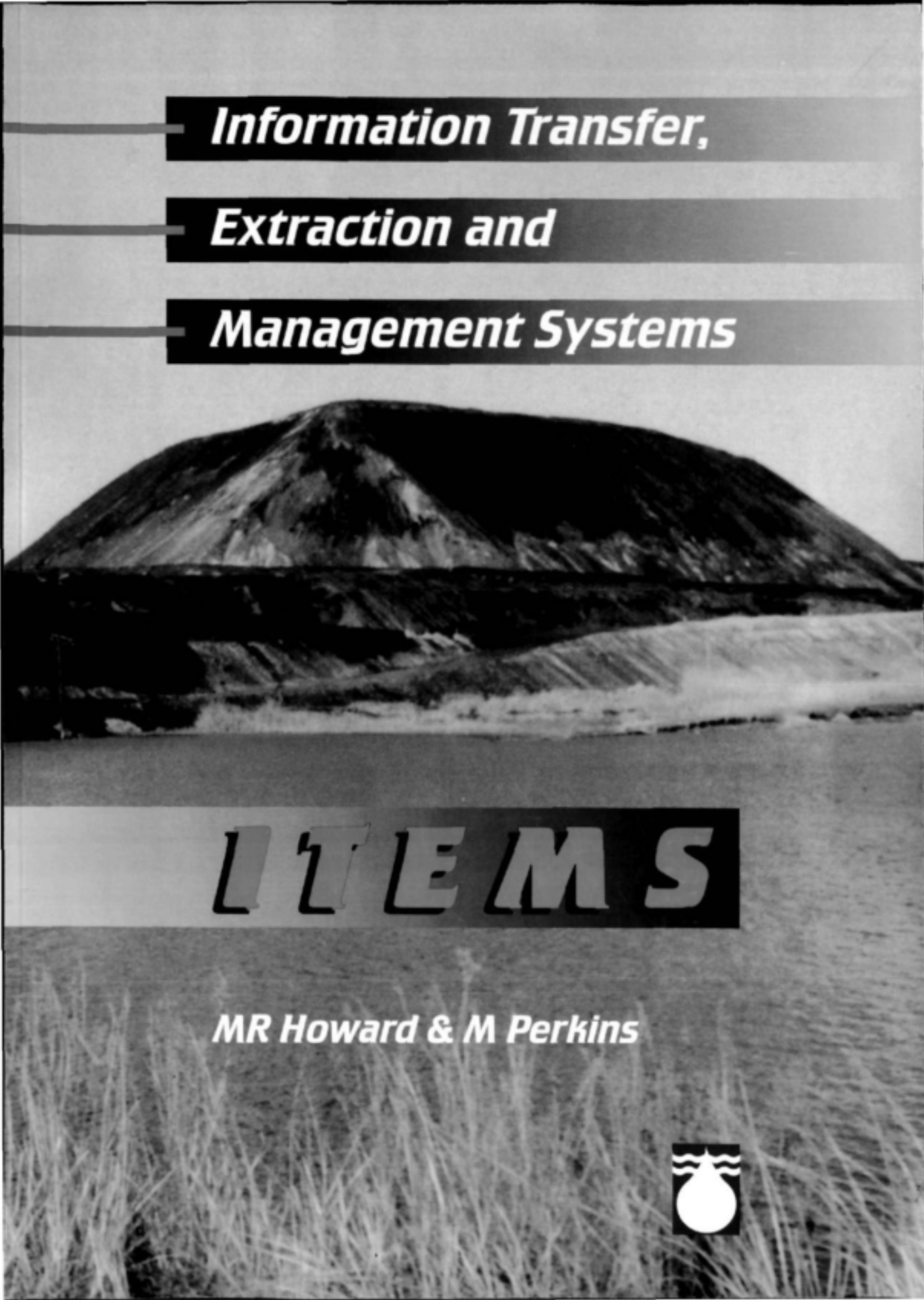
Information Transfer, Extraction and Management Systems



ITEMS

MR Howard & M Perkins

INFORMATION TRANSFER, EXTRACTION AND MANAGEMENT SYSTEM (ITEMS)

Report to the Water Research Commission by:

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NOTE

Answers to any queries regarding the application and operation
of the computer programme, ITEMS, are obtainable from
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EXECUTIVE SUMMARY

Pressure is mounting on regulators and mine operators to address the negative impacts of mining on the water environment. Millions of Rands are spent annually on mining related research which could help them to do so but most water users are unaware of this ever-increasing mass of useful information. Others find that use and accessible information, generally in full written report format, is difficult and time-consuming.

Although the need for effective information transfer has long been recognised, most water users lack the capability to keep abreast of technological developments. Research organisations and consultants keep up to date and "Guideline Documents" have been produced, but again as written reports with limited cross-referencing.

This project aimed a partly solving some of these problems with a computerised Information Transfer, Extraction and Management System (ITEMS) which gives users access to local and international information on mine water quality, management treatment and research.

The information requirements on the mining industry, government departments and other interested organisations were investigated and assessed and a range of databases available worldwide and locally were accessed and evaluated. The result is ITEMS: 18 databases containing approximately 200 tables of data each holding between 20 and 100 records. The total computer file size of the database is 90 Mb.

An uncluttered interface has been developed and a simple step-by-step procedure elicits the specific information required. Software is on CD for ease of installation.

The ITEMS system enables users to obtain access to information, which includes the following:

- DWAF water quality guidelines
- International water quality guidelines
- Water chemistry calculations
- Relevant research projects undertaken
- Manual to assess and manage the impact of mining on surface water quality
- Manual on current mine-water management and treatment practices
- Extended literature database on mine water

ACKNOWLEDGEMENTS

The research for this project was funded by the Water Research Commission. The contributions of the Working Group members are gratefully acknowledged. The Working Group comprised the following persons:

Mrs F Swart	Iscor Mining Ltd
Mr H Nicholls	Anglo American Civils
Dr V Cogho	Ingwe Coal
Mrs E Mostert	Ingwe Coal
Mr J Papini	AngloVaal
Mr B Breetzka	Goldfields of SA
Mr A McLaren	Goldfields of SA
Mr S Bullock	Goldfields of SA

TABLE OF CONTENTS

1. BACKGROUND

Millions of Rands are spent annually on mining related research in South Africa and many times more is spent internationally. Despite this level of effort and financing, most local users remain unaware of the information that is available to them to assist in managing mine water systems and resources. Where users do have access to this information, it is generally only available in written report format, normally with a non-user-friendly report structure.

There is increasing pressure on regulators and mine operators to address the negative impacts which mining has on the water environment and there is, therefore, an increasing demand for access to a wide range of technical information. Much of this information is available at present, particularly to research organisations and consultants who have a need to keep up to date on latest technological developments. However, the users such as mines seldom have the capability to keep up to date with all these developments unless they are assisted.

This need for effective information transfer has been raised repeatedly over the last number of years within the mining industry and the regulatory authorities. This has led to the development of various "Guideline Documents", again as written reports with limited cross-referencing.

A computerised Information Transfer, Extraction and Management System (ITEMS) will enable users to obtain instant and intelligent access to information which could (subject to copyright agreements) include the following:

- DWAF water quality guidelines
- International water quality guidelines
- Water chemistry calculations
- Relevant research projects undertaken
- Manual to assess and manage the impacts of mining on surface water quality
- Literature reviews on all aspects of mine water management and treatment
- Extended literature database on mine water

2. RESEARCH AIMS

The primary aim of this research project was as follows:

i. To develop a computerised Information Transfer, Extraction and Management System (ITEMS) to enable users to gain access to local and international information on mine water quality, management, treatment and research.

In order to achieve this aim, the following secondary aims were addressed:

i. To assess the need of the mining industry, government departments and other interested organisations to identify information requirements for such an ITEMS.

ii. To access and assess the various databases available for inclusion in an ITEMS. The following sources were investigated: Water Research Commission projects; Chamber of Mines research projects; international research projects; water quality guidelines, water related literature; typical water quality data (not specific to a particular mine, but generalised); water quality assessments (e.g. sodium absorption ratios, scaling potentials, corrosion potentials etc.).

iii. To develop the user interface such that a simple step-by-step procedure could be followed to extract the specific information required.

3. MEETING THE OBJECTIVES

In order to achieve the main objective, the sub-objectives were met in the following manner.

A workshop was held in July 1996 at the Milpark Holiday Inn, where nominated members of the mining industry were afforded the opportunity to make suggestions regarding ITEMS. The Chamber of Mines were approached to nominate persons to attend this workshop. All the nominated persons attended the workshop.

At the workshop, the working group decided the following:

- The basic system should not include the Chamber of Mines Guidelines, since these are normally sold to the mining industry and thus could not be included in a WRC project.

- The user interface should be as simple and uncluttered as possible, as a highly graphical interface may firstly not appeal to everyone and secondly tend to slow down the speed of the programme on older machines.

The basic ITEMS system includes the following databases:

- DWAF water quality guidelines
- International water quality guidelines
- Relevant research projects undertaken locally and internationally
- A Manual to Assess and Manage the Impacts of Mining on the Surface Water Environment (WRC Report TT 79/96)
- A Manual on Mine Water Management and Treatment Practices in South Africa (WRC Report TT 80/96)
- Extensive literature database on mine water.

These databases (18 in total) contain approximately 200 tables of data each holding between 20 and 100 records. The total computer file size of the databases is 87 Mbytes.

In order to access additional information, the following organisations were contacted:

Water Research Commission
Department of Water Affairs & Forestry
Department of Mineral Affairs
Chamber of Mines
University of Pretoria
University of Witwatersrand (Department of Civil Engineering and Schonland Research Centre for Nuclear Sciences)
Rand Afrikaans University
University of Natal (Department of Chemical Engineering and Education and Innovation Foundation)
University of Stellenbosch
University of Cape Town (Department of Materials Engineering, Chemical Engineering and Food Science)
Pennsylvania State University (US)
Loughborough University (UK)
US Department of Energy
US Geological Survey
Internet: Lycos search on Australian mining research, US mining research and European mining research.

All relevant information has been included in the specific databases.

In terms of water chemistry calculations, the system includes the following :

- STASOFT - a water chemistry programme available from the WRC. No modifications have been done. ITEMS runs the programme under an MS DOS window.

- Test a value - an interface where the user can test a specific concentration against a number of different standards and guidelines.

- Additionally, the Department of Water Affairs & Forestry's electronic version of the Water Quality Guideline Series is included. It is run from within the programme and no changes are made to the code.

The user interface has been developed such that:

- single or double clicking buttons, pictures or lines of text select the required option
- the results screens have a similar layout
- graphics have been kept to a minimum
- the colours used are non-intrusive
- the general layout will be familiar to Windows users.

As part of the ease of use, the software comes on a CD for ease of installation. With CD installation the programme files are copied to fixed disk and the databases remain on the CD. This requires that the CD has to be inserted in the CD-ROM whenever the programme is run.

In addressing each of these sub-objectives the main objective has been met, namely to develop a computerised Information Transfer, Extraction & Management System (ITEMS), which enables users to gain access to local and international information on mine water quality, management, treatment and research.

4. GETTING STARTED

4.1 System requirements

The following minimum requirements are needed to install and run ITEMS:

For CD installation

- 486 CPU
- 16 Mbytes RAM
- 10 Mbytes hard disk space
- VGA monitor operating at 800 x 600 dpi
- Mouse
- Windows 95

NB. This programme only runs on 800 x 600 dpi VGA resolution.

4.2 Installing ITEMS

To set up ITEMS on your system:

1. Insert CD into CD-ROM drive

2. Select START and choose RUN

3. Run Setup.exe

4. Follow installation instructions.

NB. Close all open programmes before installing software.

4.3 Starting ITEMS

The Setup programme creates a programme group called ITEMS. To run ITEMS select ITEMS from the list of programmes in Program from START.

4.4 Exiting ITEMS

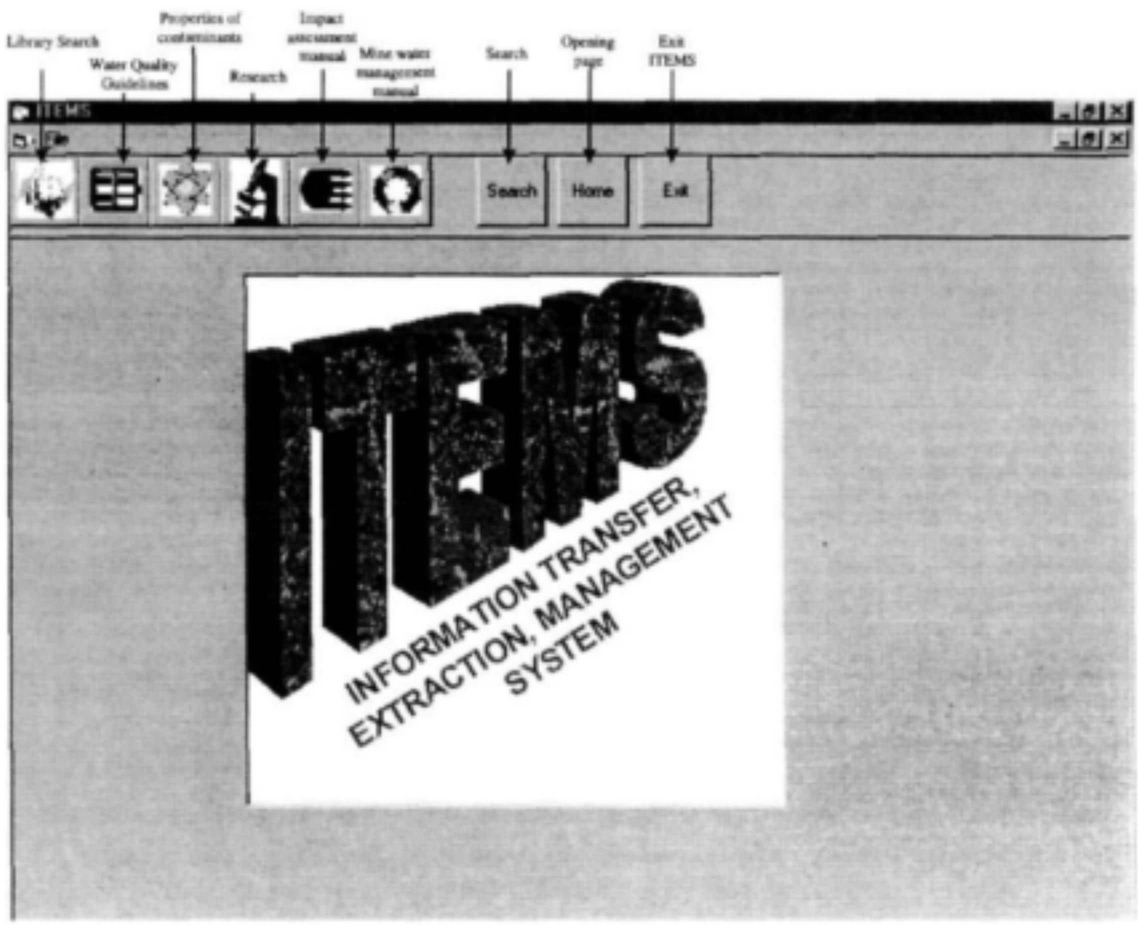
There are two ways to exit ITEMS.

1. Select File and then Exit from the menu;

2. Select Exit from the Toolbar.

4.5 The ITEMS Desktop

The picture below illustrates the opening screen.



All functions on the Toolbar remain on the desktop during the running of the programme.

5. MODULES

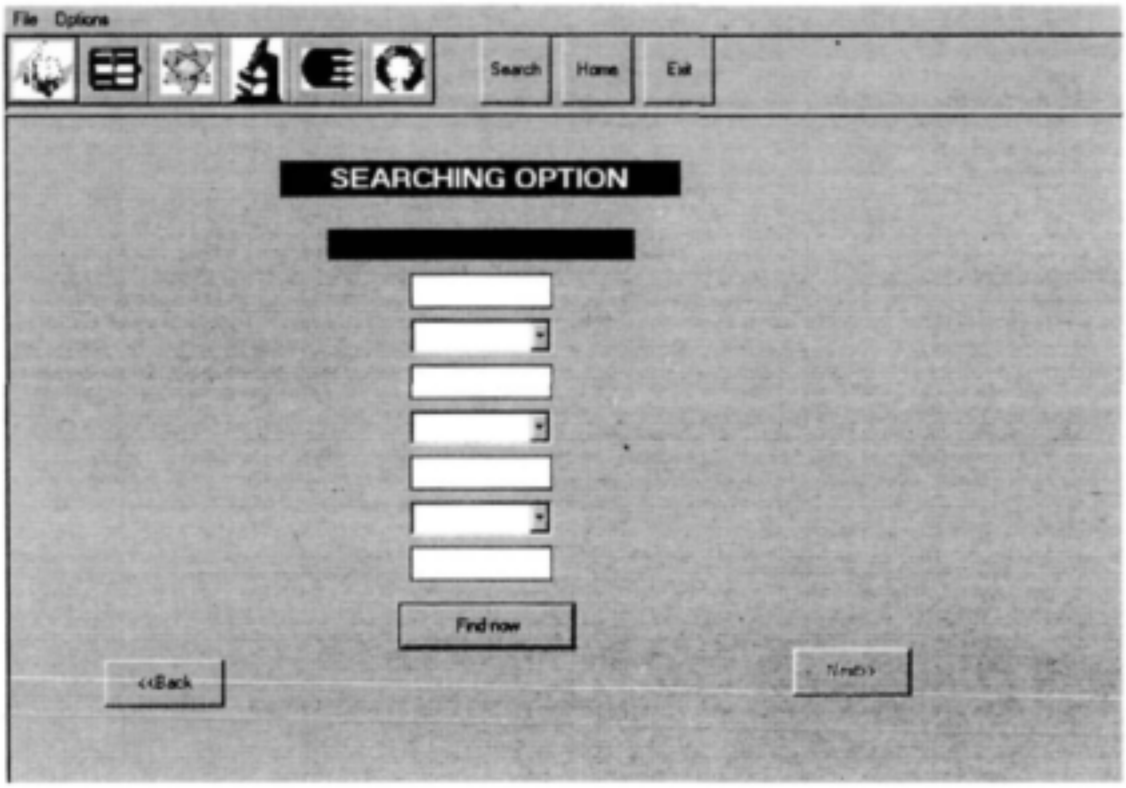
There are six modules in ITEMS:

1. Literature module
2. Water quality guidelines module

3. Properties of contaminants module
4. Research module
5. Impact assessment manual module
6. Mine water management manual module

5.1 Literature module

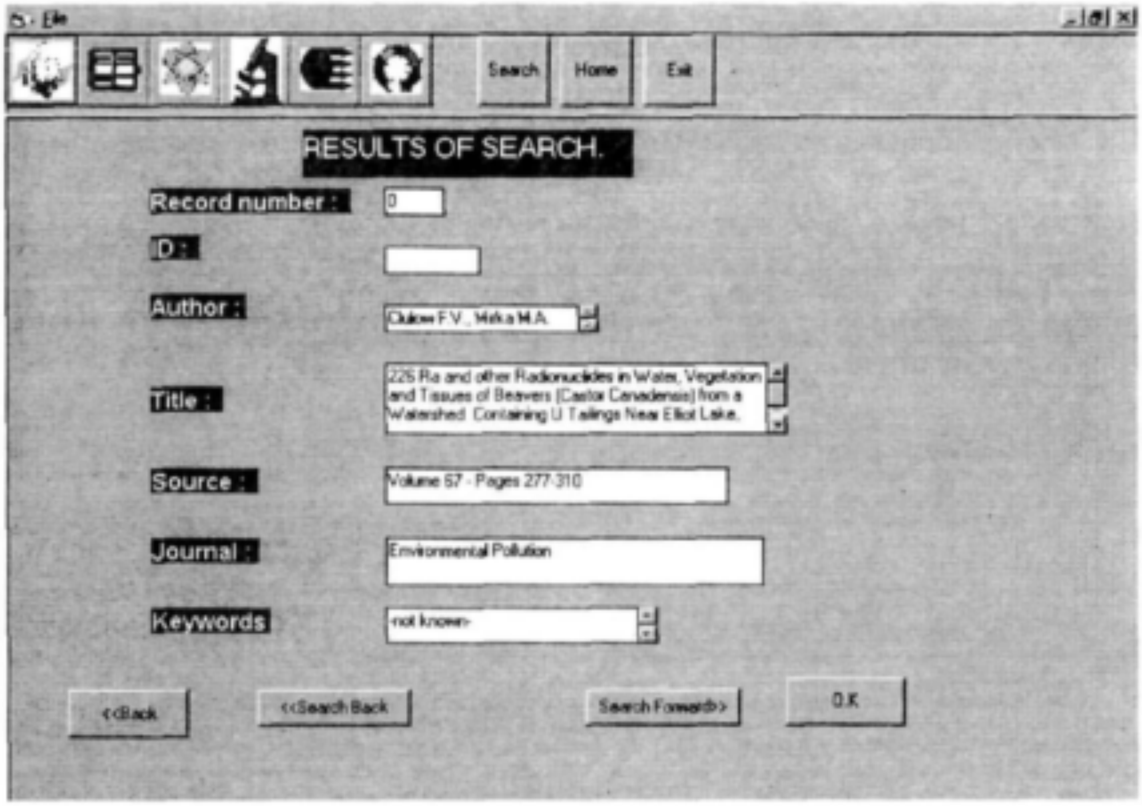
The picture below illustrates the opening screen.



Search words can be entered into one of the four open blocks. If two or more words are entered, then the operators AND / OR / NOT can be selected.

Note : The field to search must first be selected from the Options menu.

Once the search words have been entered, select the Find Now button. The results of the search are presented on a screen similar to the one below.



The results can be printed one at a time by pressing the Print button on the screen.

The reference list can be given to the user's librarian for collection through inter-library loan. All references were sourced from Pulles Howard & de Lange Inc.

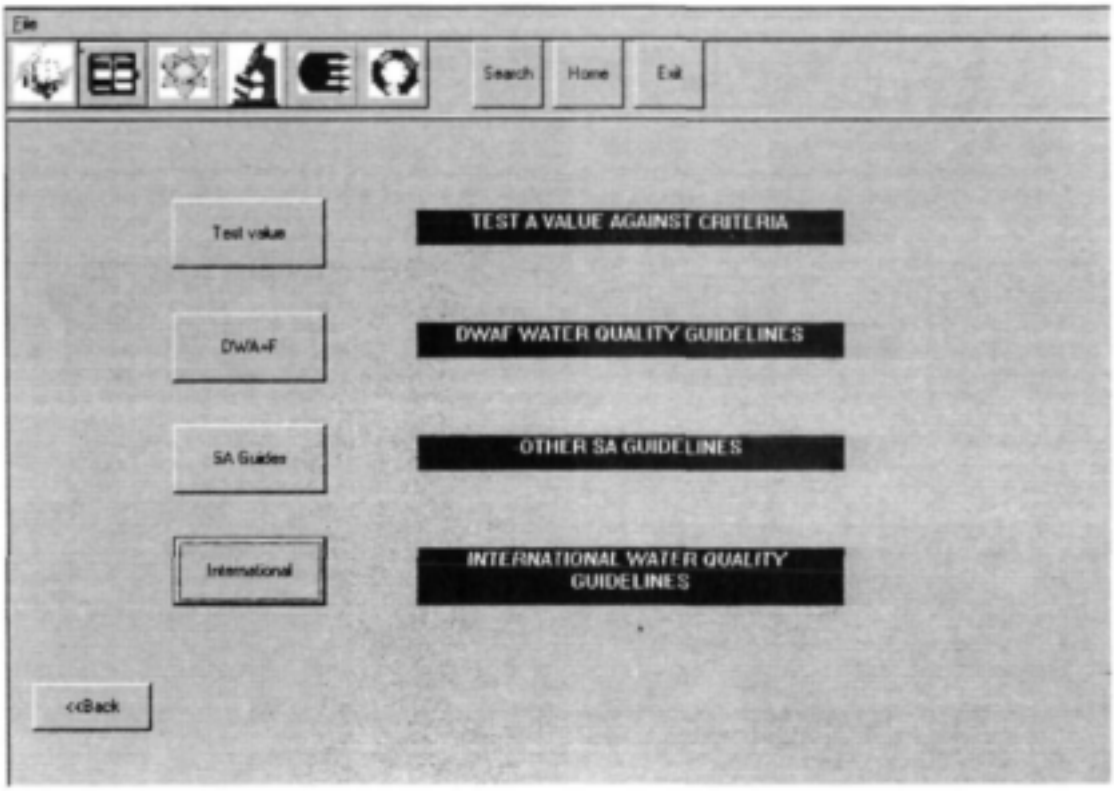
There are over 16 000 references in the database. The database can be searched by the following fields:

Author
Title
Journal
Source
Keyword (where available)

Because certain records have no keywords, the keyword search automatically combines the title and the keyword into a single search.

5.2 Water Quality Guidelines Module

The picture below illustrates the opening screen.



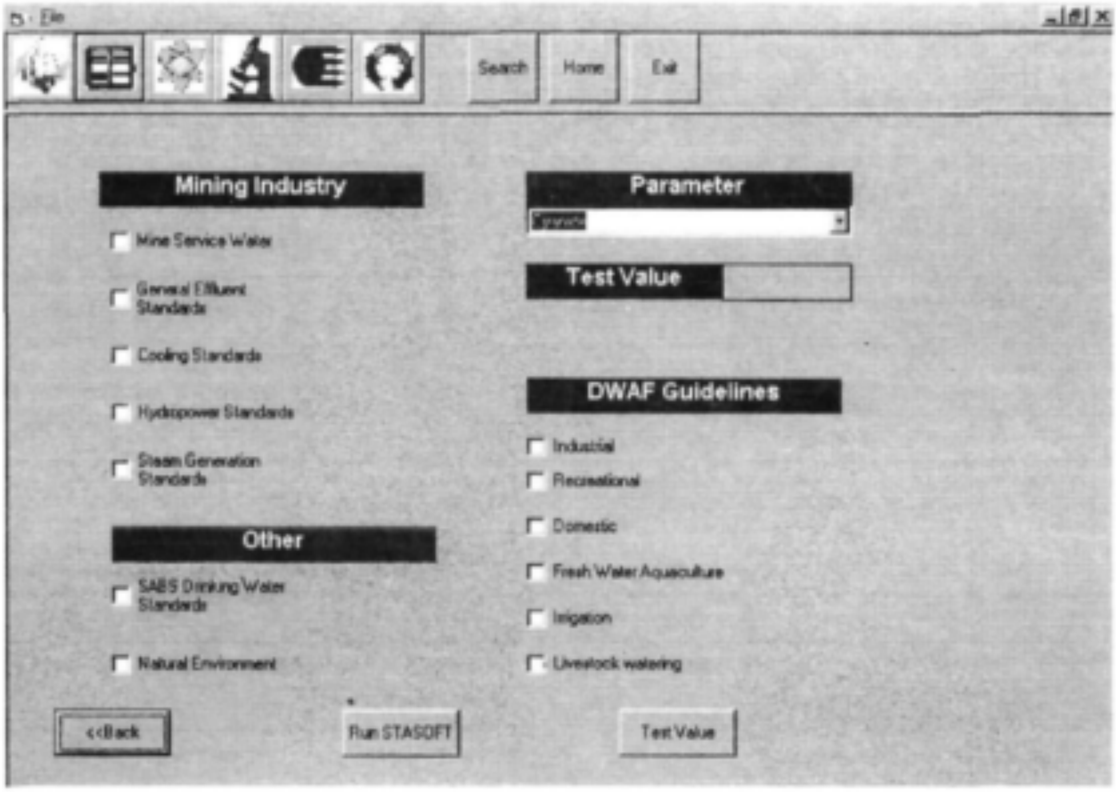
The following options are available:

1. Test a value
2. DWAF Water Quality Guidelines programme
3. Other SA Guidelines
4. International Water Quality Guidelines

The following sections describe the operation of each of these sections.

5.2.1 Test a value

The picture below illustrates the opening screen.

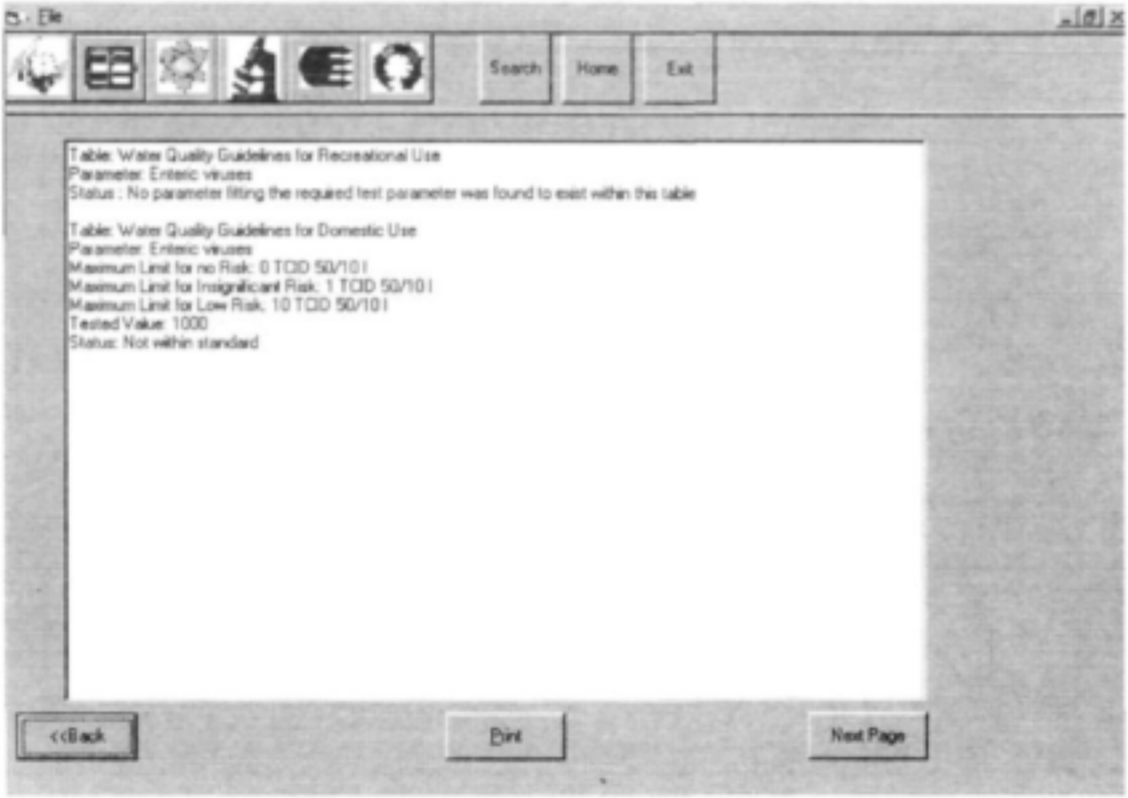


In this section, the user can select a parameter to be checked against a number of water quality guidelines and standards. The parameter to be tested is selected from a pull-down menu. The value to be tested is entered via the keyboard into the appropriate box. For chemical elements the default unit is mg/l. For other variables the default is unit, e.g. for pH the default is the pH unit.

The guidelines or standards to be tested are selected by clicking the appropriate box. The test commences by selecting the Test Value button.

The user can also run the programme STASOFT. This is a water chemistry programme developed by the Water Research Commission. For instruction on the use of STASOFT, obtain the manual from the Water Research Commission.

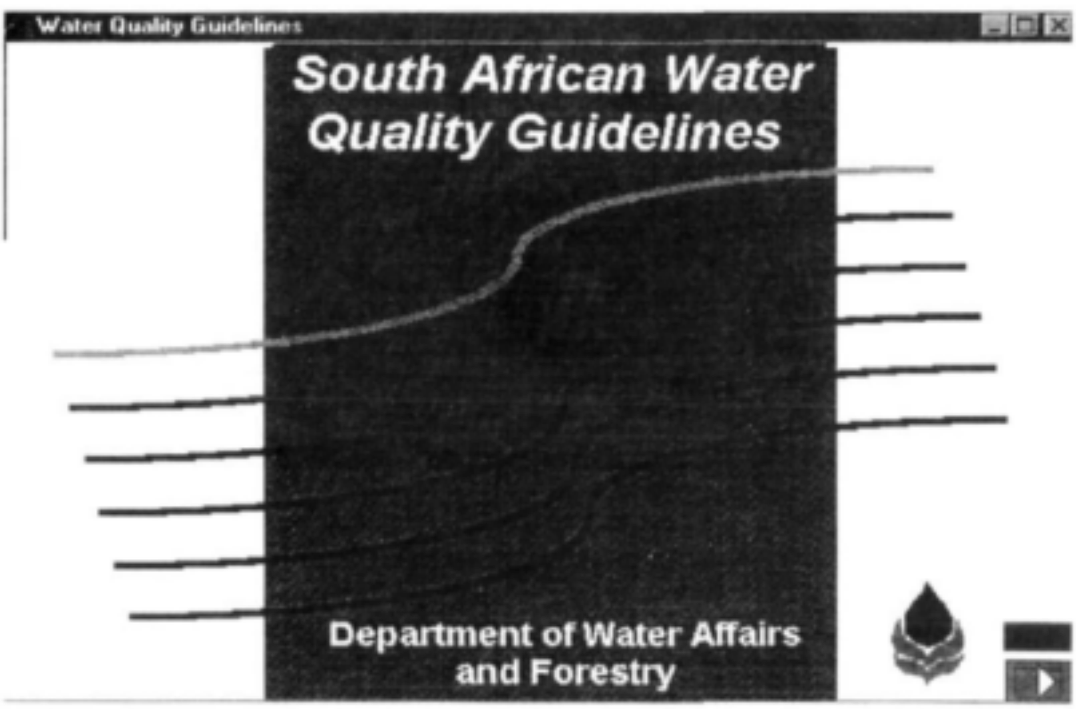
The results for the Test a Value operation are presented in a screen similar to the one below:



Selecting the Back button takes the user back, one screen at a time.

5.2.2 DWAF Water Quality Guidelines programme

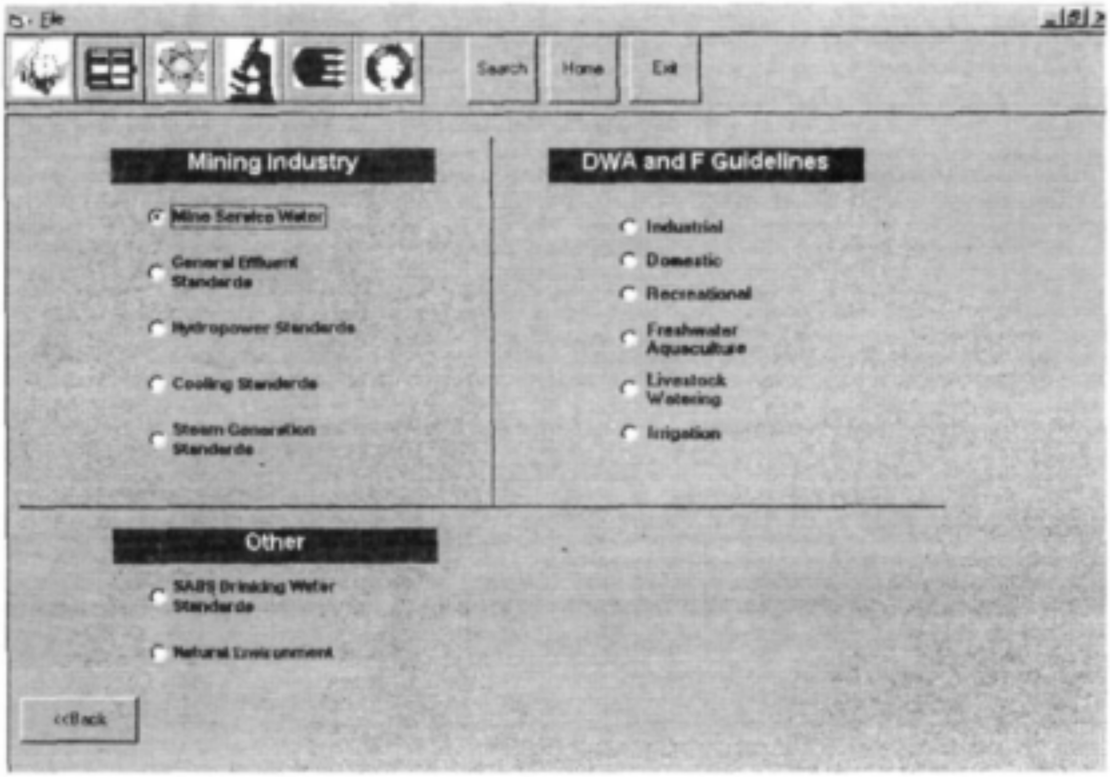
The picture below illustrates the opening screen.



Instructions on how to use this programme are presented on-line within the programme. On exiting the programme, the user returns to ITEMS.

5.2.3 Other SA guidelines

The picture below illustrates the opening screen.

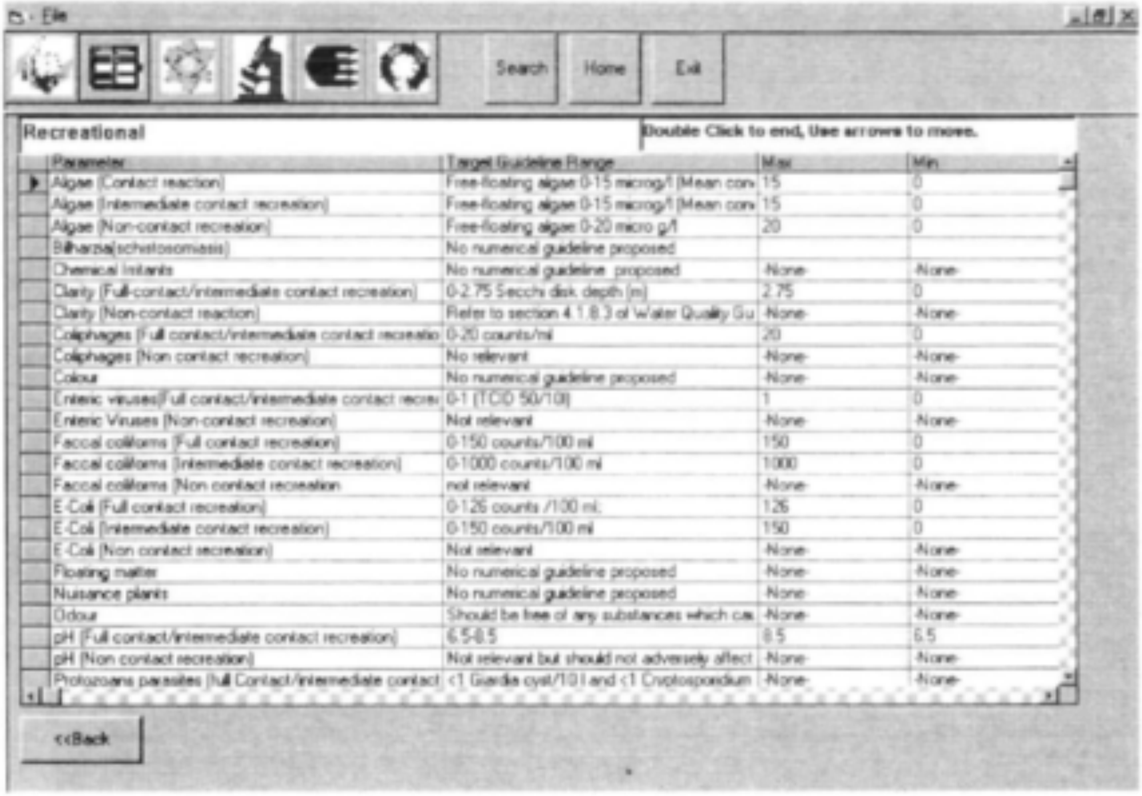


In this section, the user can view any of the available guidelines by selecting the item on the screen.

The guidelines referring to the mining industry on the left of the screen are taken from the Chamber of Mines' Guidelines as developed by the Chamber of Mines Research Organisation.

The DWAF guidelines referred to on the right of the screen are the water quality guideline series.

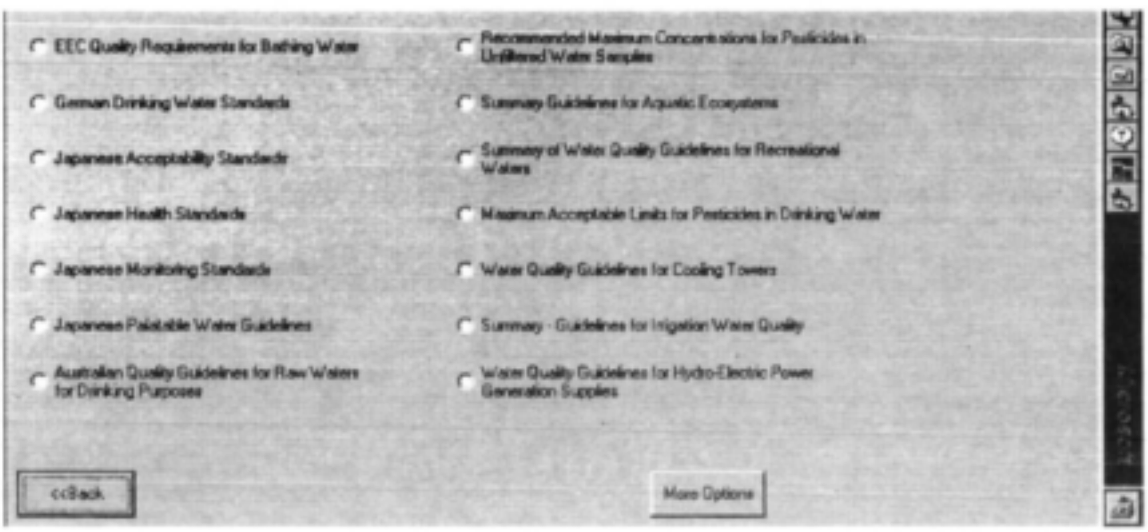
The results of selection are similar to that depicted in the following picture:



Parameter	Target Guideline Range	Max	Min
Algae (Contact reaction)	Free-floating algae 0-15 microg/l (Mean conc	15	0
Algae (Intermediate contact recreation)	Free-floating algae 0-15 microg/l (Mean conc	15	0
Algae (Non-contact recreation)	Free-floating algae 0-20 micro g/l	20	0
Bilharzia(schistosomiasis)	No numerical guideline proposed		
Chemical Irritants	No numerical guideline proposed	-None-	-None-
Clarity (Full-contact/intermediate contact recreation)	0-2.75 Secchi disk depth (m)	2.75	0
Clarity (Non-contact reaction)	Refer to section 4.1.8.3 of Water Quality Gu	-None-	-None-
Coliphages (Full contact/intermediate contact recreatio	0-20 counts/ml	20	0
Coliphages (Non contact recreation)	No relevant	-None-	-None-
Colour	No numerical guideline proposed	-None-	-None-
Enteric viruses(Full contact/intermediate contact recre	0-1 (TCID 50/10l)	1	0
Enteric Viruses (Non-contact recreation)	Not relevant	-None-	-None-
Faecal coliforms (Full contact recreation)	0-150 counts/100 ml	150	0
Faecal coliforms (Intermediate contact recreation)	0-1000 counts/100 ml	1000	0
Faecal coliforms (Non contact recreation	not relevant	-None-	-None-
E-Coli (Full contact recreation)	0-126 counts /100 ml;	126	0
E-Coli (Intermediate contact recreation)	0-150 counts/100 ml	150	0
E-Coli (Non contact recreation)	Not relevant	-None-	-None-
Floating matter	No numerical guideline proposed	-None-	-None-
Nuisance plants	No numerical guideline proposed	-None-	-None-
Odour	Should be free of any substances which ca	-None-	-None-
pH (Full contact/intermediate contact recreation)	6.5-8.5	8.5	6.5
pH (Non contact recreation)	Not relevant but should not adversely affect	-None-	-None-
Protozoans parasites (full Contact/intermediate contact	<1 Giardia cyst/10 l and <1 Cryptosporidium	-None-	-None-

5.2.4 International Water Quality Guidelines

The picture below illustrates the opening screen.

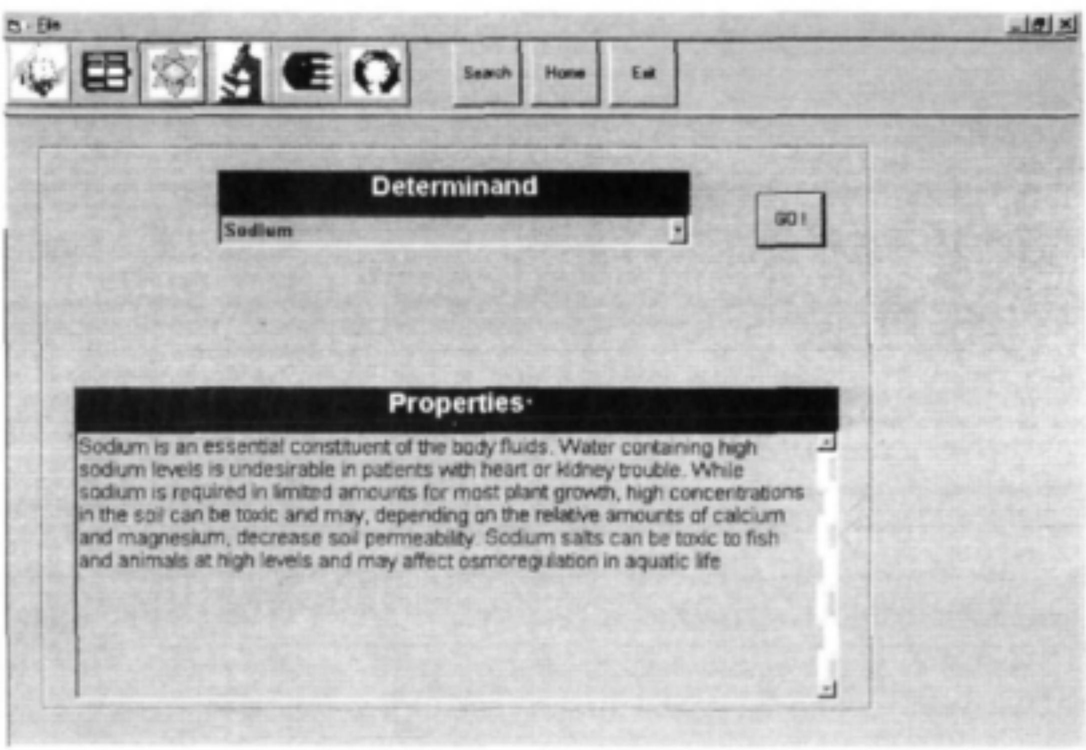


The user can select tne international guidelines for viewing, by clicking on the appropriate selection.

Substance	Maximum Allowable
Aluminium	0.2mg/l
Ammonium	0.5mg/l
Arsen	50µg/l
Cadmium	5µg/l
Calcium	/
Chloride	/
Chrom	50µg/l
Cyanide	50µg/l
Flouride	1500µg/l
Haloforme	/
Iron	200µg/l
Lead	50µg/l
Magnesium	50mg/l
Mangan	50µg/l
Natrium	175mg/l
Nickel	50µg/l
Nitrate	50mg/l
Nitrite	0.1mg/l
Phenole	0.5mg/l
Phosphor	5000µg/l
Potassium	12mg/l
Selenium	10µg/l

5.3 Properties of contaminants module

The picture below illustrates the opening screen.



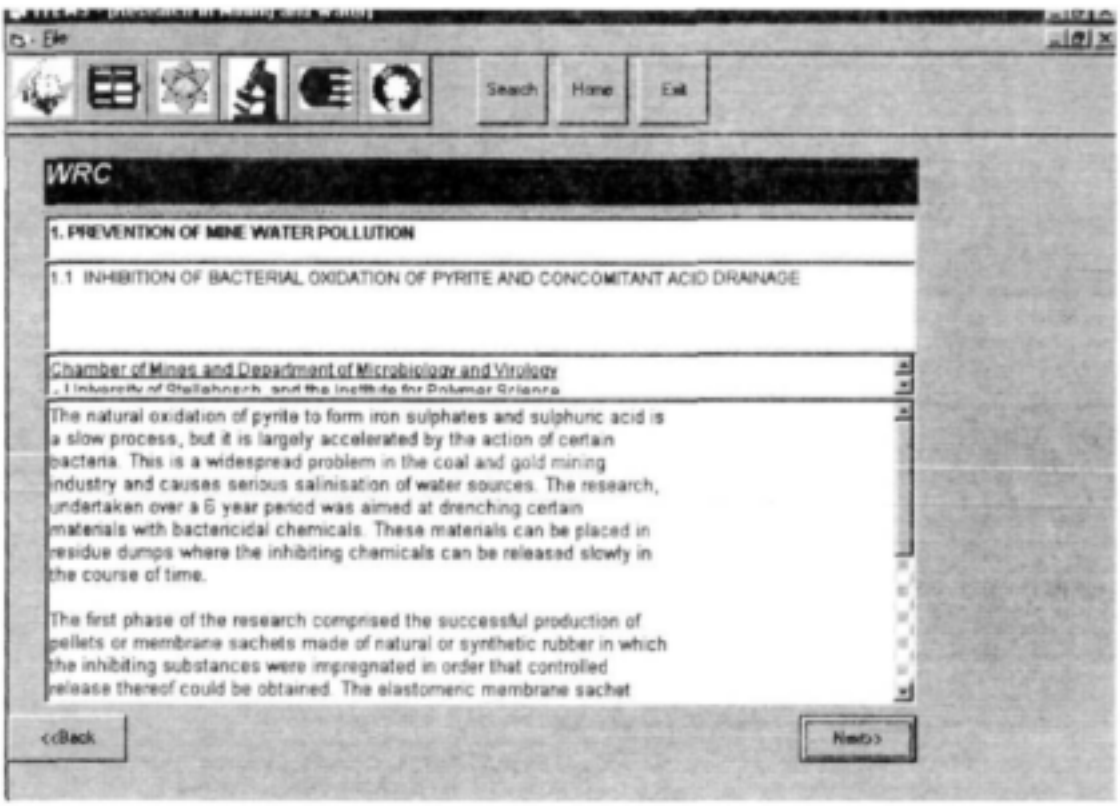
The user can select a determined from the pull-down list. Once selected, the user selects the Go button to start the search. The results are presented in the Properties box.

Over 40 potential contaminants are listed. They cover biological and chemical elements and the description is designed to be simple and yet informative. It is not intended to be a scientific definition.

To print the contaminants, the user is required to generate a report. How to do this is explained at the end of the chapter. Please refer to that section if printing is required.

5.4 Research module

The picture below illustrates the opening screen.



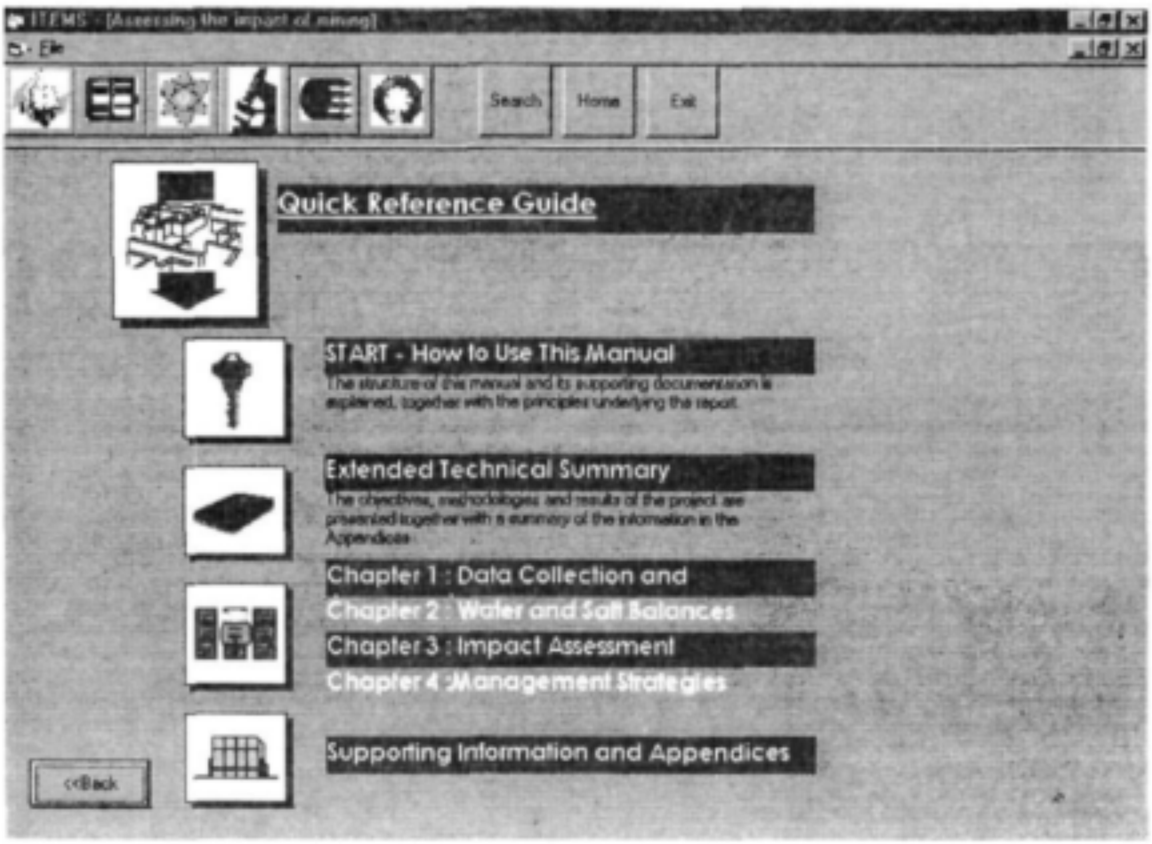
In this section, the user can scroll through all the WRC's research that has a specific bearing on the mining industry.

5.5 Impact assessment module

The section of the programme includes the electronic version of the following documents:

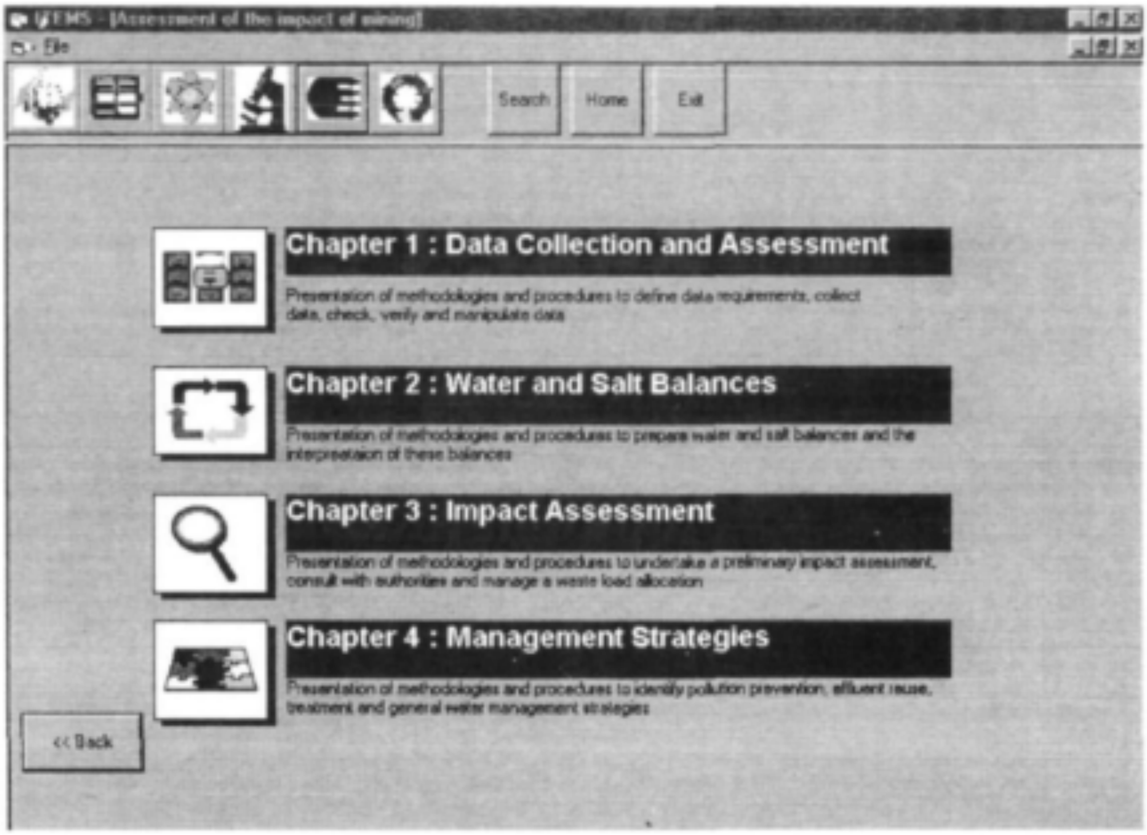
A Manual to Assess and Manage the Impact of Gold Mining Operations on the Surface Water Environment (WRC TT 79/96)
Detailed Site Visit Reports for Case Study Mine 1
Detailed Site Visit Reports for Case Study Mine 2
Detailed Site Visit Reports for Case Study Mine 3

The picture below illustrates the opening screen.

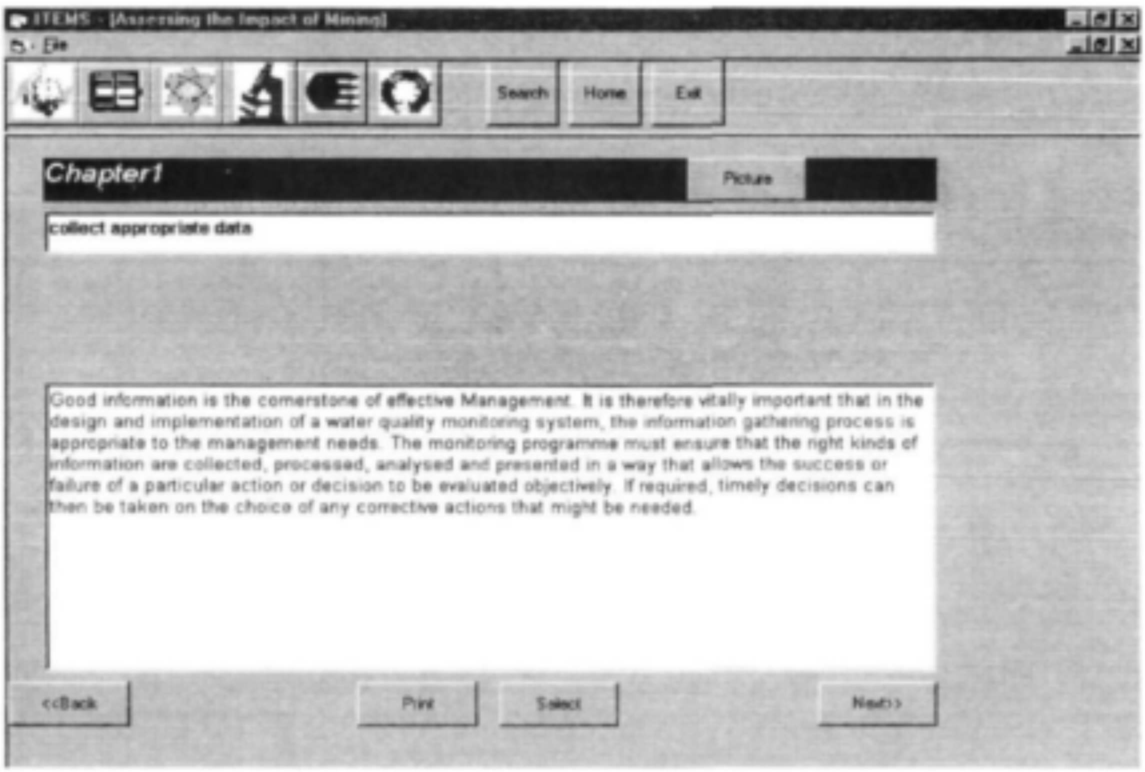


The user can select from the icons on the screen into which section they wish to enter. Each of the screens is self-explanatory and is activated or de-activated by icons and buttons.

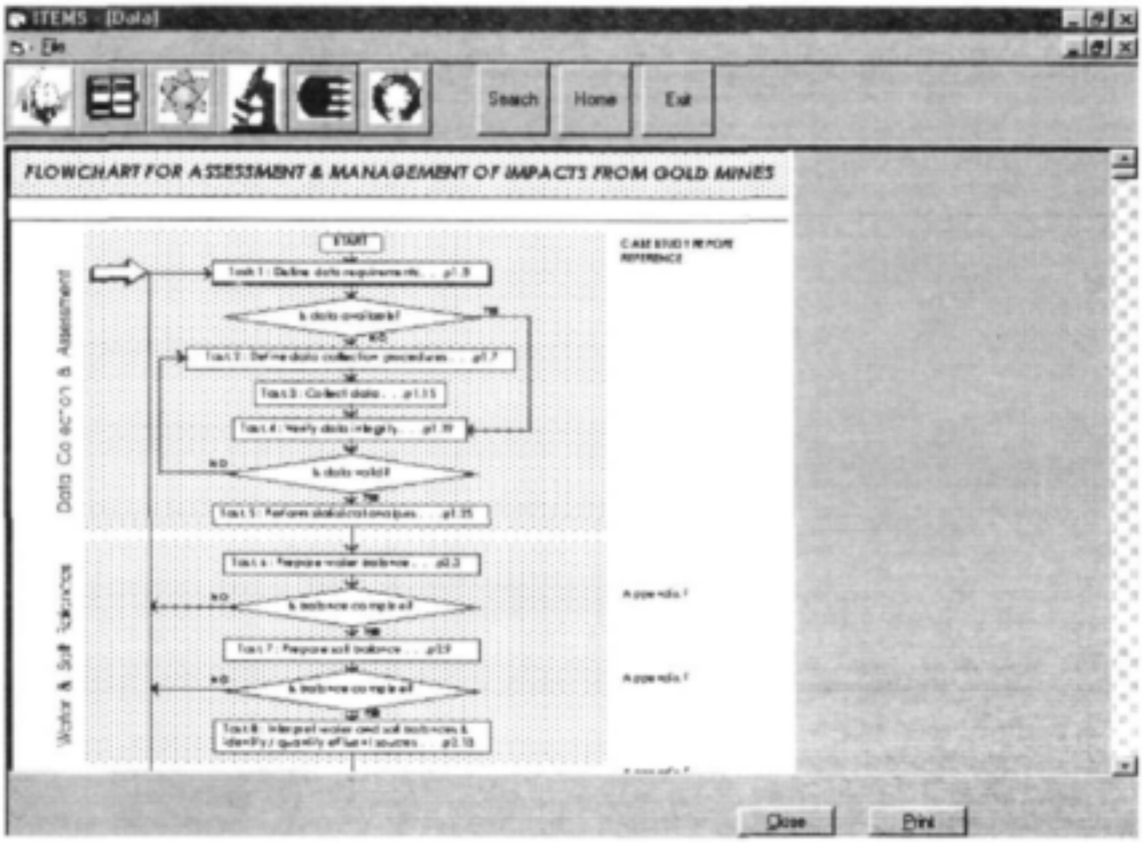
For example, selecting the button opposite the Chapter labels leads to the following section, which is the main report.



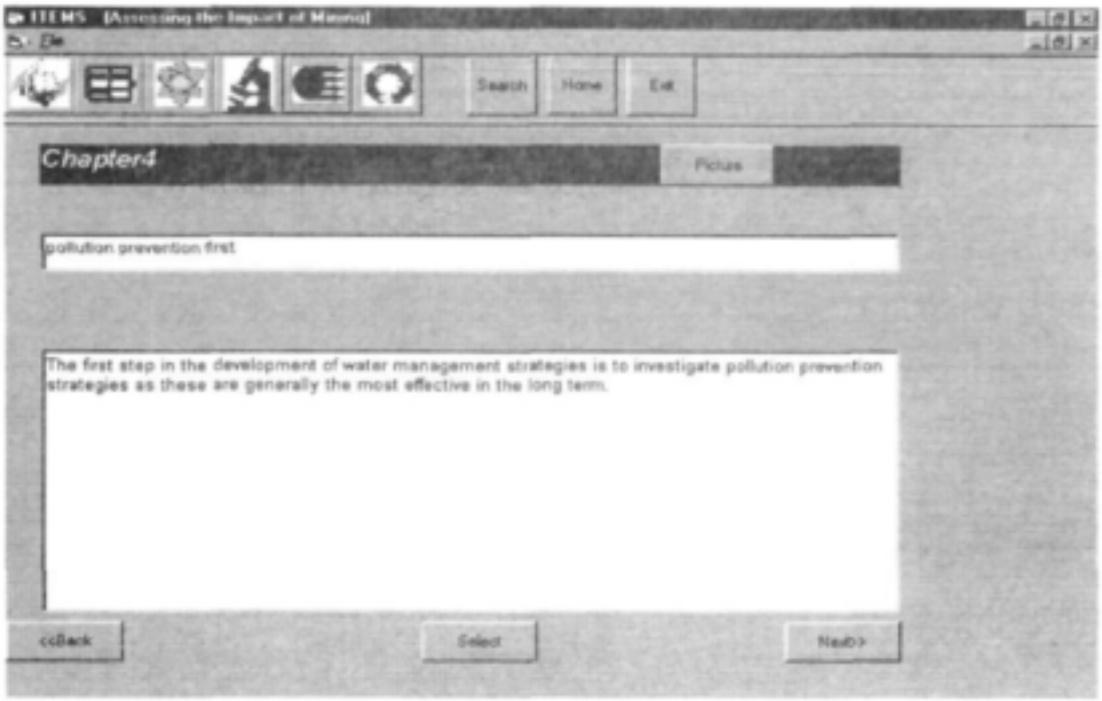
The opening screen for Chapter 1, Data Collection and Assessment is presented in the screen below.



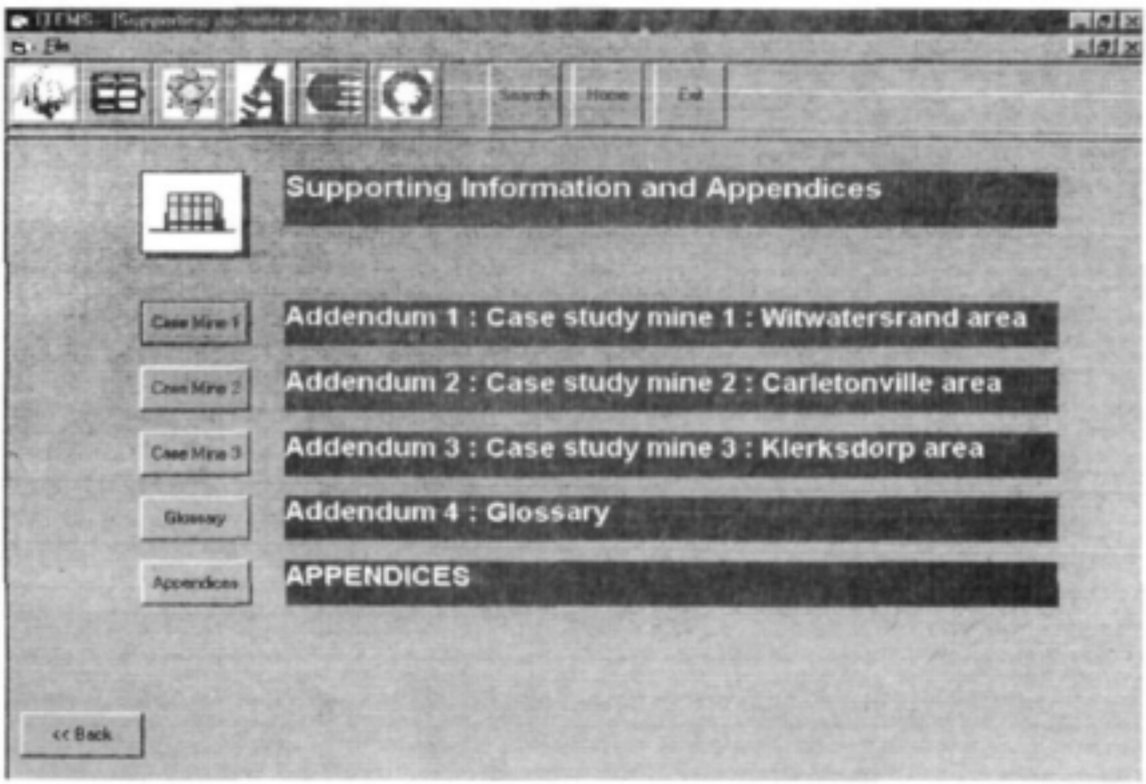
At certain sections within the programme a button titled Picture or Table will be displayed. This informs the user that there is either a Figure or a Table which can be displayed by clicking on the button. The results would appear similar to that shown below.



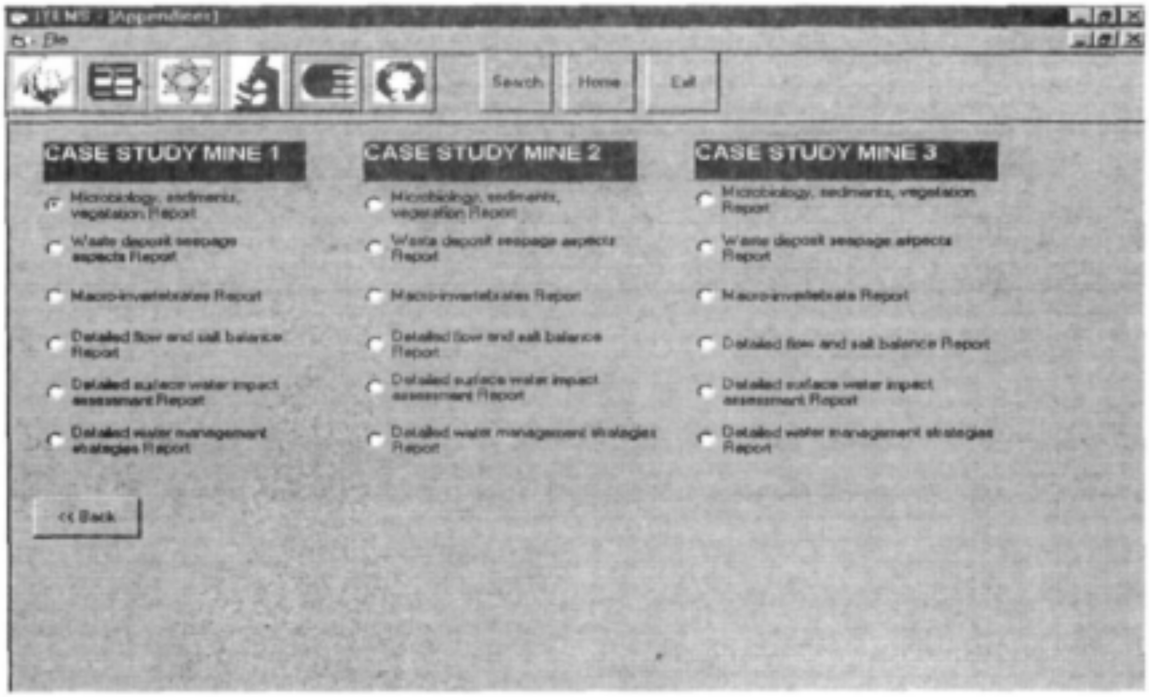
Chapters 2 to 4 are similar to Chapter 1. To demonstrate this, the opening screen for Chapter 4 is presented below.



Once the user has selected the section, the result screen (as above) will be displayed. To move to the next page, the user selects the Next button. To change topic, the user presses the Select button. This takes the user back to the main screen. The Back button takes the user back one screen at a time. In the supporting documentation section, more detailed information is available. The following choices are available:



The user can select one of the options to view specific detailed information. The user can print any section by selecting the Print button.

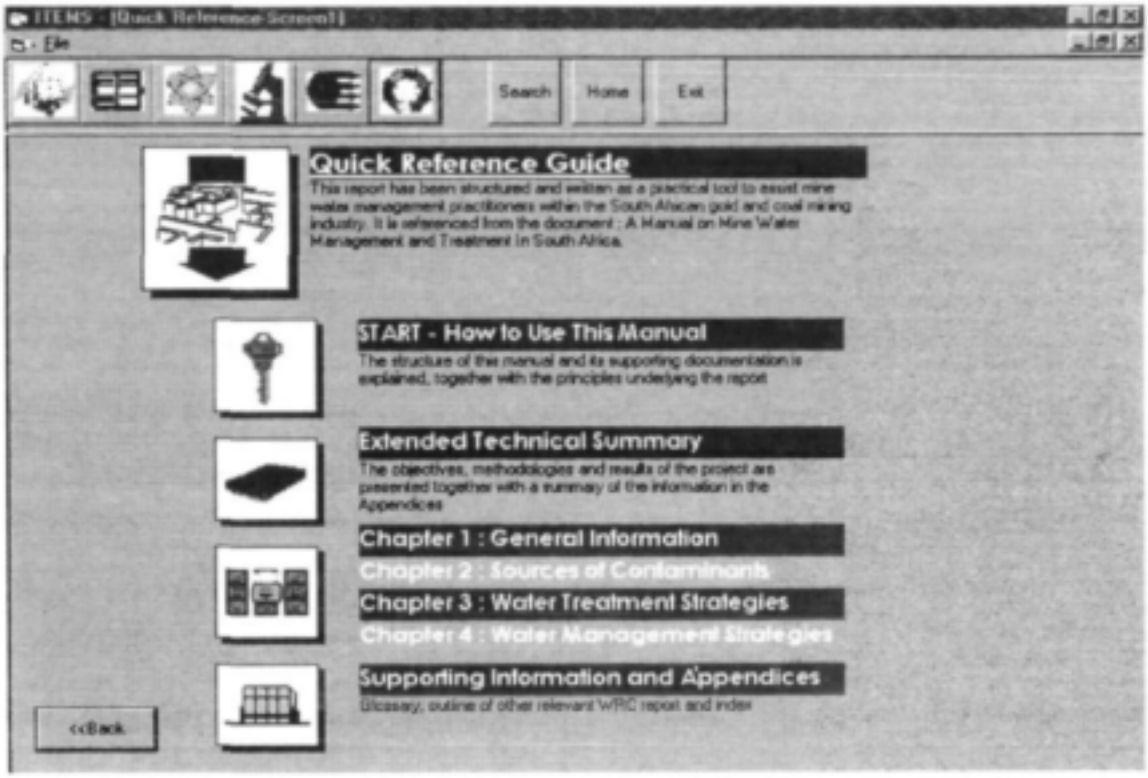


5.6 Mine water management module

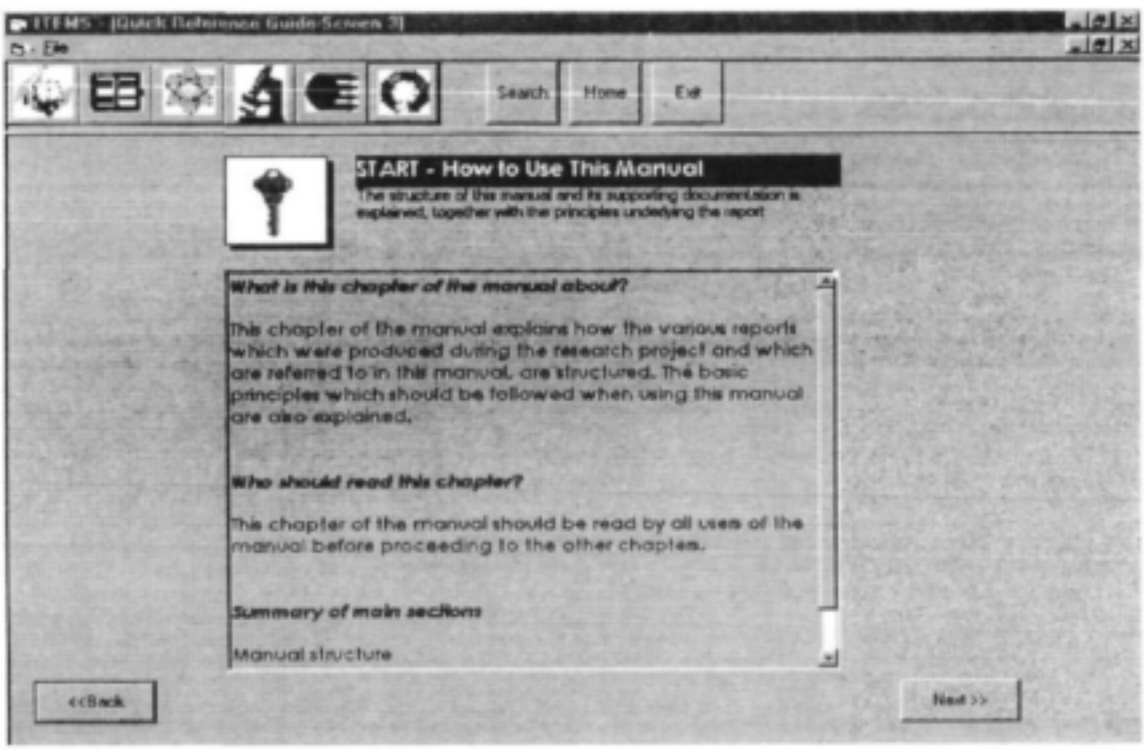
This section of the programme includes the electronic version of the following documents:

A Manual on Mine Water Management and Treatment Practices in South Africa (WRC TT 80/96)
Detailed Literature Reviews
Detailed Site Visit Reports for Gold and Coal Mines
Detailed Site Visit Reports for Overseas Study Tour

The structure of this section of the programme is similar to that of the impact assessment module.

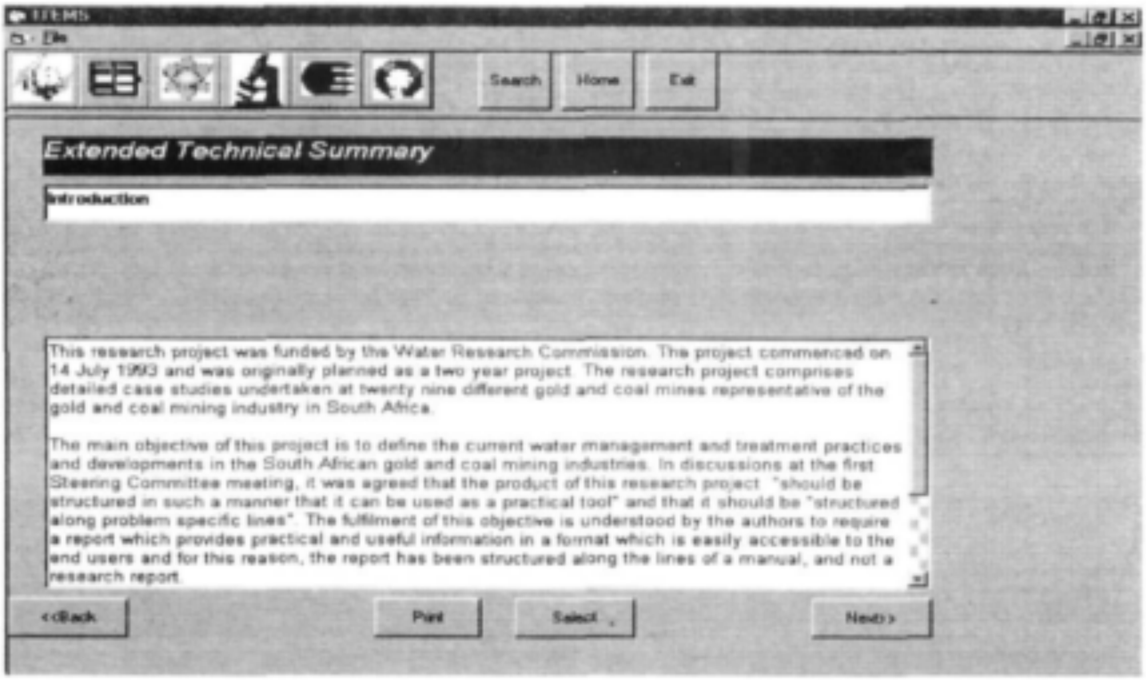


The user makes the appropriate selection by clicking on the picture. The first screen that is available is the START – How to Use this Manual screen. This is shown in the following picture.

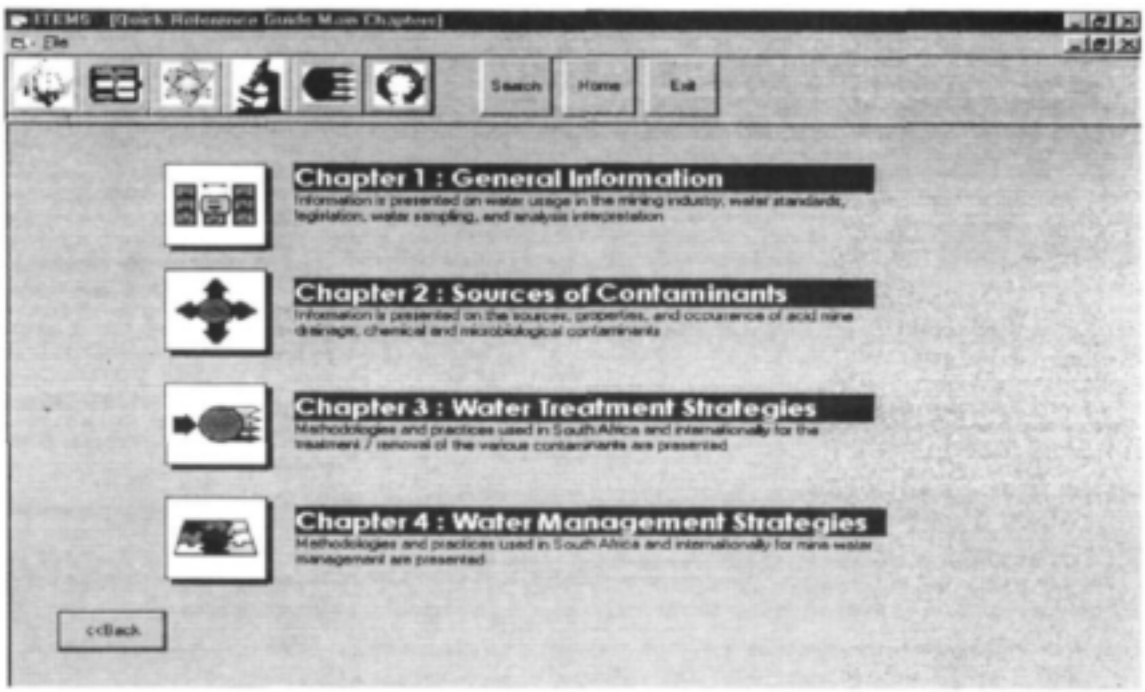


The user can navigate to other information sections by using the Next and Back buttons on the screen.

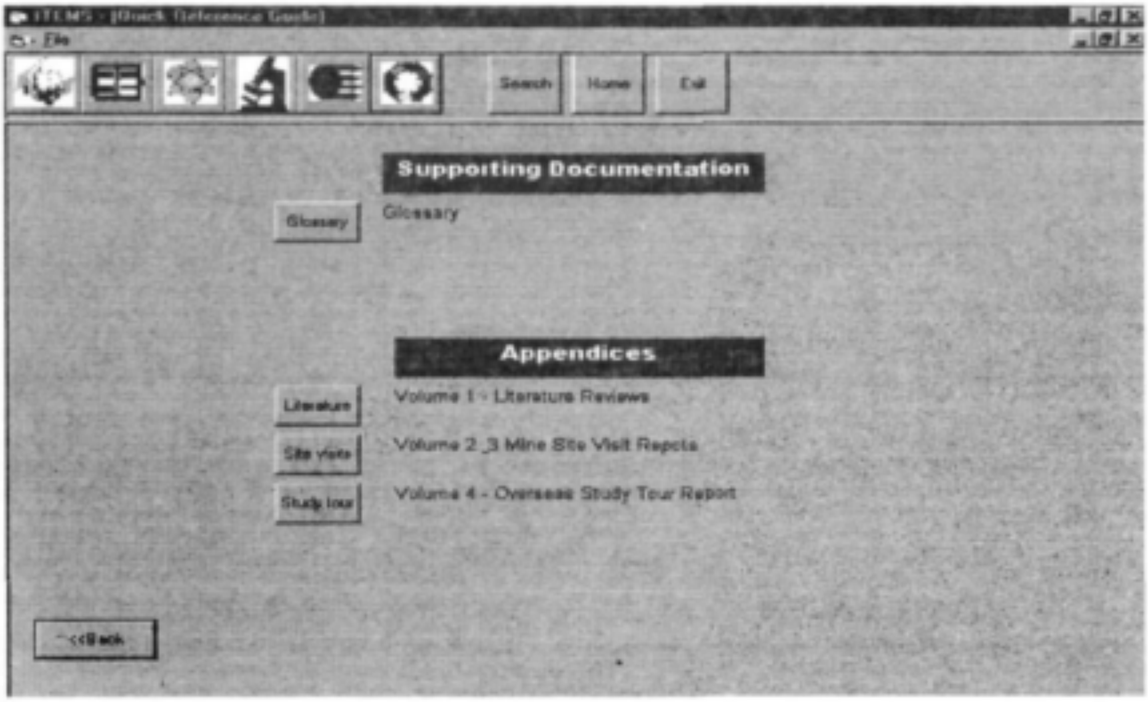
Should the user wish to view the Extended Technical Summary, then from the first screen the second option is chosen.



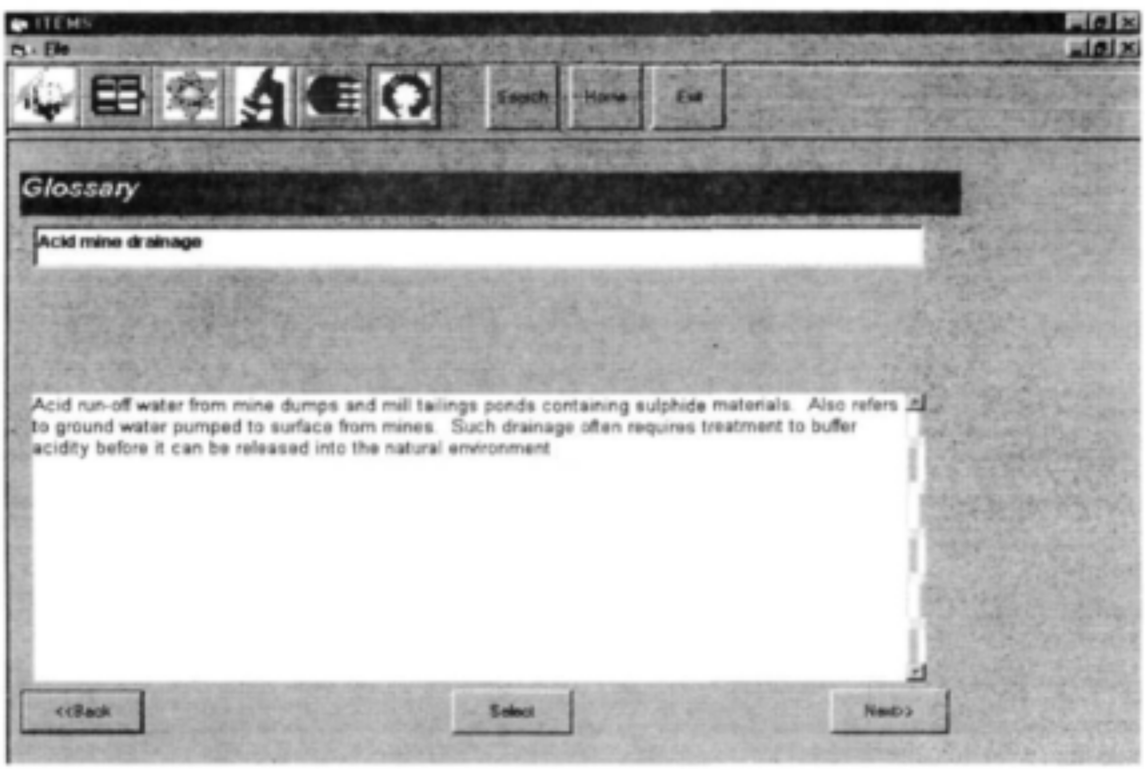
To view the content of the main report, the user selects the Chapters button from the first screen and the following screen is displayed. On selecting any of the four Chapters, the following typical screen is presented.

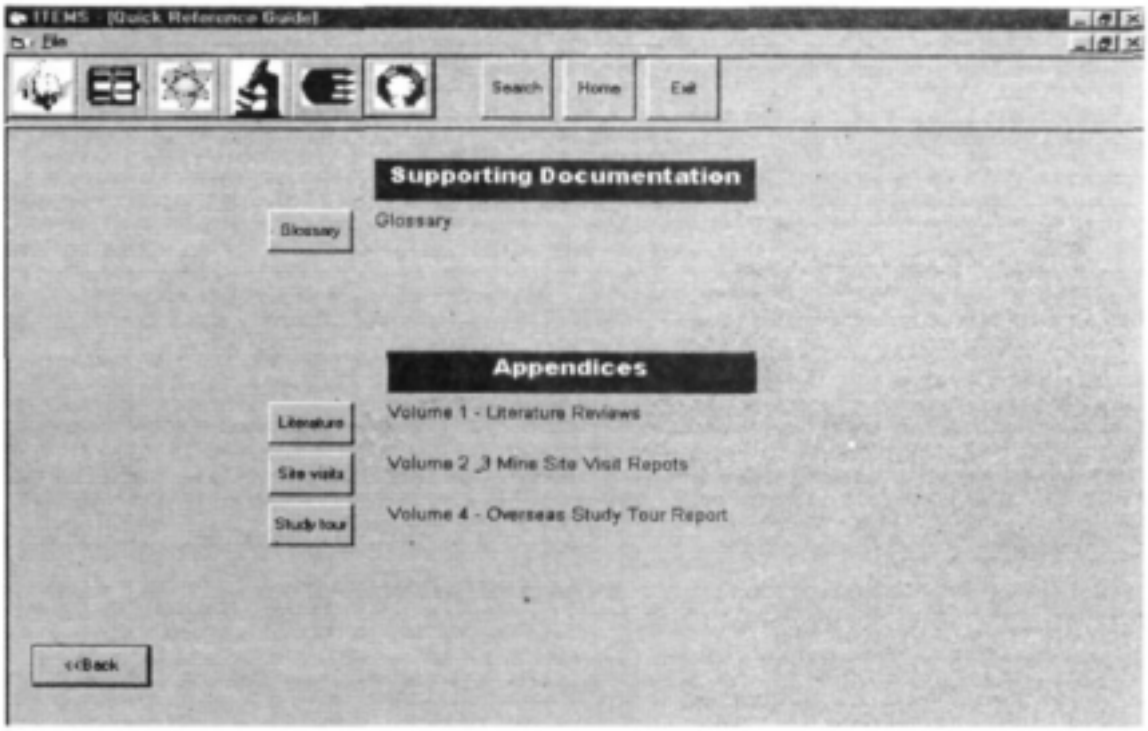


As with the "Manual to Assess and Manage the Impact of Gold Mining on the Surface Water Environment", a large database of supporting information has been included. This data is accessed via the Supporting Documents button on the first screen.

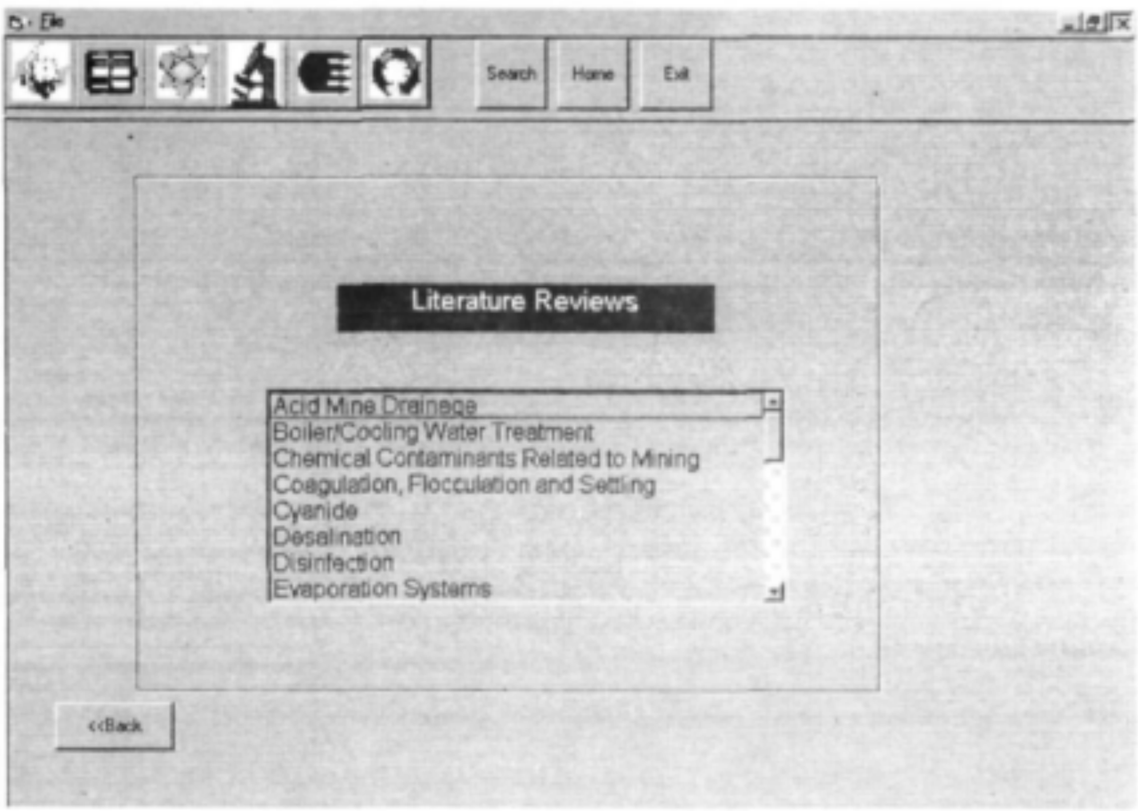


A Glossary of Terms is included to provide a quick reference to terminology used within the report.





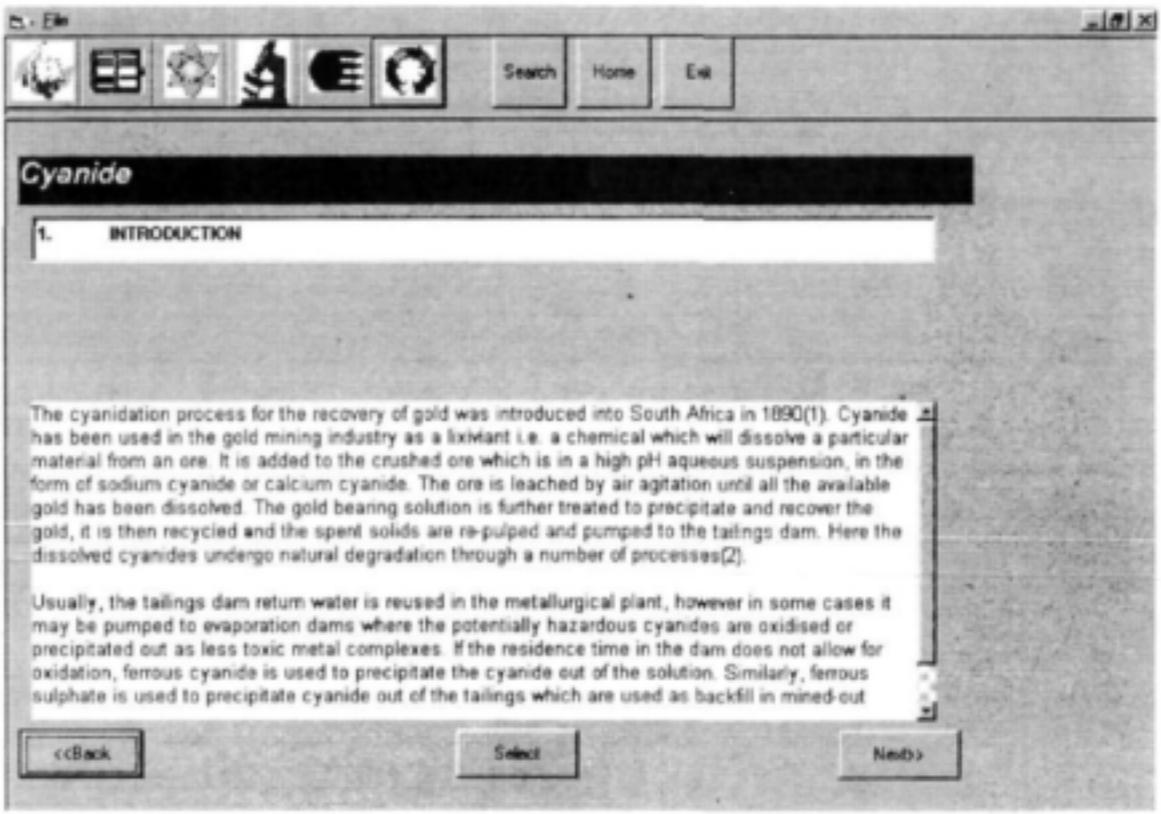
If the user selects Literature Reviews from the Supporting Documents screen, the following screen is displayed. Over twenty detailed literature reviews are included, each relating to specific aspects of water and mining.



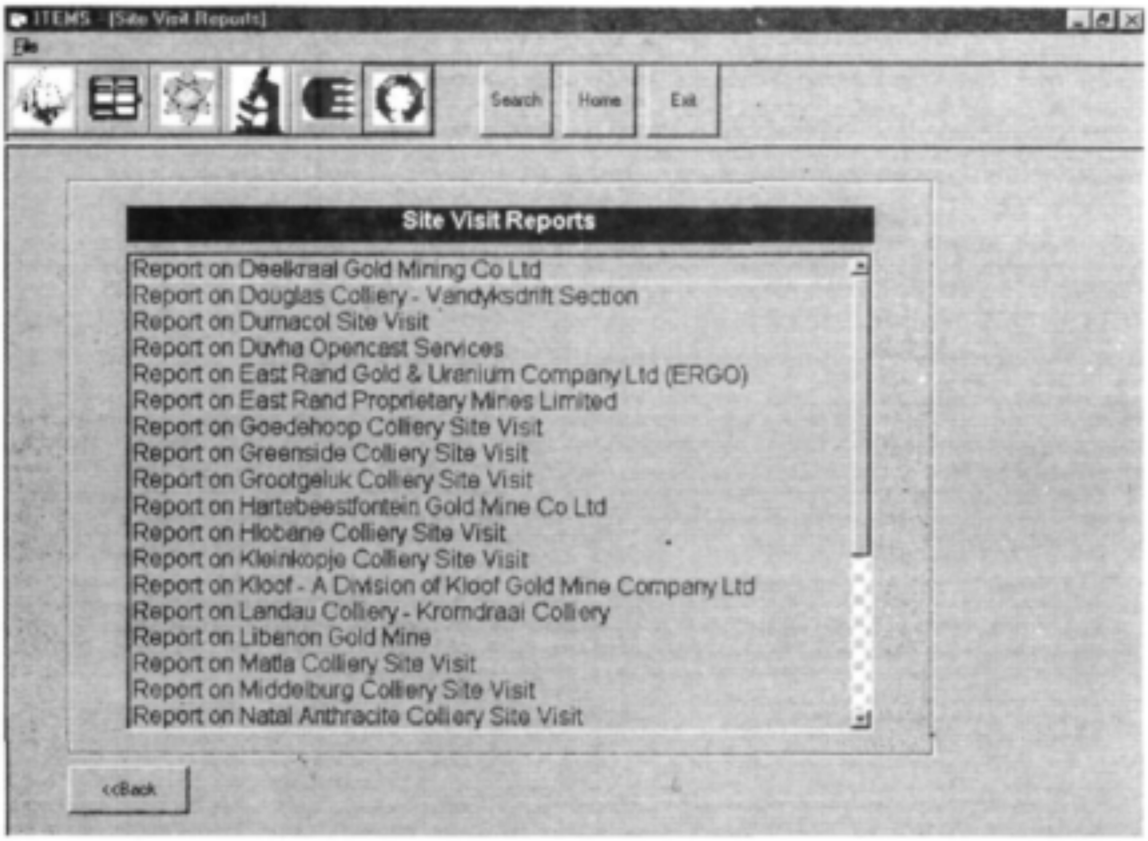
Once the user has identified the specific area he wishes to access, a pull-down box allows the user to make a selection. The following picture demonstrates an example of one of the sections. The user selects the desired literature review by clicking on the text at the appropriate line. The programme will then access the literature review database and return with a screen similar to the one below.

The user pages through the report using the Next and Back buttons. As the user pages through the report, two buttons may appear on the coloured bar at the top of the screen. These buttons are labelled 'Table' and 'Figure'. If these buttons are highlighted, the user can select the button to display either the figure or the table referred to in the text.

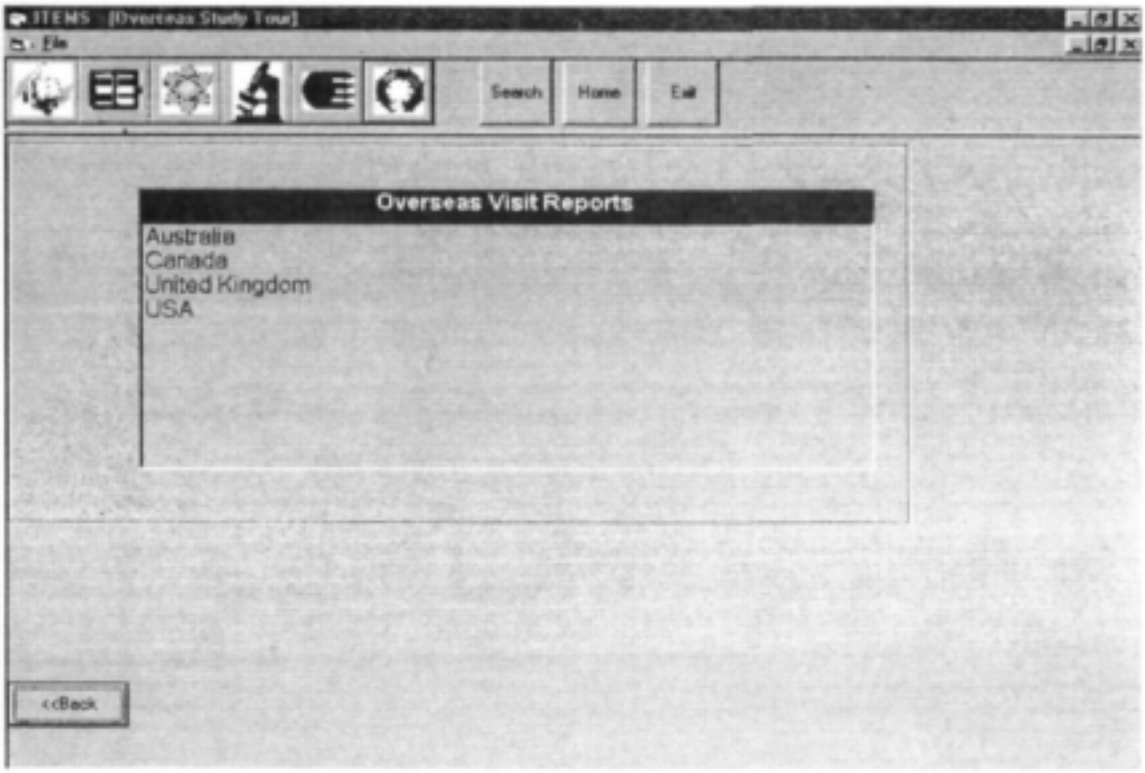
Should the user with to print, then the appropriate button can be selected.



In a similar manner, the user can select to view a Site Visit report:



Or the user can view one of the Overseas Site Visit reports:



6. SEARCHING FOR SPECIFICS

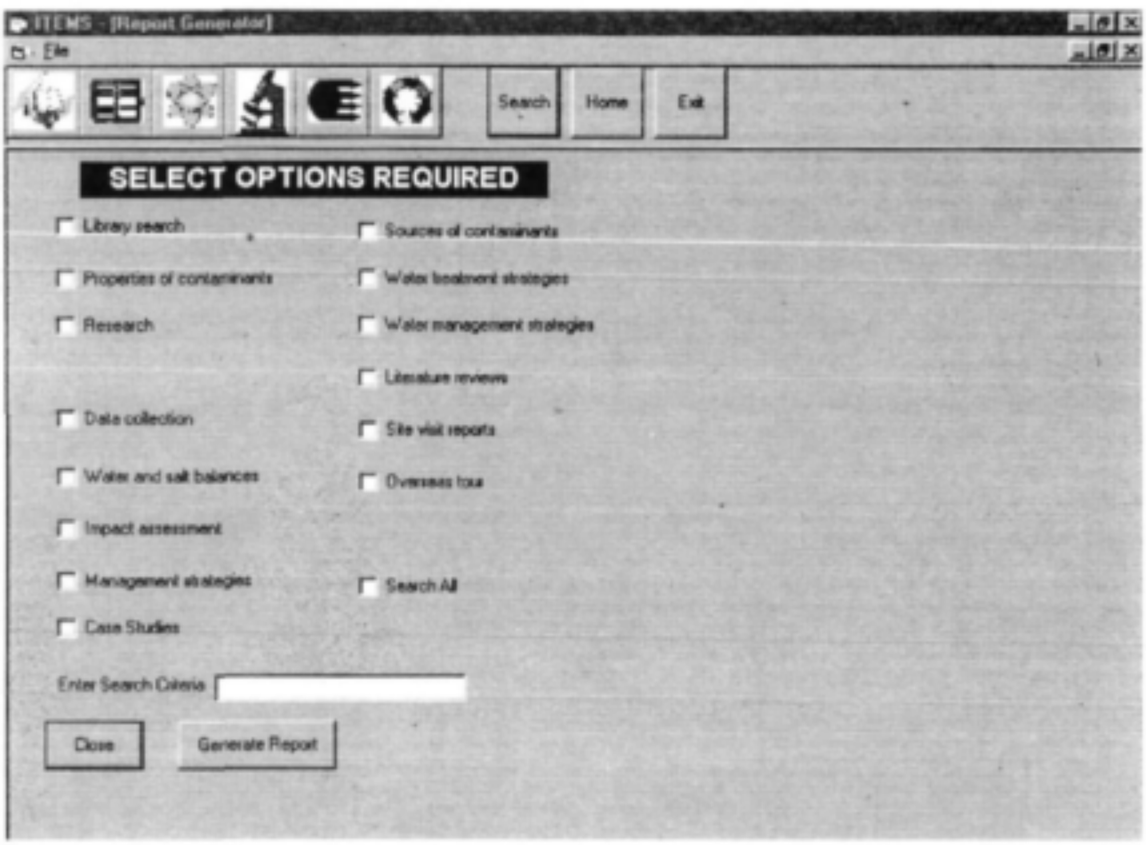
To search for specific information the user can select the Search button. The user is then prompted for the search text required. If the user has selected text using Windows Copy command, then the user can paste the text into the prompt box. If not, then the user can type his search query. Once completed, the user must select from the various modules. Please note that if more than one module is selected, then the time required for the search increases.

Once the user has chosen the section for searching, two results may occur:

1. The search terms were successful. The results for the search terms only are returned. This means that only those sections which comply with the search terms will be returned. The user must select OK to continue within the search or Cancel to stop that search.

2. The search terms were unsuccessful. If the system cannot find any corresponding matches for the search text, an error is generated and the user is advised as such. The full report is then loaded.

The search screen is presented below.



To print the results of a search, the user must use the Report Generator described in the next section.

7. REPORT GENERATOR

ITEMS allows the user to generate specific custom reports. This is done in the Report Generator section of the programme. To access the Report Generator section, select it from the File menu.

The Report Generator has exactly the same format as the search function. The difference is that the output from the Search function is to the screen and the output from the Report Generator is to the printer.

The user can select a number of options for inclusion in the report. Once all the options have been set, the user selects the Search Text button to enter the search text. Once this has been entered, the user selects Generate Report. At this stage the programme opens each database sequentially to check for the required text. As expected this will take some time to complete.

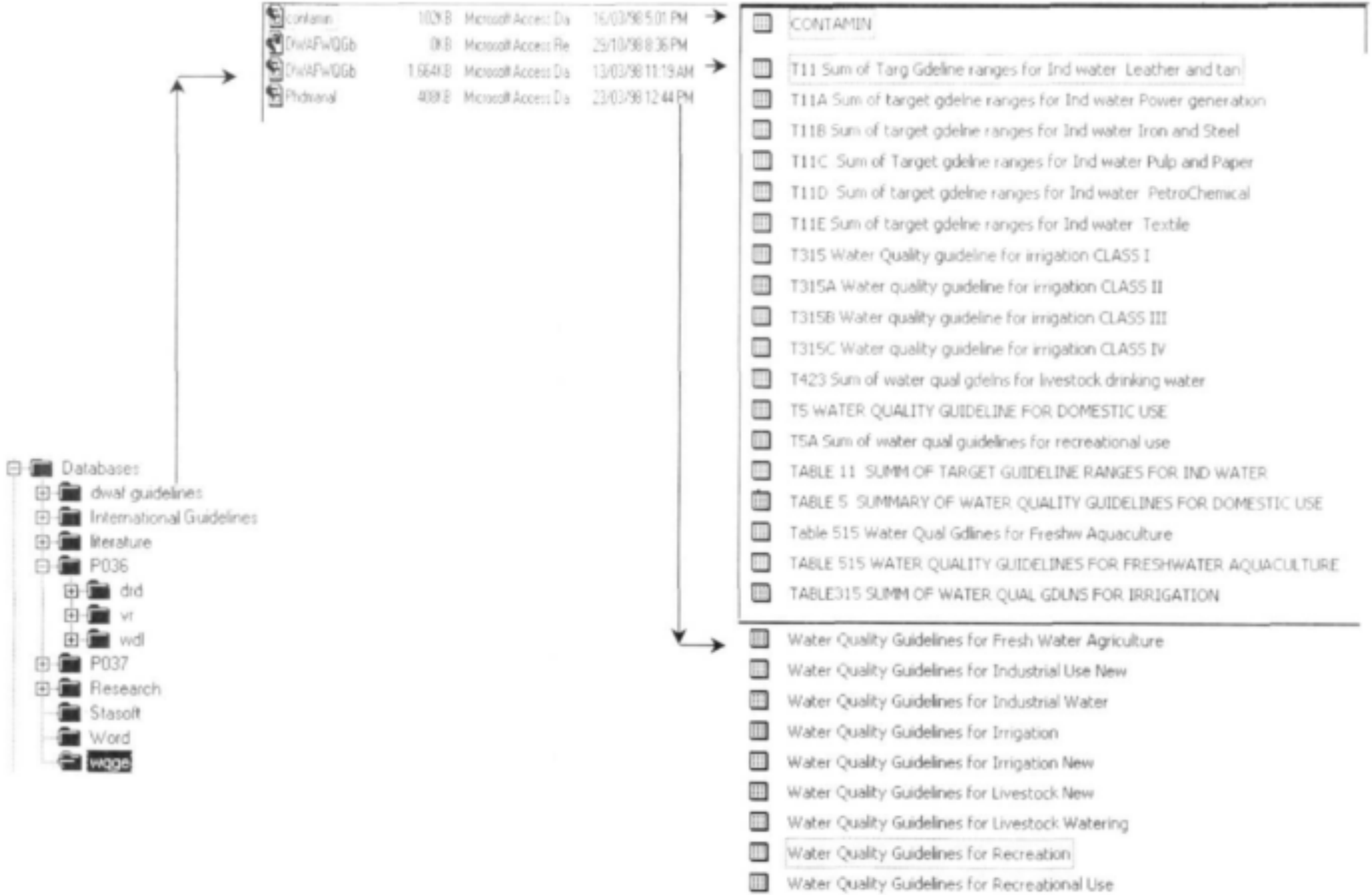
Once the report has been generated it will be printed.

8. CONCLUSION

ITEMS has been developed as a tool which can be used by a variety of organisations. It is intended to be a source of information and does not endeavour to be a modelling or calculation tool. All the information contained in the databases is freely available. Information which is not freely available has not been knowingly included in the programme.

All rights to the software remain with the authors and the WRC. Copyright on the material exists.

Appendix 1



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T11D Sum of target gdelne ranges for Ind water PetroChemical
T11E Sum of target gdelne ranges for Ind water Textile
T315 Water Quality guideline for irrigation CLASS I
T315A Water quality guideline for irrigation CLASS II
T315B Water quality guideline for irrigation CLASS III
T315C Water quality guideline for irrigation CLASS IV
T423 Sum of water qual gdelns for livestock drinking water
T5 WATER QUALITY GUIDELINE FOR DOMESTIC USE
T5A Sum of water qual guidelines for recreational use
TABLE 11 SUMM OF TARGET GUIDELINE RANGES FOR IND WATER
TABLE 5 SUMMARY OF WATER QUALITY GUIDELINES FOR DOMESTIC USE
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TABLE 515 WATER QUALITY GUIDELINES FOR FRESHWATER AQUACULTURE
TABLE315 SUMM OF WATER QUAL GDLNS FOR IRRIGATION
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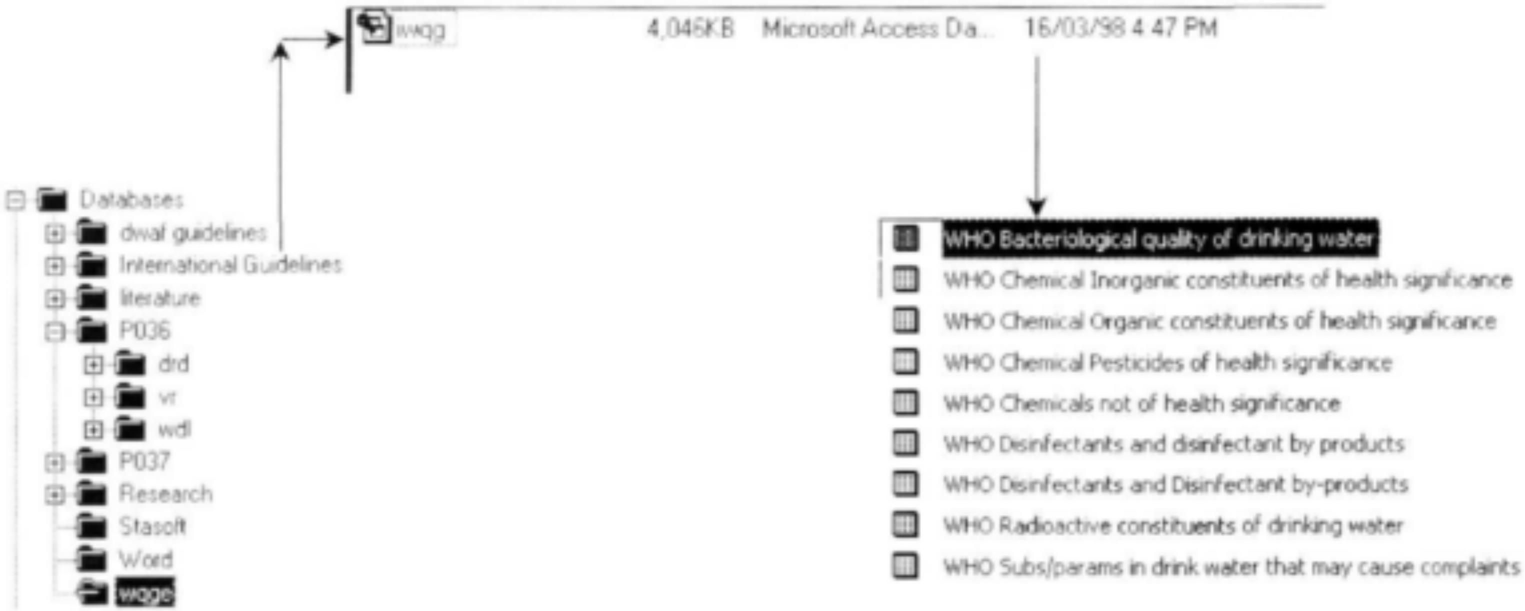
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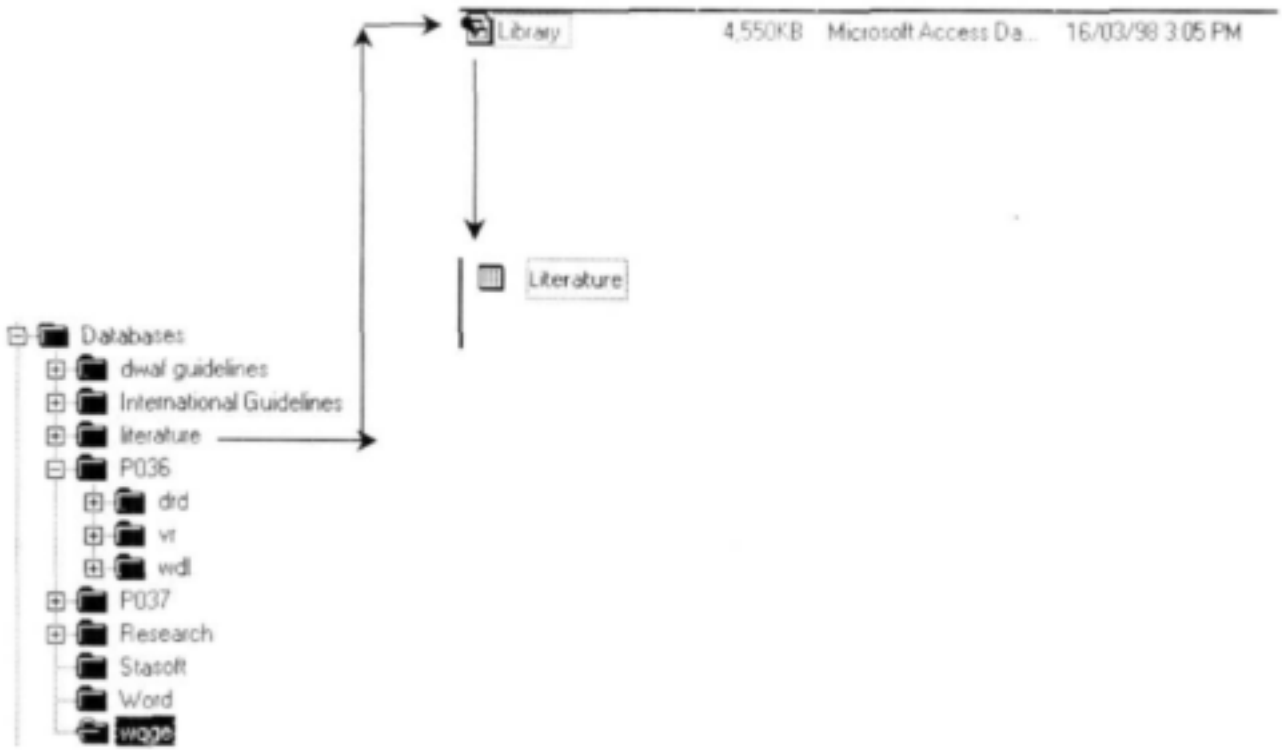

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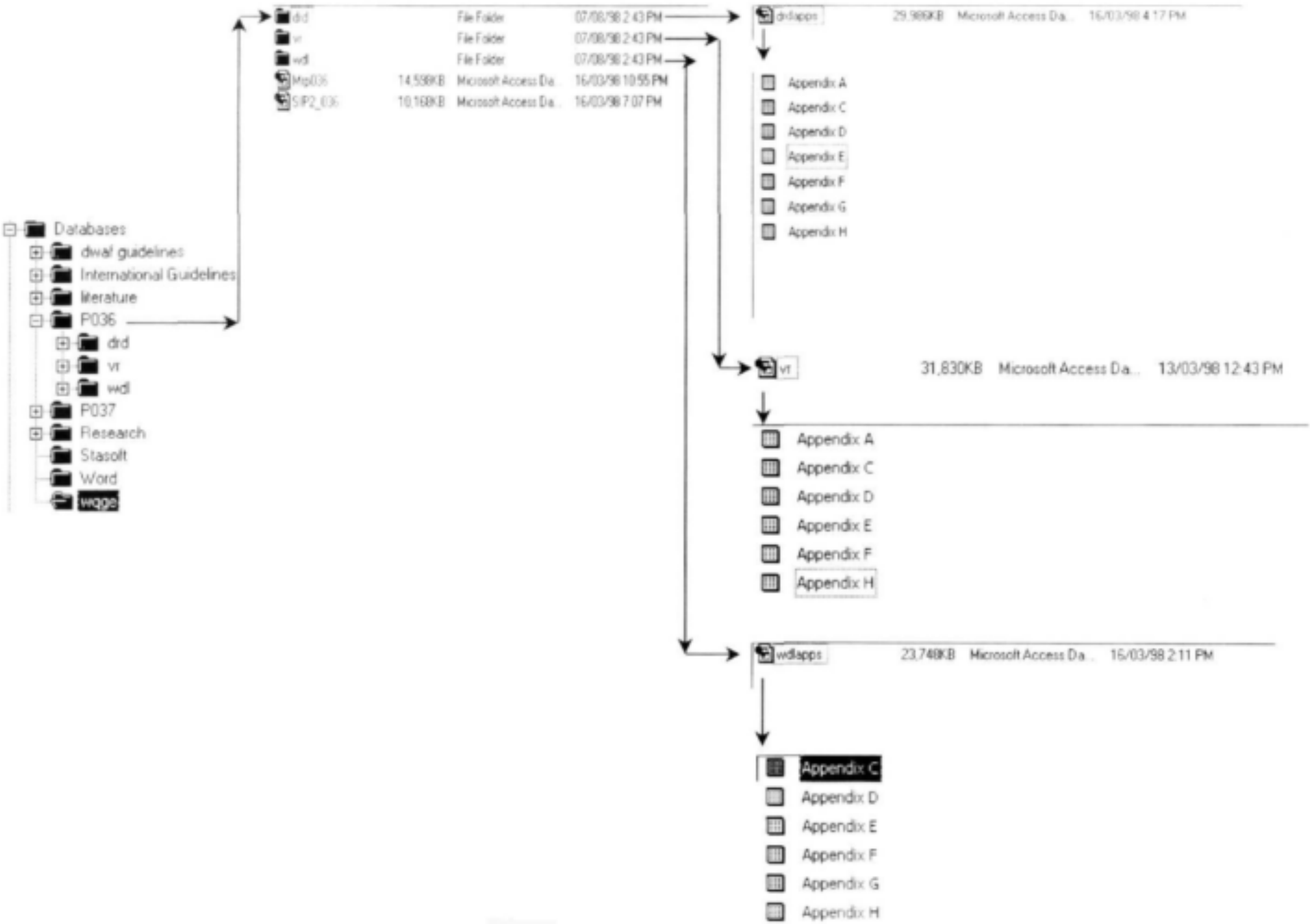
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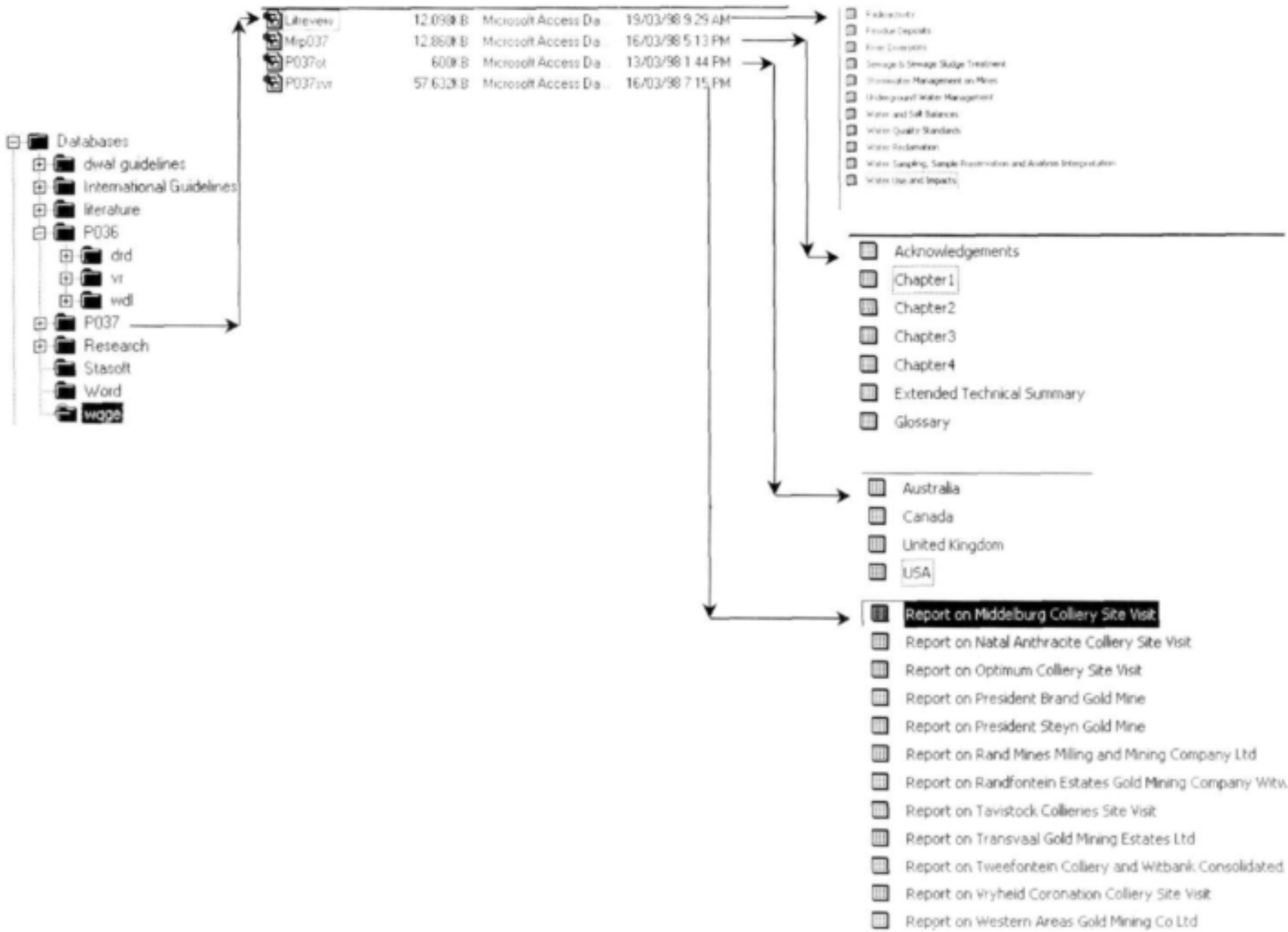

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Stormwater Management on Mines
Underground Water Management
Water and Salt Balances
Water Quality Standards
Water Reclamation
Water Sampling, Sample Preservation and Analysis Interpretation
Water Use and Impacts
Acknowledgements
Chapter1
Chapter2
Chapter3
Chapter4
Extended Technical Summary
Glossary
Australia
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Report on Middelburg Colliery Site Visit
Report on Natal Anthracite Colliery Site Visit
Report on Optimum Colliery Site Visit
Report on President Brand Gold Mine
Report on President Steyn Gold Mine
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Report on Randfontein Estates Gold Mining Company Witw
Report on Tavistock Collieries Site Visit
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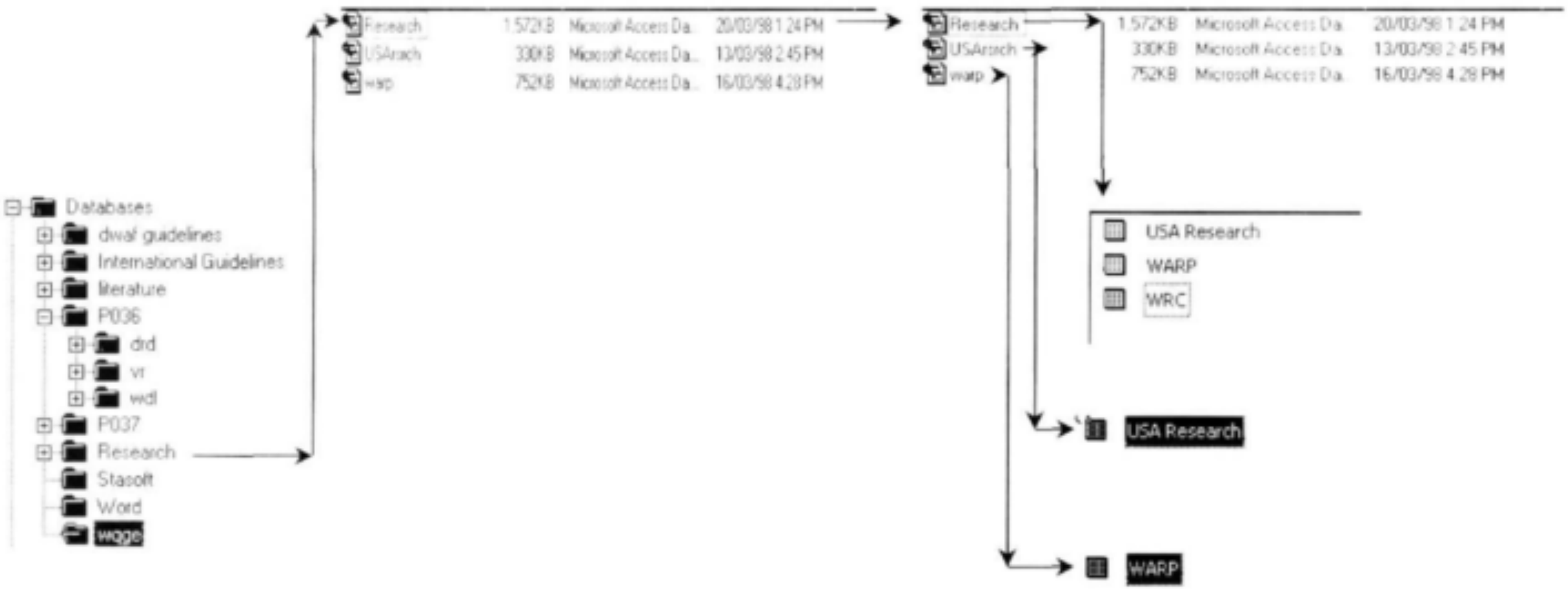

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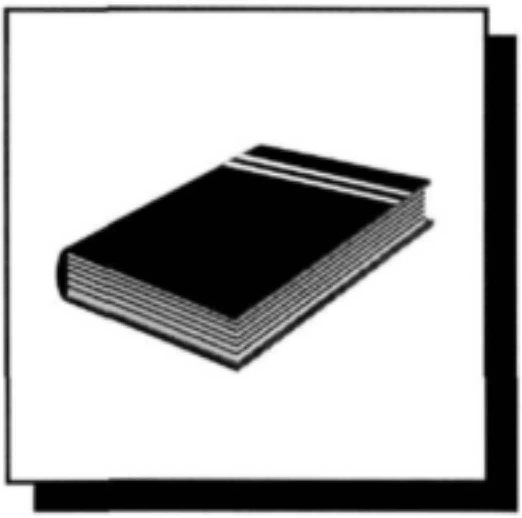


Extended Technical Summary

The extended technical summary summarises the research project which led to this manual and provides information on the aims and objectives of the study; the methodology which was followed; how and where the objectives of the research project are addressed and the conclusions and recommendations resulting from the project. This chapter provides additional technical information which is not critical for all users of the Manual.

Extended Technical Summary

Introduction

This research project was funded by the Water Research Commission. The project commenced on 14 July 1993 and was originally planned as a two year project. The research project comprises detailed case studies undertaken at twenty nine different gold and coal mines representative of the gold and coal mining industry in South Africa.

The main objective of this project is to define the current water management and treatment practices and developments in the South African gold and coal mining industries. In discussions at the first Steering Committee meeting, it was agreed that the product of this research project "should be structured in such a manner that it can be used as a practical tool" and that it should be "structured along problem specific lines". The fulfilment of this objective is understood by the authors to require a report which provides practical and useful information in a format which is easily accessible to the end users and for this reason, the report has been structured along the lines of a manual, and not a research report.

The end users of the findings of this study will include mine management, mine engineering staff and mine water management practitioners and specialists. The different end users have different information requirements and accordingly this report has been structured in the following manner:

- main report for all users
- appendices for mine water management practitioners and specialists

Background and Approach

The South African mining industry is made up of a large number of independent mines covering a vast geographical area. The different mining sectors (gold and coal), as well as individual mines within each sector, experience different water management problems in terms of both quality and quantity. Some mines experience problems with large inflows of fissure water, which may be of a good or poor quality depending on mine location, while other mines have little or no fissure water ingress. Some mines experience severe problems with the generation of sulphuric acid in the underground water systems while other mines have little or no acid problems.

Over the last number of years, the mines have applied a number of different water management strategies which are aimed at reducing their fresh water intake, reducing the volumes of effluent discharged to the environment, minimising the deterioration in water quality in the mine circuits and treating the water to the required level for reuse or discharge. These developments have occurred in different ways:

- through application of research funded partially or wholly by the mining industry and undertaken on a cooperative basis, largely through the Chamber of Mines;
- through application of research funded by individual mining groups or mines and undertaken on a contract basis by various organisations;
- through application of research funded by the Water Research Commission and undertaken on a contract basis by various organisations;
- through application of research funded by the Department of Water Affairs and Forestry (DWA&F) and undertaken on a contract basis by various organisations; and
- through application of research undertaken in other mining countries.

The recent introduction of the Environmental Management Programme Report (EMPR) as the vehicle for environmental and water management on the mines has also resulted in major advances in the understanding of water management issues on the mines. One of the fundamental issues embodied in the EMPR is that the mines should be applying the Best Available Technology Not Entailing Excessive Cost (BATNEEC) in their water management programmes.

While this project did not set out to define BATNEEC, one of its stated objectives is to:

Prepare a comprehensive document setting out the current "state of the art" with regard to water management and treatment in the mining industry, which can be used as a practical tool by water management practitioners in the mining industry, and as baseline information which can make an input into the definition of Best Available Technology Not Entailing Excessive Cost (BATNEEC).

Goals / Objectives

In order to ensure that the project delivers the required products it is appropriate to restate the main objectives of the research project:

1. Establish current water management and treatment practices and developments in the South African gold and coal mining industry.

2. Establish, through a literature survey and by utilising international expertise to access unpublished information, which mine water treatment and management systems being applied internationally, have potential for application in South Africa.

3. Prepare a comprehensive document setting out the current "state of the art" with regard to water management and treatment in the mining industry, which can be used as a practical tool by water management practitioners in the mining industry, and as baseline information which can make an input into the definition of Best Available Technology Not Entailing Excessive Cost (BATNEEC).

4. Identify knowledge gaps with regard to mine water treatment and management which should be addressed by future research projects.

In order to ensure that the project objectives are met, it is necessary to analyse each objective in some detail.

Establish current water management and treatment practices and developments in the South African gold and coal mining industry.

The keywords in this objective are "current", "practices", "developments" and "South African".

- *"Current"* refers to actions presently being taken and systems presently installed and in operation.

- *"Practices"* refers to various means such as actions, strategies, systems, technologies, etc., used to address water management and treatment issues.

- *"Developments"* refers to changes (improvements) to existing actions, strategies, systems, technologies, etc., which are presently being investigated and which may be implemented in future.

Establish, through a literature survey and by utilising international expertise to access unpublished information, which mine water treatment and management systems being applied internationally, have potential for application in South Africa.

The keywords in this objective are "literature survey", "unpublished information", "internationally" and "potential for application in South Africa".

- *"Literature survey"* refers to obtaining published information which can be accessed through recognised computerised data bases.
- *"Unpublished information"* refers to information which cannot be accessed through recognised computerised data bases.
- *"Internationally"* refers to countries outside South Africa.
- *"Potential for application in South Africa"* refers to current practices and developments which are judged by the researchers to have a reasonable probability of improving South African practices or addressing South African knowledge gaps.

Prepare a comprehensive document setting out the current "state of the art" with regard to water management and treatment in the mining industry, which can be used as a practical tool by water management practitioners in the mining industry, and as baseline information which can make an input into the definition of Best Available Technology Not Entailing Excessive Cost (BATNEEC)

The keywords in this objective are "comprehensive", "state of the art", "practical tool", "baseline information" and "input into the definition of BATNEEC".

- *"Comprehensive"* refers to a document which will give a detailed coverage of all relevant information generated during the research project.
- *"State of the art"* refers to current practices (water treatment and management) employed within the South African mining industry.
- *"Practical tool"* refers to the user-friendliness of the report. According to a decision taken at the first Steering Committee, this required a report which is "structured along <u>problem specific</u> lines".
- *"Baseline information"* is similar to "state of the art" in that it refers to the existing situation within the South African mining industry. The existing situation will be seen as the "bottom line" in determining BATNEEC.
- *"Input into the definition of BATNEEC"* refers to defining the existing situation in the South African mining industry and reporting on relevant local and international developments which may have a positive impact on the current practices.

Identify knowledge gaps with regard to mine water treatment and management which should be addressed by future research projects.

The keywords in this objective are "knowledge gaps" and "should be addressed".

- *"Knowledge gaps"* refers to those aspects of mine water management and treatment which are not adequately addressed by current practices or developments and where additional information is required.
- *"Should be addressed"* infers that a judgement of the priorities of the knowledge gaps has been made and that the most important aspects which require priority attention have been identified.

Where and How are Goals / Objectives Addressed

In order to address the terms of reference of this project 17 coal mines and 12 gold mines were selected to undergo detailed assessments of their water management and treatment practices. In addition, 21 operational and defunct gold, coal and base metal mines were visited in Australia, the USA, Canada and the United Kingdom and visits were made to 12 research organisations, consultants and environmental regulatory authorities in these same countries.

Objective 1 was addressed by undertaking the mine surveys to define current practices. The literature survey and liaison with the South African mining industry, various research bodies and consultants address the issue of current developments.

Objective 2 was addressed by undertaking a literature survey which accessed a large number of relevant local and international databases. Unpublished information was accessed by setting up communication channels with prominent individuals and organisations throughout the world and by undertaking the study tour to selected individuals and organisations in Australia, the United States of America, Canada and the United Kingdom.

Objective 3 essentially describes the major deliverable of the project - this manual which is an integration of many of the individual phases of the project.

Objective 4 has been addressed in this manual by combining the results of the mine surveys with the information on local and international developments to identify the residual needs. The identified knowledge gaps should be considered by the WRC's Co-ordinating Committee on Mining Related Water Research (CCMRWR) for incorporation into its strategic mine water research plan.

Each of the above objectives is addressed in this manual, particularly in Chapters 4 and 5, while some of the objectives are also met with the detailed information contained in the five volumes of the Appendices. The structure and linkages between all the reports are discussed in the Manual in the chapter "START : How To Use This Manual". The goals set out above are addressed in the following manner:

- Goals 1, 2, 3 and 4 are addressed in this manual.
- Goal 1 is addressed in more detail for each of the 17 surveyed coal mines in Appendix Volume 2, and for each of the 12 surveyed gold mines in Appendix Volume 3.
- Goal 2 is addressed in more detail by the 28 literature reviews contained in Appendix Volume 1 and the overseas study tour report contained in Appendix Volume 4.
- Goal 4 is supported by the catalogue of relevant Water Research Commission projects contained in Appendix Volume 5.

Note : The Manual is structured such that it can be used both by water specialists and by mine staff who only have a rudimentary knowledge of water management issues. The Manual itself can be used by all persons, while the different Appendix volumes are directed more at the specialists.

Project Methodology

On commencement of the project in July 1993, the first activity which was undertaken was a detailed project planning exercise comprising the following two tasks :

- definition of the detailed scope of work; and
- detailed work breakdown structure and critical path scheduling.

The project scope of work and the methodology which was followed are divided into the following distinct phases:

- Definition of the scope of work and preparation of a project plan.
- Undertaking of an information survey
- Undertaking of a survey of the coal mining industry
- Undertaking of a survey of the gold mining industry
- Undertaking of an international study tour

Two specialist liaison groups (coal and gold) were set up to provide more detailed technical input and guidance in defining the coal and gold mine surveys. A description of the work which was undertaken under each of the phases is given below.

Phase 1 : Definition of the scope of work and preparation of a detailed project plan

In this initial phase of the project, the project objectives and deliverables were defined in more detail and were submitted to and accepted by the project steering committee. Each phase of the project was defined in terms of detailed activities that needed to be undertaken to meet the project objectives.

Phase 2 : Undertaking a local and international literature survey of mine water treatment and management systems

Extensive retrospective literature searches were done on all the technical topics relating to mine water management and treatment and the relevant papers, articles and reports were accessed. Literature searches were made of the following databases:

- Pulles Howard & de Lange's computerised mine water database & library
- The CSIR's Waterlit library and database
- International databases accessible through Worldnet Gateway

A monthly literature profile was set up at Waterlit to ensure that all relevant new literature entering the system after the retrospective searches was also obtained.

In order to access additional information which might not be available in computerised databases, a document discussing the project objectives and summary scope of work was prepared and sent to 180 organisations and key individuals throughout the world. This document was sent under a covering letter which requested information on relevant topics to be forwarded to the research team. Letters were sent to Australia, USA, Canada, United Kingdom, New Zealand, Poland, Hungary, Philippines, Mexico, Malaysia, China, Brazil, Japan, Korea, Peru, Germany, Czechoslovakia and Pakistan. Positive replies, accompanied by useful literature was received from a number of the persons contacted.

All the literature which was accessed was used to prepare the Manual and the 28 literature reviews contained in Appendix Volume 1.

Phase 3 : Survey of current water management and treatment practices in the South African coal and gold mining industries

The primary activity of this research project was to visit a number of mines selected and nominated by the industry to be representative of the industry. The purpose of these visits was to objectively and visually assess the current water management and treatment practices in the mining industry. These site visits also attempted to identify novel and innovative practices that are of potential benefit throughout the industry.

Through the Chamber of Mines, the different mining groups were requested to submit candidate mines to be included in the survey. The Coal and Gold Specialist Liaison Groups, which were drawn from the mining industry, considered the nominations and selected the mines which were included in the survey.

The following 17 coal mines were selected and visited : Alpha Anthracite; Durban Navigation; Duvha; Goedehoop; Greenside; Grootgeluk; Hlobane; Kleinkopje; Landau; Matla; Middelburg; Natal Anthracite; Optimum; Tavistock; Tweefontein, Van Dyksdrift; and Vryheid Coronation.

The following 12 gold mines were selected and visited : Deelkraal; ERGO; ERPM; Hartebeestfontein; Kloof; Libanon; President Brand; President Steyn; Randfontein Estates; RM3 Crown Mines; TGME; and Western Areas.

The site visits were undertaken with the aim of achieving the following objectives:

1. To assess the level of involvement and training of the responsible personnel with regard to mine water management and treatment.

2. To define the mines' approach to water management as well as their definition and perceptions of the advantages, disadvantages, incentives and obstacles of an established water management strategy.

3. To define the mines' perception of the short, medium and long term objectives of a water management strategy.

4. To visit surface and underground water treatment facilities.

5. To obtain information with regard to all aspects related to water management and treatment practices such as:

   - Water sources and water resource planning
   - Surface water quality management and the different treatment processes
   - Underground water quality management and the different treatment processes (where applicable)
   - Water quality monitoring procedures
   - Effluent disposal
     - surplus underground water
     - sewage water
     - normal runoff water from workshops, roads, wash bays etc.
     - storm water runoff
     - seepage from stockpiles and discard dumps
     - effluents from coal wash plants
     - effluents leaving the mine boundaries
   - Impact of legislation

6. To identify practices which are novel and should ideally be communicated to other mines, which practices are not on a par with other mines with similar problems, and which practices are only viable at a particular location due to site specific circumstances.

7. To identify particular needs and possible knowledge gaps as experienced by the water management practitioners.

The site visits to the survey mines all included a tour and visual inspection of all aspects of the mine's operations which relate to its water management or treatment practices. Photographs were taken of key elements and pH and conductivity readings were taken of various streams on the mine. A detailed questionnaire was filled in during an interview(s) with relevant mine staff. A site visit report was prepared for each mine, and these are included in Appendix Volumes 2 and 3.

A short questionnaire was compiled and sent to all South African coal mines not visited during the survey. The response to this questionnaire was extremely poor and a similar questionnaire was not sent to the gold mines not included in the mine survey, as had originally been planned.

Phase 4 : Undertaking of a study tour to evaluate international practices in mine water management and treatment

An extensive six-week study tour was undertaken to Australia, the United States of America, Canada and the United Kingdom in order to visit mines and regulatory authorities, research organisations and consultants who deal with mine water management and treatment. The following organisations were visited during the study tour, over the period 4 August 1994 to 16 September 1994:

Australia
Collinsville Coal Company (Pty) Limited
Ravenswood Gold Mine
Mt Leyshon Gold Mines Limited
Hunter Valley Coal Mine
Environmental Protection Authority - Newcastle
BHP Research Laboratories - Newcastle
Australian Nuclear Science & Technology Organisation

United States Of America
Knight Piesold & Co. - Denver, Colorado
Sleeper Gold Mine
Newmont Gold Quarry Mine
Genesis Gold Mine
Goldstrike Mine
Tennessee Valley Authority (TVA)
US Bureau Of Mines (USBM) In Pittsburgh

Canada
Ministry Of Environment & Energy
Falconbridge Mines
Laurentian University
Inco Plants
Pamour - Royal Oak Mines
Dome Mine
Wastewater Technology Centre - Toronto
Senes Consultants Ltd

United Kingdom
National Rivers Authority (NRA)
Wheal Jane Pilot Passive Treatment Site
Steffen Robertson & Kirsten

Information obtained during this study tour is included in the Manual and is set out in detail in the study tour report in Appendix Volume 4.

Phase 5 : Definition of past and current research activities relating to mine water management and treatment

In order to be able to properly identify and plan research needs relating to mine water management and treatment, it is essential to know which research projects have already been done and which are currently being done. Lack of this knowledge could result in large scale duplication of effort and a waste of scarce human and financial resources.

Although an attempt was made on two occasions to obtain details on research projects being undertaken within the different mining groups, the response was poor. As a result, only the research programme financed by the Water Research Commission (WRC) was evaluated and a catalogue of relevant WRC projects has been prepared and is attached as Appendix Volume 5.

Phase 6 : Workshop to undertake a formal analysis of water quality management needs

When the project was originally devised and planned, it had been intended to organise a one day workshop to identify and analyse the detailed water quality management needs of the mining industry. However, subsequent to this, the WRC formed the Coordinating Committee for Mining Related Water Research (CCMRWR) which, at a workshop in late 1993, developed a strategic plan for mine water research in South Africa.

One of the objectives of the CCMRWR is to coordinate mining related water research in South Africa and to prevent duplication of effort. For this reason, it was decided not to hold the workshop, but rather to submit the research needs identified during the site visits to the CCMRWR for consideration and incorporation into its strategic plan.

Phase 7 : Project reporting

A total of 60 reports have been prepared as part of the final reports to be issued by this project. These reports are the following:

- A Manual on Mine Water Treatment & Management Practices in South Africa
- 29 Mine Site Visit Reports
- 28 Literature Reviews
- Overseas Study Tour Report
- A Catalogue of Relevant WRC Research Projects

Summarised Results from Project

The research project and its products, i.e. this manual, are very broad in scope and do not lend themselves to summarised results. However, in terms of the main contaminants which need to be removed and the main water management issues which apply at South African coal and gold mines, certain summary statements can be made.

Acidity

The standard neutralisation practice in South African mines, both on surface and underground, is the addition of chemicals (predominantly slaked or unslaked lime), in a poorly or manually controlled manner.

Arsenic

The standard practice in South African mines is to apply no treatment for arsenic removal - essentially because arsenic is not considered a problem.

Calcium and Magnesium

The standard practice in South African mines is to apply anti-scalants to condensor circuits and to apply ion exchange/demineralisation for boiler feed water. With the exception of Gold Fields' mines which use soda ash as a neutralising agent, no treatment is undertaken for calcium and magnesium removal in mine service water circuits - other than dilution with fresh make-up water.

Chloride and Sodium

The standard practice in South African mines is to apply no treatment for the removal of chloride or sodium. Waters high in these contaminants and which cannot be discharged are generally evaporated.

Cyanide
The standard practice in South African mines is to apply the ferrous sulphate process to immobilise cyanide in backfill. No chemical oxidation or cyanide recovery is practised. Natural degradation is applied at one mine. Normally waters containing elevated levels of cyanide are not discharged.

Fluoride
The standard practice in South African mines is to apply no treatment for the removal of fluoride. Fluoride is only a potential problem at certain of the coal mines.

Iron and Manganese
The standard practice in South African mines is to apply no treatment for the removal of iron and manganese. There appears to be one exception, ERPM gold mine, which applies lime precipitation in the form of the High Density Sludge (HDS) process.

Metals
The standard practice in South African mines is to apply no treatment specifically for the removal of metals. However, the neutralisation of effluents to pH 7 or thereabouts, will result in the removal of a certain amount of metals. ERPM gold mine which applies lime precipitation in the form of the High Density Sludge (HDS) process will obtain even greater removal of heavy metals.

Microorganisms
The standard practice in South African mines is to apply chlorine disinfection for underground circuits, although chlorine/bromine programmes are rapidly superseding straight chlorine programmes. For sewage works, chlorine disinfection programmes are most common, although in certain instances, maturation ponds are being used.

Nitrogen Compounds
The standard practice in South African mines is to apply no treatment for the removal or management of nitrogen compounds.

Phosphate
The standard practice in South African mines is to do no phosphate removal from the sewage effluents.

Radionuclides
The standard practice in South African mines is to apply no treatment for the removal of radionuclides from mine water. There is, however, one gold mine which applies a weekly lime precipitation treatment with the specific purpose of removing radionuclides. At least one mining group, with high levels of uranium in its water circuits, has a policy of applying tight pH control (pH 7-8) at its underground settlers with the purpose of precipitating the uranium nuclides. In practice, however, most mines are not capable of applying tight pH control at their underground settlers.

Sulphate
The standard practice in South African mines is to apply no treatment for the removal of sulphates. Where effluent problems are experienced, the most common practice is evaporation on tailings dams and/or in evaporation dams. The rehabilitation of residue deposits and opencast coal mines is a strategy which is universally practised. This practice has, as one of its objectives, the reduction in the production of acid mine drainage (and sulphate).

Suspended Solids
The standard practice in South African gold mines is to apply flocculation and settling to spent mine service water in the underground settling installations, followed by separate pumping circuits for clear water and mud. These settlers are typically poorly operated and are often inappropriately designed to deal with flow and quality fluctuations experienced underground. In isolated cases, the settled water is filtered in sand filters (typically on surface) before being reused. In some mines, the mud removed in the underground settlers is filtered to produce a cake

which is then hoisted, rather than pumped, out of the mine. For surface water circuits, the prime source of suspended solids is the tailings from the reduction works and these solids are deposited in tailings dams with the drainage water being returned to the reduction plant.

In coal mines, gravity separation is used in the coal beneficiation process and the fine solids are removed in slurry dams, with the drainage water being reused within the beneficiation plants. Filtration is not typically applied in coal mine water circuits.

Water and Salt Balances

Mines have been preparing water balances for permit purposes for the Department of Water Affairs and Forestry for many years. These balances are generally inaccurate and based on estimates and assumptions. In terms of the EMPR requirements, mines have recently prepared more detailed and accurate water and salt balances. Generally, however, these balances still contain estimates and assumptions due to the historical lack of proper monitoring systems (particularly with regard to flow measurement) and are not being used properly for management purposes. In many cases, once the EMPR has been prepared, the water and salt balances remain the same and are not updated to keep them useful. There is a general lack of understanding of the utility of water and salt balances for water management purposes.

Stormwater Management

The standard practice on South African mines varies considerably from mine to mine although all of them do apply at least certain elements of stormwater control, particularly at those sites, such as active residue deposits, where the most polluted runoff occurs. However, many mines do not apply the fundamental principles of keeping clean and dirty water separate and preventing clean water from becoming contaminated. Although most mines will capture the most polluted runoff, this is often diluted with clean runoff water.

Residue Deposits

Residue deposits can generally be considered to be one of the most important sources of diffuse water pollution from the mining industry. In the coal mining industry, many of the older residue deposits were badly sited and constructed and considerable effort is being expended at present to upgrade and rehabilitate these facilities. However, in many cases, the pollution resulting from ongoing seepage cannot be stopped and pollution collection and treatment systems will be required. These residue deposits also contribute significantly to the pollution problems at old defunct mines where the State has pollution control responsibility.

In the gold mining industry, the problems experienced with residue deposits is perhaps more severe in that these facilities cover vast areas and that many were constructed in totally inappropriate areas from a water management viewpoint. Many of these facilities are still in operation today and continue to present major problems with regard to ground and surface water pollution. Defunct operations, particularly on the Witwatersrand, also contribute substantially to pollution of the regional water resources.

Current practice at gold mines today is to institute seepage and runoff control measures as far as possible. Most return water dams supply water back to the reduction works for reuse, although a number of these dams are incapable of dealing with the input flow and regularly overflow to the surface water courses.

With some exceptions, rehabilitation of residue deposits is generally not up to date and this aspect is left to the decommissioning phase. Slimes delivery pipelines are generally not constructed and operated in a manner which ensures minimum risk to the water environment and spillages due to pipeline failures occur too frequently.

The long term problems associated with seepage from slimes dams situated on the dolomites are unknown although they may prove to be of great significance.

In general, the mining industry is presently having to cope with the consequences of poor practices of the past which were condoned and approved by the regulatory authorities at the time. Although these facilities are a major pollution problem now and will continue to be in the future, current practices should ensure that similar problems do not arise in future from facilities designed and constructed today.

Underground Water Management

The most common practice in the mines is to neither attempt to separate clean and dirty water nor to prevent clean water from becoming contaminated - all water entering the underground workings is simply collected and routed to the underground settlers - most typically by gravity drains along the footwalls. Typically, no flow balancing is carried out. There are one or two exceptions where an attempt is made to separate the major flows of clean fissure water and to keep them from becoming contaminated. Some mines do pump their spent service water to the settlers, while at least one mine has underground dirty water flow balancing dams.

In the underground coal mines, the general practice appears to be to allow the water to drain to the natural low points from where it is either pumped to surface or reused underground. No major attempt appears to be made to prevent water from becoming contaminated by intercepting clean water and pumping it directly out of the mine.

Water Reclamation

Water reclamation is applied to varying degrees at different mines and for different water circuits. In general, however, the gold and coal mines still exhibit enormous potential for improving their water reclamation strategies and, at the same time, reducing their effluent discharges and fresh water intakes. Most mines do not appear to understand the negative effects which poor water quality may have on their processes and few, if any, user fitness-for-use requirements have been set.

Monitoring and Instrumentation

The standard practice at many South African mines in the past was fairly poor with regard to water quality and flow monitoring and many mines have almost no historical records. A number of the mines, however, have had fairly detailed water quality monitoring programmes in place for many years, although water flow records are almost universally inadequate.

The emergence of the EMPR and its inherent need to determine impacts and to monitor impacts and the effect of management strategies has resulted in a major review of monitoring programmes at almost all the mines, to the point where fairly intensive and comprehensive monitoring systems are being implemented.

One of the most important deficiencies in the use of instrumentation in mines is with regard to the monitoring and control of water treatment installations - particularly those located underground in the gold mines. The vast majority of the pH control installations where lime or soda ash is being dosed upstream of the underground settlers, have no pH monitoring or control equipment installed. Incorrect concepts of pH control abound and, as a result, attempts are made to dose neutralising chemicals from declining head dosing tanks, with no consideration of changing pH or flowrate. The same applies to the control of flocculant dosing and settler desludging and, as a result many settlers operate very inefficiently and have to cope with pH values of between 3 and 12.

Ground Water

Most South African mines, till recently, had a very limited knowledge and understanding of the local and regional ground water systems and the impact of their mining operations thereon. This situation was particularly true for most of the gold mines, whereas many of the coal mines, by having a more direct impact on the shallow aquifers, had a better understanding of their impact thereon. There are exceptions on both sides and their are a number of gold mines, particularly those in the dolomites, who have a long and detailed understanding of their impact on the aquifers, while there are also various coal mines who have not paid adequate attention to their impacts on ground water.

This situation has changed fairly dramatically in the last few years, particularly in the coal mining areas, with the arrival of the EMPR and many mines already have or are developing fairly detailed ground water models and management strategies for the protection of the ground water resources.

River Diversions
A number of the opencast coal mines in the Eastern Transvaal have undertaken river diversions in order to mine through the watercourse, the most recent and well publicised example of which is Optimum Colliery. Extensive river diversions and canals have been constructed in the West Rand from Randfontein through to Carletonville in order to divert the rivers over and around the sinkhole areas.

Information Management
Historically, most mines kept their water quality data in hard copy in files, although the current trend is to use computer based spreadsheet packages for this purpose. A few of the mines use specialised database programs such as Hydrocom. The use of GIS packages is very uncommon and no mines visited had access to a Management Information System (MIS). Nearly all the mines visited had inadequate information management systems and were not aware of relevant water management and treatment developments in South Africa, let alone internationally. Many of the water management staff were also very susceptible to being misled by salesmen due to their lack of access to up-to-date technical information.

Management Structures
The standard practice at mines varies quite considerably. A number of the mines have well defined and coordinated water management structures in place, staffed by people who are suitably qualified and motivated. Other mines, typically the smaller ones, have no coordinated water management strategy or structure and the little that is done, is done by persons who are not suitably qualified for the task. The importance of environmental and water management and the impact which it can have on a mine's short and long term profitability is slowly being recognised and the mines are developing and instituting appropriate management structures and systems. Again, the EMPR appears to be the vehicle which drives the process.

What are the Knowledge Gaps?

Acidity/pH
A major knowledge gap is the development of reliable control strategies and techniques to ensure tight and accurate pH control at the underground settler installations.

Arsenic
No knowledge gaps are identified.

Calcium and Magnesium
No knowledge gaps are identified.

Chloride and Sodium
No knowledge gaps are identified.

Cyanide
The development / specification of design and operational guidelines for systems for the natural degradation of cyanide under South African conditions is required.

Fluoride
No knowledge gaps or research needs are identified.

Iron and Manganese
It appears that researchers in North America are starting to question the validity of regulation of iron and manganese in effluents, based on the apparent limited toxic effect thereof. A need can, therefore, be identified to research and review the basis of the very stringent South African limits for the discharge of manganese (0.4 mg/l). A research need can also be identified to investigate the removal of manganese in passive treatment systems through the use of selected algae.

Metals
No research needs are identified and existing technology can be applied to address metal removal problems.

Microorganisms
No knowledge gaps or research needs are identified.

Nitrogen Compounds
A research need can be identified which relates to managing the source of nitrogen compounds in mine service water circuits, specifically the use of alternative explosives and the improvement in the management of the use of explosives.

Phosphates
No knowledge gaps or research needs are identified.

Radionuclides
A research need is identified to develop simple and reliable techniques which can be applied underground for the removal of all or most of the radionuclides of concern. Lime treatment alone may not achieve this as the pH will need to be maintained above 10, which will cause severe scaling problems unless the pH is again reduced to circumneutral - with the associated cost. The application of biological techniques to remove radionuclides also warrants further investigation, as does the use of filtering mechanisms - be it by fluidised-bed settlers or through sand or multi-media filters.

Sulphate
No knowledge gaps or research needs are identified that are not being addressed by current research projects.

Suspended Solids
The efficient control and operation of underground settling operations, including the pretreatment operations of neutralisation and flocculation, remain a research need for the gold mining industry. The vast majority of underground settlers are being poorly operated, or have been badly designed.

Water and Salt Balances
Various components which are required for the development of accurate mine water balances can be identified as knowledge gaps, including factors for evapotranspiration from wetlands, evaporation from slimes dams and slurry ponds. There is also a need for reliable and universally applicable computer models to prepare and manage water and salt balances.

Stormwater Management
The contribution of contaminated runoff from various disturbed mine areas, particularly for coal mines, such as rehabilitated pits, spoils, haul roads, to the pollution load emanating from mines needs to be defined so that appropriate stormwater management strategies can be developed. Appropriate hydrological models which accommodate land types found on mines and which have a resolution appropriate for modelling at mines, are required.

Residue Deposits
Although a lot of research has and is being undertaken on various aspects relating to residue deposits, the following research needs can still be identified:

- Water balance around residue deposits - is it preferable, from a water pollution and management viewpoint, to retain water on the tops of dumps where it may contribute to an increased salt load discharged from the deposit due to seepage, or should the water be encouraged to run off and perhaps be discharged?

- The long term impacts of residue deposits in the dolomitic areas need to be researched and appropriate management strategies, if any, need to be identified.

- Guidelines for the design, construction, operation and maintenance of slimes delivery pipelines together with appropriate pollution control measures to prevent contamination of water resources.

- Water balance techniques for the determination of accurate water balances around residue deposits, particularly slimes dams. This research should include improved techniques for determining evaporation and water retention rates for slimes dams.

Underground Water Management
There is a need to develop water balance techniques for underground mine water circuits in order that the benefits of proper underground water management can be assessed.
There is a need for the development of general guidelines and procedures to separate clean and dirty water circuits underground and to minimise the contamination of the water in these circuits.

Water Reclamation
The most important knowledge gap which needs to be addressed is the development of fitness-for-use criteria for the various users on gold and coal mines.

Monitoring and Instrumentation
The development of appropriate control and monitoring systems for underground neutralisation, flocculation and settler operations is considered an urgent research need. The development of integrated monitoring strategies on the basis of water and salt balances for all mines is seen as a research need. The use of common approaches and principles will assist in the regional coordination of water management strategies.

Ground Water
No major knowledge gaps have been identified which are not currently being researched by the Water Research Commission or individual mines and mining groups.

River Diversions
Once the details of the research being undertaken by one of the mining groups are known, knowledge gaps can be defined.

Information Management
A major knowledge gap exists in terms of information and technology transfer to water management practitioners on the mines. A user-friendly system which takes account of the type of information and assistance required by typical mine staff is required. As the mine staff do not appear to have the time to read through and file/classify various reports, a computerised system may be more effective.

Management Structures
No general research needs are identified.

Conclusions

The project team is comfortable that the objectives originally set out for this study have been met in the various reports and the "Manual on Mine Water Treatment & Management Practices in South Africa".

There are fundamental differences between mine water treatment and management practices in South Africa and other countries. These differences are due to various factors, including those that follow:

- different regulatory environment with a focus on different contaminants
- different mining techniques
- different climatic conditions
- different surface and ground water hydrology

A common approach appears to be the focus on passive treatment systems in those areas with appropriate climatic conditions - particularly for defunct mining operations. Across the world, environmental regulations are becoming stricter, which requires good monitoring and information systems for water management purposes.

In South Africa, the EMPR has been by far the most important factor which has lead to an increased awareness and a "quantum leap" in the understanding of water management and treatment options by mine staff.

Recommendations

The following recommendations are made:

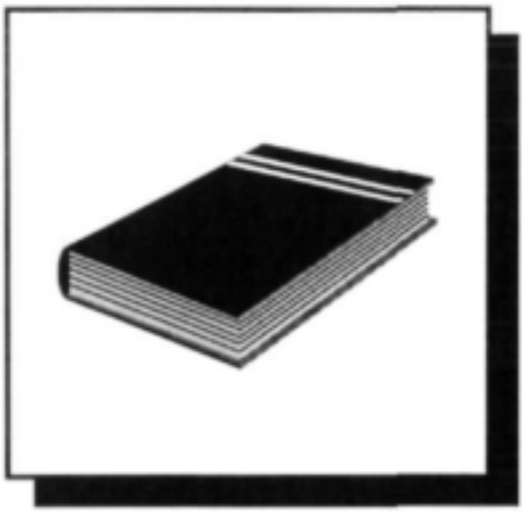
1. This manual should be widely distributed to the target audience, namely mine personnel who are involved in the development and management of surface water resources on gold mines and personnel within the Departments of Water Affairs & Forestry, Mineral & Energy Affairs, and Environment Affairs who have responsibility for monitoring and managing impacts from gold mining operations.

2. The usefulness of the Manual should be assessed via feedback from the users to the Water Research Commission, the Chamber of Mines and the project team after 6 - 12 months. If this manual is assessed to be useful, it could be updated according to any further requirements set by the users and could serve as a prototype for future projects delivering products of a similar nature.

3. The Manual should be made more useful and accessible by being computerised in a user-friendly hypermedia system.

4. Various research projects, as listed above, should be undertaken to improve the state of mine water management and treatment.

Appendix 3



Extended Technical Summary

The extended executive summary summarises the research project which led to this manual and provides information on the aims and objectives of the study; the methodology which was followed; how and where the objectives of the research project are addressed; a summary of the findings of each individual case study mine and the conclusions and recommendations resulting from the project. This chapter provides additional technical information which is not critical for all users of the manual.

Extended Technical Summary

Introduction

This research project was jointly funded by the Water Research Commission and the mining industry. The research project commenced on 2 January 1992 and was completed on 31 December 1994. The research project comprises of three detailed case studies undertaken at three different gold mines representative of three typical gold mining regions of South Africa. Case study mine 1 is situated on the Witwatersrand, Case study mine 2 on the West Wits line, near Carletonville while case study mine 3 is located in the Klerksdorp area.

The main objective of this project is to define technically and economically viable procedures for ameliorating the impact of gold mining operations on the surface water environment. The fulfilment of this objective is understood by the authors to require a report which provides practical and useful information in a format which is easily accessible to the end users.

The end users of the findings of this study will include mine management, mine engineering staff and mine water management practitioners and specialists. The different end users have different information requirements and accordingly this report has been structured in the following manner:

- main report for all users
- appendices for mine water management practitioners and specialist

Finally, the information in these reports is applicable to case study mines 1 to 3 and similar mines, with certain generic information being applicable to the whole deep gold mining industry.

Background and Approach

Three different gold mines considered to be representative of a typical gold mine in each of the following regions - Witwatersrand, Carletonville and Klerksdorp were studied. These Case study mines had differing water circuits with Case study mine 1 being an open circuit (most of effluent released), Case study mine 2 recycling most of its effluent and Case study mine 3, although mainly recycling its effluent, is situated on dolomite.

Case study mine 1 is situated on the Witwatersrand and is considered to be representative of a typical gold mine in this and other regions that have been in operation for at least 50 years and which presently have little or no recycle of underground mine service water. Such mines have extensive worked out areas underground, which produce acidic and saline seepage. The water reporting to the underground settlers in such mines will typically have a low pH and a high sulphate content, which, combined with calcium added through lime, will make the water scaling and difficult to recycle.

Case study mine 2 is located on the West Wits line, near Carletonville. This case study is considered to be representative of other gold mines in this area which have been in operation for less than 20 years and which presently recycle most of underground mine service water. Such mines are also typically influenced by the inflow of good quality dolomitic water. These mines generally recycle most of their water and have water qualities which exhibit moderate salinity and moderate scaling potential.

Case study mine 3 is located in the Klerksdorp area and is considered to be representative of a typical gold mine in this and other regions that have been in operation for at least 50 years. Such mines have extensive worked out areas underground, which produce acidic and saline seepage. The water reporting to the underground settlers in such mines will typically have a low pH and a high sulphate content, which, combined with calcium added through lime, will make the water scaling and difficult to recycle. To complicate matters in this region the dominant underlying geology, being dolomites, results in the neutralisation of acidic seepage waters.

Due to the fact that mines typical of case study mines 1 and 3 have been in operation for 50 years or longer, the surface water systems will typically be characterised by aspects such as :

- strong point source effluents discharging saline and acidic effluent to the surface water environment;
- old, non-operational slimes dams (often poorly- or un-rehabilitated) in or close to natural water courses, resulting in substantial highly saline and acidic diffuse pollution sources;
- extensive old surface infrastructure (including various defunct shafts) which cannot be properly maintained due to lack of staff and funds - typically associated with declining ore grades;
- ongoing reclamation of surface sand and rock dumps.

Goals / Objectives

In order to ensure that the project delivers the required products it is appropriate to restate the main objectives of the research project:

1. To define technically and economically viable procedures for ameliorating the potential impact of gold mining operations on the surface water environment with regard to proposed new mines, existing mines and mines requiring closure;
2. To define procedures which will assist the gold mining industry in undertaking and preparing environmental impact assessments, environmental audits and Environmental Management Programme Reports;
3. Establish, characterise and quantify the potential sources of pollution to the surface water environment; and
4. Determine the significance of the potential biophysical impacts of water pollution from gold mining operations on the surface water environment.

In order to ensure that the project objectives are met, it is necessary to analyse each objective in some detail.

To define technically and economically viable procedures for ameliorating the potential impact of gold mining operations on the surface water environment with regard to proposed new mines, existing mines and mines requiring closure.

This objective is seen to be the most important one which describes the practical deliverables for the project.

'*Technically and economically viable procedures*' refers to practical procedures which could fairly be described as BATNEEC. It is assumed that this objective, in addition to requiring identification of appropriate procedures which are currently available, also places an additional onus on the researchers to identify potentially promising procedures which would require further research. In other words, the researchers need to exhibit an understanding of mining systems which will enable them to identify novel approaches worthy of further investigation. The principles of source reduction, recycling and finally treatment and disposal will be adhered to in seeking appropriate solutions.

`*Gold mining operations*' refers to the activities that occur in removing ore from deep gold mines and processing the ore on the surface. These operations include.....effluent treatment and reuse, waste disposal (rock and slimes dumps)

`*Ameliorating ... impact ... on surface water environment*' restricts the scope of the management strategies which need to be identified and specifically excludes strategies relating to ground water systems.

`*New mines, existing mines and mines requiring closure*' indicates that, where appropriate, management strategies should distinguish between mines on the basis of their age. This implies that BATNEEC could be differentiated on the basis of a mine's age (or history), i.e. a new mine could be subject to more stringent BATNEEC than an existing mine.

To define procedures which will assist the gold mining industry in undertaking and preparing environmental impact assessments, environmental audits and Environmental Management Programme Reports.

This objective aims to provide practical procedures which were identified, utilised or developed by the researchers on all the case study mines. This objective requires the production of a document which contains information on procedures for:

- Collection of data
- Preparation of water and salt balances
- Definition of key water users in the system
- Definition of impacts
- Development of management strategies

This objective is addressed in the final project report.

Establish, characterise and quantify the potential sources of pollution to the surface water environment.

The keywords of this objective are `establish', `characterise', `quantify' `sources of pollution' and `surface water environment'.

`*Establish*' refers to the identification of the different pollution sources.

`*Characterise*' refers to a qualitative description of the nature of the source and its pollution.

`*Quantify*' refers to a quantitative description of the source and its resultant pollution.

`*Sources of pollution*' refers to the root cause and nature of the pollution.

`*Surface water environment*' restricts the scope of the pollution sources which need to be identified and specifically excludes sources impacting on the ground water systems.

This objective will essentially be addressed by producing a fairly detailed water and salt balance for the system being investigated.

Determine the significance of the potential biophysical impacts of water pollution from gold mining operations on the surface water environment.

'*Significance*' is a quantitative and qualitative term which is difficult to define. One view is that a significant impact will have considerable influence on some aspect of **human** well-being. The judgement as to what is significant, requires consideration of the spatial, duration and intensity of the effect. An alternative and perhaps more practical view is that significance will be determined for each site through consultation with authorities and interested and affected parties (Anon 1992).

'*Biophysical impacts*' indicates that impacts relating to both water quality and ecological components of the aquatic systems need to be addressed.

'*Surface water environment*' restricts the scope of the impacts which need to be identified and specifically excludes impacts on the ground water system.

Where and How are Goals / Objectives Addressed

In order to address the terms of reference of this project three case study gold mines where selected with different water circuits.

Objectives 1, 3 and 4 are addressed individually for each case study mine. Objective 2, together with objectives 1, 3 and 4 on an industry-wide basis, are addressed in this Manual.

It was further intended that the case study sites should be selected in order to allow extrapolation of research data to the rest of the mining industry, i.e. the benefits of the research must not be confined to the specific case study mines only. In terms of each case study mine, therefore, this report must contain information which addresses objectives 1, 3 and 4 in such a manner as to allow extrapolation of the information to other similar mines.

Each of the separate case studies have Appendices A to H. The synthesis reports of each of the case studies are included in the Manual as Addendum A to C. The structure and linkages between all the reports is discussed in the Manual in the chapter "START : How To Use This Manual". The goals set out above are addressed in the following manner:

- Goals 1, 2 and 3 are addressed in this Manual.
- Goal 1 is addressed in more detail for each case study mine in Appendix H to each case study report.
- Goal 3 is addressed in more detail for each case study mine in Appendix F to each case study report.
- Goal 4 is addressed in more detail for each case study mine in Appendices C, D, E and G to each case study report.

Note: Procedures and guidelines set out in the project report are generally presented as guiding principles and not prescriptive step-by-step instructions. The target audience for the report is Engineering Managers, Section Engineers, Environmental Engineers and Water Technologists, i.e. persons with a reasonably high degree of technical expertise.

Project Methodology

The same sampling techniques and sampling duration (13 months) were used at all three case study mines:-

Abiotic components

Water Sampling Survey

Weekly samples at identified sampling points. These samples were analysed for a wide range of contaminants, which include the following : -

suspended solids, total dissolved solids, alkalinity/acidity, total hardness, ammonia, nitrite, nitrate, phosphate, boron, cadmium, copper, gold, iron, lead, manganese, nickel potassium, calcium, magnesium, sulphate, chloride, sodium, fluoride, silica, total aluminium, and zinc.

Sediment Survey

Physical and chemical factors affecting sediment-trace element chemistry include the following physical factors : -

- Grain-size and the effect of grain size;
- Chemical analyses of various grain sizes in bottom sediments;
- Effect of grain size on concentrations of trace elements in samples collected from the same and different basins;
- Effect of sediment surface area;
- Importance of surface area to sediment-trace element concentrations.

The sediments of the aquatic system where the surveys were being conducted were sampled on a monthly basis and analysed for the major constituents found in the water sampling survey.

Seepage Survey

The seepage survey investigated the following sedimentological and hydrological variables:

- Textural analysis of the slimes dam sediments up to a depth of 1 200 mm;
- Comprehensive chemical analyses performed on water and sediment samples;
- Determination of seepage rates during both dry and wet seasons.

The role of the seepage from the slimes dams and sand dumps on the surface water quality was assessed in this programme and the quantification of impact used in the development of management strategies.

Biotic components

Bacteriological

Bacteriological analyses such as total plate count, faecal coliform, faecal streptococci and coliphages were carried out on a three monthly basis.

Flora

The dominant aquatic and semi-aquatic as well as certain algal species were monitored to evaluate the ability of these plants to accumulate heavy metals. The method of analysis included the division of the plants into different plant tissues (i.e. roofs, stems, leaves, fruits, seeds) to compare the uptake and accumulation of heavy metals by the different plant species and tissues. Collection of the flora occurred on a monthly basis at the same sampling localities as for sediment and water.

Fauna

Samples were collected and analysed for the dominant aquatic and semi-aquatic species which includes the fish populations, macroinvertebrates, plankton, epibioton (periphyton), nekton and neuston with regard to species diversity and numbers. Quarterly, quantitative grab sampling of macro invertebrates occurred at the sampling localities for sediment and water to evaluate the influence of the different mine effluents on species diversity in these communities.

Summarised Results from Case Study Mines

Case study mine 1

The research undertaken at case study mine 1 has indicated that the primary source of pollution is a point source effluent with the secondary source being seepage from old rock dumps, sand dumps and slimes dams. It is believed that many of the older mines in the Witwatersrand will exhibit similar problems. This is primarily due to such mines having extensive worked out areas underground, which produce acidic and saline seepage. The water reporting to the underground settlers in such mines will, therefore, typically have a low pH and a high sulphate content, which, combined with calcium added through lime, will make the water scaling and difficult to recycle. As a result, and due to the high costs of desalination which is required to make these water suitable for reuse, the mine finds it necessary to discharge large volumes of saline calcium-sulphate waters.

In terms of surface contributors to the water pollution problems, seepage from various waste deposits was identified as the most important. Although seepage contributed only about 11% of the overall salt load, the contribution of certain heavy metals ranged from 75 to 85%. It can be anticipated that for old defunct mines which lack the strong point source associated with mining activities, the seepage will be the most dominant problem.

Contaminated surface runoff and other diffuse pollution sources were found to make a minor contribution to the salt load.

Case study mine 2

The research undertaken at case study mine 2 has indicated that the primary source of pollution is seepage from old rock dumps, sand dumps and slimes dams. It is believed that many mines in the Carletonville area and elsewhere will exhibit similar problems. The water quality problems experienced at this case study mine were less than those identified at older mines with essentially an open water circuit. Reuse of water in an almost closed circuit elevates the net contribution to the salt load from the waste deposit sites to a significant level.

Seepage contributed about 30 - 40% of the overall salt load for Mine Section A and about 45% for Mine Section B. The implementation of management strategies to address this source of salt load is therefore important.

Contaminated surface runoff and other diffuse pollution sources were found to also make a contribution to the salt load. At mine Section B, the contribution was estimated at 30%. According to the flow and salt balance for Mine Section A, very little effluent was discharged from North Boundary dam in the winter months. However, during the summer months, this dam was observed to overflow into the surface water systems. A larger proportion of the inflow to the North Boundary Dam originates in the metallurgical plant area and accordingly, when overflow does occur, the metallurgical plant becomes a significant contributor to the discharged salt load.

Case study mine 3

The research undertaken at case study mine 3 has indicated that the primary source of pollution is seepage into the groundwater from old rock dumps, sand dumps and slimes dams. It is believed that many mines in the Klerksdorp area, and elsewhere where dolomite geology is present, will exhibit similar problems. Reuse of water in an almost closed circuit elevates the net contribution to the salt load from the waste deposit sites to a significant level.

The high electrical conductivity and sulphate values in the groundwater and Vaal River are associated with the mining processes and originate from slimes dump runoff into groundwater and runoff into the river during heavy rains.

Due to the dominant underlying dolomite geology, there is a neutralisation of acidic seepage waters. Calcite and/or dolomite neutralisation of acid mine drainage occurs. It could probably be safely said that were it not for the presence of calcite and/or dolomite in the area, many of these waters would be significantly more acidic.

It can also be mentioned at this point that the increase in pH caused by mixing with other water sources which then increases the solubility of calcite and dolomite above zero will tend to make these waters potentially scaling. That is, scaling in pipes and pumps used to move such waters can be expected.

It can also be pointed out that these conditions are conducive to the occurrence of subsidence and sinkholes, particularly if the calcite and dolomite occur in large homogenous masses or if they occur in sufficient quantity that removal (through dissolution) would significantly weaken the structure of the surrounding rock.

The ability of waters with pH's less than 8 to dissolve dolomites also creates problems for the control and management of surface waters at Case study mine 3. There is a large unaccounted for load of water quality constituents to the Vaal River that can only be associated with the groundwater geohydrology. This source of pollution to the Vaal River is difficult to manage with conventional surface water treatment techniques.

What are the Potential Pollutants and Where to Look?

The following table is a summary of the major gold mining contaminants, there typical sources and the areas that are affected by these contaminated effluents.

Typically the major sources of contamination in deep gold mines originate from either underground or surface sources, or a combination of both. The typical underground sources of contamination are:

- pyrite oxidation of stopes
- inadequate underground settling
- fissure water
- waste explosives
- faecal contamination of underground water

Summary table of contaminants, their sources on the mine and areas impacted.

Contaminant	Typical source	Areas affected
Metals Iron Manganese Zinc Lead Copper	Pyrite oxidation in underground stopes & surface rock and sand dumps & slimes dams with dissolution of metals	sediment, groundwater, surface waters, macrophytes, biota
Sulphate	Pyrite oxidation in underground stopes & surface rock and sand dumps & slimes dams with production of sulphates	sediment, groundwater, surface waters
Cyanide	Spillage from: plant areas, ruptured slimes delivery pipeline and slimes dams	sediment, groundwater, surface waters, macrophytes, biota
Suspended solids	Inadequate underground settling, runoff from surface rock, sand dumps & slimes dams	sediment, groundwater, surface waters, biota
Sodium	Fissure water, addition of sodium based neutralisation chemicals	sediment, groundwater, surface waters, macrophytes, biota
Chlorides	Fissure water	sediment, groundwater, surface waters, macrophytes, biota
Nitrogen compounds	Waste explosives in underground stopes, gaseous by-products from explosives, sewage and contaminated run-off from hostels	groundwater, surface waters
Phosphates	Sewage and contaminated run-off from hostels	groundwater, surface waters
Acidity	Pyrite oxidation (underground, surface dumps (rock, sand & slimes), spillage from plant areas	groundwater, surface waters, macrophytes, biota
Radionuclides	Pyrite oxidation in underground stopes & surface rock and sand dumps & slimes dams with dissolution of radionuclides	sediment, groundwater, surface waters, macrophytes, biota
Microbes Faecal coliforms Coliphages	Faecal contamination of u/g mine service water, poorly treated sewage, run-off from hostel areas, livestock grazing	sediment, groundwater, surface waters, macrophytes, biota

The typical surface water sources of contamination are:

- surface rock dumps
- surface sand dumps
- slimes dams
- neutralisation chemicals
- spillage from plant areas, pipelines and slimes dams
- sewage
- contaminated run-off from hostels
- livestock grazing

The impacts result primarily from the following water quality problems:

- nutrients - mainly nitrate, ammonia and phosphate
- high pH
- metals - manganese, lead, copper, zinc, cadmium and nickel
- salts - calcium, sulphates
- microbiological - faecal coliforms
- toxins - cyahide

Management Strategies

The identification and definition of water management strategies should be preceded by:

- identification of pollution sources
- quantification of pollution loads
- assessment and quantification of pollution impacts on all downstream water users

Once these actions have been undertaken for all the pollution sources, then the pollution problems can be ranked in terms of impacts and priority of mitigation. The basic tools that are used for this process are the water and salt balances.

The guiding principle that should be applied when defining the most appropriate management actions is that the priority sequence of such actions should be:

Prevention at source -> effluent reuse -> treatment and disposal of effluents

In addition to significance of impacts and priority of mitigation thereof, the following aspects should also be taken into account when developing an overall integrated management strategy:

- cost of management action
- probability of success
- ease and time frame within which management actions can be applied

In terms of the assessed priority pollutants and their impacts, a number of management strategies were identified and will be of interest at the following three levels: specific case study mine; similar mines; and the whole gold mining industry.

In order to ensure that these management strategies are more useful and applicable to other similar mines the following subsections, based on the source and nature of the problem, were used:

- water discharged from plant areas
- seepage, decant and spillage from waste deposits
- groundwater capture and control
- treated sewage
- contaminated runoff from hostels and other mine areas
- general water management

All these subsections have, where appropriate, been further divided into four as follows:

- source reduction strategies
- effluent reuse strategies
- effluent treatment strategies
- general management strategies

The priority of implementation will generally be highest for source reduction and general management strategies, lower for effluent reuse strategies and lowest for effluent treatment strategies. These priorities may be changed by practical and financial considerations.

Source reduction strategies

The first step in the development of a water management strategy is to investigate pollution prevention strategies as these are generally the most effective in the long term. *The fundamental principle of pollution prevention is to stop, inhibit or retard* the hydrological, chemical, microbiological or thermodynamic processes which are resulting in the contamination of the water systems. Some of the main pollution prevention strategies that were suggested as pollution prevention management strategies are:

- prevent/retard pyrite oxidation in stopes
- rehabilitate/vegetate waste deposits
- prevent and contain spillage
- improve water and stormwater management
- effective final treatment of sewage
- maintain paddocks and return water dams
- improve management of explosives

Effluent reuse strategies

If all the effluent problems cannot be resolved by pollution prevention then effluent reuse strategies should be investigated as a second option. The fundamental principle of effluent reuse and reclamation is to supply each water user with the worst quality that can be tolerated without causing problems of a technical, financial, operational or safety nature. Some of the main effluent reuse strategies that were suggested as pollution prevention management strategies are:

- develop detailed water balances (internal and external)
- develop fitness-for-use criteria for all users
- define existing reticulation systems and piping
- evaluate technical water quality aspects of reuse strategies
- evaluate engineering feasibility of reuse strategies

Effluent treatment strategies

If all the effluent problems cannot be resolved by pollution prevention and effluent reuse, then effluent treatment strategies should be investigated. The fundamental principle of effluent treatment is to define the most practical, technically and economically feasible option to reliably produce a water which meets the set requirements. Prior to evaluating and specifying effluent treatment options, it is vital that the nature of the effluent being treated and the characteristics of the treatment process be properly understood. Some of the main effluent reuse strategies that were suggested as pollution prevention management strategies are:

- neutralise water in chemical plant
- neutralise water in passive treatment system
- install chloride or non chloride based disinfectant plants
- install maturation plant
- install desalination plant
- install evaporation facility
- install cyanide recovery or removal plants
- install softening plant
- add anti-scalant to reuse water
- precipitate metals (chemically or passively)
- remove nutrients (denitrification plant or passive wetland)
- remove phosphates (removal plant or passive system)
- remove sulphate (removal plant or wetland)
- install settling dams, clarifier and/or filtration plants

General management strategies

In conjunction with the implementation of pollution prevention, effluent reuse and effluent treatment strategies, the mines also need to implement general water management strategies. The fundamental principle of the general water management strategies is to provide information and institutional support to the water managers for implementing the identified strategies. Some of the main general water management strategies that were suggested are:

- develop detailed water and salt balances for all internal and external water circuits
- institute detailed water quality and flow monitoring
- develop fitness-for-use criteria for all major users
- appoint an environmental manager
- integrate environmental management into all mine activities
- keep all clean and dirty water circuits separate

In discussing the management strategies presented in this study, an assessment was made of the applicability of each strategy in addressing problems at other similar mines, in addition to addressing the specific problems at each case study mine. It must be emphasised that a number of the identified management strategies are at present only potential strategies which require additional research, outside the scope of this research project, before being practically implemented.

Conclusions

The project team is comfortable that the objectives originally set out for this study have been met in the case study reports and the "Manual to Assess and Manage the Impacts of Gold Mining Operations on the Surface Water Environment".

The ongoing interactive approach undertaken in this study ensured that there was good collaboration with and feedback from the mining industry throughout the three years of the study. This interaction occurred at various levels, ranging from monthly meetings with representatives of the mining industry to weekly interactions with mine personnel on site as part of the case study monitoring programmes.

This approach enabled the proposed end users of this Manual to assist in its design, thereby ensuring the development of a user-friendly document to assist in the assessment, management and mitigation of the impacts of gold mining operations on the surface water environment.

Recommendations

The following recommendations are made

1. This Manual should be widely distributed to the target audience, namely mine personnel who are involved in the development and management of surface water resources on gold mines and personnel within the Department of Water Affairs & Forestry, Mineral & Energy Affairs, and Environment Affairs who have responsibility for monitoring and managing impacts from gold mining operations.

2. The usefulness of the Manual should be assessed via feedback from the users to the Water Research Commission, the Chamber of Mines and the project team after 6 - 12 months. If this Manual is assessed to be useful, it could be updated according to any further requirements set by the users and could serve as a prototype for future projects delivering products of a similar nature.

3. The Manual should be made more useful and accessible by being computerised in a user-friendly hypermedia system.

4. Research should be undertaken on the prevention or retardation of pyrite oxidation in underground stopes as this is a dominant source of pollution within the gold mining industry.

5. Research should be undertaken on the management of explosives in the stopes with the view towards reducing the source of nitrogen-based contaminants.

6. Research should be undertaken on the development of passive treatment systems for removing contaminants originating from mining operations.

7. Research should be undertaken to develop user water quality guidelines for all major water users within the mining industry in order to facilitate the implementation of effluent reuse strategies.

8. Mechanisms and systems should be developed to ensure that water and salt balances become a standard water management practice on all gold mines.