>, <***Water Demand***>, <***Existing Water Use***> and <***Existing Water Services***>.

It is recommended that the required surveys are carried out by a project community facilitator in consultation with at least one delegated community representative. When the community survey has been completed, and the information has been input to the respective Components in <***Water Services Requirement***>, then the next step recommed is to report back on findings to the Water Committee and obtain agreement on future strategy before continuing to process the <***Water Resources Options***> component. Computer calculations require that all relevant parameters have been estimated by the user.

Any existing reports demonstrating the need and priority of the proposed project, including any data on inadequate facilities or incidence of water related diseases, should be attached to the Business Plan.

5.1.2 Water Resources Options (Component B.1.2)

Sub-components to be processed include <***Survey details***>, <***Desk Study***>, <***Hydrocensus***> and <***Development Options***>. Figure B.5 provides the flow chart for the Water Resources Option sub-component. Guidelines for the <***Desk Study***> section contained in Sami and Murray (1998), Chapters 1, 3 and 4 have been supplemented for practical applications from specialist literature as well as field study experience. The objectives of the Desk Study sub-component are provided in Table B.6.

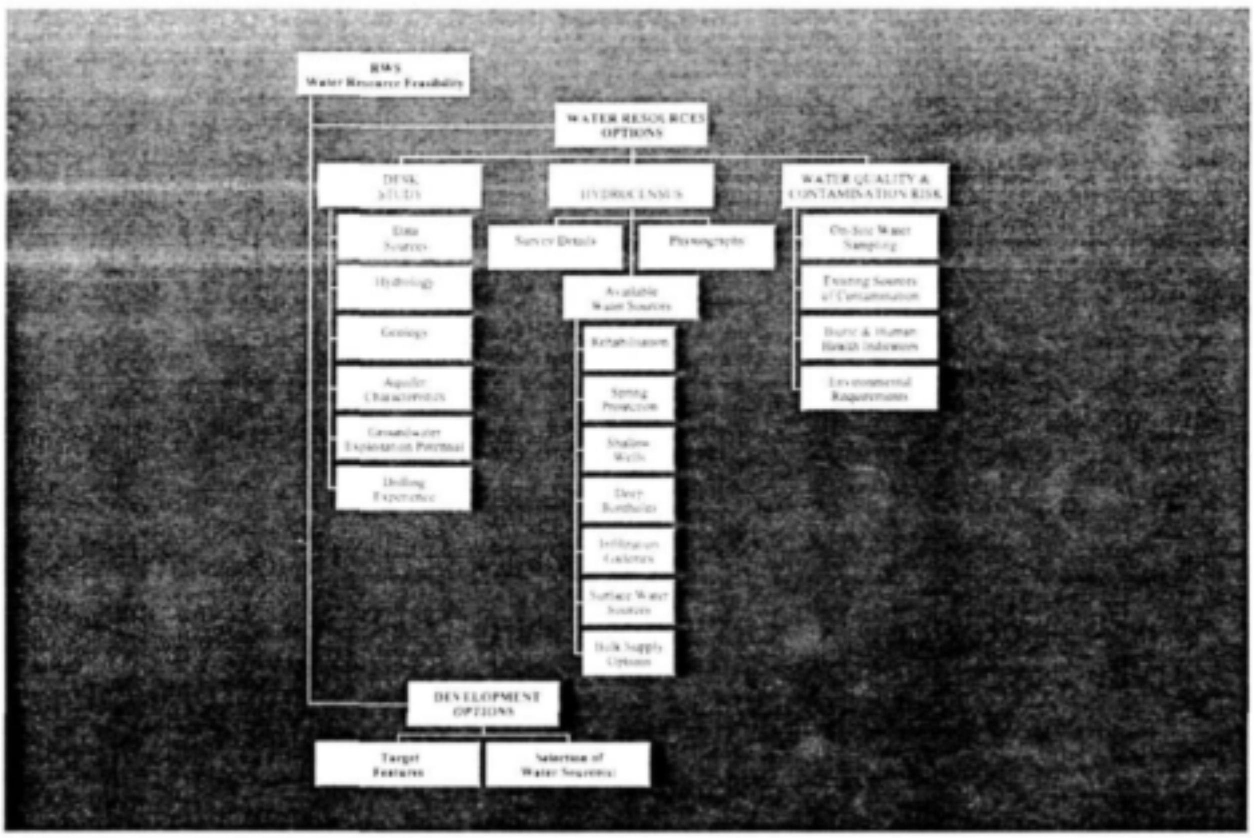


Figure B.5 RWS-DSS Water Resources Options Bitmap/Flowchart

Table B.6 RWS-DSS Desk study objectives and required steps

Objectives	
1	Desk study:
1.1	Assessment of the hydrological potential of the area
1.2	Assessment of the geology, groundwater potential and drilling experience in the area
1.3	Assessment of regional development planning
Steps	
1	Literature review, accessing of existing reports, maps (ortthographical, topographical, geological and groundwater potential) and information review
2	Data collation, evaluation and preparation of base maps and hydrogeological cross-Components
3	Development of a conceptual understanding of the groundwater system
4	Identification of basic gaps in the data and planning of reconnaisance survey
6	Reporting of results

The data review involves the collation and interpretation of orthographic, topographic, geological & hydrogeological maps, aerial photographs, satellite images (if available), accessible databases, manuals and available reports or other existing records.

Guidelines for the <***Hydrocensus***> component are contained in Sami and Murray (1998), chapters 2, 6 and 11.1 & 11.3. Other sub-components are also updated from literature review and include water quality recommendations made in the WRC Report Number 339/54/92. Table B.7 provides the objectives of the Hydrocensus sub-component and the steps required for sub-component processing.

The <***Hydrocensus***> sub-component includes recommendations for the survey and evaluation of available and potential water sources (including: Spring Protection, Shallow Wells, Deep Boreholes, Infiltration Galleries, Surface Water Sources and Bulk Supply Options) as well as water quality and contamination risk. It is suggested that these be processed to serve as guidelines prior to selection of the water source(s) in the <***Development Options***> sub-component.

Table B.7 RWS-DSS Hydrocensus objectives and required steps

Objectives:	Rapid reconnaisance survey and ground-truth verification
1	Location and inventory of all existing water source installations and identification of any physical restrictions to these sources (depth, water volume, quality, etc.), within a minimum of a 3 km radius of the community
	Assessment of the potential for rehabilitation of existing water source installations
2	Identification of other available but undeveloped water resources with the technical potential for development within a minimum of a 3 km radius of the community.
3	Survey of existing sources of contamination and assessment of any risk to existing or potential water sources and the need for water source protection
4	Assessment of field survey equipment availability and accessibility
STEPS:	
1	Local interviews
2	Groundwalkover field survey and data gathering
3	Flow and water level measurements, water quality sampling and on-site analyses
4	Collation, review and analysis of information
5	Construction of site location base map showing: - topography and drainage, - important surface features, - the locations of reservoirs, weirs, sand dams, river flow gauging stations, springs, shallow wells and boreholes as well as all water quality sampling points, - existing water supply infrastructure.
6	Reporting of results

5.1.3 Development options (Component B.1.3)

Guidelines contained in Sami and Murray (1998), chapter 6, should be supplemented by local information and field observations. Table B.8 provides the objectives of the Development Options sub-component contained in Section B.1.3.

Table B.8 RWS-DSS Development options objectives

Objectives:	
1	To select sites for surface water intakes
2	Identification of target features/areas for more detailed groundwater investigation surveys
3	To prioritise all available water source options and select the sources with the potential for the most sustainable development

Sub-components to be processed include <***Target Features***> and <***Selection of Water Source(s)***>.

5.2 INSTITUTIONAL FEASIBILITY (Component B.2)

Guidelines contained in Sami and Murray (1998), Chapters 2, 3, 4 and 14, as restructured (where applicable) according to DWAF's ISD package (1999) and DFID's Guidance manual (1999). Table B.9 provides the objectives of the Institutional Feasibility sub-component and the steps required when using Component B.2. Figure B.6 provides the corresponding flow chart to assist in user orientation.

Table B.9 RWS-DSS Institutional feasibility objectives and required steps

Objectives	
1	To obtain and promote an understanding of existing institutions; their roles and responsibilities as well as their present competence and capacity within the context of ensuring sustainable water service provision for the project.
2	To identify potential Water Services Providers for project implementation as well as operation and maintenance institutional support.
Steps	
1	Interviews and meetings with community representatives, Local Authorities, Water Boards, financial institutions, material suppliers and industry with an emphasis on community involvement.
2	Assessment and evaluation in terms of socially appropriate interventions and community willingness and ability to assume ownership of the project.
3	Reporting back to the community.

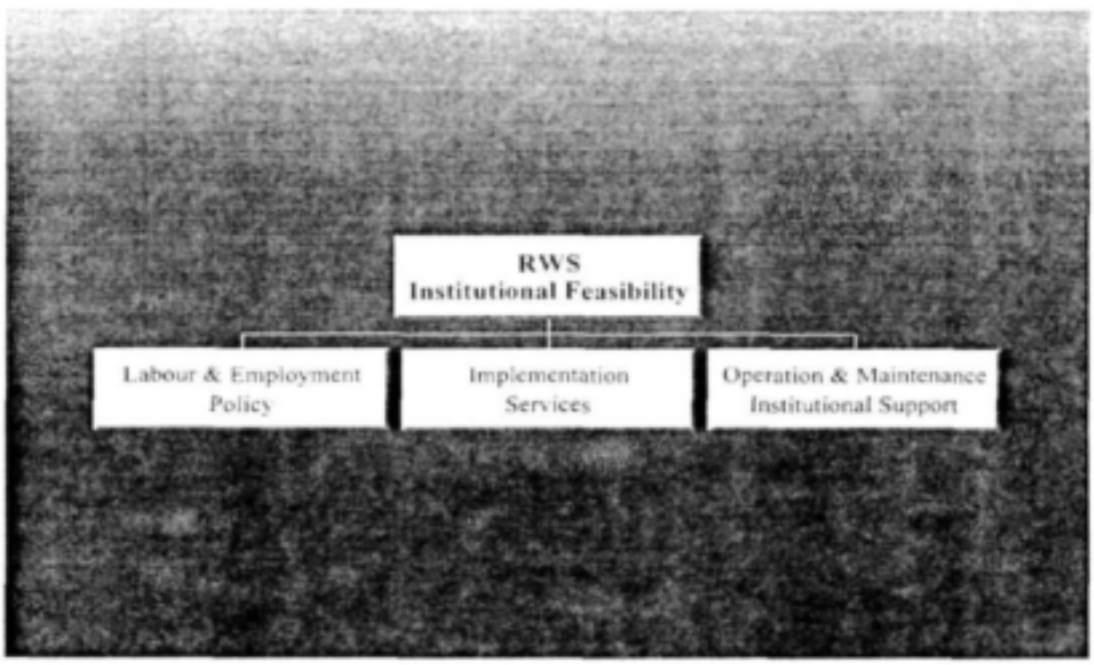


Figure B.6 RWS-DSS Institutional Feasibility Bitmap/Flowchart

Components to be processed include <***Labour and Employment Policy***>, <***Implementation Services***> and <***Operation and Maintenance Institutional Support***>.

5.3 SOCIO-ECONOMIC FEASIBILITY (Component B.3)

Guidelines contained in Sami and Murray (1998), Chapters 2, 3, 4 and 15, are restructured (where applicable) according to DWAF's ISD package (1999) and DFID's Guidance manual (1999). Table B.10 provides the objectives of the Socio-Economic Feasibility sub-component and the steps required when using Section B.3. Figure B.7 provides the corresponding flow chart to assist in user orientation.

Components to be processed include <***Community Project Support***>, <***Social Appropriateness of Design***>, <***Community Project Management***> and <***Community Willingness and Ability to Pay***>. The user is asked to provide answers to listed criteria as reported during interviews with community representatives for the purpose of evaluation and ranking of possible options and assessment of the degree of community committment to the proposed project plan. 'Help'Components include <***Principles of Community Interaction***> and <**Factors for Consideration**>.

Table B.10 RWS-DSS Socio-economic feasibility objectives and required steps

Objectives	
1	To ensure direct community involvement from the start of the rural water supply project planning process until the end of the design life of the scheme.
2	To assess the feasibility and sustainability of the community's preferred water supply option and level of service cost recovery
Steps	
1	Interviews and meetings with Local Authorities, Water Boards, material suppliers and industry with an emphasis on existing locally emerging contractors.
2	Assessment and evaluation of socio-economic criteria as key indicators for community involvement and the satisfactory completion of project activities.
3	Reporting back to the community.

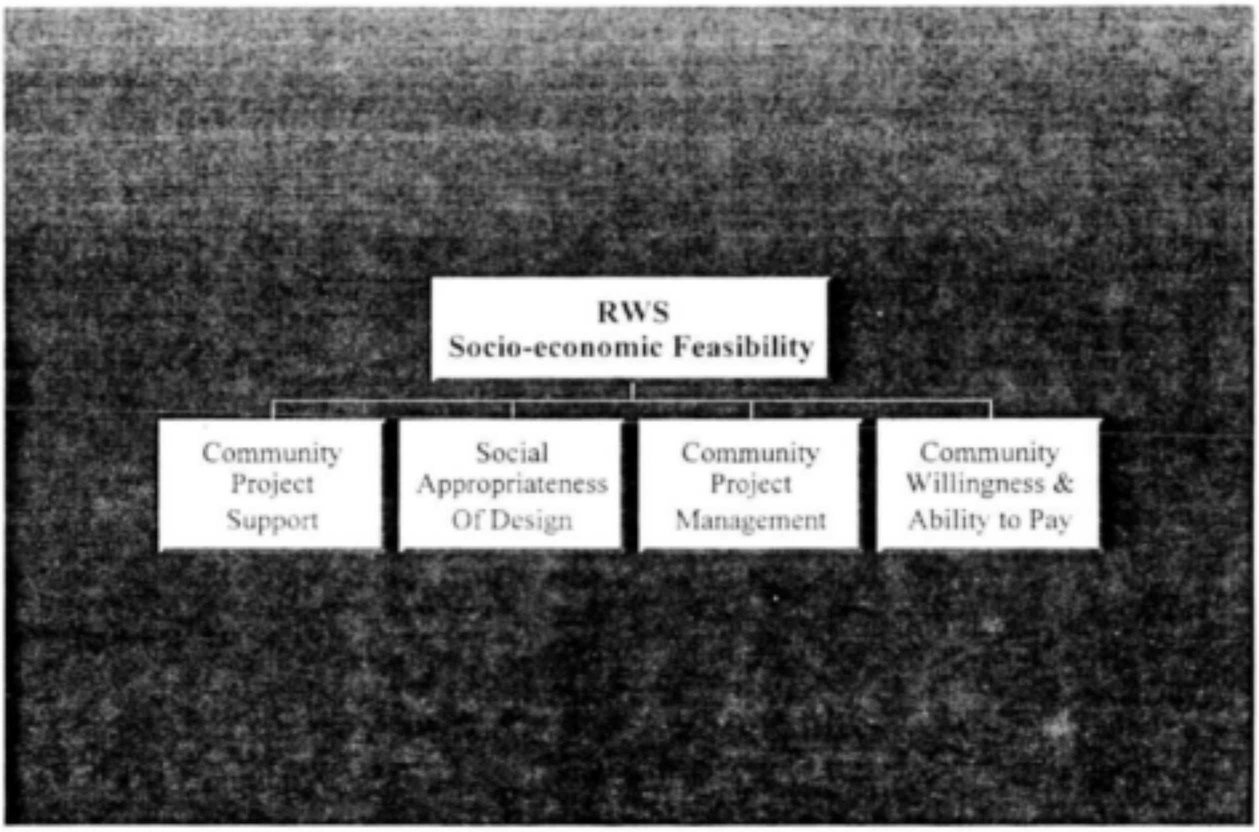


Figure B.7 RWS-DSS Socio-Economic Feasibility Bitmap/Flowchart

6. DETAILED SURVEY COMPONENT (C)

Except where stated, when alternative methodologies are provided, guidelines are contained in Sami and Murray (1998), Chapters 5 to14, as restructured (where applicable) according to DWAF's Minimum Requirements for groundwater exploration and development (1997) and other sources. Table B.11 provides the objectives of the Detailed Survey component and the steps required when using component C. Figure B.8 provides the corresponding flow chart to assist in user orientation.

Table B.11 RWS-DSS Detailed survey objectives and required steps

Objectives:	
1	To provide guidelines for the application and selection of appropriate field survey equipment.
2	To provide methodologies for the analyses and evaluation of all available rural water supply sources and guidelines for the recommendation of sustainable yield.
3	To provide a facility for the compilation of results to ensure that records are maintained in a generally accessible format for assessment and future monitoring.
STEPS:	
1	Exploration
2	Data analysis and interpretation
3	Resource evaluation
4	Data recording and reporting.

Sub-components to be processed include <***Practical Field Guide***>, <***Surface Water Yield***>, <***Ground Water Yield***>, <***Results Records***>, <***Water Quality***> and <***Project Design***>.

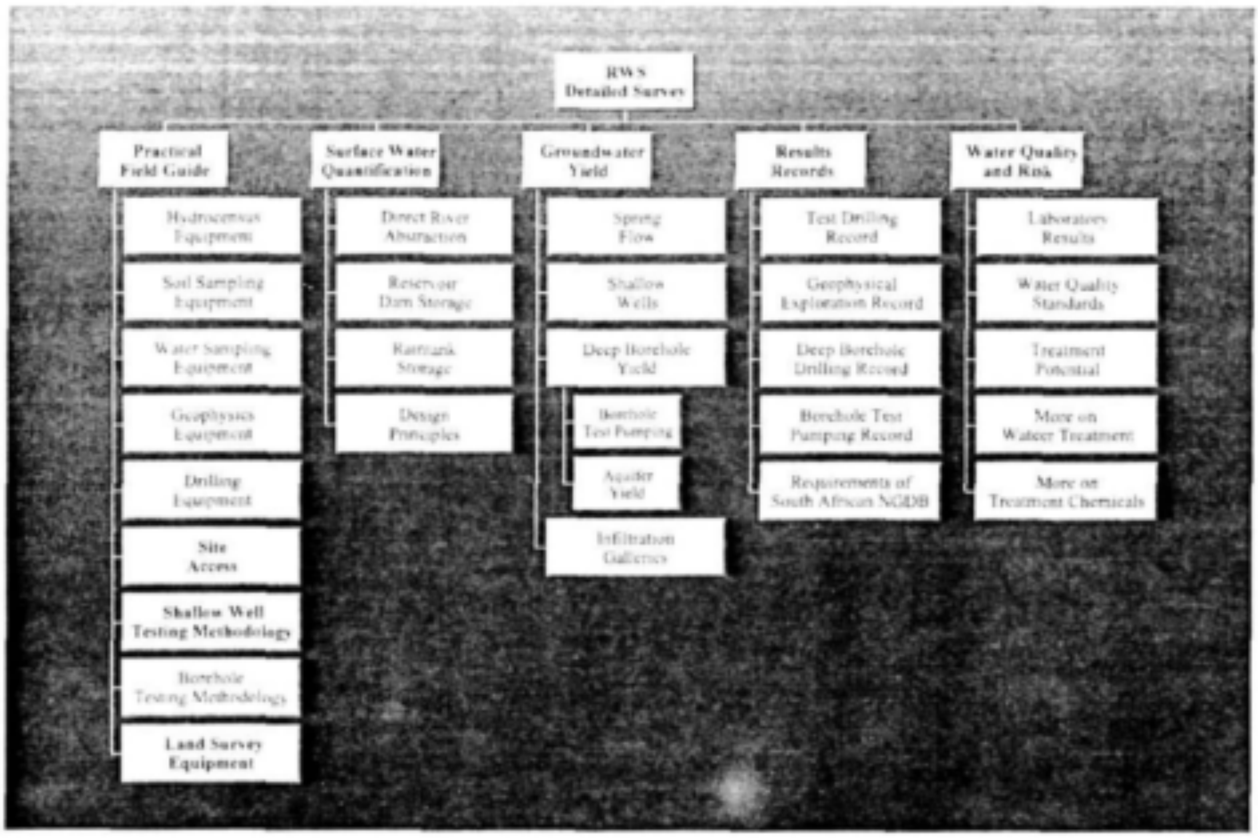


Figure B.8 RWS-DSS Detailed Survey Bitmap/Flowchart

6.1 PRACTICAL FIELD GUIDE (Component C.1)

Guidelines are provided in the Minimum standards and guidelines for groundwater resource development for the community water supply and sanitation programme (South African DWAF, 1997) as well as in other specialised field hand books. Table B.12 provides the Practical Field Guide flow diagram and format contained in sub-component C.1.

Table B.12 RWS-DSS Practical field guide flow diagram and format

Feasibility field survey completed?

YES -> Desk top study findings combined with field reconnaisance suggest that existing surface water sources may not be adequate?
YES -> At the same time, information relating to groundwater occurrence is either not available or is grossly inadequate for planning purposes?
YES -> Detailed hydrogeological/groundwater survey
-> Excavation equipment is available?
YES -> Investigate shallow aquifers with trial pits
-> Geophysical equipment is available?
YES -> Geophysical exploration
-> Drilling equipment is available?
YES -> Shallow groundwater test drilling exploration.
-> Sites are accessible for drilling rigs?
YES -> Deep borehole drilling:
- Geological borehole logs,
- Penetration rates,
- Blow yields.
-> Geophysical logging.
-> Test pumping.

Optional Components with the objective of providing information for the user include <***Objectives of Groundwater Exploration***>, <***Hydrocensus Equipment***>, <***Soil Sampling Equipment***>, <***Water Sampling Equipment***>, <***Geophysics Equipment***>, <***Test Drilling Equipment***>, <***Direct Drilling Equipment***>, <***Site Access***>, <***Shallow Well Testing Methodology***>, <***Borehole Testing Methodology***> and <***Land Survey Equipment***>.

The <***Geophysics Equipment***> section is a guideline to users about the advantages, constraints and acceptability of results interpretation for geophysical work undertaken by project consultants.

Two or more geophysical techniques should be used to locate groundwater drilling targets. Conditions for application and selection of the appropriate equipment are described but skilled personnel are required to conduct these survesy and interpret the reesults. This is a costly part of any detailed survey component involving groundwater and can lead to the siting of dry boreholes if not conducted correctly and/or if undertaken by personnel less than qualified for the job.

6.2 SURFACE WATER YIELD (Component C.2)

Guidelines are contained in WR90 (Midgley et al., 1994) in preference to Sami and Murray (1998), i.e. Chapter 8 of the inception report for the RWS-DSS which is not used. Table B.13 lists the Surface Water Source Options contained in sub-component Section C.2.

Table B.13 RWS-DSS Surface Water source options

Small localised streams or larger nearby rivers: - River direct pump abstraction (no impoundment) - Reservoir impoundment Rainwater collection systems: - Roof runoff to raintanks

Components to be processed include <***Reservoir/Dam Storage***> and <***Raintank Storage***>. A 'Help' section contains a description of <***Surface Water Design Principles***>.

The simple methods to quantify storage yield, contained in the RWS-DSS, are based on a new database developed for regional parameters of the storage-yield relationships using cumulative data at all quaternary catchment outlets of WR90. To facilitate rapid data manipulation and surface water resource quantification the DSS shell system has been coded to read this matrix data into the RWS-DSS when the correct Quaternary catchment number is entered into the appropriate input box.

6.2.1 Direct river abstraction (Component C.2.1)

In South African rural areas, daily flow data of sufficient duration and reliability to calculate the safe pumping yield from direct river abstraction is not always available. Even where such data does exist available methodologies to estimate reliable river flow require a combination of specialist technical skills and experience.

Direct pumping or river impoundment can be used as the main water source if there is enough good quality water available. But, because such techniques can result in highly unreliable results when used by non-experts these methods are not presented for use in the RWS-DSS computer program at this time.

6.2.2 Reservoir/dam storage (component C.2.2)

Guidelines are contained in WRC Report No. 298/1/94 (WR90 User's Manual, Midgley et. al., 1994). Table B.14 provides the objectives of the Reservoir Storage Design sub-component contained in Section C.2.2.

Table B.14 RWS-DSS Reservoir storage design objectives

Objectives:	
1	Identification of dam site
2	Checking of water rights
3	Delineation of catchment boundaries and estimation of area
4	Estimation of the total demands on the reservoir, i.e. the duty
5	Calculation of the volume of storage needed to meet the given duty, i.e. how big to make the dam
6	Meeting of the prescribed degree of assurance/return period reliability
7	Construction of dam at minimum cost (including environmental damage)

Raw data source: WR90 Book of Maps and Appendices (Volumes I to VI)
Method used: Storage-Draft-Frequency Curves

Sub-components to <***Estimate Reservoir Storage Volume***> include <***Hydrological Parameters***>, <***Reservoir Storage and Surface Area***>, <***Gross Evaporation***>, <***Drought Rainfall and Net Evaporation***>, <***Reservoir Storage Evaporation***> and <***Gross Draft and Live Storage***>. A 'Help' section describes the principles of a <***Reservoir Design Guide***>.

Step-by-step guidelines provided within the RWS-DSS computer package, described below, can be used with or without the WR90 database. The Reservoir Guide for design parameter estimation are contained Tables B.15 to B.20.

Table B.15 Step 1 RESERVOIR GUIDE: Hydro parameters

ACTION	
1	Obtain map coordinates (latitude and longitude) of settlement/area of interest.
2	Select the correct SWRSA volume number (I to VI).
3	Select the BASE MAP in the Book of Maps and locate the nearest largest town.
4	Locate the coordinates for the settlement/area of interest on the selected Base Map.
5	Note the quaternary subcatchment Drainage Region Number, e.g. X31J.
6	Select the RUNOFF map in the Book of Maps for the Drainage Region
7	Locate the Drainage Region Number and read off the Hydrological Zone (alphabet letter designated in red type) e.g. Drainage Region X31J is in hydrological zone VI-C
8	Select Appendix 8, locate the subcatchment Drainage Region No. and read off the Evaporation Zone, the Mean Annual Evaporation (MAE mm), Rain Zone, the Mean Annual Precipitation (MAP mm) and the Mean Annual Runoff (MAR mm) e.g. Drainage Region X31J is in Evaporation Zone 5A, has an average MAE of 1 400 mm, is in Rain Zone X3A, has an average MAP of 902 mm and an average MAR of 189 mm.
9	Estimate the catchment drainage area: Use a 1:50 000 topographic map to outline and trace the catchment area above the dam site. Draw a line along the highest points around the headwaters of all tributaries above the dam to separate the catchment from tributaries draining other catchments. Overlay the tracing on 1 cm^2 graph paper and count the number of squares for conversion to area in km^2, e.g. a catchment area measuring 68 cm^2 is equal to 68 km^2 because 1 cm^2 is equal to 1 km^2.
10	Catchment runoff is calculated by multiplying the area by the depth of MAR, e.g. a total catchment area of 68 km^2 multiplied by a MAR of 189 mm is equal to 12.8×10^6 m^3 or 12.8 ML
11	The Water use Gross Draft for reservoir design, before consideration of water losses, is based on the Average daily Water Demand (ML or 10^3 m^3), e.g. and is equal to 2.5 10^6 m^3.
12	Express Water Use Gross Draft as a percentage of catchment area runoff (MAR), e.g. a gross draft of 8.3×10^6 m^3 divided by a catchment runoff of 12.8×10^6 m^3 is equal to 0.6484 or 64.84%.

Table B.16 Step 2 RESERVOIR GUIDE: Storage/Area

ACTION	
1	Estimate the storage requirement and reservoir area for different selected rainfall return periods.
2	Go to Appendix 11.1 and select the page corresponding to the Storage-Draft-Frequency curve for the predetermined hydrological zone, e.g. V1-C.
3	Interpolate Live Storage (% MAR) from the calculated value of Gross Draft (% MAR) for different Recurrence Intervals, e.g. in Hydro Zone V1-C a Gross Draft of 64.84% would require a Live Storage of 34 % of catchment area runoff (MAR) for a 20 year Recurrence Interval but the Live Storage requirement for a 50 year Recurrence Interval would be 57 % catchment area runoff (MAR).
4	Estimate the reservoir area for the selected rainfall return periods using the Storage-Area equation. The Storage-Area equation used to estimate the surface area of a planned reservoir is: $A = 0.39 \times S^{0.5}$ where: A = Reservoir surface area S = Reservoir storage (10^6 m^3) For example: 0.39 multiplied by a reservoir storage equal to 4.4 x 10^6 m^3 to the power of 0.5 will produce a surface storage area of 0.82 km^2. Source: SWRSA 1990

Table B.17 Step 3 RESERVOIR GUIDE: Gross Evaporation

ACTION	
1	If <Catchment parameters> file not processed then select Appendix 8, locate the subcatchment Drainage Region No. and read off the Evaporation Zone and the Mean Annual Evaporation (MAE mm).
2	Select Appendix 3.2 to obtain the disaggregated figures for monthly evaporation as a percentage of MAE for the Evaporation Zone, e.g. Evaporation Zone 5A has 9.50% of MAE in October and 9.48 % in November etc. OR use local station readings.
3	Convert monthly evaporation as a percentage of MAE to reservoir evaporation (mm) as a proportion of total MAE, e.g. For Evaporation Zone 5A the MAE equals 1 400 mm and if the October evaporation is 9.5% of MAE then the monthly depth of reservoir evaporation is equal to 133 mm.
4	Select Appendix 3.3.1 to obtain monthly Symons pan factors for open water evaporation, e.g. October pan factor equals 0.81, November equals 0.82 etc.
5	Multiply monthly Symons pan evaporation (mm) by the monthly lake pan factor to obtain gross lake evaporation (mm), e.g. October Symons pan evaporation of 133 mm multiplied by a lake pan factor of 0.81 gives a gross lake evaporation of 108 mm for the month.

Table B.18 Step 4 RESERVOIR GUIDE: Drought Rainfall/Net Evaporation

ACTION	
1	If <Catchment parameters> file not processed then select Appendix 8, locate the subcatchment Quaternary catchment No. and read off the Rain Zone and the Mean Annual Precipitation (MAP mm). Drought rainfall is calculated as a fraction of MAP. For rapid preliminary estimations this is typically taken to be 0.7 of MAP.
2	Subtract drought rainfall from lake evaporation to calculate drought net evaporation, e.g. MAP of 902 mm multiplied by 0.7 equals a drought rainfall of 631.4 mm so say 630 mm.
3	Select Appendix 2.2 to obtain the disaggregated figures for monthly rainfall as a percentage of MAP for the Rainfall Zone, e.g. Rainfall Zone X31J has 6.85% of MAP in October and 13.08 % in November etc. OR use local station readings.
4	Convert monthly rainfall as a percentage of MAP to drought rainfall (mm) as a proportion of total MAP, e.g. For Rainfall Zone X31J the drought MAP equals 630 mm and if the October rainfall is 6.84 % of MAP then the monthly drought rainfall is equal to 43 mm.
5	*Obtain an estimate of the drought net evaporation by subtracting the monthly drought rainfall* from the monthly gross lake evaporation, e.g. October's gross lake evaporation of 108 mm minus October's drought rainfall of 43 mm is equal to a net drought lake evaporation of 65 mm.

Table B.19 Step 5 RESERVOIR GUIDE: Storage Evaporation

ACTION	
1	Apply the Universal Evaporation Loss Equation to estimate the probable volume of net evaporation loss (10^6 m^3) over the critical drought period (Ev). $Ev = 0.001 \times En \times Af \times ((1+Sr)/2)^b \ (10^6\ m^3)$ For example if: En = Net evaporation loss = 547.1 mm/a Af = Full reservoir area = 0.82 km^2 Sr = Se/Sf = 0 because Se = Reserve storage volume (10^6 m^3) = 0 Sf = Full storage volume (10^6 m^3) b = 0.5 Then: $Ev = 0.001 \times 547.1 \times 0.82 \times (0.5)^{0.5}$ $= 0.32\ (10^6\ m^3)$

Note: If reserve storage is close to zero then Sr can be set to zero, i.e. assumes no reserve storage.

Table B.20 Step 6 RESERVOIR GUIDE: Gross Draft/Live Storage

ACTION	
1	Gross Draft volume: Add the critical evaporation loss to the water use gross draft, e.g. for a water use gross draft of 8.3 (10^6 m^3) plus a critical evaporation loss of 0.32 (10^6 m^3) is equal to a Gross Draft of 8.62 (10^6 m^3).
2	Gross Draft % MAR: Divide the Gross Draft volume by the catchment area runoff volume and then multiply this by 100, e.g. Gross Draft volume of 8.62 (10^6 m^3) divided by a catchment area runoff volume of 12.8 (10^6 m^3) multiplied by 100 is equal to 67% of MAR.
3	Live Storage % MAR: Go back to Appendix 11.1 and select the page corresponding to the Storage-Draft-Frequency curve for the predetermined hydrological zone, e.g. V1-C. The different Gross Draft values calculated below for the different Return Periods will provide different values of Live storage % MAR. Interpolate Live Storage (% MAR) from the calculated value of Gross Draft (% MAR) for different Recurrence Intervals, e.g. in Hydro Zone VI-C a Gross Draft of 68.0 % would require a Live Storage of 55.0 % of MAR for a 20 year Recurrence Interval but the Live Storage requirement for a 50 year Recurrence Interval would be 70 % of MAR.

Warning: The step-by-step guidelines should be followed in the order presented to ensure the correct computerised estimation of yield.

6.2.3 Raintank storage (Component C.2.3)

Guidelines are contained in WRC Report No. 298/1/94 (WR90 User's Manual, Midgley et al., 1994). Table B.21 provides the objectives of the Raintank Storage Design sub-component contained in Section C.2.3.

Table B.21 RWS-DSS Raintank storage design objectives and required steps

Objectives:	
1	Rainwater collection directly from household roofs, before it drains to the ground.
2	Raintank storage to provide good quality water for drinking and cooking.

NOTE: - Raintanks, generally, are best suited for use as a supplementary supply of fresh water for personal consumption. Raintank storage will not provide enough water for all rural water supply needs and water quality may be a problem. Raw data source: WR90 Book of Maps and Appendices (Volumes I to VI) and method used: Storage draft analysis for low flow sequences.

Sub-components to <***Estimate Raintank Storage Volume***> include <***Hydrological Parameters***>, <***Household Drinking Water Demand***>, <***Effective Monthly Roof Runoff***> and <***Raintank Storage***>. A 'Help' section describes the principles of a <***Raintank System Design Guide***>.

Step-by-step guidelines provided within the RWS-DSS can be used with or without the WR90 database. The Raintank Guide for design parameter estimation is contained in Tables B.22 to B.25.

Table B.22 Step 1 RAINTANK GUIDE: Hydro parameters

ACTION	To obtain rainfall values (Mean Annual Precipitation (MAP) and month by month):
1	Obtain map coordinates (latitude and longitude) of settlement/area of interest
2	Select the correct WR90 volume number (I to VI)
3	Select the BASE MAP in the Book of Maps and locate the nearest large town
4	Locate the coordinates for the settlement/area of interest on the selected Base Map
5	Note the Quaternary subcatchment Drainage Region Number, e.g. X31J
6	Select Appendix 8, locate the Quaternary catchment Drainage Region No. and read off the Rain Zone e.g. Drainage Region X31J is in Rain Zone X3A.

The time period of data capture would ideally be a minimum of 50 years for reliability of forecast.

Table B.23 Step 2 RAINTANK GUIDE: Household drinking water demand

ACTION	
1	The Water use Gross Draft for raintank design, before consideration of water losses, is based on a household monthly water demand for personal consumption (drinking and cooking) calculated from 6 litres/capita/day, e.g. 6 people in one household requiring 6 litres each per day need a total of 36 litres/day multipied by 30 days = 1 296 litres/month or 1.3 m^3/month.

Table B.24 Step 3 RAINTANK GUIDE: Effective monthly roof runoff

ACTION	
1	Select the correct rain zone in Appendix 2.2 and pick out the dry year of interest. The monthly rainfall expressed as a percentage of the MAP is estimated in a stepwise manner, starting with an assumed situation for the end of a drought and working in reverse chronology over the preceding 5 years, i.e. for a total of 60 months beginning with the last month of the driest year. Enter the rainfall as a percentage of the MAP for allmonths.
2	Convert the precipitation as a percentage of MAP into depth of rainfall (mm), e.g. 605 mm MAP and monthly rainfall of 4.42% = 605 x 4.42/100) = 26.74 mm/month.
3	Estimate the roof catchment drainage area, e.g. 50 m^2.
4	Estimate the Rainfall Splash factor to account for rainfall intensity, i.e. to deduct a percentage for initial water losses due to wetting of the roof surface, splash, overflowing or leaking gutters and water losses due to evaporation and roof leakage. In most cases a rainfall splash factor of 0.8 can be used to account for losses (Hofkes, 1983). This design runoff will not exceed 80% of the design rainfall, i.e. for every 1 mm of MAP a yield of 0.8 litres can be expected per 1 m^2 of roof area.
5	Roof catchment runoff is calculated by multiplying the roof area by the monthly depth of MAP multiplied by the splash factor, e.g. a roof catchment area of 50 m^2 multiplied by a monthly rainfall of 26.74 mm and a splash factor of 0.8 is equal to 1 069 litres/month or 1.07 m^3 /month.

NOTE: Seasonal distribution of rainfall is important because the available storage must be equal to the drinking water demand multiplied by the longest expected period without rain. This may mean, in effect, that an area with all year round rainfall could require a relatively smaller rain tank storage capacity than another area with a marked seasonality of rainfall because a larger proportion of the MMR would need to be stored to meet demand during dry periods. Similarly an area with a high MAP but high seasonality could require larger tanks than another area with lower MAP but falling throughout the year. As demand increases however this situation may be reversed.

Table B.25 Step 4 RAINTANK GUIDE: Storage

ACTION:	
1	Stepwise solution for Live Raintank Storage equation: Estimate raintank storage for monthly household drinking water demand in a stepwise manner. Start with the assumed situation at the end of a drought, when the storage state is equal to zero, and work in reverse chronology until a maximum storage state is defined. Sb = Se + Um - Im Where: Sb = Storage state at month beginning Se = Storage state at month end Um = Draft (usage) from raintank during month Im = Net inflow to raintank during month, i.e. effective monthly roof runoff.
2	Check the mass balance over the critical period, viz. for the period it takes for the raintank to go from the maximum storage state until it isempty (or has reached a stipulated dead storage). For example for the time period including the driest year in 1926 for Grahamstown the critical period is 10 months - from December 1927 to September 1926. But for Beufort West the critical period is 57 months january 1921 to September 1925. Note that this critical period requires a very large storage volume which may not be practical or economic.
3	Dead storage: To account for unusable storage below the tap outlet enter a dead storage factor to calculate a value for dead storage. For example, if the maximum storage state is 4.83 m^3/month and the dead storage factor is 0.1 then the dead storage requirement will be 4.83 x 0.1 = 0.483 m^3/month.
4	Calculate total raintank storage requirement by adding the live storageand dead storage values together. For example, a live storage of 4.83 m^3 plus a dead storage of 0.483 added together results in a total raintank storage requirement of 5.31 m^3/month.
5	Storage/yield relationship for various tank sizes: It may not be economical to provide a large enough storage tank to collect all effective runoff and meet the total raintank storage requirement. The effective storage requirement can be limited by reducing the live storage. If required enter a drinking water demand factor as a fraction less than 1.0. This will result in a shortfall in demand. For example, if the household drinking water demand is 1.2 m^3 a drinking water demand factor of 0.8 will reduce this demand to 0.96 m^3/month.

Warning: The step-by-step guidelines should be followed in the order presented to ensure the correct computerised estimation of yield.

6.3 GROUND WATER YIELD (Component C.3)

All guidelines for the quantification of ground water resources are based on methodologies contained in Water Research Commission Report No. 677/1/98, Chapter 7. The computer calculations for yield recommendations apply standard formulas currently in use by most specialists working in the groundwater sector. Table B.26 provides the Ground Water Abstraction Methods contained in component C.3.

Table B.26 RWS-DSS Ground Water abstraction methods

Ground Water Source Options:

- Spring flow protection and storage
- Shallow wells
- Deep boreholes (Tube wells)
- Infiltration galleries

The choice of application depends on depth to the water table, the geology, hydrogeology, available drilling equipment and the potential sustainable yield.

Components containing methods for computer analysis include <***Spring Flow***> and <***Deep Borehole Yield***>.

6.3.1 Spring flow (Component C.3.1)

Guidelines are contained in Sami and Murray (1998), Chapter 9. Table B.27 provides the objectives of the Spring Flow sub-component and the steps required when using component C.3.1.

Table B.27 RWS-DSS Spring flow objectives and required steps

Objectives	
1	Estimation of spring flow volume.
2	Estimation of storage requirement when peak demand exceeds spring flow.
Steps	
1	Spring flow measurement(s)
2	Estimation of drought yield

Components to be processed include <***Estimate Spring Flow***> and <***Estimate Spring Flow Storage***>. 'Help' Components provided include <***Principles of Spring Flow Quantification***> and <***Need for Spring Flow Storage***>.

The method used by Sami and Murray (1998), to estimate low spring flows during drought in the absence of long-term field measurements, is the only method available at the present time (pers. comm. Sami, 1999). Long-term field measurements are time-consuming and costly but in their absence the recommended method may be used but with extreme caution.

6.3.2 Shallow wells (Component C.3.2)

The RWS-DSS methods recommended for the analyses of test pumping results are specifically designed to interpret data obtained from boreholes drilled into hard rock terrain; typically found in South African conditions. *Because shallow wells lie close to the surface and are generally restricted to primary aquifers, in unconsolidated material, the recommended methods for test pumping analysis are* ***not applicable****. More traditional methods of test pumping analyses based directly on the Theis equation should therefore be applied.*

Yield testing of small diameter auger holes should be undertaken to determine the optimum shallow diameter before they are excavated. In general, if a 0.1 metre diameter test hole yields greater than 500 l/h then a smaller diameter (0.05 m dia.) hand drilled or augured well would be sufficient. This would also avoid the de-watering problems associated with digging by hand below the water table.

Guidelines for a methodology to test shallow wells, contained in Sami and Murray (1998), Chapter 6.4, are included in the <***Practical Field Guide***> sub-component.

6.3.3 Deep borehole yield (Component C.3.3)

Guidelines are contained in Sami and Murray (1998), Chapter 7. Table B.28 provides the objectives of the Deep Borehole Yield contained in component C.3.3.

Table B.28 RWS-DSS Deep borehole yield objectives

Objectives:	
1	Identification of borehole site(s)
2	Checking of water rights
3	Drilling and test pumping programme (if required)
4	Assessment of recharge and aquifer area
5	Recommendation of groundwater yield
6	Meeting of the prescribed degree of assurance/return period reliability
7	Construction of borehole at minimum cost (including environmental damage)

Sub-components containing guidelines for the methods to be processed include <***Borehole Test Pumping***> and <***Aquifer Yield Estimation***>.

There are no definitive methods yet available for recommending single borehole abstraction rates when drilled into secondary, confined, aquifers in hard rock. The methods used in the RWS-DSS have been developed to be applicable to boreholes drilled into aquifers of limited exploitation potential in predominantly semi-arid climates and hard rock characterised by low porosity (storage) and low permeability (connectivity of pores/rate at which the water can move towards the borehole).

The RWS-DSS methods applied include:

- Constant discharge rate test data analysis methods including: drawdown-to-boundary, distance-to-boundary and late-time methods.
- Recovery test data analysis method.
- Two methods used to estimate aquifer yield, i.e. the recharge and storage methods.

Conditions required for the application of the respective methods are described and it is recommended that several of the methods considered to be the most appropriate are used in order to verify recommended results.

Note: Failure to meet the specified conditions for the estimation of any parameter can lead to incorrect yield results and consequent inaccurate borehole yield recommendations.

Borehole test pumping (Component C.3.3.1)

Four methods are presented for the recommendation of borehole yield from analysis of test pumping data. The methods include: Drawdown-to-Boundary; Distance-to-Boundary; Late-Time; Recovery Test. These methods are specifically designed for application to double porosity fractured rock aquifers specifically found in Southern African environments. The basic equation used is provided in Table B.29.

Table B.29 RWS-DSS Basic equation adapted for test pumping data analysis in Sami and Murray (1998)

Data analysis is based on various adaptations of the Cooper-Jacobs approximation of the Theis equation:

$$Q = 4phiTs\,[2.3\log(2.25Tt/r^2S)]$$

where:

Q = sustainable yield (m3/d)
T = transmissivity (m^2/d)
s = available drawdown (m)
t = pumping time (days)
S = storativity

Sub-components to be processed include <***Enter CD Test Results***>, <***Drawdown-to-Boundary Method***>, <***Distance-to-Boundary Method***>, <***Late-Time Method***> and <***Recovery Method***>. 'Help' Components include <***Basic Equation***>, <***More on Borehole Yield Quantification***>, <***More on Regional Storativity***> and <***Guidelines for Application***>.

Borehole test Components require the entry of measured field data and a graphic manipulation process for computer analysis and substitution of results into the relevant equations to recommend sustainable yields, i.e. the yields cannot be quantified without processing this facility. Each of the presented methods for computer assisted borehole test pumping data analysis contain step-by-step guidelines within the computer program and each contain the following components: <***Explanation of Method***>, <***GRAPH***>, <***How to Use Graph***> and <***Storativity Values Table***>.

All of the recommended techniques for data collection and interpretation should be applied with the assistance of hydrogeologists with specialist skills.

Aquifer yield estimation (Component C.3.3.2)

Two aquifer yield estimation methods have been selected, from those methods presented in Sami and Murray (1998), for application within the RWS-DSS and the recommendation of borehole yield. These are based on recharge to the aquifer and the volume of water held by the aquifer in storage. To apply either, or both, of these two methods the user must be able to estimate as accurately as possible certain specified aquifer parameters which may include: aquifer type, recharge area, aquifer thickness, seepage face width and degree of anisotropy. It is also necessary to specify whether the borehole penetrating the aquifer is in the zone of maximum or minimum transmissivity. Wherever required each of these parameters is explained in attached 'Help' Components along with guidelines for application.

Sub-components to be processed include <***Aquifer Recharge Method***> and <***Aquifer Storage Method***>. The main 'Help' Components include <***More on Aquifer Yield***>, <***More on Aquifer Recharge***> and <***More on Aquifer Storage***>.

Aquifer yield Components require specialized knowledge and experience of hydrology and geology to estimate the required parameters for yield recommendations and should be used with caution.

6.3.4 Infiltration galleries (Component C.3.4)

Infiltration galleries are increasingly being developed for use in rural areas where there is no other potential source of water available to a community. The technique of installing collector pipes into a trench, or system of trenches, is used to abstract groundwater from the weathered zone and can sometimes be used in hard rock terrain; if fractures and other interconnected groundwater flow pathways are limited.

In such areas it may not be cost effective to instal groundwater abstraction devices which collect water from a single point. There may, however, be enough water stored in the weathered zone for community needs if it is collected from a wider area that extends across the shallow water-bearing zone.

Methods to assess the potential yield from infiltration galleries are currently being developed (current Water Research Commission project involving experiments with pipe diameters and test pumping) but are not yet available.

6.4 RESULTS RECORDS (Component C.4)

Some guidelines are contained in Sami and Murray (1998), Chapter 6 while others are derived from DWAF's Minimum Requirements for the NGDB or from generally available texts for field applications. Table B.30 provides the objectives of the Results Records sub-component and the steps required when using Section C.4.

Table B.30 RWS-DSS Results records objectives and required steps

Objectives	
1	Post field work exploration, testing and recording of results.
2	Maintenance of data records according to standard practice.
3	Updating of data bases according to governmental requirements
Steps	
1	Data analysis and results recording.
2	Information transfer to recognised data bases.

Components to be processed after completion of the groundwater exploration Components include <***Test Drilling Record***>, <***Geophysical Exploration Record***>, <***Deep Borehole Drilling Record***> and <***Deep Borehole Test Pumping Record***>. Guidelines are provided in the <***Requirements for the South African NGDB***> 'Help' section.

Previous records may be the only information available prior to the implementation of any project and can be of invaluable use to practitioners. In the south African context the NGDB is the official national groundwater data base with a record of more than 200 000 boreholes. However, it is recognized that much of the data is lacking in detail and some incorrect and an effort is currently being made to update this system. To assist in this process forms are provided for straight data and results input in order to record information and to encourage this habit as standard practice. This also might be used to supplement the GIS database for rural water supply recently developed by DWAF.

6.5 WATER QUALITY (Component C.5)

Guidelines are contained in Sami and Murray (1998), Chapter 11, Components 2 to 7. Table B.31 provides the objectives of the Water Quality sub-component and the steps required when using Section C.5.

Components to be processed include <***Laboratory Results***>, <***Water Quality Standards***> and <***Treatment Potential***>. 'Help' Components include <***More on Hydrogeological Risk***>, <***More on Water Treatment***> and <***More on Treatment Chemicals***>.

Table B.31 RWS-DSS Water quality objectives and required steps

Objectives	
1	To record laboratory results and determine the water quality classification according to recognised standards for rural water supply.
2	To assess the risk of groundwater pollution from existing sources of contamination.
3	To assess whether or not water treatment is required.
4	To assess whether or not the community will have the capacity to successfully manage the treatment process on a sustainable basis.
Steps	
1	Water quality laboratory analysis.
2	Results recording and evaluation.
3	Information transfer to recognised data bases.

6.6 SUMMARY OF PROJECT SYSTEM DESIGN (Component C.6)

This section is a constructed to summarize system design. More detailed guidelines are contained in Sami and Murray (1998), Chapter 12. Table B.32 provides the objectives of the Project Design contained in Component C.6.

Table B.32 RWS-DSS Project design objectives

Objectives	
1	To summarise the selected water source construction design and power supply (if appropriate).
2	To summarise the design level of service of the distribution and reticulation network.
3	To record the community level of service preference.

7. DETAILED DESIGN COMPONENT

While section 6.6 (included at the end of the <***Detailed Survey***> component) outlines the selected project design, a <***Detailed Design***> infrastructure component has not been included. Experienced engineers who customarily design rural water supply infrastructure requirements on a routine basis consider that this aspect is unique to every individual project and the generic approach adopted in the RWS-DSS may not be appropriate. This was attempted by the Bill of Quantities list recommended for use by the Build, Operate, Train and Transfer (BOTT) program but was reported by engineers involved in the sector to very often not be sufficiently comprehensive for useful application to project design and, in fact, extremely time-consuming when it was required to be used in project proposals because of frequent omission. Similarly discussions with Mr Oli Glatz, DWAF, King William's Town emphasized the enormity of tackling this aspect on a generic basis and that time may better be spent on other aspects of the RWS-DSS required by DWAF.

While other components contained in the RWS-DSS, although large, have been encoded within the RWS-DSS it is suggested that a decision support system for this aspect may constitute a WRC project in its own right, comparable, for example, to that currently being completed at the CSIR for Water Quality.

8. TRAINING COMPONENT (D)

Guidelines for factors to be considered for pre-project and project implementation training have been designed according to recommendations developed by the Rural Development Services Network (RDSN) for use on Mvula Trust projects as restructured (where applicable) according to DWAF's ISD package (1999). Guidelines for operation and maintenance training are included in Sami and Murray (1998), Chapters 14. Table B.33 provides the objectives of the Training component and the steps required. Figure B.9 provides the corresponding flow chart to assist in user orientation.

Table B.33 RWS-DSS Training objectives and required steps

Objectives	
1	To ensure that an adequate pool of local people have all of the skills necessary to be involved in all stages of the rural water supply project planning and construction process
2	To ensure that community members have all of the required skills to take ownership for system operation, maintenance and monitoring
3	Assessment of the community's training needs
4	Planning of training modules
Steps	
1	Community liaison and interaction during all phases of the project cycle beginning at the point of registration of need up until after project commissioning and post-project evaluation

Sub-components to be processed include ***<Training Needs Assessment>*** and ***<Planning Training Modules>***.

The training needs assessment sub-component is designed to encourage the user to consider all aspects of ***<Pre-Project>***, ***<Implementation>*** and ***<Post-Project>*** training and mentoring needs in terms of whether or not the community's skills base is perceived to be inadequate, marginal, adequate or fully satisfactory. In this way it is possible to assess the degree of training required for project success or if in fact some factors require no training.

Components the user is encouraged to consider when planning training modules include ***<Community Awareness>***, ***<Organisational Skills>***, ***<Project Management>***, ***<Financial Skills>***, ***<Technical Construction Skills>***, ***<Operation and Maintenance Skills>***, ***<Health and Hygiene>***, ***<Water Source Monitoring>*** and ***<Post-Project Evaluation and Mentoring>***.

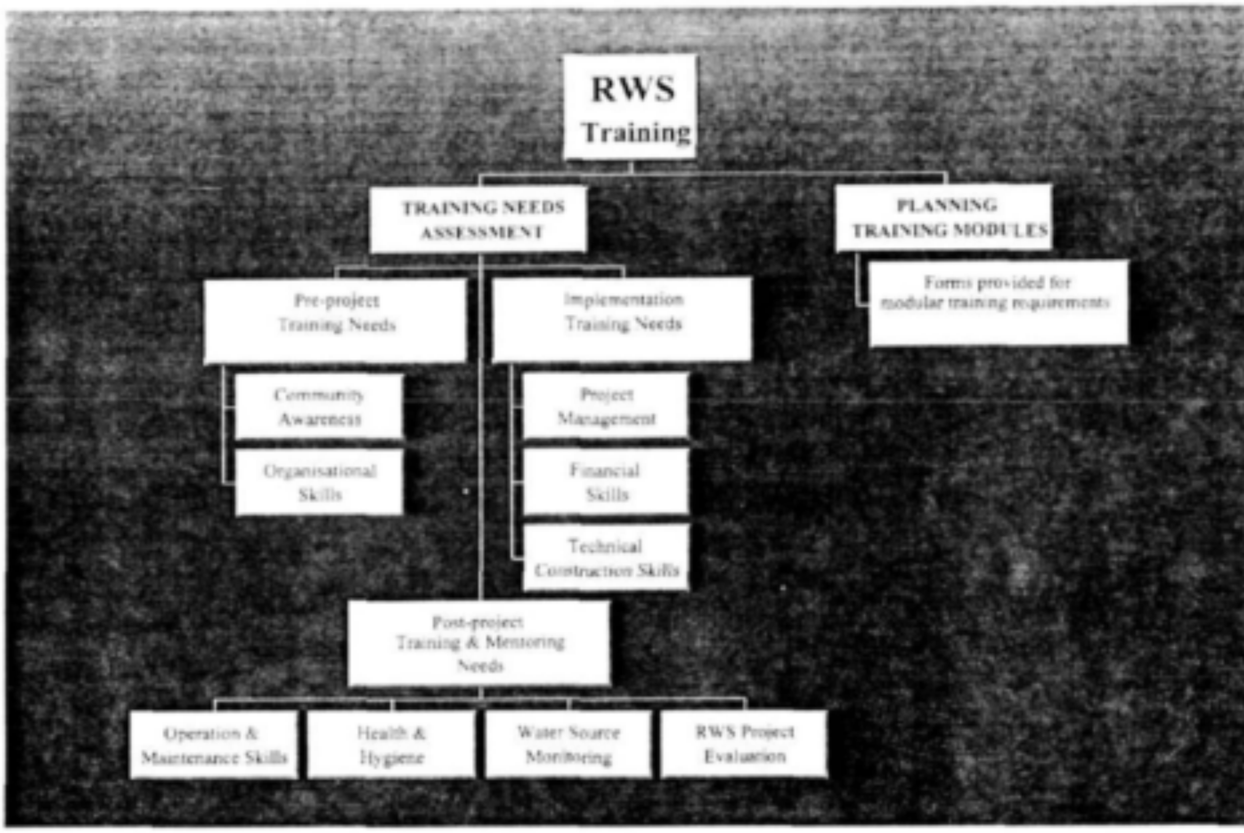


Figure B.9 RWS-DSS Training Bitmap/Flowchart

9. OPERATION AND MAINTENANCE COMPONENT

Operation and maintenance is included in the context of other Components (where appropriate), such as, the <***Training***> and <***Budget***> components. Guidelines used are contained in Sami and Murray (1998), Chapter 14, as restructured according to formats which have been developed for practical use by organizations working closely with communities since the implementation of the Reconstruction and Development Programme. Methodologies have often been developed by trial and error by Non-Governmental Organizations, such as Mattcom, who have worked in the sector over the last five years.

10. BUDGET COMPONENT (E)

Summary guidelines are contained in Sami and Murray (1998), Chapters 2, 14 and 15 as restructured to incorporate appropriate details included in DWAF's ISD Package (1999), DWAF's Minimum Requirements Guidelines (1997) and DFID's Guidance Manual (1999) as well as details included in the Bill of Quantities recommended by BOTT and a format used by the KwaZulu/Natal Joint Services Board for application to rural water supply groundwater projects. Table B.34 provides the objectives of the Budget component and the steps required when using component E. Figure B.10 provides the corresponding flow chart to assist in user orientation.

Sub-components to be processed include <***Decision-Support Costing***> and <***Detailed Costing***>.

Table B.34 RWS-DSS Budget objectives

Objectives:	
1	Decision support to compare alternative water supply options
2	Detailed breakdown of costs for selected project - Source exploration and development - Survey and design - Project construction - Community training - Operation and maintenance

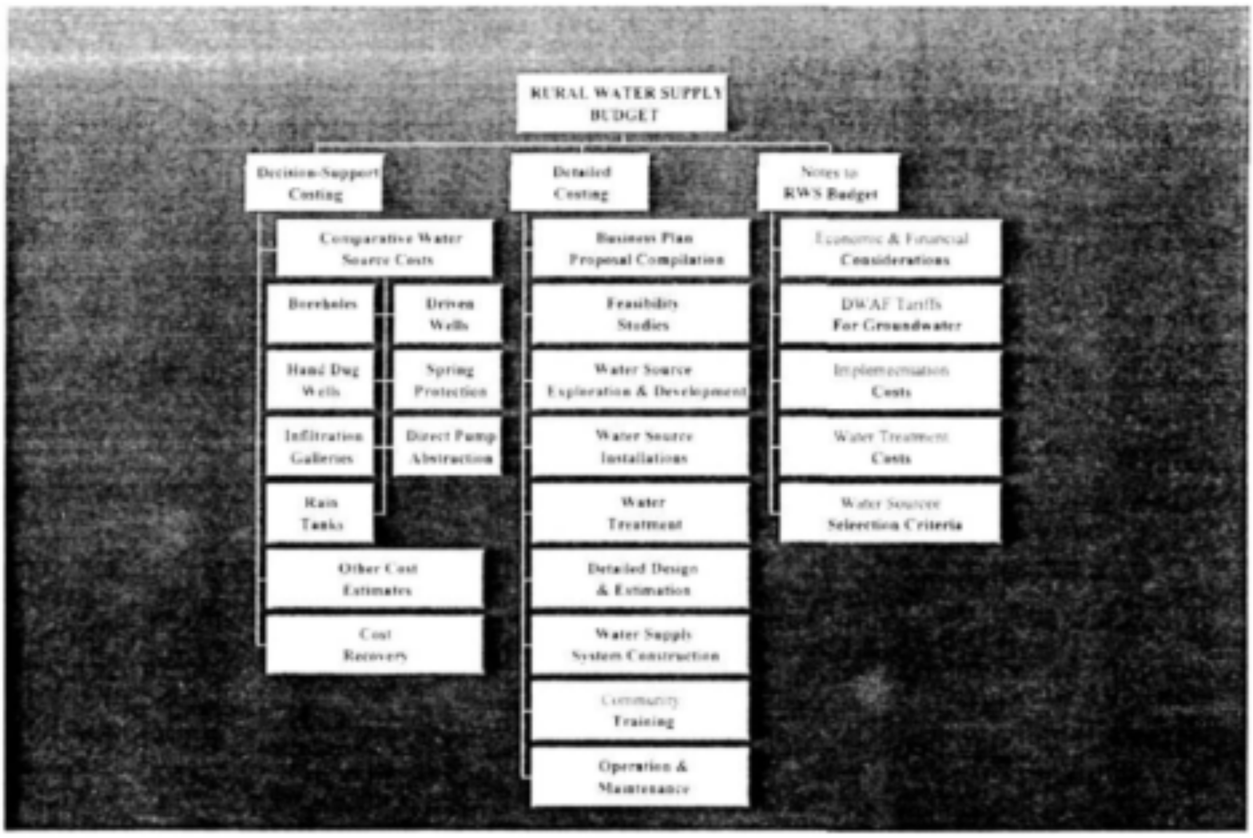


Figure B.10 RWS-DSS Budget Bitmap/Flowchart

10.1 DECISION-SUPPORT COSTING (Component E.1)

Table B.35 provides the objectives of the Budget component E 1.

Table B.35 RWS-DSS Decision-Support Costing objectives

Objectives	
1	Estimates of capital costs for different available water sources
2	Evaluation of the relative benefits of all of the available options
3	Estimates of associated overhead costs for project implementation
4	Estimates of associated operation and maintenance costs.
5	Assessment of potential for operation and maintenance cost recovery for the different options under consideration.
6	Selection of least cost alternative

Components to be processed include <***Comparative Water Source Costs***>, <***Other Project Costs***> and <***Cost Recovery***>.

The user is encouraged to compare and evaluate the relative costs and benefits of all of the water supply options that might be available to a community. Sub-components for consideration in the <***Comparative Water Source Costs***> section include <***Boreholes***>, <***Driven Wells***>, <***Hand Dug Wells***>, <***Spring Protection***>, <***Infiltration Galleries***>, <***Direct Pump Abstraction***>, <***Reservoirs***>, <***Raintanks***> and <***Conjunctive Use***>. Sub-components for consideration in the <***Other Project Costs*** > section include overheads such as <***Feasibility Studies***>, <***Water Supply Design and Estimation***>, <***Community Training***> and <***Business Plan Proposal Compilation***> as well as <***Water Supply Network Costs***> capital costs.

The relative costs for small-scale, low income operation and maintenance are also considered. The computer generated table of results for a borehole water source, for example and comparison against other potential sources, would include: Present population, Total capital cost, Cost per capita, Annual repayment cost, Monthly surcharge cost per capita, Number of boreholes drilled, Number of boreholes rehabilitated, Cost per cubic metre, Total monthly operation and maintenance cost, Monthly communal service tariff, Monthly private connection tariff, Total set monthly tariff, Expected monthly tariff recovery, Expected monthly available subsidies and Expected total monthly income.

10.2 DETAILED COSTING (Component E.2)

Table B.36 provides the objectives of the Budget component contained in Section E 2.

Table B.36 RWS-DSS Detailed costing objectives

Objectives:	
1	Itemised costing of selected project water source exploration costs.
2	Itemised costing of selected project water source development costs.
3	Itemised costing of selected project overhead costs.
4	Itemised costing of selected project implementation capital costs.
5	Itemised costing of selected project operation and maintenance costs.

Components to be processed include <***Business Plan Proposal Compilation***>, <***Feasibility Studies***>, <***Water Source Exploration and Development***>, <***Detailed Design and Estimation***>, <***Water Supply System Construction***> (Land, Materials, Machinery and Tools, Labour, Existing Infrastructure Replacement, Site Supervision, Water Committee Costs and Community Training) and <***Operation and Maintenance***>. 'Help' Components include <***Notes to RWS Budget***>, <***Economic and Financial Considerations***>, <***DWAF Tariff of Fees and Disbursements for Ground Water***>, <***Implementation Costs***>, <***Water Treatment Costs***> and <***Water Source Selection Criteria***>.

11. BUSINESS PLAN COMPONENT (F)

The objective of a Business Plan is to summarise the proposed project for submission to potential funders. A <***Business Plan***> format based on the recommendations contained in Sami and Murray (1998), Chapter 3, is contained within the RWS.DSS files. Figure B.11 provides the flow chart to assist in user orientation through Business Plan component contained in Section F.

Given the recent changes and restructuring contained in DWAF directives, this section is not interactive with other components of the RWS-DSS at present. The user is requested to enter information directly into this component for testing and then to provide feedback to the program developers about the content and structure contained, i.e. is the section as presently constructed of use and, if not, what would be a better format for the reporting facility designed to summarise the RWS-DSS program users results?

Sub-components to be processed include <***Registration of Need for RWS Development***>, <***Project Management Structure***>, <***Proposed Project Scheme Design***>, <***Regional Setting and Development Plans***>, <***Training Needs***>, <***Labour Management and Employment Policy***>, <***Sourcing of Services***>, <***Operation and Maintenance Institutional Support***>, <***Budget***>, <***Requested Funding***>, <***Operation & Maintenance Financial Strategy***>, <***Time Frames***> and <***Checklist: Project Preparation Cycle***>.

To assess how much of the rural water supply project preparation cycle has been completed a section has been constructed requiring the user to answer certain recognised criteria as follows: <0> for not begun, <1> for currently in process or <2> for satisfactorily completed.

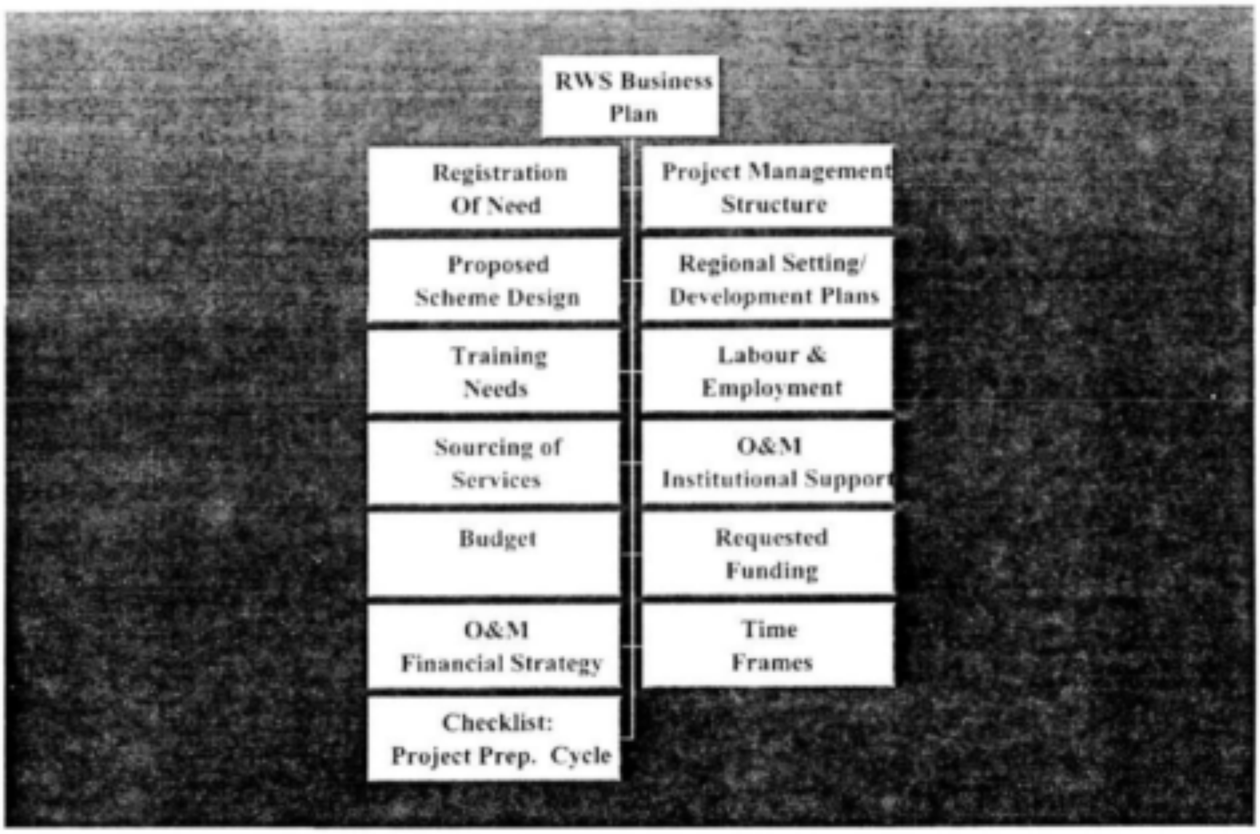


Figure B.11 RWS-DSS Business Plan Bitmap/Flowchart

SECTION C

IWR DSS SHELL SYSTEM

This part of the report provides the technical detail about the generic Descision Support System Shell that has been designed for use with a range of possible DSS applications by the Institute for Water Research. Section C therefore effectively represents a manual that can be used by those users who wish to modify the content of the Rural Water Supply DSS. The skills required to carry out such modifications include the ability to edit simple text (ASCII) files in a Windows environment and a detailed understanding of the contents of this section. Training in the use of the shell system can be made available by the Institute for Water Research by arrangement. Prof. Denis Hughes should be contacted in the first instance (Denis@iwr.ru.ac.za).

1. INTRODUCTION

The DSS Shell System was designed as a generic approach to providing a decision support system that could be applied to virtually any subject, not just the rural water supply design that was the subject of this project. The low-level programming of the DSS Shell has been carried out by Mr David Forsyth of the IWR project team, using the visual language DELPHI. This shell is now available to any DSS designer to use and this section of the final report provides an explanation of the facilities available to the designer and some basic instructions in their use. It is, however, recommended that some further training and instruction in the use of the shell would facilitate efficient and effective design. The DSS user (the end 'client') is not required to understand either the computer code underlying the design of the shell, nor the details of how to establish a DSS using the shell. The end user is only required to have some basic knowledge of how to operate a Windows based computer (i.e. combination of mouse clicks and keyboard input) and be familiar with the topic that the DSS is designed to address.

In establishing the basic philosophy behind the design of the shell, it was recognised that compromises would be required. These compromises arise out of the need to create a system that is generic and can be considered to be generally applicable. It is a well know fact that developing generic software is a far more difficult task than developing software for a specific purpose with very clear specifications. The basic system requirements, identified when the initial design specifications were drawn up, were as follows :

- A specific DSS should be able to be established by a designer who is not familiar with computer programming using a low level language (such as C, BASIC, PASCAL or similar).

- The operation of the system should be driven by relatively simple instructions contained within readily editable text files.

- The instruction set that is made available to the designer should be kept to a minimum, while at the same time should be flexible enough to allow the designer to develop a relatively sophisticated DSS that can address complex issues.

- The last point implies that the instruction set would be required to permit the input of both text and numeric type information and that flow control within the DSS should be able to be based on either text or numeric type decisions.

- Flow control within a DSS needs to be flexible and it should be relatively easy for a DSS designer to modify without having to totally restructure the driving text files.

- Some limited facilities for displaying graphical information were considered desirable, while at the same time it was accepted that there would be inevitable constraints on the extent to which such facilities could be included (it was never the intention to try and reproduce the type of data graphing facilities included in a spreadsheet, for example).

- It was also considered desirable to include some facilities for linking to external datafiles which may already exist, or which are generated by related software.

- ❑ Information which is entered through a specific DSS should be retrievable from one session to another and should be able to be summarised through some kind of reporting system.

- ❑ Where a component of a DSS is beyond the capabilities of the shell, the system should be capable of calling an external computer program and capable of exchanging information, or data, between the shell and the external program. It was also recognised that only limited facilities of this type could be developed, given the project resource (in terms of staff time) constraints.

2. SYSTEM OVERVIEW

The shell system operates by implementing a generalised set of functions which are controlled by text instructions within input files established by the DSS designer. These input files have a rigid structure and syntax which determine :

- ❑ How and where DSS text (information and/or questions) and data are displayed.

- ❑ Where and as what type data are entered, calculated and stored.

- ❑ Flow control (movement from one part of the DSS to another).

- ❑ The format of any generated reports.

A DSS can be designed using a number of separate input files, where flow control can be passed within the same file, or across different files. The files within a specific DSS all have the same filename, but have different extensions made up of any sequence of 3 alphanumeric characters (e.g. rwssys.a10, rwssys.a11, rwssys.b20, etc.). The maximum number of possible files in any single DSS is therefore 46000 and the only restriction is that the first file to be loaded must have the extension ***MAS***, designating it as the *master* file. The master file will normally contain the instructions for setting up the main menu of the DSS which will display the choices that control flow to the other components contained within the secondary files.

All files which from part of a DSS design should be located within a common directory, referred to as the *System Directory*. Each specific DSS must reside in its own system directory.

Each text file is made up of a series of numbered sections, which may contain sub-sections defined by standard keywords and followed by user defined parameters. Each section represents a component of the DSS which can be independent of other sections, or dependent upon other sections for data. The standard keywords allow the designer to specify what program actions are taken when flow control is passed to the section and therefore what the user sees on the screen, what calculations are performed and what section flow control passes to when the current section is completed. All keywords (instructions to the DSS shell to perform a defined function) in an input file are preceded by a '*' character. The following keywords are currently available for designing a DSS and the first group can all act as section headings (i.e. the start of a section block), while the second group must fall within a section and are therefore sub-section commands :

Keywords that start a section and must not appear within other sections :

*TITLE	Special case of a section header for specifying the DSS title in a master file.
*TREE	Section header specifying the source of text for a tree structure display.
*MAP	Section header specifying the source of a bitmap background display.
*SECTION	Section definition header in a DSS process definition text file.
*REPORT	Section definition header in a reporting definition text file.

Keywords used within sections to define sub-sections :

*VARDEF	For defining variables to be used in the DSS.
*TEXT	For specifying text information to appear in a window.
*INPUT	For specifying data input window.
*CALCDEF	For performing calculations.
*GRAPH	For displaying data graphically, and obtaining related user input.
*FILE	For specifying data input from an external file.
*SELDEF	End of section keyword defining user selectable flow control.
*CONTDEF	End of section keyword defining automatic, conditional flow control.
*OUTTEXT	For outputting text to a plain ASCII file

3. KEYWORDS STARTING A SECTION

These keywords can be placed at the start of a section.

3.1 *TITLE* KEYWORD

A special case of a section heading can be contained within the *master* file (usually as the first line). The keyword syntax is as follows, where the text on the line after the keyword is displayed in the program title bar for all windows of the DSS :

```
*TITLE
Title to be used for the whole DSS
```

The text of the title is restricted to 100 characters. If a master file is loaded, the software searches for the TITLE keyword and if none is found the default title for the DSS is set to '*This system has no title*'.

3.2 *TREE* KEYWORD

Tree files are separate files (located in the same directory as the input files) used to specify a quickjump tree display, which enables a user to jump directly to certain sections, bypassing the normal flow control options that occur at the end of other sections. A tree file can be specified in any DSS source file, but only once per file (any subsequent uses of the *TREE keyword within the file will be ignored). Tree files can also be shared across a range of source files. To include a tree file the following syntax is used :

*TREE
treefilename.TRE

It is suggested that the 'treefilename' used should be the extension of the source file this tree is associated with. Using 'tre' as the extension on tree files makes it easier to keep track of the files, though it is not mandatory. However, the extension **is** limited to 3 characters. For example, assuming one had a DSS that included a input source files named *rocketdss.abc* and *rocketdss.xyz*, one would then create tree files named *abc.tre* and *xyz.tre* associated with them.

A tree file consists of a number of lines of text, describing the section to be jumped to and optionally followed by an input file extension and section number, i.e.

My section heading name, *ext*, *num*

A line that has no , *ext*, *num* at the end, will simply be displayed, and the user will not be able to jump after selecting it. As can be seen in the example screen display below (associated with the example tree file), the 'display only' line is selected and the 'GO' button is grayed out, indicating that it cannot be selected for jumping. Lines that have a file extension and section number defined, as shown in the example, will enable the 'Go' button when selected. When the user presses the 'Go' button, the system will immediately load the defined file and section. Care must be taken to ensure that all jump destination sections in the trees do not violate process rules within the DSS. For example, consider a DSS with a file having 5 sections, numbered 1 to 5, and within that files structure the logic of the process demands that section 3 be completed before section 4, and 4 before 5, and that if section 4 or 5 were visited before 3, errors would occur in calculations. It would not be logical or correct to include sections 4 and 5 in a tree, as this may encourage a user to operate the system in such a way as to cause errors.

An example tree file is provided below and the associated screen display is illustrated in Figure C.1 :

```
RWS-DSS Main Menu
      Specific Context,cnx,1
      Business Plan,bsp,1
      Feasibility Studies,fsb,1
      Detailed Survey,grt,1
            Surface Water,swl,1
            Groundwater,gwl,1
      Detailed Design,inf,1
      Training Interventions,trn,1
      Budget,eco,1
```

Figure C.1 Example screen display of a tree file used for moving between sections of a DSS

Tree file structure, summary of rules:

- Files may not contain blank lines.
- Lines with no extension and section number cannot be selected by the user in the tree view.
- Tree views are only available for sections that have *TEXT displayed others cannot have them since it would provide a means for bypassing essential inputs and calculations.
- The software uses the extent to which the text is indented in the tree file to determine the tree structure and different levels. The number of spaces in front of the text is not critical as long as the spaces are all multiples of the first space used.

When the tree file is loaded, the structure will be displayed to the penultimate level. Pressing the 'Expand' button will expand all levels, while the 'Collapse' button will collapse all levels.

In Figure C.2 the buttons for activating Tree's and Map's are shown. When pressed the Tree button displays the currently defined tree. If the file is not found nothing will be displayed, not even an error message.

Figure C.2 Tree and Map (see section 3.3) Activation buttons.

It should be evident that in a complex DSS the tree structures could become very unwieldy. It is therefore up to the designer to decide what a potential user is likely to find useful as part of a tree at different levels within the DSS. It is possible to include the full tree structure within all the input text files, so that full navigation around the system is possible at any stage. However, this is likely to be too confusing for a user because of the amount of detail included. Careful structuring of both the DSS itself as well the navigation aids, such as the tree files, is required.

3.3 *MAP* KEYWORD

Map files are bitmaps which are displayed on the background of the main program window. The default display is a modification of the Institute for Water Research logo. The specification of a bitmap background display is performed in a similar way to the tree files, using the syntax.

```
*MAP
mapfilename.bmp
```

The files must be standard Windows bitmaps format, in either 256 (8 bit) or 16 colors (4 bit) and not more. The files should be a maximum of 800x600 pixels in size. These files can be used to display anything, from maps to adverts. If an input file does not have a *MAP section, then the standard logo will be displayed. On slower computers, large image files will cause significant delays between sections, and thus a button is provided so that the user can turn off map display (Figure C.2). This button sets a flag, and the current map will be removed when the next source file is loaded, ie, the effect of turning map files on or off *is not immediate*.

During operation, text and input boxes can be minimized or moved around, or minimised, in order to view the background display. An example is shown in Figure C.3, where a *TEXT box has been moved to make the background image visible. Background displays are intended as an auxiliary data display mechanism, and are not a primary process function of the DSS system. They are commonly used to provide a more visual impression of the structure of the DSS so that the user can refer to them from time to time.

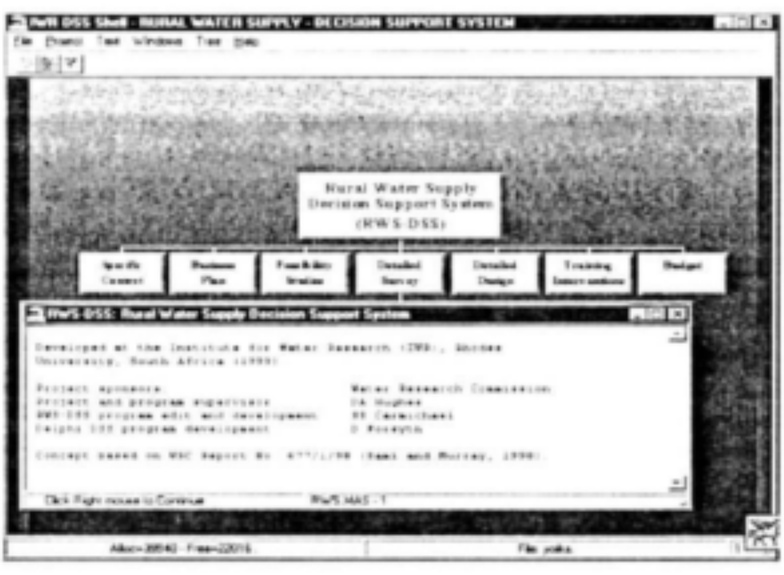


Figure C.3 Example of a bitmap display established using the *MAP keyword.

3.4 *SECTION* KEYWORD

This is the main header keyword and is used to establish the main instruction blocks within a DSS input file. The syntax is :

*SECTION <number>, Comment text for the section window is placed here

Where the <number> can be any integer value between 1 and 32000 and need not be in sequence in the input file and the comma and comment text are optional. The section numbers can be used to define groups of instructions, giving numbers 1000-1020 to a set of sections dealing with one topic and numbers 2000-2017 to another topic within the same file. Other files may have the same numbers, since they would be distinguished by the name of the file that they are contained within.
The comment text will be displayed in the title bar of each **TEXT* or **INPUT* subsection window within the section. Thus it can be used as a header for the section, helping to clarify the purpose of the section to the user. If no comment has been included, the system title appears in the title bars.

3.5 *REPORT* KEYWORD

Instead of running the main DSS instructions and navigating through the various sections, it is possible to establish a text input file that generates a report. This is setup by the DSS designer using the REPORT keyword to start a section instead of the SECTION keyword. While the syntax for *REPORT is the same as for *SECTION, there are a few more restrictions on the contents of report sections.

- ❑ The input file may only contain subsections defined by the keywords *VARDEF, *TEXT, *CONTDEF and *SELDEF

- ❑ A *SELDEF section (see later) may only make use of the EXIT and NULL constructs, on a single line, since the report must proceed to it's end automatically and the user should not have the opportunity of choice in flow control.

- ❑ Nothing is displayed on the screen (except a progress bar) while the report is generated, the report output is to a text file. The user is then free to import that text file into a standard word processing package and format it to their requirements.
- ❑ All the required sections of a report must be contained within a single report file. This is so that the user can select one report file (with a .REP extension) from the file list without getting confused by other files. There is nothing to prevent a DSS designer from setting up a range of report formats contained within separate files. The user, however, is only able to select one at a time.

Reports are generated by selecting *Project - Report* from the menu line at the top of the screen. This displays a report dialog box (Figure C.4) which expects the user to type or select the report format file to be used and creates a file with the same name and a TXT extension that will contain the results of the report. The button at top right allows the user to access a file selection listbox that contains all the valid report format files for the specific DSS. Once a valid filename is selected, the GO button is enabled. Clicking the GO button begins the report generation.

During generation, the progressbar (blank area below the filenames) attempts to indicate progress. Since it is impossible for the program to know exactly how many *REPORT sections it will be processing, this indication is only approximate.

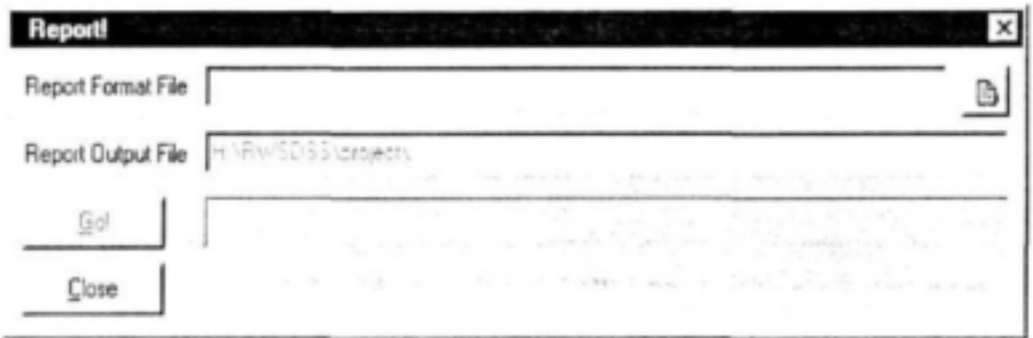


Figure C.4 Report dialog box for the selection or specification of a report format file.

The report function needs to be activated separately from the DSS because the project audit file, containing the stored data, needs to be opened. As this audit file is open during normal DSS processing, the DSS needs to be 'Quit' so that the report can access the file.

The concept of the reporting system is based on the use of *CONTDEF keywords to decide what *REPORT sections to include in the output file. Once the user has entered values in the various sections of the DSS, these values, or values calculated from them, can be queried and used to change the report output. For example, in a DSS for designing flower beds, if the user entered a number of flowers per row of 15, and a row length of 10 m, then a spacing between plants of 0.66 m is calculated. If it is known that a spacing of less than 0.25 m or greater than 0.75 m will cause the plants to die, the report can be constructed to display different results, depending on the current value of the spacing variable. Thus, part of the report file may read :

```
*REPORT 55
*VARDEF
spacing,aud88,f8.2,0,100,0.5
*TEXT
Report on plant spacing.
Note that the relevant variable MUST exist for this to succeed, and the
VARDEF keyword is used, with a default value, to force it's existence.
*CONTDEF
spacing,aud88,F8.2
0.25,REP,56,<
0.75,REP,56,>
ELSE,REP,57

*REPORT 56, Out of bounds
*VARDEF
spacing,aud88,f8.2,0,100,0.5
*TEXT
The plant spacing you have chosen is either too small or too big.
The current spacing is ##spacing## and outside the range of 0.25 to 0.75m.
Problems with plant growth will be experienced outside this range.
*SELDEF
null,rep,58

*REPORT 57, Within Range
*VARDEF
```

```
spacing,aud88,f8.2,0,100,0.5
*TEXT
The plant spacing chosen is within bounds for good plant growth
The chosen spacing is ##spacing##
*SELDEF
null,rep,58

*REPORT 58, next section of report
*TEXT
This section would then report on some other aspect of the
designed garden layout. In this example, this is the last
section of the report and the SELDEF uses the 'EXIT' keyword.
*SELDEF
end,EXIT
```

The proper use of *CONTDEF keywords is critical to the success of the report generation. It is advisable to construct all such sections with definitive tests, or an ELSE clause, so that no value tested can ever have 'no successful match'. The DSS designer needs to carefully construct tests such that out of range and default values are reported on correctly. The use of *flags* (variables that are set to specific values in order to indicate successful completion of sections) within a DSS to indicate completion of sections is encouraged, since these flags can then be used in the reports to easily identify incomplete sections and report accordingly. It makes no sense to have a detailed report for a topic that was never visited by the user. Thus the flag could be checked at the beginning of a report subsection, and depending on it's value the next section would be either a short section that simply says '*the relevant section of the DSS has not been visited*', or a section that produces an in depth report on the topic. Thus, in the gardening DSS mentioned above a *REPORT section immediately preceding those shown might read:

```
*REPORT 50
*VARDEF
spacingflag,aud80,I1,0,1,0
*TEXT
Example of checking a flag
*CONTDEF
spacingflag,aud80,I1
0,rep,54,=
1,rep,55,=
```

The above section would route the report to *REPORT 54 (not provided) if the spacing topic had never been visited, or had been visited but not completed, such that the spacingflag variable was set to 0. Alternatively, the report would go to *REPORT 55 (previously given) to report on the spacing if the value was 1. Using this approach, a whole report can be built that will only include reports on those topics in the DSS that have been visited and completed by the user. The report can make decisions on the suitability of results obtained in the DSS, and can display warning text messages where required.

4. KEYWORDS USED WITHIN SECTIONS TO DEFINE SUB-SECTIONS

*These keywords can only be used within a *SECTION or *REPORT*

4.1 *VARDEF* KEYWORD

The VARDEF keyword is used to declare variables (numbers or text strings) that are to be used in any following subsections within the current section. The syntax of the instruction is as follows :

```
*VARDEF
name,auditno,vartype {,minvalue} {,maxvalue} {,defaultvalue}
```

Where the { } brackets indicate components that are optional in certain cases and examples are given below.

```
*VARDEF
agent,aud15,S70
cost,aud1,F11.2,0,100000
vat,aud2,I2,0,99
vattemp,audNS,I2,0,99
integerarray,aud10,AI8,10
floatarray,aud11,AF10.2,20
```

The variable definition subsection serves to inform the DSS of the number, names, audit number and types of variables to be used within the current section. There are three basic types (String, Float and Integer), and one extended type (Arrays of Float or Integer).

Note: variables are searched for by name by the system an dso names are permanently linked to audit numbers. The name/audit number relationship must therefore be unique, except in the case of audNS variables. *audNS* indicates that the variable value will not be stored in the audit file, and is used for temporary variables during complex calculations in *calcdef subsections.

4.1.1 String type

```
agent,aud15,S70
```
name, auditno, S*size*

name:

This is the local (to the current section) name of the variable and would normally be chosen to be meaningful in the context of its use. The example given above ('agent') might be used for the name of a rural water supply implementing agent. There is a limit of 20 characters length.

auditno:

This is an important parameter equating the variable with the location in which it is stored and retrieved from in the project audit file. The **Audit file** is a file created by the system for each project analysed, and is used to store every variable used within the project if it has a valid number. Each stored variable must have a **unique number**. Once a variable has been created with a particular name and type, it is not possible top change either the number or the type. Attempting to define a variable with the same number, but a different type is strictly forbidden, and will stop the program with a fatal error message, except in the case of integer and float types. These will cross convert, but precision will be lost. By using 'aud**NS**' it is specified that the variable will NOT be written to the audit file. This kind of variable can be used as temporary storage for values that will not be needed later, for example as an intermediate result in a series of formulas. The process used to manage the audit file is that when a variable definition is read, the audit file is searched for a variable with the given number. If one is found, it's value is read and used as the variables default value. If it is not found, it is created and the default value (if any - not relevant to string variables) in the definition is used. If no default value is defined then the specified *minimum* value is used. When a section terminates, all variables will have been written to the audit file.

size:

The size field in a string type defines how many characters the user will be able to store in this variable. Only make this as big as needed, as large but unused string fields will use up disk space.

4.1.2 Float type

```
cost,aud1,F11.2,0,100000
```
name, auditno, ***F****digits.decimals, minimum, maximum {, default}*

name & auditno:

The same rules apply as for string variables.

F:

This indicates that it is a floating point number. Floating point numbers are those numbers that have, or could possibly have, digits after the decimal point. They can also store very large positive or negative numbers with high precision.

digits:

This number indicates the maximum number of digits (including the decimal point) to display when printing this number to the screen.

decimals:

This indicates the number of digits to place after the decimal point. The number will be rounded to the last digit for display purposes.

minimum, maximum:

The allowed minimum and maximum values for this variable. In an INPUT subsection the user is restricted to entering values within this range, while if a value is calculated in a CALCDEF and falls outside the range it is restored to the maximum or minimum (depending on which is closer) and the user issued with a message that indicates that the program has done this.

default:

An optional default value for the variable when it is first used. After that the default value will be retrieved from the audit file.

4.1.3 Integer type

```
vat,aud2,I2,0,99
```
name, auditno, **I***digits, minimum, maximum {,default}*

name, auditno, minimum, maximum & {,default} :

Previously defined above for string or float variables.

I:

Code to indicate that this is an integer field (i.e. whole numbers without decimal places). Integers can store whole numbers (no decimal point) with values between -2 billion and 2 billion.

digits:

The maximum number of digits for display in the integer number. This will normally be the number of digits in the *maximum* value

4.1.4 Array types (extended types)

```
intarray,aud10,AI8,10
floatarray,aud11,AF10.2,20
```
name, auditno, **A***numerictypedigits{.decimal}, count*

name, auditno, digits & decimal:

As previously defined.

A:

Code to indicate that the variable name refers to an array, rather than a single variable.

numerictype:

I or F, to define an integer or floating point number array.

count:

The number of values to allocate to the array.

Arrays, in programming terms, are used when a collection of related variables are needed. Instead of having to define 20 (say) separate variables when calculating a set of related results from, for example, a formula, we use an array to store the 20 variables within itself. An array can be viewed as a set of postboxes, each uniquely numbered, each independent of the next, though referred to by name and number (called the *index)*. In the DSS, array indexes will always start with 1, and end with the number of variables in the array defined by *count*. Further explanation of the usage of array variables will be given under 'formulas', and in the *graph section since the graph results are returned in an array. **Note that the number of elements in any array is limited to 1000.**

4.2 *TEXT* KEYWORD

The TEXT keyword is used to display a window of text information and under normal circumstances all sections will have at least one text sub-section. The text window will be displayed while the current section is active and any other windows that are displayed within the same section will be placed over the text window. The format of a text section is simple and can also display the values of variables declared using a *VARDEF :

```
*TEXT
This text will be displayed in a window on the screen
for the duration of this section.

Population in 1990          ##pop##
Total income in 1990        ##income##  USD

Per capita income           ##incpcap## USD/person
```

The *##variable name##* construct tells the program that it must substitute the value of the variable into the text display at this point. The length of the displayed value will be dependent upon the way in which it was declared. The assumption in the above example is that the three variables (pop, income and incpcap) have all been declared at the start of the current section (using a VARDEF) and either read from the audit file, or calculated before the text sub-section (using a CALCDEF). Lining up the units (USD and USD/person) can be achieved on the basis of the length of the two variables preceding them, as defined by the *digits* field.

All text, including blank lines, will be displayed, until the next keyword is found. Since keywords start with *, this means that no text within any subsection may start with this character. The text is displayed using a monospaced font so that if the designer is using a text editor (such as the 'DSSED' program that is included as part of the DSS Shell software package) to prepare the input files, then the format in the window displayed by the software will be the same as the format during preparation of the file. Care is required to ensure that the text is formatted correctly for the program to display in a readable manner.

4.3 *INPUT* KEYWORD

Input subsections are used to enter or edit the values of variables declared within the same section. The syntax of an input line consists of prompting text, variable names enclosed in ##...##, or variable name equations enclosed in $$....$$. The position of the variable input box within the screen window will be determined by the spacing and any following text by the width of the input box, which is calculated from type and format of the declared variable

```
*INPUT
Implementing agent                    ##agent##
Address                               ##agentadd##
Cost                                  ##cost## (Rands)
Vat (at 14%)                          ##vat##  (Rands)
Total Cost                  (Rands)   $$cost+vat$$

Manager                               ##manage##
string                                ##string##
```

The variable names are enclosed in ##, which indicates to the DSS that this piece of text is a variable name and should be used to create an input box on the screen, instead of simply displaying it . The system will attempt to position the input boxes at the screen position of the first # from the left.

The $$.....$$ fragment indicates that the result of the formulas given must be displayed at that position. This calculation is done each time the user switches from one numeric input box to the next one, usually by using the TAB key. This is called a *LiveUpdate* and the results obtained from the formula are only displayed, and not stored in any variable at any time. Thus, if the DSS requires the result at some later point, the source file must include a CALCDEF following the input which performs the required calculation and stores it in an appropriate variable. Any valid formula as defined within the CALCDEF (see below) can be used, provided the variables exist in the current section. Note in the example that no text is places after the LiveUpdate. Any text after the LiveUpdate will cause the LiveUpdate to be obscured. Care must be taken to ensure that it is not possible to attempt to divide by a zero value in the formula.

Lines in an INPUT section may not be longer than 255 characters *after the variables have been filled in!*. This means you should ideally not have physical lines longer than about 220 characters, taking special care with string variables.

4.4 *CALCDEF* KEYWORD

A CALCDEF subsection contains a set of formulas which will calculate values from those provided to it by existing variables. It has no visual component during the running of the program, but merely calculates new values and updates the audit file, where appropriate. All variables used must have been previously defined by a VARDEF subsection within the section. The format of the formulas is very much like Quattro Pro (or similar spreadsheet software) cell formulas, except that instead of using cell references, variable names are used. Take care to use variable names that are not the same as function names! In the example below, the formula calculates the total of some price (cost) plus an added percentage of tax (vat), and leaves the result in the variable 'total'. The example also includes some illustrations of more complex formula types which are discussed below.

```
.
.
*VARDEF
cost,aud1,F10.2,0,100000
gwatercost,aud2,F10.2,0,100000
consultcost,aud3,F10.2,0,100000
vat,aud4,I2,0,99,14
total,aud5,F10.2,0,100000
recharge,aud6,F10.2,0,500
KarooRecharge,aud7,F10.2,0,200
GraniteRecharge,aud7,F10.2,0,300
processnumber,aud8,I2,0,10
arbvar,aud9,F8.4,-1000,1000
somevar,aud10,F8.4,-1000,1000
someothervar,aud11,F10.2,0,360
.
.
*CALCDEF
cost=gwatercost+consultcost
total=cost+(cost*(vat/100))
```

```
recharge=(processnumber=1) ? KarooRecharge : 0
recharge= processnumber=2 ? GraniteRecharge: 0
arbvar=(somevar>=5)?@log(arbvar):@sin(someothervar)
arbvar=(Bvar<>0)?(Someothervar<>0)? arbvar/(someothervar*Bvar):0:1
```

Note that the formula to the right of the = sign cannot be longer than 200 characters. When values that are outside the hardware limits of the computer are involved, the calculation will more than likely have involved a division by zero. Division by zero is strictly not allowed in computers, and every effort must be made to prevent software even trying it. An error such as this caused by the calculation will result in the DSS Shell program terminating with a fatal error. Divide by zero is prevented by using the **?:** structure as in the last example above. Note that only two **?:** sequences may be interleaved as shown and no more. If you need to check for more complex divisors, then you need to use a temporary variable as follows:

```
*VARDEF
tempvar,audNS,-1000,1000
...other vars defined
*CALCDEF
tempvar=someothervar*Bvar
arbvar=(tempvar<>0)? arbvar/tempvar:0
```

Should a result value be outside the minimum and maximum value set for that variable a warning message will be displayed and the value written to the audit file will be the closer of the maximum or minimum to the calculated value.

@ functions and other math operators

The system will support various standard mathematical functions as follows:

+ add - subtract * multiply / divide (open parenthesis and) close parenthesis, where open and close must be matched and can be used to control the order of calculation. You can nest up to 20 pairs of parentheses.

@ABS(x)	Absolute value of x, discards any negative sign
@ARCTAN(x)	Arc tangent
@COSH(x)	Hyperbolic cosine
@COS(x)	Cosine if angle x (all angles in **radians**)
@COTAN(x)	Cotangent of x
@EXP(x)	Exponent, *e* to the power of x
@LOG10(x)	Log to the base 10 of x
@LOG2(x)	Log to the base *2* of x
@LOGN(x,n)	Log to the base *n* of x
@LN(x)	Log to the base *e* of *x*
@POW(x,y)	x to the power of y
@SINH(x)	Hyperbolic sine
@SIN(x)	Sine
@SQRT(x)	Square root
@SQR(x)	Square

@TAN(x)	Tangent
@TRUNC(x)	Truncate x, discard digits to the right of the decimal point, result is an integer type.
@MIN(x,y)	Minimum of x and y
@MAX(x,y)	Maximum of x and y
@CEIL(x)	Round x UP to the nearest whole number
@FLOOR(x)	Round x DOWN to the nearest whole number

A few example formulas:

```
angle=@tan(oppositeside/adjacentside)
pink=red+white
lightpink=(red+white)/2
integervariable=@floor(float1/@sin(float2))
bignumber=@pow(23,56)
```

As can be seen, the x and y values for any function, can be the result of another function/calculation portion. Note that some functions have mathematical limitations imposed by the number system and by the computer hardware. Before doing any calculation that *might* result in a divide by 0 (however remote the chance) the x?y:z construct (explained below) should be used to test for zero in the divisor. Also, functions like the @POW function can generate internal divide by zero conditions (in the case of the POW function, raising x<=0 to the power of a negative number, is not possible).

The *x?y:z* construct is the equivalent of saying

"if (somecondition) then (dothis) else (dothat)"

"(*somecondition*)**?***dothis***:***dothat*"
"(*somecondition**1*)**?** (*somecondition**2*)**?***dothis**2***:***dothat**2*" **:***dothat**1*"

This is a useful construct, allowing one to test a condition and perform a calculation depending on the condition in one or two statements. Note that the 2 condition format must appear as given. If *somecondition**1*** is true, then the second condition is evaluated. *Dothat**1*** cannot be another condition, only a normal formula.

An example that helps to explain it is as follows :

```
recharge= (processnumber=1) ? KarooRecharge : 0
```

Starting at the left is the variable name '*recharge*', which can be any numeric type variable. This is in the **x** position, and will be the place where the result is stored. Next is the condition **(processnumber=1)**. The parentheses are not required, but serve to make the structure clearer. The condition can use any one of the conditions, [< , > , <= , >= or <>]. On either side of the condition symbol can be either a variable name (eg the name *processnumber*), or a constant (eg the number *1* above). Both sides can be a variable name, but it makes no sense to have a constant on both sides, since the condition will always have a fixed value. In operation, the first item is compared to the second item using the comparison operator given, and the result is either true or false. In the example given, if the value of variable *processnumber* is equal to the value 1, then the result is true, while if *processnumber* is any other value, the comparison result is false.

The **?** symbol serves to separate the condition from the formula parts and following it must be two formulas, and a colon (:) to seperate them. In the example, the variable name **KarooRecharge** represents the first formula, while the constant **0**, represents the second. A single variable or a constant can also be used as formula. More complex formulae are also possible :

```
arbvar = somevar>=5 ? @log(arbvar)*5 : @sin(someothervar)/5
```

In the first example, if the value of *processnumber* is 1, then the value of *Karoorecharge* is assigned to the variable *recharge*. On the other hand, if *processnumber* is not 1, then the value **0** is assigned to the variable *recharge*.

4.5 *GRAPH* KEYWORD

The Graph facility is designed to be very general in nature and is not designed to perform specific graphs that pertain to any specific problem. The DSS designer has to specify very clearly what the graph function must do within the limits of it's capabilities. It should be fairly clear that compromises have been made and that the same degree of functionality that is found within graphing facilities of spreadsheet programs (for example) is not present within this relatively simple facility.

The basic functions of the graph are :

- To display data with no user input.
- To display data and return the coordinates of 1 or 2 points defined by the user.
- To display data and return specifications of 1 or 2 lines defined by the user.

Both points and lines can be requested from the user at the same time. The Graph form has a 'close' button which will only be active after the user has selected all the input required. If no return data are requested, the close button will be active by default.

Data that is to be displayed is specified to the graph as being contained in an array variable or as the set of results from a formula. Both types can be used in one graph. In addition, for array data the graph can be requested to add intermediate points using linear interpolation to enable the user to select points along the normally straight segments of the graphed lines.

The Graph section can contain the following items: (any item that has options separated by / has the default value on the right. If this item is not supplied, the default value will be used). **There must be no spaces between the equal sign and the other text of the option lines.**

Interpolate=yes/no This option sets the interpolation of extra points on or off and only applies to *array* type series, not *formula* types. When the option is on the graph function will add an extra 10 points between each supplied point, thus allowing the user to select a point between the graph points in the defined array. This will apply to all array series in the graph.

title=text This supplies the text for the main graph title.

xtitle=text This supplies the text for the graphs X axis title.

ytitle=text This supplies the text for the graphs Y axis title.

point=yes/no This allows the user to select a point.

point2=yes/no This allows the user to select a second point.

line1=yes/no This allows the user to define a line.

line2=yes/no This allows the user to select a second line.

For both lines, the user can select any position on the graph and draw a line to a second point by clicking and holding down the left mouse button at the start position, dragging the mouse cursor to the end position and then releasing the button.

xaxis=log/lin Select Log or Linear X axis

yaxis=log/lin Select Log or Linear Y axis.

When a log axis is selected the validity of the input data should be checked (i.e. zero and negative values cannot be plotted). It is also necessary to interpret the returned line data in the correct way and these are always in ordinary values (i.e. not log values). A further point is that a straight line drawn on a log axis will not be straight on a normal axis and intercept values could be meaningless.

formula=seriesname,someformula,xmin,xmax{,steps}

Defines a graph series with a formula. The *seriesname* will be used as a legend for the series. Any spaces in it will be removed, and it may not contain () or commas. The formula must be in standard format as per the CALCDEF sections right hand side part, eg **@log(x)*somevar**. Where 'x' is predefined by the graph package as the value on the X axis, and 'somevar' is any normal DSS variable defined in a preceding VARDEF section. **Since the 'X' value is defined by the graph package, there is no need to define it in a vardef statement.** The 'xmin' and 'xmax' values will define the starting and ending values for x applied to the formula. The optional value 'steps' specifies the size of the steps to use when calculating values between xmin and xmax. If steps is not supplied then 10 steps will be used, therefore generating 10 points on the graph, equally spaced along the x axis. There can be more than one formula line in a graph section.

array=seriesname,Xarrayvarname,Yarrayvarname{,startindex,endindex}

Specifies a graph series defined by two arrays. The *seriesname* will be used as a legend for the series. Any Spaces in it will be removed, and it may not contain () or commas. Both arrays must be defined and filled with valid values by preceding VARDEF and CALCDEF or FILE subsections. By specifying the optional '*startindex*' and '*endindex*' values it is possible to specify which values within the arrays are plotted on the graph. The '*startindex*' and '*endindex*' values may be specified as constants or by previously declared and calculated integer variables. The values apply to both X and Y axis arrays. Given the definition ***array=xvals,yvals*** and having the xvals ansd yvals arrays defined to have 50 elements, the graph will display all 50 elements. Using the definition ***array=xvals, Yvals,12,24*** will result in only 13 values being graphed, starting with the 12th element and ending with the 24th element. There can be more than one array line in a graph section and these can be mixed in with the formula lines.

An example is provided below :

```
*GRAPH
interpolate=no
title=Distance-to-Boundary: Constant discharge rate
xtitle=Time (minutes)
ytitle=Drawdown (m)
point=yes
line1=yes
line2=yes
xaxis=log
yaxis=lin
array=DTBseries,time,drawdown,1,62
```

Once the graph form is closed by the user, the selected data are returned to the DSS system in the form of a standard array variable named **GD**. This array will contain the following 20 values:

GD[1] = Point 1 X value
GD[2] = Point 1 Y value
GD[3] = Data Series in which the point 1 lies
GD[4] = Line 1 Start X
GD[5] = Line 1 Start Y
GD[6] = Line 1 Stop X
GD[7] = Line 1 Stop Y
GD[8] = Line 1 Slope
GD[9] = Line 1 X intercept at Y = 0
GD[10] = Line 1 Y intercept at X = 0
GD[11] = Line 2 start X
GD[12] = Line 2 Start Y
GD[13] = Line 2 Stop X
GD[14] = Line 2 Stop Y
GD[15] = Line 2 Slope
GD[16] = Line 2 X intercept at Y = 0
GD[17] = Line 2 Y intercept at X = 0
GD[18] = Point 2 X value
GD[19] = Point 2 Y value
GD[20] = Data Series in which the point 2 lies

The values returned to GD[3] and GD[20] represent the order in which the data series (either formula or array) that were passed to the graph were specified. Since some lines that can be selected by the user cannot generate all of these values a missing data code of -9999.9 is used when :

- ❑ The line is vertical. In this case the slope is infinite and is set to -9999.9, the line never intercepts the Y axis so the Y intercept is also -9999.9.

- ❑ The line is horizontal. In this case the line never intercepts the X axis and the X intercept is -9999.9, therefore only the Y intercept and the slope values are valid.

The values from the GD array that are to be used in a later calculation, or that might be stored in the audit file, **must** be tested and confirmed to be accurate and meaningful.

4.6 *FILE* KEYWORD

The file section is used to read values from a data file into an array variable that has been previously declared using a VARDEF. The data file formats are defined by the DSS Delphi program and can be added to at a later stage if required and the format can be relatively simply defined. The simplest format of data file is the so-called '*spreadsheet*' format, in which all data is contained in rows and columns in a standard ACSII format text file, files saved from Quattro Pro and other spreadsheet programs are not readable, but the data within these can be exported to text files and read by the DSS. The FILE section will always follow a VARDEF section since it needs predefined array variables in order to function.

The FILE section components are as follows :

type=spreadsheet This defines the type of file to be read from. At this time only the 'spreadsheet' format is valid.

name=full or relative path and filename This provides the path and filename of the file to be read. If it cannot be found the user will be presented with a *fileopen dialog* box with which to find the file. This provides a mechanism for requesting a file from the user. If the file cannot be found either by the system or by the user, the DSS system will exit with a fatal error.

var=arrayvarname,rowstart,rowend,colstart,colend[,sname]

> *arrayvarname* provides the array variable name to write the data to.
> *rowstart, rowend* provide the line numbers within the file from which to read values.
>
> *colstart, colend* provide the column numbers within the file from which to read.
> *sname* (Optional field) name of a string type variable. The second column of the file will be read into this variable as a string. This is ONLY used with a string variable in *rowstart* and *rowend*.

The column and row specifications interact as follows: one set of figures must be equal, ie either rowstart=rowend or colstart=colend. If the row figures are equal, the values will be read across the columns as per the *colstart* and *colend* values. If the column figures are equal the system will read values from that vertical column, from the *rowstart* line in the file to the *rowend* line in the file. This means that it is only possible for a single *FILE subsection to read within a single column or row. If it is required to read more than one column or row into the same array, then more than one *FILE subsection would be required.

While it is possible to read fewer values than the declared number of elements in the given array, it is NOT possible to read more values than the array size. Thus the data files and the DSS text files must be set up carefully so that this does not happen. Values within a data file must be separated by spaces or commas.

The values of *rowstart*, *rowend* may be represented by string variable names as follows:

```
*VARDEF
ref,aud100,S10
values,aud101,AF10.2,12
astr,aud102,s10

*INPUT
enter a keyword to find in the data file
       keyword ##ref##

*FILE
type=spreadsheet
name=xxxxx.yyy
var=values,ref,ref,2,14
var=values,ref,ref,3,14,astr
```

The above example defines '*ref*', a string variable and '*values*', an array of 12 floating point numbers. The INPUT subsection prompts the user for a reference keyword. The FILE subsection then loads 12 values from the line starting with the value in '*ref*'(which should exist in the file. IF it is not found, the array will be filled with zeros and an error message will be displayed). It does this by searching for the value of '*ref*' in the first column in the file.
The second line is an example of using the optional '*sname*' field. A string variable 'astr' is defined. After the read, the value of the 2nd column will be in this variable. Since that value will normally be text, one cannot read column 2 into the array variable when using the 'sname' field.

4.6.1 File Error Codes

When errors are encountered during file reads an error code will be displayed on the screen. These error codes have the following meanings:

>0	Some low level error opening the data file, make sure no-one else has it open on the network	- check network file access.
-1	Invalid variable type, variables must be arrays	- check DSS input file.
-2	Too many data items for the array were specified	- check DSS input file.
-3	Column in the data line was not found	- check data file.
-4	Value of the data was not convertable to a float value	- check data file.
-5	Tag value not found - enter a valid tag. This is a non fatal error and the DSS will continue, though the array will contain invalid values.	

4.7 *SELDEF* KEYWORD

The SELection DEFinition subsection provides the user with a way to chose the next section to proceed to in the support system and essentially represents a flow control **menu**. The following example (Figure C.5) shows the most basic operations available, that of selecting a new section, or exiting from the program. The syntax of each line in the SELDEF is as follows :

texttodisplay, ext, number

and as an example

```
*SELDEF
Water Sources,TX1,2
Main menu,MAS,1
Quit,EXIT
```

or

```
*SELDEF
NULL,mas,1
```

Texttodisplay

This provides the text to be displayed to the user. It needs to be short and to the point, as it will be used within a menu structure for on screen selection. The number of characters should not exceed 80.

Ext

This defines the next file to be used, and consists only of the extension portion of the filename, since the name portion is already defined for the whole project.

Number

This gives the section number within the defined file to use next.

The ***EXIT*** option is a separate definition structure, and simply indicates to the system that it should cease processing sections entirely and return to the startup screen.

The ***NULL*** construct is used to move from a completed section directly to the next section without offering any menu choices. It will most commonly be used after INPUT and CALCDEF sections. The implication is that the word NULL cannot be used as a menu text line.

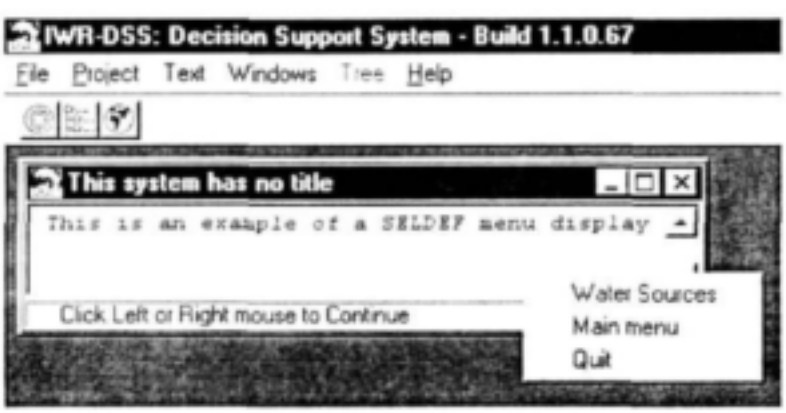


Figure C.5 Example of a display of a SELDEF

4.8 *CONTDEF* KEYWORD

The CONTDEF subsection provides an alternative to the SELDEF section as a way to select the next section to process. It allows the system to use a variable value as a basis for flow control by comparing it to predefined values. The comparison operator can be one of :

=	equal to	>	greater than
<	less than	>=	greater than or equal to
<=	less than or equal to	<>	not equal to

The first line of a CONTDEF is the same as a line in the VARDEF subsection and represents a declaration of the variable that will be used to determine which section to proceed to and will **not** need a VARDEF to define it. This is to simplify the low level programming of this construct. All variables for comparison must be of the same type as the defined variable, otherwise an error will be reported. The syntax of the following lines is as follows :

comparisonvalue, ext, sectionnumber, compareoperator

comparisonvalue,	Value to compare the variable to. The variable will always be on the left of the comparison (variable >= *comparisonvalue).*
ext,	Extension of an input file in the specific DSS.
sectionnumber,	Section number within the input file to proceed to.
compareoperator	Operator to use when comparing the value to the variable, this operator is used to determine the logical result of the equation. Is (Variable **operator** *comparisonvalue*) *true?*

In the following example a string field is compared to determine whether the user answered yes or no to a previous question. String comparisons are not case sensitive and therefore YES, NO, Y or N could have been used as well. The compare strings (if comparing strings) cannot be longer than 100 characters. Note that all variations of an answer need to be catered for, but that the construct also offers an '*else*' clause, should there be no exact match to the other comparisons.

```
*CONTDEF
v,aud100,S8
y,MAS,8, =
yes,MAS,8,=
n,MAS,9, =
no,MAS,9, =
else,MAS,1
```

Looking at a numeric example in more detail:

```
*CONTDEF
mar,aud10,F10.2,0,10000
0,err,1,<
```

```
3,rn1,5,<=
3,rn1,7,>
else,mas,1
```

The first line defines the variable to be used, named MAR, number 10 in the audit file. The next lines define comparisons and section numbers. Each comparison will be tested, starting with the first one. When a comparison result is true, the system will go to the section indicated, and the rest of the comparisons will be ignored. The sequence of processing is as follows :

- Fetch the variable value from the audit file.

- For each comparison, ask the question
  If (variable *compareoperator* value) is true go to the file and section number given.
  Specifically, in this example:
  If (mar < 0) goto file ERR, section 1
  If (mar <= 3) goto file RN1, section 5
  If (mar > 3) goto file RN1, section 7

- If none of the conditions are satisfied go to the file and section number given in the *else* statement, or if no *else* statement exists a fatal error occurs.

4.9 *OUTTEXT* KEYWORD

This keyword provides a simple mechanism for outputting DSS data to a disk file. All components of the *outtext subsection are the same as a *text subsection, with the difference that the user will be prompted for a filename. The contents of the text block will not be displayed, but instead will be written to the named file. This section will normally be used in conjunction with other *text subsections to inform the user as to what is happening, or with a seldef 'null' keyword to automatically continue to the previous or next section.

5. BUILDING THE INPUT FILES AND SECTIONS

It should be reasonably apparent that developing a specific DSS through the construction of input files can be quite a time-consuming task that requires a great deal of careful thought and understanding of the various keywords and parameter constructs. This is inevitable and it suggests that the conceptual design of the DSS should be thoroughly clear before beginning to type instructions into the input files.

There are various approaches that could make the task easier and these will largely depend upon how familiar the DSS designer is with standard computer software and the use of Windows tools. One approach is to build up a list, or 'dictionary', of all variable declarations to be used in the system within a separate text file. When these are required within a specific input file section they can be simply cut and pasted from the dictionary. The same approach could be used with the keywords and other components of the DSS shell system.

5.1 TEXT INPUT FILE VIEW AND EDIT UTILITIES

A utility program (DSSVIEWER) allows the user to create a text file (with a .viw extension) which lists all the components of a DSS in logical sequence (similar to the list contained within Section D of this report) and including reference to the file extensions and section numbers. An example of part of a '.viw' file is provided below.

```
A: WATER SUPPLY PROJECT CONTEXT                                    CNX,1
                                                                   CNX,3
      A.1  Registration of need                                    CNX,5
                                                                   CNX,6
      A.2  Water Committee Constitution                            CNX,4
                                                                   CHK,1
      A.3  Project Agent details                                   CHK,7
                                                                   CHK,2
      A.4  Community project statement                             CHK,4
                                                                   CHK,3
      A.5  Tasks checklist                                         CHK,5
      A.5.1  Project preparation cycle                             CHK,6
      A.5.2  Water Supply/Services                                 KEY,1
      A.5.3  Institutional Audit                                   KEY,2
      A.5.4  Socio-Economic Assessment                             KEY,3
      A.5.5  Community project preparation                         KEY,4
      A.5.6  Community implementation process                      FSB,1
      A.6  Key indicators                                          TSS,1
      A.6.1  Water Supply/Services                                 FSS,1
      A.6.2  Socio-Economic Assessment                             IDD,1
      A.6.3  Institutional Audit                                   DEM,1
```

The utility program displays all the text lines and file extension, section number references in a list box. Double clicking with the mouse on a single line then displays the relevant section details within a memo box. The DSS Shell keywords are highlighted in bold, while other Shell language elements are highlighted in red.

This facility has been added because it is possible that a new user, who wishes to look at the detail of how different components have been coded in the text input files, will find it quite difficult to understand which input file is associated with a specific component.

A further utility (DSSED) is available to actually edit the text input files and includes a number of useful facilities which enhance the users ability to edit the DSS Shell keywords or other language elements. DSSED can be used to establish a specific DSS from scratch and it largely depends upon the personal preference and skills of a potential user as to whether they decide to use DSSED, or to code the text files with a standard text file editor.

SECTION D
RWS-DSS CONTENTS

This section contains the contents of all files (Sections A to F) that form part of the RWS-DSS as well as the name of the file extension, where every sub-section can be located in the system, and its section number.

For example, the details for component A.6.6, Community implementation process can be found in the text file RWS.CHK under the section heading number 6. This information is provided for future developers of the system rather than conventional users, who do not need to access the text files, except through the system.

SECTION E
GLOSSARY OF TERMS AS USED IN THE RWS-DSS

This section contains the Glossary of Terms used within this report and which has been compiled from a variety of sources including previous reports for the Water Research Commission (WRC), standard text books, field guides and dictionary definitions.

1. WATER DEMAND

Average design water demand (ADWD): Average total daily community water demand estimated for the projected design population at the end of the planned scheme design life.

Basic household functions: Water use for drinking, cooking, personal hygiene, washing.

Communal standpipe: Tap water outlet located in a street, or any other communal area, for general use.

Demography: Population characteristics: size, structure, growth rates, mobility, etc..

Design capacity: Maximum possible storage volume, discharge rate capacity, etc. as determined by the size of the system components.

Design period: Length of time (years) for planning the design of any rural water supply scheme during which time the design water supply should meet the design water demand and the infrastructure should be capable of meeting the planned level of service.

Design population: Projected population at the end of the design period as estimated from the present population and the expected population growth rate.

Distribution network: Pipework, fittings and ancillary works for the distribution of water from the point of the water supply outlet at the transmission mains through the network to tap outlets.

Dry sanitation: Sanitation facilities that do not require water for the disposal of sanitary waste.

Household: Number of people living within a building, or collection of buildings, as part of a single family unit and sharing costs.

House connection: Tap water outlet located within a house for private family use.

Illicit connections: Water outlets that were not planned to be part of the scheme design and that have been installed illegally.

Infrastructure malfunction: Breakdown of any system components installed at any point from the water source through the transmission mains and distribution network water supply lines to the tap outlets.

Institution: A society or organisation of a group of people with relevant skills established for the implementation of a specified service function.
Irrigation: The application of water to crops in the absence of enough rainfall for healthy crop growth.

Irrigation efficiency: The efficient use of water for crop growth will ensure that crop water requirements are met at any particular growth stage with the minimum amount of water possible being lost to excess evaporation, evapotranspiration, ponding or leakage with the aim of minimising water wastage.

Leakage: Loss of water through cracked or broken system components, such as storage tanks or pipes.

Level of service: The amount of water to be supplied to each person each day and the desired method selected for water distribution.

Maximum Daily Water Demand (MDWD): The maximum volume of water required by the community daily during periods of increased consumption and use.

Per capita consumption: The amount of water required by one person in one day.

Peak factor: A value by which to calculate the expected increase in ADWD to estimate the PHWD.

Peak Hourly Water Demand (PHWD): The maximum volume of water required by the community during the hour of the day when water demand is greatest.

Population growth rate: The rate of annual increase in the number of people to be served by a rural water supply scheme based on a percentage of the present population; the growth rate may be natural or artificial.

Reservoir storage capacity: The maximum volume of water that can be contained by a storage reservoir, including live storage for use and dead storage below the water outlet.

Reticulation network: Netlike structure of pipes, fittings and ancillary system components carrying water from the transmission mains water supply line outlet to tapstands or other points of water distribution for the users.

Rural: Villages or other small communities remote from urban centres and services and often in areas where access is limited or non-existent.

Sand filtration: A method for water treatment that uses sand beds to filter and purify water before its distribution.

Simultaneous use: Water use for more than one purpose from the same water source at the same time.

Source capacity: The maximum volume of water that can be abstracted daily on a sustainable basis from a selected water source.

System capacity: The maximum volume of water that can be stored and/or transported by system components from the water source through the transmission mains to the reticulation network and water distribution outlets.

System design: The design plans for the water supply network inclusive of water source, transmission mains and reticulation network.

Target year: The last year of the rural water supply scheme design life.

Transmission mains: Main water supply line, inclusive of pipes, fittings and ancillary system components, designed to carry water from the source to the inlet for the reticulation network.

Upgradability: A system design that incorporates the capacity for improving the level of service that could be provided in the future.

Waste water disposal: The disposal of excess water that has already been used by the consumers and that, as a result, is of poor quality.

Water accessibility: Distance and elevation difference between the community and the water source (present or proposed).

Water losses: The net loss of water from the system defined by the difference between the planned water volume and the actual amount of water that is available for the end user. For example, due to water lost from the transmission mains and/or the reticulation network due to system component breakage/leakage and/or water losses through illicit connections.

Water meter: An apparatus for measuring the quantity of water used, i.e. a water gauge.

Water shortfall: A situation that occurs when the quantity of water available from the water source(s) is less than the required community water demand.

Water storage: A facility designed to hold a specific volume of water either for the direct storage of surface water precipitation or for the management of groundwater abstraction.

Water treatment works: A facility designed for water purification in situations where the water quality is considered to be poor/otherwise detrimental to health.

Water users: The community members for whom the rural water supply system has been designed; these will include upstream and downstream users who must be supplied from a system designed to provide equal amounts of water for every household regardless of location within the system.

Water wastage: Water lost from the supply system due, for example, to taps left running, over-consumption or water being used for irrigation from a system designed for domestic supply only.

Wet sanitation: Sanitation facilities that do require water for the disposal of sanitary waste.

Yard connection: Tap water outlet located within a household area for private family use.

2. GROUND WATER

Abstractable proportion of recharge: The proportion of an aquifer's exploitation potential that can be abstracted from a single borehole.

Anisotropic: Not isotropic, showing differences of geological property or of effect in relation to groundwater movement in different directions, i.e. the degree of preferential flow in the x-y plane where x is in the down gradient direction.

Annulus: Ring-shaped space between the outer wall of a borehole casing/screen and the borehole wall.

Anomaly: Irregularity: deviation/departure from a pattern/trend being recorded during geophysical traversing and measurement of subsurface properties.

Aquiclude: A geological formation with extremely low permeability.

Aquifer: A water bearing geological formation capable of yielding ground water in useful amounts: can be a primary (unconfined) aquifer directly below the surface or a secondary (confined) aquifer protected from the surface by less permeable layer(s). Aquifers have further been subdivided into three broad classes for the purpose of borehole designs:
1. Crystalline aquifers are typified by igneous and metamorphic rocks which have no primary porosity or permeability and no well defined base. Water-bearing voids are usually in the form of fissures or in weathered zones and, in an open borehole, these rocks usually do not need support. N.B. Basalt successions commonly behave like consolidated aquifers rather than crystalline formations;
2. Consolidated aquifers are sedimentary formations, of limited thickness, that retain some of their initial - primary - porosity and permeability, and normally have clearly defined tops and bases. Groundwater flow is normally through fissures or zones of enhanced permeability and these rocks usually have sufficient strength to stand in an open borehole without support. N.B. Exceptions may include sedimentary strata that has become so compacted that it loses its primary porosity and become entirely crystalline, for example, quartzites or marbles;
3. Unconsolidated aquifers are sediments which cannot stand in an open borehole, for example, alluvium and many Tertiary and Mesozoic sandstones. Any borehole in such formations will require support by casing and screens. N.B. Parts of consolidated aquifers may lose their cement through solution and revert to the character of unconsolidated aquifers.

Aquifer area: Lateral and vertical extent (dimensions) of a water bearing geological formation.

Aquifer hydraulics: The hydrodynamics or conveying of water through an aquifer.

Aquifer storativity: Has two definitions depending upon whether storage is unconfined (specific yield) or confined (the storage coefficient). The specific yield of an aquifer is the volume of water which will drain from a unit volume of aquifer under gravity alone. The storage coefficient of a confined aquifer is the volume of water released from storage per unit surface area of aquifer per unit change in head (related to the compressibility of water and the aquifer fabric). The specific yield is usually about three orders of magnitude greater than the storage coefficient of the same aquifer.
Aquifer thickness: Depth from the top to the bottom of a single water bearing geological formation.

Aquitard: A geological formation of low permeability but through which measurable leakage of groundwater can occur. In a system of aquifers, separated by aquicludes, each aquifer may have a different piezometric or hydraulic head and may contain water of a different quality.

Auger drilling: Auger rigs vary from small-diameter manual augers for soil sampling to large truck or crane-mounted augers used for drilling shafts that are more than a metre in diameter.

Blow yield: The preliminary estimation of a borehole's yield as determined immediately after the borehole has been drilled and during borehole development.

Borehole: For the purposes of the RWS-DSS a borehole is defined as a water well drilled for the principal purpose of obtaining a water supply. Synonyms are tubewell or production well/borehole.

Borehole casing: Non-perforated material and corrosion resistant, which can be plastic, fibre-glass or steel, generally used to seal off sections of impermeable unstable geological formations (aquicludes) in a borehole. Also used to case-off sections of aquifer containing low quality groundwater when additional sealant is required. N.B. In most crystalline aquifers only the upper few metres need casing and grouting, to seal off surface water, and the rest of the borehole can be left open.

Borehole collar: Height of borehole casing extending above the ground.

Borehole construction: Borehole drilling and installation including, for example, casing, screens, formation stabiliser, gravel packs, grouting, sanitary seal and protective apron. The types of drilling methods, machinery and materials used will depend on the nature of the geological formations, e.g. soft, unstable formations and/or hard rock, and the anticipated maximum depths and diameter to be drilled.

Borehole depth: The total depth drilled including an allowance for several metres of sump below the pump installation depth to collect fines and other material falling down the borehole.

Borehole design: Identification of probable aquifer type, borehole dimensions (depth and diameter) and optimum borehole depth in relation to probable yield as determined from the results of previous drilling experience, geological formation sampling and water sampling. Designation of the purpose of the borehole (exploration, observation and/or production). Selection of the materials to be used for borehole construction (including health requirements), selection of drilling method and selection of type of rig required.

Borehole development: After drilling a borehole it is developed to repair any damage done to the borehole face and adjacent aquifer matrix during drilling (smeared clay/mud cake on the walls, mud filtrate in fissures and/or dirty water blocking pores within the matrix and/or formation invasion by fines from the formation being drilled), improve the flow of water into the borehole and restore the borehole's potential performance. A secondary aim is also to develop the aquifer adjacent to the borehole itself by removing the fine fraction of the aquifer itself and increase the transmissive properties to values greater than they actually were before drilling. Development methods may include the use of: wall scratchers, surge blocks and bailers, surge pumping, jetting, polyphosphate dispersants and/or acidization.

Borehole diameter: The lateral dimension of a borehole when drilled. The borehole diameter very often is reduced with depth but must be large enough to accomodate the outside diameter of the required pump, plus casing, at the required depth of installation.

Borehole log: A verbal or pictorial description of a borehole based on on-site hydrogeological examination during drilling, geophysical logging and laboratory sample analysis to record: the sequence of lithological formations drilled, the drill bit penetration rate, the occurrence of groundwater strikes, the geophysical characteristics of the borehole and the borehole construction.

Borehole prospects: The percentage of successful/wet boreholes, drilled previously and recorded in borehole records, per total number of boreholes previously drilled, i.e. the probability of drilling a wet borehole based on a pre-specified range of borehole yields, for example, 0.5 to 2.0 *litres*/second.

Borehole screens: Perforated material, which can be plastic, fibre-glass or steel, generally inserted into a borehole to allow water to pass through but prevent particles from entering the borehole in sections of unconsolidated/unstable permeable geological formations (aquifers). The type of screen will depend on a combination of material strength and corrosion resistance, the slot design, the open area (the proportion of a screen face made up of open slots) and the required flow from the aquifer (the open area of a screen should be as great, or greater than, that of the aquifer).

Borehole stability: The strength of the borehole walls which will be dependent on the type of geological formation drilled.

Boundary conditions: An aquifer's hydraulic boundary: A barrier boundary stops ground water flow into or out of the aquifer in that direction. For example, an aquifer can be abruptly terminated by a geological fault which acts as a barrier boundary and stops ground water flow to the borehole, or a low permeability dolerite dyke can often act as a barrier to flow and result in groundwater compartments. In a water table aquifer the opposite to a barrier boundary can occur at the area of flow recharge (defined by a topographic divide) or at the area of flow discharge to a stream providing the baseflow of that stream. A boundary defines the maximum possible radius of influence of a pumping borehole.

Capture zone: The area of an aquifer affected by a pumping borehole which is defined by the cone of depression.

Cone of depression: The action of pumping water from a borehole lowers the ground water level and creates a hydraulic head difference between the water in the borehole and that in the aquifer. This head difference causes water to flow into the borehole and so lowers the hydraulic head in the aquifer around the borehole. The effects of pumping spread radially through the aquifer causing the lowering of either the piezometric surface or the water table in a cone of depression around the borehole.

Constant discharge rate test: A type of pumping test designed under controlled conditions to measure the borehole performance, to obtain values of the aquifer transmissivity and storativity and to obtain some indication of the aquifer geometry. The objective is to predict long-term borehole and aquifer performance and estimate the sustainable yield. The analyses of constant discharge rate tests are dependant on the observed behaviour of the groundwater levels with the theoretical behaviour in a perfect aquifer, as defined by the Theis equation or its variants.

Dipping strata: Geological formations that are inclined at an angle to the horizontal.

Double/Dual porosity: An aquifer where ground water can flow through the voids of both primary and secondary porosity. In fissured aquifers, for example, the fissures usually are highly transmissive but have low storage, while the rock matrix has a high storage but a low transmissivity.

Drilling success rate: The percentage of successful/wet boreholes drilled per total number of boreholes drilled.

Drawdown: The depth of the reduction in water level in a borehole caused by pumping the borehole.

Dyke: A linear ring-like feature of basic igneous rock that has intruded through any other geological formations.

Dynamic water level: The changing water level in a borehole during pumping or during recovery after pumping.

Early-time: The Time (t) shown on a semi-log graph of time-drawdown, plotted from test pumping data, from just after the beginning of pumping (after borehole effects have stabilised) until an obvious point of inflection on the curve. Applicable to a double-porosity aquifer.

Exploitation potential: The probable water yield that might be expected from a borehole drilled into a particular type of geological formation/aquifer based on previous drilling and test pumping records.

Exploration borehole: A borehole drilled for the specific purpose of obtaining information about subsurface geological formations or the ground water. Synonyms are investigation borehole or pilot borehole.

Fault: A fracture in the earth's crust resulting in the relative displacement of the rocks on either side.

Formation: A geological formation can be of igneous, sedimentary or metamorphic rock type but has certain physical characteristics in common including composition, texture and colour.

Formation sampling: The recovery of different types of rock materials from a borehole when drilling for laboratory analysis. Disturbed samples can be used to establish the lithological succession (the different geological formations drilled) and the aquifer grain-size distribution. Undisturbed samples can be used to establish hydrogeological chracteristics, for example, porosity and permeability. This information, in turn, can be used for the design of casing and screens; particularly in instances when multiple aquifers have been drilled.

Gravel pack: Artificial gravel packs can be inserted into the annulus of boreholes drilled through fine, well-sorted and heterogeneous aquifers. These consist of material that is coarser-grained than the aquifer material and hence screens with larger slot sizes can be used. Natural gravel packs can be produced during borehole development in an unconsolidated aquifer when it is coarse-grained and ill-sorted to draw out the finer fraction and leave behind a stable envelope of coarser, and therefore more permeable, aquifer material between the borehole wall and the screens.

Ground water flow path: From the point of inflow/recharge to the point of outflow/discharge groundwater flows through the line of least resistance either via zones of enhanced porosity and hydraulic conductivity within the matrix and/or along fissures in the rock itself.

Ground water sampling: The taking of water samples for laboratory analysis from increasing depths in a borehole, as it is being drilled, when any aquifer water strike is encountered. Synonymous with stratified sampling. Water samples are tested to establish aquifer water quality, class, and whether the water can be used for long or short term potable supply or if it is of too poor quality to be used in any circumstances. This information, in turn, can be used for borehole design when aquifer sections of poor water quality require to be cased-off.

Groundwater travel time: Rate of groundwater flow per unit distance per unit time.

Homogeneous: Of uniform nature.

Hydrogeology: The study of the distribution, aquifer hydraulics, geophysics, geochemistry, conservation, use, etc. of ground water and its interactions with the hydroshpere.

Hydraulic conductivity: The rate at which water is transmitted through a unit cross-sectional area of aquifer under unit hydraulic gradient. Also commonly called the aquifer permeability or coefficient of permeability and not to be confused with the intrinsic permeability of a porous medium. In intergranular aquifers the hydraulic conductivity will depend on the aquifer material and the degree of cementation. In fissured aquifers the hydraulic conductivity will depend on the intensity of fissuring and the openness and continuity of individual fissures.

Hydraulic head: The difference in level of the groundwater surface between the recharge and discharge areas; the driving force of groundwater flow.

Induration: The hardening of an aquifer material.

Infiltration capacity: The maximum rate of water absorption into voids/pores in a unit volume of soil/aquifer.

Infiltration gallery: A technique used to abstract groundwater stored in the weathered zone of hard rock terrain, from a system of trenches/specially designed pipes, when the groundwater potential is too low to justify the costs of installing any other type of groundwater device designed to abstract water from a single point source.

Intrinsic permeability: Is independent of the liquid involved, is characteristic of the aquifer alone and is related to the hydraulic conductivity by the equation: $k = K\nu/g$ where k = intrinsic permeability (length^2); K = hydraulic conductivity (length/time); ν = fluid kinematic viscosity (length^2/time); g = gravitational acceleration (length/time^2).

Isotropic: Not anisotropic, showing similarities of geological property and of effect in relation to groundwater movement in all directions.

Joint: A crack in a rock along which no displacement has occurred.

Karst: Characteristically limestone plateaus and underground streams, gorges, caverns, etc.

Laminar flow: Nonturbulent motion of water in which parallel layers have different relative velocities.

Late-time: The Time (t) shown on a semi-log graph of time-drawdown data from an obvious point of inflection on the curve (end of early-time) until either a further point of inflection (after which the drawdown stabilises) or until the end of the pumping test. Applicable to a double-porosity aquifer.

Lineaments: Linear zones of weakness, any long narrow cleft or crack in a rock such as fractures, faults and joints as well as linear or ring dykes.

Lithological contacts: The interface between two different lithological units.

Matrix: Nonfissured aquifer rock of greater or lesser permeability and hydraulic conductivity depending upon rock type. The matrix can form the Tmin zone of a double porosity system in a fractured aquifer.

Massive rocks: Rocks of generally low porosity and hydraulic conductivity: either homogeneous igneous rocks having no stratification, cleavage, etc. or sedimentary rocks arranged in thick poorly defined strata.

Monitoring borehole: A borehole constructed to obtain long term information on variations in the ground water level or quality.

Multiple aquifers: A series of aquifer layers, of varying thicknesses, separated by intervening aquicludes (impermeable formations) all penetrated by a single borehole.

Observation borehole: A borehole constructed to measure the cone of depression around an abstraction well during test pumping.

Optimal drilling depth: Because both fissuring and weathering of crystalline aquifers decrease with depth there will normally be a depth beyond which the cost of drilling outweighs the chance of significantly increasing the yield of a borehole. This depth is the optimum total borehole drilling depth, which will vary from place to place, and is unlikely to exceed 100 m in fracturesd aquifers.

Overburden: The rock and weathered or other material that covers an aquifer.

Penetration rate: The time taken for a drill to penetrate through each metre drilled. The rate will vary significantly depending upon the kind of material being drilled. For example, it will take much less time to penetrate through a soft sedimentary material than it will to penetrate through a massive igneous rock material.

Perched aquifer: A water bearing geological formation of limited extent located within a geological formation with extremely low permeability.

Percolation: The gradual penetration and permeation of water through a porous material.

Piezometer: A small-diameter borehole or tube specially constructed for the measurement of hydraulic head at a specific depth within an aquifer system or thick aquifer. The screened section in a piezometer is very short compared with that in a normal observation borehole.

Piezometric surface: Water level in a borehole penetrating a confined aquifer.

Porosity: The porosity of an aquifer is the proportion of the aquifer material made up of voids. Primary porosity represents those voids present from the period when the sediments making up the aquifer were laid down, for example, the intergranular pores in a sandstone. Secondary porosity has resulted from changes in an aquifer after its formation, for example, fissures along joints or bedding planes.

Production borehole: A wet borehole that has been constructed and installed with a pump for water supply.

Pump capacity: Maximum economic pumping rate for any particular pump size, type, and model.

Pump depth setting: Depth of pump installation below the main water strike and above the borehole sump.

Pumping head: The maximum height that water is carried to above a pumping installation plus frictional head losses (pipe friction) is a measure of the pressure at that point.

Pumping test: The disturbance ot the natural flow of groundwater by the pumping of a borehole, under controlled conditions, so that the effects can be analysed to evaluate the hydraulics of the pumping borehole and the aquifer characteristics of the exploited aquifer. The disturbance to groundwater flow is observed by measuring the changes in the water levels in the pumping borehole and observation borehole(s) drilled in the vicinity of the pumping borehole.

Recharge: The amount of rainfall that penetrates through the ground far enough to reach the water table/piezometric surface and add to the ground water storage as a percentage of Mean Annual Precipitation (MAP).

Recovery test: The measurement, under controlled conditions, of the ground water levels after pump testing has stopped as they return to the static water level (undisturbed state) is the converse of the pumping test water level drawdown. The analysis of the recovery test data (residual drawdown) can then be used to compare against the the results obtained from test pumping data analysis as well as to estimate the number of hours that a borehole can be pumped on a daily basis.

Rising main: Pipes and fittings connecting the pump installed in a borehole to the surface.

Saturation: When all pores/voids in a soil/rock are filled with water and no further recharge can take place even if additional water is available, i.e. the state of a soil/rock when it can hold no more water.

Seepage: Either, the state when water passes gradually, or leaks as if through small openings, from a less permeable to a more permeable geological formation, or, a when water oozes through the ground to form a small spring or wetland area.

Seepage face: The width of the aquifer's outlet where seepage occurs at a borehole.

Slug tests: The lowering of a large cylinder (a slug) on a line into the water column in a borehole so that the water level is instantaneously raised by a few metres and the subsequent monitoring/measurement of the reduction of the water level over time to its undisturbed state. Alternatively, a slug test can be conducted by the rapid removal of a measured volume, or a 'slug', of water from a borehole to produce a drawdown and the subsequent monitoring/measurement of the recovery of the water level over time.

Shallow well: A large-diameter, shallow water well constructed by manual labour. Synonyms are open well, hand dug well or driven well (when constructed using manually powered drilling equipment).

Snatch sampling: The taking of single water samples from each of various water sources during the feasibility survey hydrocensus. These water samples can be tested on site for basic water quality determinands or stored and then sent to the laboratory for more detailed analysis. Synonymous with composite sampling.

Solution channels: Zones of weakness within an aquifer rock where geochemical processes cause the rock in the immediate vicinity to dissolve and widen the opening.

Spring: A natural outflow of ground water, as forming the source of a stream.

Static water level: The depth of the water level in an undisturbed borehole, i.e. when the borehole is not being pumped.

Stratigraphy: The study of the compositions, relative positions, etc. of rock strata in order to determine their geological history.

Stratified aquifer: More or less water bearing strata/layers penetrated by a borehole, i.e. some strata are more permeable/porous and therefore better capable of storing and transmitting water than other strata.

Test borehole: An exploratory borehole drilled to test an aquifer by means of test pumping.

Tested yield: The recommended borehole yield that is estimated from the results of analysis of the test pumping data.

Tracer: A substance, such as a dye or a radioactive isotope, with unique identifying properties which is introduced into a known point of ground water recharge with the objective of identifying certain groundwater characteristics including following the ground water flow pathway, detecting the point of ground water discharge and/or ascertaining the ground water travel time.

Tracer travel time The time taken by a tracer to travel between two boreholes/monitoring points.

Transmissivity: The rate at which water can pass through the thickness of sturated aquifer of unit width under a hydraulic gradient. The transmissivity in a uniform aquifer will be the hydraulic conductivity multiplied by the saturated aquifer thickness but, as uniform aquifers rarely occur in nature, the transmissivity should be considered as a summation of the permeabilities of unit thicknesses through the aquifer section.

Turbulent flow: Nonlaminar motion of water in a state of instability and agitation. For example, the velocity of ground water in an aquifer under natural conditions is very slow but, near to a discharging borehole - particularly when the discharge rate is high, or if the flow is restricted to fissures or to thin, highly permeable, zones - the velocity can be very high and the flow may become turbulent.

Variable discharge rate test (step drawdown test): A type of pumping test designed to measure the borehole efficiency, to measure the borehole performance and to measure the variation of performance with variation in discharge rate under controlled conditions. The drawdown in the pumped borehole is measured while the discharge rate is increased in steps. The discharge rate during each step is kept constant through the step.

Water level: Depth of water surface in a borehole.

Water strike: Depth in a borehole being drilled where a water bearing layer is penetrated.

Water table: Depth of water surface below the ground surface in an unconfined aquifer.

Weathered material: Rock that has been broken down due to the effects of exposure to physical and/or chemical processes.

3. SURFACE WATER

Baseflow: Mainly supplied from the discharge of ground water into a stream. Since water flowing at depth beneath the surface moves relatively slowly, its outflow as baseflow into the stream lags behind the occurrence of rainfall and tends to be very regular. Groundwater flow thus often maintains a steady basal flow throughout the dry season. But, if pumping from a borehole lowers the water table below the elevation of that stream then the baseflow increment from ground water is intercepted, stopped and may be replaced by a net loss of river flow resulting in the surface stream drying up completely.

Critical drought period: The maximum expected prolonged period of scanty rainfall or shortage of rainfall as predicted from long-term records.

Dam/Reservoir/Impoundment: a) A barrier of concrete, earth, etc., built across a river to create a body of water; b) A reservoir of water created by such a barrier; c) Something that resembles or functions as a dam.

Evaporation: The loss of water to the atmosphere through a change in state of water held in an open water body or bare soil from a liquid to a vapour.

Evapotranspiration: The loss of water held by plants, especially through the stomata of the leaves, to a vapour in the atmosphere.

Flow duration curves: Show the frequency (percent of time) with which stream discharges of different magnitude are equalled or exceeded.

Hydrology: The study of the distribution, conservation, use, etc. of the water of the earth and its atmosphere.

Mean Annual Evaporation (MAE): The middle value in a range of measured depths of evaporation (mm) in a specified place for a one year period.

Mean Annual Precipitation (MAP): The middle value in a range of measured depths of precipitation (mm) in a specified place for a one year period.

Mean Annual Runoff (MAR): The middle value in a range of measured depths of runoff (mm) in a specified place for a one year period.

Meterorology: The study of the earth's atmosphere, especially of weather-forming processes and weather forecasting.

Precipitation: The deposition of rain, snow, sleet, dew, etc., formed by condensation of water vapour in the atmosphere, on the earth's surface.

Quaternary catchment: A river basin containing a number of tertiary catchments but itself forming a sub-catchment of a primary catchment (the entire catchment area of a main river system).

Raintank: A tank made of plastic, fibreglass, metal or other material designed to hold rainwater collected from a roof catchment or specially prepared ground surface and with sufficient capacity for seasonal household potable water requirements.

Rainwater harvesting: The collection of rainwater falling directly onto roofs or pre-prepared ground surfaces for diversion to raintank storage and direct use.

Recurrence interval: The expected return period of a specified depth of precipitation/flood event based on rainfall records, i.e. the frequency or average time interval within which a given depth of precipitation/flood of a given size will occur.

Sediment load: The combined material supplied to a stream for transport and deposition and which can be subdivided into dissolved load (material transported in solution), suspended/wash load (particles <0.064 mm and finer than those usually found in the bed and moving rapidly in suspension) and bed-material load (including all sizes of material >0.064 mm found in appreciable quantities in the stream bed).

Stream discharge: The product of cross-sectional stream area and stream velocity and which is highly correlated with drainage/catchment area.

Streamflow: Total flow is subdivided into direct or storm runoff, and baseflow. The distinction is based on the time of arrival in the stream rather than the route followed although the two are necessarily related.

Direct runoff: Consists of surface flow (Horton or saturation overland flow) from precipitation and a substantial part of the subsurface flow.

Tertiary catchment: A small river basin system/collection of smaller tributaries that collectively form a sub-catchment of a Quaternary catchment.

Throughflow: When the maximum rate of absorption (infiltration capacity) exceeds the rate of receipt (normally expressed by rainfall intensity), water infiltrates the surface and either moves downwards to replenish the ground water reservoirs or flows laterally as throughflow; particularly in soils with impeding horizons of low permeability.

Turbidity: Muddy or opaque water clouded with suspended particles.

Variability: Liable to or capable of change: degree of rainfall variability.

Weir: A low dam that is built across a river to raise the water level, divert the water, or control its flow.

Wetlands: An area of land that is moistened, covered, saturated, etc., with water.

4. BUDGET

Economy of scale: The relative costs of resources as related to quantity/size.

Economic criteria: Any test, rule or standard for the assessment and evaluation of relative available water sources and levels of service provision during the planning, implementation, operation and maintenance of a rural water supply system.

Low-cost approach: The application of low-level, low cost and appropriate technology in relation to the paying capacity of the target community in order to ensure project sustainability during the design life of a rural water supply scheme. N.B. This should not necessarily be interpreted as least/cheapest cost.

Operation and maintenance costs: The running costs for rural water supply scheme administration, operation and maintenance after the rural water supply scheme has been constructed and commissioned.

Paying capacity: The unit amount of money that the combined members of each household have available/can afford to pay for the planning, implementation, operation and maintenance of a rural water supply scheme

Project capital costs: The cost of all materials and equipment required for rural water supply project implementation.

Project overhead costs: The cost of planning, liaison, surveys, design, administration, training, supervision, transport, allowances and accommodation for rural water supply project implementation.

Relative costs: The variation in costs associated with different types of available water sources, levels of service and any associated water treatment requirements.

Water purchase: The payment for water provided from pre-existing water supply schemes with excess capacity located closeby to the project area.

Water tariff: The cost to each community household for operation and maintenance of the water supply scheme based on the type of water source selected, the desired level of service and any water treatment that may be required.

5. GENERAL WATER SOURCES

Abstraction: The removal or extraction of water from any source.

Acceptable risk: The permissible percent of time when there is known to be a chance of failure of a water supply source because of unpredictable rainfall patterns resulting in water shortfalls. Synonymous with reliability.

Available water sources: Any existing or potential source of surface or ground water located within the land area of the target community.

Biodegradation: The decomposition of materials by bacterial, fungal or other biological action, i.e. the natural break down of materials into constituent elements

Bulk supply: Large-scale water delivery system designed to supply the water requirements of an urban settlement and/or a number of rural communities. Synonymous with regional water supply schemes. When a bulk supply scheme has excess capacity there may be enough water available to supply the target community.

Community preference: The system design selected from all of the options available to a community by the people who are to be served by the rural water supply. Includes selection of type of water source, power supply for the pump and level of service for water delivery.

Conceptual model: The building up of an idea of site conditions from desk studies of maps, reports and other records of previous work done in the area and verified by feasibility studies.

Conjunctive use: The use of more than one water source to supply enough water for community water demand.

Contamination risk: The possibility of good quality water source(s) being affected by nearby activities or natural hazards which are likely to cause pollution of the water supply. Exposure or vulnerability of the water supply to pollution.

Critical parameters: Essential constants or limiting factors used in rural water supply evaluation, selection, construction, operation and maintenance. For example, a water supply system must be designed within the parameters of budget and practicality.

Excess capacity: Water surplus or more than enough water to supply community water demand. The amount by which the quantity of water available from the source/system exceeds community water demand.

Generic: General, applicable to any type of RWS-DSS.

Gravity fed system: A water supply network installation that is supplied by water flowing under the force of gravity alone and where no power is required to move the water through the system from the source to the user.

Ground truth: Verification of information obtained during a desk study, from existing maps, reports and other records, by field survey and measurements.

Hydrocensus: A survey of existing and potential water sources including information such as type of source, estimated discharge/yield, water quality, condition of equipment (if already installed), etc.

Institutional feasibility study: A study designed to determine whether or not a plan for a rural water supply scheme can be put into effect successfully based on institutional capacity.

Intake structures: A construction designed for the abstraction of water from any source.

Over-utilization: When the amount of water used by consumers is more than the system design capacity as defined by the amount of water available from the water source, i.e. the sustainable yield. This may cause system failure.

Power supply: The source of energy for water pump operation which could be from diesel, electricity, solar, wind, water or hand.

Pumping head: The difference in height between the water pump and the point of distribution or storage.

Resource evaluation: The assessment of the water source(s), institutional, social and economic capacity of the target community.

Rural water supply: The adequate provision of enough water to satisfy the requirements of a community living at some distance away from urban centres and where on-line services may be lacking.

Skilled personnel: People trained in a particular skill for a specified task or tasks.

Source failure: The situation when, after a period of time of successful operation, according to the design specifications, there is no longer enough water to meet the design water demand either because of over-utilization or because the intake structure stops operating or working properly.

Source protection: Any construction (lining and/or surface works) designed to protect the area immediately surrounding a water source from pollution (by infiltrating surface water flow back, throughflow from contaminated areas, rubbish or other wastes).

Source vulnerability: The potential for water source contamination from pollution, i.e. the contamination risk.

Spatial: Existing or happening in space, i.e. across any area.

Socio-economic feasibility study: A study designed to determine whether or not a plan for a rural water supply scheme can be put into effect successfully based on socio-economic capacity.

Source exploration: Hydrological assessments for surface water sources and geophysical surveys, test drilling and pump testing to assess the potential of ground water sources.

Sustainable yield: The estimated quantity of water that can be abstracted from a given water source with a specified degree of assurance without exhausting the resource in the long term. Synonymous with safe yield or recommended long-term yield.

Target feature: An object or area identified during feasibility studies with the potential for water source development for further more detailed investigations/exploration.

Temporal: Existing or happening in time, i.e. during some period.

Under-utilization: When the amount of water used by consumers is less than the water system design capacity as defined by the amount of water available from the water source, i.e. the sustainable yield. This will result in water surplus.

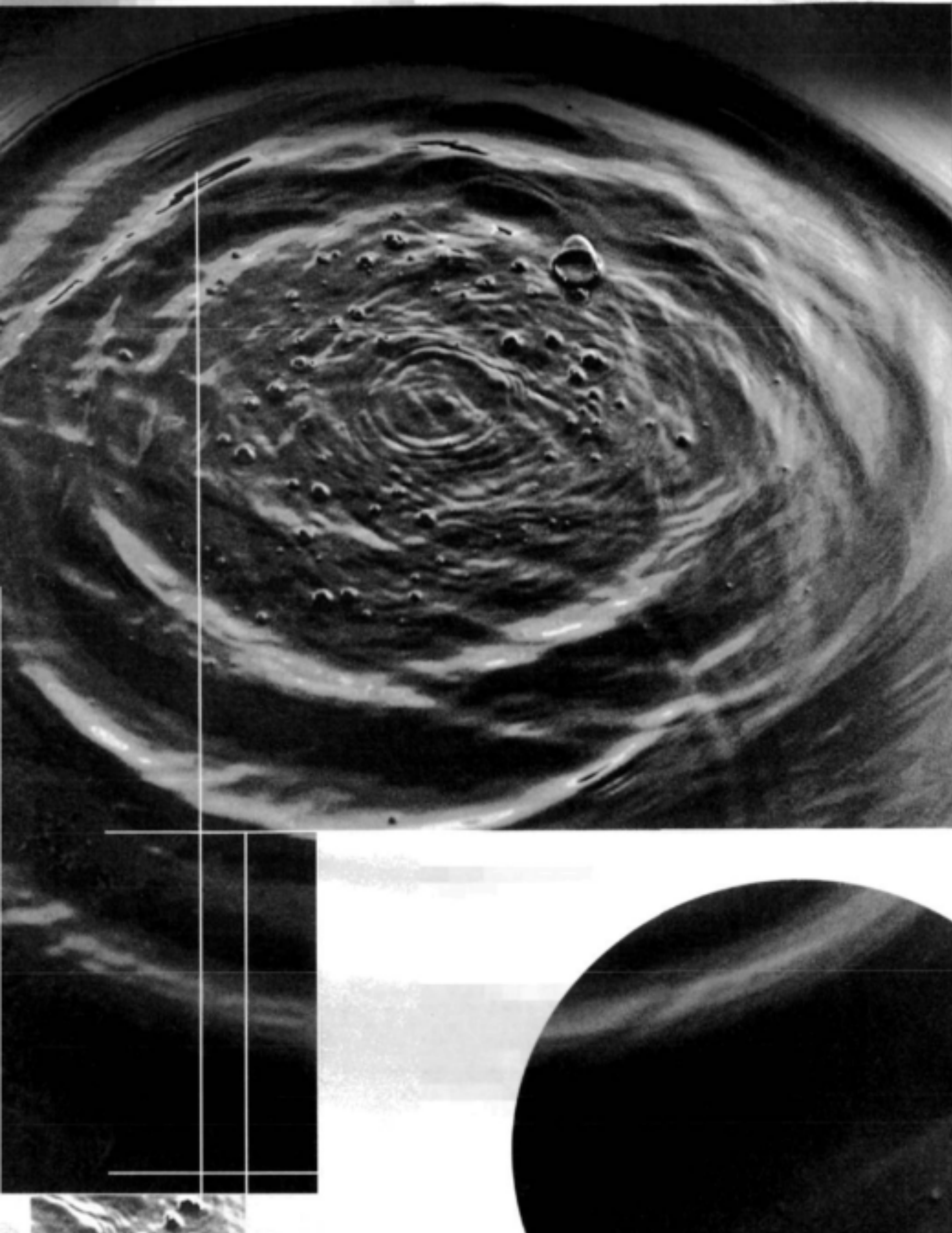
Water management: The control and administering of the water supply for water distribution to the users according to the system design specifications; ideally no over- or under-utilization should occur.

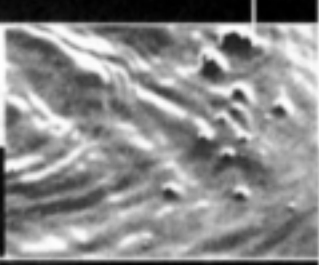
Water outlet: A device designed for the delivery of water to the user.
Water pressure: The force of a unit volume of water discharged in a unit area per unit of time.

Water quality: An accepted or approved standard of water acceptability for use as determined from sampling and analysis.

Water resource feasibility study: A study designed to determine whether or not a plan for a rural water supply scheme can be put into effect successfully based on socio-economic capacity.

Water treatment: The application of processes or chemicals for the purification of water of sub-standard quality.





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